FCEM

Forest Carbon and Emissions Model

GREENHOUSE GAS EMISSIONS FROM FOUR CALIFORNIA WILDFIRES: OPPORTUNITIES TO PREVENT AND REVERSE ENVIRONMENTAL AND CLIMATE IMPACTS

FCEM Report No. 2

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Forests and forestry are playing an increasingly important role in sequestering carbon and reducing greenhouse gas emissions, especially during a period of rising concerns about global warming. The Forest Carbon and Emissions Model (FCEM) used in this study estimates forest carbon storage, sequestration, and greenhouse gas (GHG) emissions using equations from recognized scientific sources.

The purpose of this report is to provide estimates that illustrate the impact of wildfires on greenhouse gas emissions and the importance of thinning forests to protect forests and communities, and to prevent emissions from combustion and decay. It also focuses on the significance of removing dead trees and replanting to restore forests and recover greenhouse gases released by wildfire.

Reducing the Threat of Wildfires

Some people argue that we have to live with fire. On the contrary, an industrialized world can't live with fire. We would have to move out of our forests to be safe and get out of our cars to eliminate tailpipe emissions to make up for the greenhouse gases that wildfires emit into the atmosphere, and that isn't realistic. The only solution is to fight global warming and protect our communities and forests by reducing the threat of catastrophic wildfires.

The Angora Fire of 2007 blackened 3,100 acres of forest and destroyed 254 homes in the Tahoe Basin because most of the forest was so dense. Using pre-fire data for the forest, FCEM estimates that combustion emissions could have been lowered from 46.2 tons per acre to 12 tons per acre if the density of trees had been reduced from 273 per acre to the more natural density of 60 per acre.

A fire burning in the same forest after thinning would not have been catastrophic. It would have killed few large trees, covered less acreage, and left adjacent communities relatively unharmed. That is what could have been, but it also illustrates the opportunity that still exists to fight global warming and protect the rest of the Tahoe Basin as well as other forests and communities in California and the West.

Climate Impacts of Wildfires

This report analyzes four catastrophic California wildfires using FCEM: the Angora, Fountain, Moonlight, and Star Fires. Together these wildfires burned over 144,825 acres of forestland.

Those who have not stood in the midst of flames 200-feet high, felt the overwhelming heat from a temperature more than 3,000 degrees Fahrenheit, and smelled the smoke and gases released, cannot fully appreciate a catastrophic wildfire. It is awesome and terrible, and firefighters who brave these conditions deserve our respect.

The catastrophic wildfires that ravage California each year don't resemble the historic fires that took place in these forests for millennia. Most natural fires didn't sweep across landscapes destroying whole forests as wildfires do today. The underlying cause of modern catastrophic wildfires is too many trees.

The four forests burned by these wildfires were overcrowded with trees — with trees of all sizes intermixed to form a uniform mass of fuel spreading over the landscape. They averaged 350 trees per acre when 50-60 trees per acre would be natural. They also contained unnaturally heavy surface fuels composed of litter, duff, down dead wood, shrubs, and small trees that ranged from an estimated 25 to 40 tons per acre. Tree density, especially young trees growing under larger trees as ladder fuel, and surface fuels are the two most important contributors to the size and severity of wildfires.

Consequently, when the massive amounts of fuel in these forests burned, they released an estimated 9.5 million tons of greenhouse gases into the atmosphere just from combustion. That is an average of about 63 tons per acre. However, combustion is only part of the story because dead trees also gradually release CO2 as they decay. CO2 emissions from decay are generally three times greater than emissions from combustion because large quantities of wood and other plant material remain unburned after a forest fire.

Combining combustion and decay emissions, FCEM estimates that these four fires will emit a staggering 38 million tons of greenhouse gases into the atmosphere. The fires released one fourth of the gases during combustion, and post-fire decay will release the remainder during the next 100 years, most of it during the next 50 years.

To put these emissions from combustion and decay into perspective, they are equivalent to adding an estimated 7 million more cars onto California's highways for one year, each spewing tons of greenhouse gases out the tailpipe. Stated another way, this means 50 percent of all cars in California would have to be locked in a garage for one year to make up for the global warming impact of these four wildfires.

Opportunities for Action

One way to compensate for greenhouse gas emissions from wildfires is to lower the amount of biomass available for decay. Removing dead trees and storing the carbon they contain in the solid wood products consumers need can reduce total CO2 emissions by as much as 15 percent. Planting a young forest to replace one killed by wildfire and letting the growing trees absorb CO2 from the atmosphere through photosynthesis is another way. Doing both, especially with interim harvests for wood products after planting, effectively reverses the impact of wildfire emissions on global warming.

This report estimates accomplishments, planned and completed, to reduce and recover greenhouse gas emissions from four areas blackened by catastrophic wildfires in California. So far, FCEM estimates that these actions, in combination, will compensate for 42 to 114 percent of the actual and potential CO2 losses caused by three of the four wildfires.

Even so, opportunities still exist to do even more to restore two of the four forests burned and fight global warming. In particular, removing dead trees and planting national forest lands burned by the 2007 Angora and Moonlight Fires could recover an estimated 98 to more than 100 percent of the CO2 losses they caused. Equally important, these actions would help protect surrounding communities from a second wildfire or re-burn, which often occurs in forests that become dead-tree filled brush fields.

The immensity of greenhouse gas emissions from just these four wildfires is a warning. Clearly, we must make every effort to reduce the amount of excess biomass in forests to prevent catastrophic wildfires. That means decreasing the number of trees by thinning to make them more resistant to crown fires, which will also restore the natural health and diversity of our forests. Reducing the number and severity of wildfires may be the single most important action we can take in the short-term to lower greenhouse gas emissions and fight global warming.

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Introduction

This report analyzes four California wildfires using the Forest Carbon and Emissions Model (FCEM) (Bonnicksen 2008, also see Appendix A). They include the Angora, Fountain, Moonlight, and Star Fires. The purpose of this report is to illustrate the impact of wildfires on greenhouse gas emissions and the importance of thinning forests to prevent wildfire emissions, as well as the significance of removing dead trees and replanting to restore forests and recover greenhouse gases emitted by wildfires.

The 2007 Angora and Moonlight Fires also illustrate an opportunity that is still available to remove dead trees from public forestlands and to manufacture solid wood products before the trees lose their economic value. The money could be used to help pay for planting. This would restore these forests at minimal cost to the public, reduce and recover greenhouse gases from these wildfires, protect nearby communities from another wildfire, and help fight global warming.

Wildfires Analyzed Using FCEM

The Angora Fire: The Angora Fire burned from June 24 to July 10, 2007, sweeping across 3,100 acres of dense forest largely on national forest land west of South Lake Tahoe. The fire killed about 80 percent of the big trees and destroyed 254 homes. As of March 2008, the U.S. Forest Service has not taken action to remove dead trees and plant young trees to restore the forest.

The Fountain Fire: Recognized as one of the worst fires in California history, the Fountain Fire destroyed 59,840 acres of mostly private forestlands and more than 300 homes in the Sierra Nevada, about 40 miles east of Redding in August 1992. Unlike many other burned forests, this forest is well on its way to a full recovery because private forest landowners harvested fire-killed trees and planted young trees.

The Star Fire: The Star Fire burned 16,171 acres (about 11,930 acres of public land and 4,241 acres of private land) in September 2001 in the Tahoe and Eldorado National Forests in the northern Sierra Nevada. Fire-killed trees were harvested on 93 percent of private forestlands and young trees were planted on 52 percent. The Forest Service removed dead trees on 39 percent of their burned land and planted young trees on 19 percent.

The Moonlight Fire: The Moonlight Fire burned 65,714 acres (47,174 acres of public lands and 18,540 of private lands) in September 2007 in the Plumas National Forest in the northern Sierra Nevada, spreading smoke throughout the Sacramento Valley. Private forest landowners are removing dead trees and planting young trees, but as of March 2008, the Forest Service hasn't released a plan to restore public forestlands.

Data Sources

Data used in this report come from personal on-site visits, aerial and other photographic evidence, published materials, first-person accounts, private forest landowners, and government representatives.

Pre-fire Forests

FCEM requires a minimum of input data to analyze the climate impacts of wildfire. The first step is to describe the forest as it was before a wildfire. This provides the initial conditions that contributed to the size and severity of a wildfire.

Describing Pre-fire Forests

Input data specified by the user to describe the pre-fire forest and use FCEM include total acres, percent of acres occupied by conifers, the number of trees per acre, and the percent of trees by species (i.e., species composition) of the conifer forest. The forest can be even-aged or uneven-aged. The default forest is uneven-aged. The four wildfires analyzed in this report burned mostly in uneven-aged forests, with trees of all sizes intermixed, creating an extreme fire hazard.

If present, the user also specifies shrub and/or chaparral percent cover as well as the percentage of the acreage in shrubs, chaparral, and/or Western oak. Shrubs are normally a part of forests, occupying small openings and growing in the understory when the overstory is relatively open. Table 1 shows the proportion of four vegetation types in each burned forest.

Table 2 shows the species composition of the four forests that burned in these wildfires. It also illustrates that these are mixed-conifer forests with slightly different mixes of species.

Table 1. Vegetation types in burned forests.

Vegetation Type	Angora Fire (%)	Fountain Fire (%)	Star Fire (%)	Moonlight Fire (%)
Conifer-oak	95.0	100.0	86.2	96.3
Shrubs	5.0		2.0	2.8
Chaparral			4.8	
Western oak			7.0	0.9

Table 2. Species composition of burned forests.

Species	Angora Fire (%)	Fountain Fire (%)	Star Fire (%)	Moonlight Fire (%)
Coast redwood				
Douglas-fir		13.0	37.6	15.56
Cedar	2.0	29.0		22.34
Lodgepole pine	5.0			0.03
Ponderosa/Jeffrey pine	59.0	7.0	52.6	22.95
Sugar pine		3.0		7.01
True fir/hemlock	34.0	38.0	9.9	27.43
Oak/tanoak		10.0		4.68

Table 3 shows the specified acreage burned, density of trees greater than or equal to 2 inches in diameter at breast height (dbh), and estimated weight of surface fuels in each forest.

In addition, Table 3 makes clear that all four pre-fire forests were too dense. These overcrowded forests formed a uniform mass of fuel spreading over the landscape. They averaged 350 trees per acre when

50-60 trees per acre would be natural. They also contained unnaturally heavy surface fuels composed of litter, duff, down dead wood, shrubs, and small trees that ranged from an estimated 25 to 40 tons per acre. Tree density, especially young trees growing under larger trees as ladder fuel, and surface fuels are the two most important contributors to the size and severity of wildfires.

Even so, these forests were less dense than some forests in the Sierra Nevada that have as many as 1,000 trees per acre, including areas within the Tahoe Basin. In addition, much of the private forestlands burned in these four wildfires were in an early phase of a transition to well managed forests that would have been less vulnerable to fire.

The catastrophic wildfires that ravage California each year don't resemble the historic fires that took place in these forests for millennia. Natural fires set by lightning and Native people were frequent and light, burning mainly surface fuels and igniting only scattered small groups of trees (Bonnicksen 2000, 2007). They didn't sweep across landscapes destroying whole forests, killing wildlife, destroying habitat, baking soils into hardened clay that can't absorb rainwater, and causing massive erosion as modern wildfires do today. Unlike the overcrowded and unhealthy forests we see now, most historic forests were open, diverse, and more resistant to catastrophic fires.

Table 3. Area burned, density, and FCEM estimates of surface fuels in burned forests.

Wildfire	Area Burned (acres)	Density (trees/acre)	Surface Fuels* (tons/acre)
Angora Fire	3,100	273	25.4
Fountain Fire	59,840	301	24.5
Star Fire	16,171	400	39.7
Moonlight Fire	65,714	428	37.6

* Surface fuels include litter, duff, down dead wood, small understory trees, shrubs, and chaparral.

Mortality

Computations for estimating greenhouse gas emissions from wildfires in FCEM require the user to specify percent mortality for understory and overstory vegetation. Other factors that affect greenhouse gas emissions, such as biomass consumption by fuel component, and emissions by greenhouse gas type and fuel component are part of FCEM. These factors, as well as equations, can change as new information becomes available.

Table 4. Understory and overstory mortality in burned forests used in FCEM.

Wildfire	Understory Mortality (%)	Overstory Mortality (%)
Angora Fire	95	80
Fountain Fire	100	100
Star Fire	100	81
Moonlight Fire	95	90

Table 4 shows the percent mortality specified in FCEM for each wildfire based on available information. Even so, computer simulations show that minor changes in percent mortality have little effect on estimated greenhouse gas emissions.

Greenhouse Gas Emissions from Combustion

Table 5 shows greenhouse gas emissions from combustion caused by the four wildfires analyzed in this report. The average is 62.8 tons of greenhouse gases emitted per acre. This is typical for California fires burning in today's overcrowded forests. They exceed emissions that would have occurred in historic fires because the biomass available to burn is so much greater than it was in natural forests.

Table 5. FCEM estimates of greenhouse gas emissions from combustion by wildfire.

Wildfire	Greenhouse Gases* (tons)	Greenhouse Gases* (tons/acre)	GWP** Emissions (tons CO2e)	GWP** Emissions (tons CO2e/acre)
Angora Fire	143,129.0	46.2	156,169.7	50.4
Fountain Fire	3,196,172.2	53.4	3,489,198.2	58.3
Star Fire	1,240,688.5	76.7	1,354,463.2	83.8
Moonlight Fire	4,910,941.6	74.7	5,360,989.1	81.6

* Carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O).
** GWP means Global Warming Potential. CO_2 is the baseline at a value of 1. CH_4 has a GWP of 21x CO_2, and N_2O has a GWP of 321x CO_2 (Houghton et al. 1996, U.S. Environmental Protection Agency 2002).

The emissions in Table 5 are large and difficult to interpret without comparisons. Therefore, Table 6 shows how many cars would be added to California's highways for one year, each spewing tons of greenhouse gases out of the tailpipe, to equal combustion emissions. Seen another way, it shows how many cars in total and cars per acre burned that would have to be taken off the road and locked in a garage for one year to make up for the global warming impact of these four wildfires.

Greenhouse Gas Emissions from Combustion and Decay

Combustion emissions occur during a wildfire, but they are only part of the story because dead trees also gradually release CO_2 as they decay. Dead trees generally decompose within about 100 years, most of the decay occurring in the first 50 years. As a conservative estimate, FCEM considers dead biomass left after a fire as carbon that will decay in 100 years and computes the amount of CO_2 released accordingly.

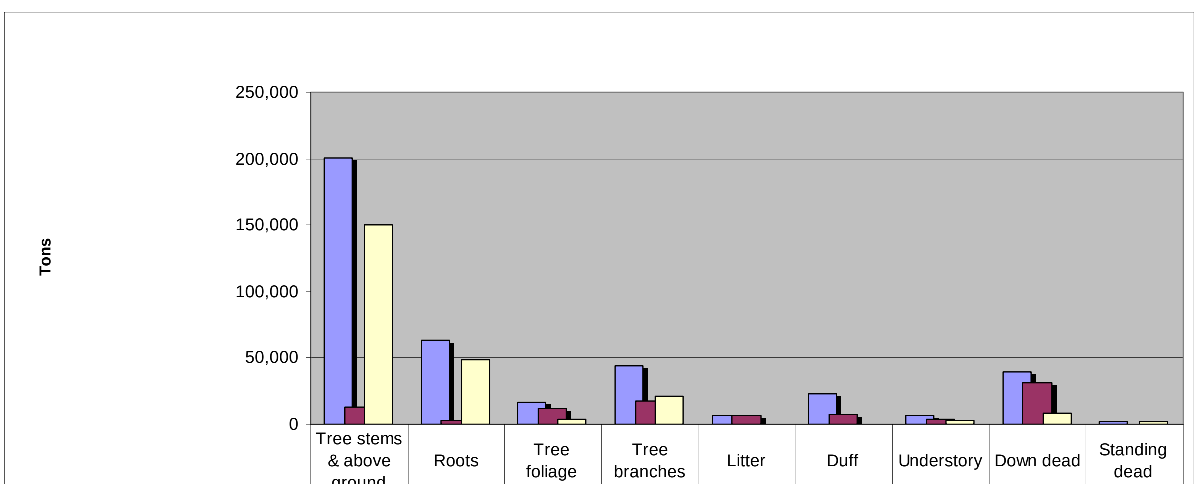
Greenhouse gas emissions from decay are generally larger than combustion emissions. The reason is that 3.67 times the carbon content of biomass is released as CO_2 during decomposition. Therefore, forests emit more CO_2 when they decay than when they burn because large quantities of biomass remain in the forest after combustion. However, chaparral and brush fields burn more completely, so combustion emissions can exceed decay emissions.

Table 6. FCEM estimates of passenger car equivalents for combustion emissions by wildfire.

Wildfire	Passenger Car Emission Equivalents* for Combustion (cars)	Passenger Car Emission Equivalents* for Combustion (cars/acre)
Angora Fire	28,166	9
Fountain Fire	629,294	11
Star Fire	244,284	15
Moonlight Fire	966,880	15

* Based on the average passenger car emitting 5.03 metric tons of CO_2e (CO_2 equivalent) per year (U.S. Environmental Protection Agency 2005).

Figure 1 demonstrates the pre-fire biomass and the amount consumed by combustion and decay in the Angora Fire, which shows relative amounts typical of the four wildfires. In FCEM, the unburned or post-fire biomass decomposes after a catastrophic wildfire in proportion to the percent overstory and understory mortality.



	Tree stems & above ground	Roots	Tree foliage	Tree branches	Litter	Duff	Understory	Down dead	Standing dead
Pre-fire biomass	200,531.56	63,564.10	16,913.00	44,281.92	6,862.10	22,642.12	6,818.41	39,593.25	1,798.71
Biomass consumed by fire	12,666.63	2,544.90	12,177.36	17,712.77	6,518.99	7,313.41	3,886.49	30,843.14	128.16
Biomass consumed by decay	150,372.22	48,719.04	3,788.51	21,255.32			2,785.32	8,312.60	1,587.02

Figure 1. FCEM estimates of pre-fire biomass and biomass consumed by combustion and post-fire decay by forest component in the forest burned by the Angora Fire.

Combining combustion and decay emissions provides a more complete picture of the impact of wildfires on global warming. In general, CO2 emissions from decay after a forest fire are three times the amount emitted during combustion. Table 7 shows the magnitude of CO2 emissions for the four forest fires analyzed, including passenger car equivalents.

Table 7. FCEM estimates of CO2 emissions from combustion and decay and passenger car equivalents by wildfire.

Wildfire	CO2 Emissions from Combustion & Decay* (tons)	CO2 Emissions from Combustion & Decay* (tons/acre)	Passenger Car Equivalents for Combustion & Decay (cars)	Passenger Car Equivalents for Combustion & Decay (cars/acre)	Proportion of Annual Passenger Car Emissions** (%)
Angora Fire	571,543.2	184.4	105,503	34	0.75
Fountain Fire	13,044,610.0	218.0	2,407,094	40	17.19
Star Fire	4,457,242.9	275.6	825,021	51	5.89
Moonlight Fire	19,657,975.0	299.1	3,629,015	55	25.9

* Includes roots, but not soil. Decay emissions occur over a 100-year period.
** Based on 14 million passenger cars on the road in California in 2005 (California Air Resources Board 2006).

The immensity of greenhouse gas emissions illustrated in Table 7 from just these four wildfires is a warning. Clearly, we must make every effort to reduce the amount of excess biomass in forests to prevent catastrophic wildfires. That means thinning trees to restore the natural health and diversity of forests and to make them more resistant to crown fires. Reducing wildfires maybe the single most important action we can take in the short-term to reduce greenhouse gas emissions and fight global warming.

Wood Products and Recovering Emissions

FCEM computes biomass, carbon, and CO2 stored in solid wood products produced by removing trees through thinning and harvesting or dead tree removal after a wildfire or insect infestation. Estimated amounts of CO2 stored in wood (as the CO2 equivalent of the carbon content) is deducted from decomposition emissions because the wood is no longer available for decay.

These estimates are conservative. In addition, this approach doesn't consider the use of wood waste, a renewable resource, for generating electricity that can substitute for electrical energy produced by burning non-renewable fossil fuels. The savings in greenhouse gas emissions can be significant.

Table 8 shows the estimated amount of CO2 recovered by removing fire-killed trees from the four burn areas analyzed in this report. In this case, recovery means preventing CO2 from being released during decay by storing the carbon content of dead trees in solid wood products.

Table 8. Area of dead tree removal on private and public forestlands burned by four wildfires and FCEM estimates of CO2 recovered by storing it in solid wood products (as the CO2 equivalent of the carbon content of wood) and preventing losses from decay.

Wildfire	Dead Tree Removal (acres)	Dead Tree Removal**** (% burned area)	CO2 Recovered (tons)	CO2 Recovered (% of loss)
Angora Fire*	0	0	0	0
Fountain Fire**	59,840	100	1,927,038.1	14.8
Star Fire	8,633	76.5	493,880.0	11.1
Moonlight Fire***	17,613	31.1	915,419.4	4.7

* The Forest Service removed some hazard trees and an unaffiliated organization removed dead trees on a small area of the burn, but data are unavailable.
** This excludes non-industrial private forestlands.
*** Dead trees removed and planned for removal only from private forestlands.
**** The total acreage burned is reduced in proportion to the percent overstory mortality. Therefore, the percent of burned area is the percent of the area with overstory mortality.

Planting and Recovering Emissions

Planting a young forest to replace one killed by wildfire or insects can recover most — if not all — the CO2 lost to the atmosphere from combustion and decay. FCEM uses the plant and minimal-management strategy for public lands because the Forest Service rarely uses herbicides, which is the most effective way to release seedlings overtopped by shrubs. Even so, FCEM considers planted areas on public lands as future forest even though many areas will become permanent brush fields.

FCEM considers unplanted areas as future brush fields because most catastrophic wildfires in California kill nearly all seed trees, as was the case in the four wildfires analyzed in this report. This aspect of FCEM can be adjusted for particular forests.

Private forest landowners use a plant and intensive-management strategy that usually succeeds. Likewise, this strategy grows trees more quickly than the plant and minimal-management strategy. That means trees absorb CO_2 from the atmosphere through photosynthesis at a greater rate as well.

The plant and intensive-management strategy also includes the storage of CO_2 in solid wood products (as the CO_2 equivalent of the carbon content of wood) because private forest landowners usually harvest trees within 40 to 80 years after planting. In addition, CO_2 absorbed from the atmosphere by replanting more than makes up for emissions from decomposition of biomass left on the ground after harvest.

Given past experience, it is unlikely that the Forest Service will harvest trees after planting. Therefore, FCEM excludes potential storage of CO_2 in solid wood products from planted public forestlands.

FCEM uses only the biomass, carbon, and CO_2 stored in stems, branches, foliage, and roots of trees on the acres planted for both the plant and minimal-management strategy and the plant and intensive-management strategy. CO_2 absorbed from the atmosphere by the planted trees and storage in solid wood products is deducted from combustion and decomposition emissions to assess the amount recovered.

Table 9 shows the area planted, and CO_2 recovered from absorption and storage in solid wood products consumers need from a single harvest on private post-fire planted forestlands. Table 9 doesn't include the removal of dead trees. Table 10 summarizes what has been accomplished and what is planned, in total, to recover greenhouse gases.

Table 9. Area planted on private and public forestlands after four wildfires, including FCEM estimates of CO_2 absorbed and stored in solid wood products (as the CO_2 equivalent of the carbon content of wood) from interim harvests on private lands.

Wildfire	Planted Private Land (acres)	Planted Public Land (acres)	Plantings on Burned Land (% area)	CO2 Recovered from Absorption (tons)	CO2 Recovered from Future Harvest (tons)	Total CO2 Recovered (tons)	Total CO2 Recovered (% of loss)
Angora Fire*	0	0	0	0	0	0	0
Fountain Fire**	59,840	0	100	10,954,924.3	1,988,954.3	12,943,878.6	99.2
Star Fire	2,230	2,185	39.1	1,589,327.5	164,083.3	1,753,410.8	39.3
Moonlight Fire***	17,613	0	31.1	6,188,153.6	1,132,210.9	7,320,364.5	37.2

* The Forest Service has no known plans to plant trees on burned areas.
** This excludes non-industrial private forestlands.
*** The Forest Service has no known plans to plant trees on burned areas. Tree planting on private forestlands is underway.

The most important question is: Can we recover from our mistake of letting forests become unnaturally overcrowded with trees and vulnerable to catastrophic wildfires? The answer is "yes", if we care about restoring our forests and fighting global warming. The results in Table 10 make the point.

Table 10. FCEM estimates of total CO_2 recovered from dead tree removal, planting, and an interim harvest of planted trees on private forestlands for the four wildfires analyzed.

Wildfire	Grand Total of CO2 Recovered (tons)	Grand Total of CO2 Recovered (% of loss)
Angora Fire	0	0
Fountain Fire	14,870,916.7	114.0
Star Fire	2,247,290.9	50.4
Moonlight Fire	8,235,783.8	41.9

This report documents accomplishments, planned and completed, to reduce greenhouse gas emissions from four areas blackened by catastrophic wildfires. Even so, opportunities still exist to do even more to restore these burned forests and fight global warming. The Fountain Fire is already a success story and private forest landowners and the Forest Service are restoring much of the area burned by the Star Fire. However, forests burned by the Angora and Moonlight Fires still present opportunities for action.

The Angora Fire

The Angora Fire of 2007 charred 3,100 acres of forest in the Tahoe Basin because the trees were so dense. High winds hurled burning embers as far as two miles ahead of the fire front. The sky rained fire on homes and forests, setting them ablaze and covering everything in ash and smoke. Many homeowners had no chance to save their houses, even with defensible space.

Using pre-fire data for the forest burned in the Angora Fire, FCEM estimates that combustion emissions could have been lowered from 46.2 tons per acre to 12 tons per acre if the density of trees had been reduced from 273 per acre to the more natural density of 60 per acre. A fire burning in the same forest after thinning would have killed few large trees, covered far less acreage, and left adjacent communities relatively unharmed.

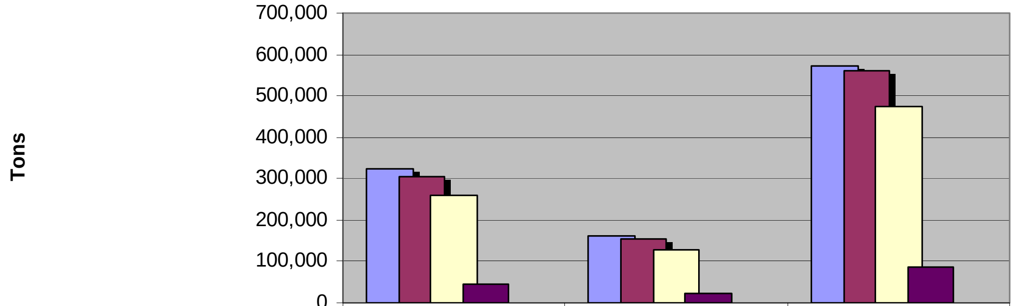
That is what could have been, but it also illustrates the opportunity that still exists to protect the rest of the Tahoe Basin, especially Lake Tahoe, and prevent massive greenhouse gas emissions. The Angora Fire illustrates a disaster that will occur again in the Tahoe Basin, but on a larger scale and with far more devastating consequences if the forest isn’t restored to its historic crown-fire resistant condition.

The next question is: What do we do on the area burned by the Angora Fire? FCEM provides estimates of the climate-related benefits of taking action now to restore the forest before the opportunity slips away.

Fire-killed trees decay rapidly. The window of opportunity for removing dead trees while they still have economic value lasts about two years, and one year has already been wasted. That means that harvesting trees in 2008 could provide the money needed to plant a new forest. Waiting another year will be too late because the trees will decay and lose their economic value. As a result, the area probably won’t be planted because the government can’t afford it.

Either way, it is essential to remove dead trees. Not only does it make it safe to plant, but it also reduces emissions from decay by storing CO_2 in solid wood products. Equally important, removing dead trees and replanting would help protect surrounding communities from a second wildfire, which is called a re-burn, that often occurs in fire-killed forests that become brush fields filled with dead trees.

Figure 2 illustrates what could be accomplished to recover greenhouse gas emissions from the Angora Fire. These estimates are based on 80 percent overstory mortality, which means about 2,356 acres of the forested portion of the 3,100 acres burned in the fire are available for dead tree removal and planting. FCEM estimates that 98 percent of CO_2 lost in the wildfire could be recovered during a 100-year period by removing dead trees before they decay, converting them into solid wood products, and planting young trees that absorb carbon from the atmosphere.



	Total Biomass (no soil)	Total Carbon (no soil)	Total CO2 (no soil)
Loss (combustion & decay)	323,057.5	161,528.7	571,543.2
Total recovered (trees & wood)	305,356.1	152,678.0	560,328.4
Recovered (planted trees)	258,993.4	129,496.7	475,253.0
Recovered (dead tree wood)	46,362.6	23,181.3	85,075.4
Recovered (harvested wood)	0.0	0.0	0.0

Figure 2. FCEM estimates of biomass, carbon, and CO2 lost from combustion and decay in the Angora Fire and the amount that could be recovered from converting dead trees into solid wood products (computed as the CO2 equivalent of the carbon content of wood) and absorption from the atmosphere by photosynthesis from planted trees. (This is a national forest, so it is unlikely that CO2 will be stored in solid wood products from the future harvest of trees planted in burned areas.)

The Moonlight Fire

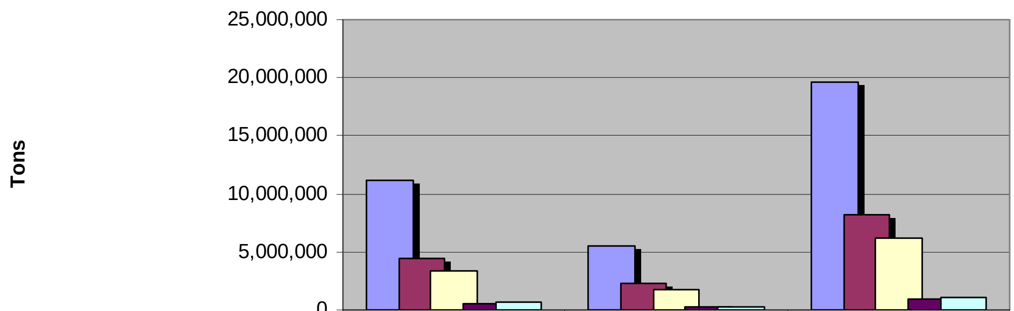
The 2007 Moonlight Fire burned 65,714 acres in the Plumas National Forest in the northern Sierra Nevada. This was a catastrophic wildfire. Private forest landowners are removing dead trees and planting young trees on their forestland. As of winter 2007-2008, the Forest Service hasn't released a plan to restore public forestlands.

Even so, the opportunity still exists to recover all the CO2 lost in the Moonlight Fire if the process of dead tree removal and planting begins in the summer of 2008. After that, it is unlikely that anything will be done on public lands because of the enormous cost.

Without money made available from harvesting and selling fire-killed trees, there is little chance that the Forest Service will be able to pay to remove dead trees, plant young trees, and manage the young forest by releasing overtopping brush to ensure that a brush field doesn't take over the area.

The Moonlight Fire killed about 90 percent of the larger trees, which means 56,972 acres of the forested portion that burned in the fire are available for dead tree removal and planting. Private forest landowners are removing dead trees and replanting on 17,613 acres, which is 95 percent of their acres. The Forest Service has 39,359 acres available for dead tree removal and planting.

Figure 3 illustrates what could be accomplished, including what private forest landowners are already doing, to recover greenhouse gas emissions from the Moonlight Fire if the Forest Service takes action to restore their forestland. FCEM estimates that 112.7 percent of the CO_2 lost in the wildfire could be recovered in 100 years by removing dead trees, converting them into solid wood products, planting young trees that absorb carbon from the atmosphere, and in several decades, creating wood products from harvesting trees from replanted private forestlands.



	Total Biomass (no soil)	Total Carbon (no soil)	Total CO2 (no soil)
Loss (combustion & decay)	11,113,808.1	5,556,904.0	19,657,975.0
Total recovered (trees & wood)	4,488,165.6	2,244,082.8	8,235,783.8
Recovered (planted trees)	3,372,290.8	1,686,145.4	6,188,153.6
Recovered (dead tree wood)	498,866.2	249,433.1	915,419.4
Recovered (harvested wood)	617,008.6	308,504.3	1,132,210.9

Figure 3. FCEM estimates of biomass, carbon, and CO2 lost from combustion and decay in the Moonlight Fire and the amount that could be recovered from converting dead trees into solid wood products (computed as the CO2 equivalent of the carbon content of wood) and absorption from the atmosphere by photosynthesis from planted trees. (This estimate includes CO2 stored in solid wood products from the future harvest of trees planted on private forestlands.)

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Appendix A: The Forest Carbon and Emissions Model (FCEM)

Only recently has it been possible to estimate greenhouse gas emissions from wildfires and insect infestations. The Forest Carbon and Emissions Model (FCEM) used in this study is at the forefront of making these estimates (Bonnicksen 2008). The model is unique among available carbon models because of its simplicity and relevance to forest management. Even so, there is no accepted standard model for greenhouse gas emissions and carbon sequestration.

FCEM is a deterministic biomass-based model that uses an Excel spreadsheet to compute estimates. The model calculates estimates by systematically linking existing equations, ratios, and conversion and emission factors from a variety of recently published peer-reviewed scientific and other technical sources. The latter sources include non-peer-reviewed reports from universities, government agencies, and consulting firms.

In particular, FCEM computes above ground tree biomass using generalized allometric equations approved by the California Climate Action Registry (2007) as shown in FCEM Report 1 (Bonnicksen 2008) and reports cited by California Climate Action Registry (Brown et al. 2004a, 2004b, 2004c). FCEM computes estimates based on formulas and data from specific areas rather than relying on extrapolating results from case studies or generic forests and applying them to other places that may or may not be similar.

FCEM is a tool for conducting preliminary inventories of forest biomass, carbon, and CO2 stored in a particular forest, now or in the future, including tree stems, roots, foliage, branches, litter, duff, understory, down dead, standing dead, and soil. Other more comprehensive models should be used for scientific investigations and carbon accounting.

FCEM also includes four scenarios for estimating the impacts of fire and insect infestations, the benefits of removing dead trees and converting them into solid wood products, thinning, and planting. The model also estimates the relative impacts of wildfire and prescribed fire on emissions, before and after thinning, and thinning with and without prescribed fire. FCEM compares impacts and benefits in terms of greenhouse gas emissions and carbon sequestration and storage.

The goal behind the Forest Carbon and Emissions Model (FCEM) is to create an awareness of the impact of wildfire and insect infestations on greenhouse gas emissions and opportunities to prevent and recover from these disasters.