Biomass thinning for fuel reduction and forest restoration—
Issues and opportunities

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Background: With the high incidence of wildfires in the West, there is interest in the methods to treat forest fuels to reduce fire hazard, their economics and infrastructure needs, and potential impacts on wildlife habitat and soils. Northern California has the most comprehensive and long-term examples of the ecological effects and economic feasibility of fuel reduction and forest restoration methods utilizing biomass thinning. This is in part due to the proximity of biomass fueled electric power plants and small log sawmills to the forests.

The nature of the problem: Some believe the size and severity of forest wildfires has increased over the past decade, increased above historic levels, and that this increase is detrimental to human property, health and lives as well as environmental values, particularly watershed, wildlife habitat, soil erosion, and scenery. Therefore, we should do what we can to minimize wildfire extent and severity. Others argue that the size and severity of fires is natural, within the range of historic variability, and therefore not detrimental, and that we should let the fires run their course to bring the forest ecosystem back into some historic equilibrium. Furthermore, human actions to mitigate fire extent and severity is as bad or worse than the wildfires themselves, so we should not do anything or just do treatments near human communities.

Fire has been a part of many forest ecosystems in the western US since the last ice age, 10,000 years ago, and those ecosystems and their species have adapted to relatively frequent fires of low to moderate intensity and severity. Depending upon forest type, the area burned could be quite large. Such fires would remove surface fuels which had accumulated since the last fire—leaves, branches, grasses, shrubs—as well as kill small trees, creating a more open structured forest.

Not all fires are catastrophic and stand replacing, or uniformly catastrophic and stand replacing for any single fire event. e.g. the 1988 Yellowstone Fire was 2 million acres in total extent but only part of that area burned severely and killed all the trees. Forest ecosystems also vary in their natural frequency and severity of fire depending upon their climate, plant species, topography.

Biomass thinning:
Historic photos, fire histories constructed from tree fire scars, and historic written accounts suggest a significant proportion of the interior, ponderosa pine dominated forest was more open, less densely stocked than today. (Figure 1).

Lassen NP
Early 20th Century — Same place 1992

Figure 1— Repeat photo at Lassen Volcanic National Volcanic Park showing increase in understory vegetation.

Today's dense stocking of understory trees constitute fuel ladders which carry surface fires into the crowns of the larger overstory trees, producing crown fires which are difficult to suppress. These understory trees also represent competition for limited soil moisture (and nutrients to a lesser extent) and produce stress, especially during droughts, which make trees more susceptible to bark beetles and disease. Thus removing or thinning the understory trees can both remove ladder fuels and reduce moisture stress.

Understory trees comprising ladder fuels are usually small, 2 to 6 inches at DBH (diameter at breast height, 4.5 ft. above ground surface) and 10 to 40 ft. in height. Trees 6 to 10 inches DBH are probably not ladder fuels, but do represent competition for soil moisture, and are part of the increased density of the forest due to past fire suppression. Depending upon local timber markets, trees 6 to 10 inches DBH can be merchantable and capable of paying their way out of the forest and to a sawmill. Trees which are not merchantable must be disposed of on site by burning or mastication, or chipped and hauled away at a cost of $100 to $500 per acre or more. Thus a major issue for biomass harvesting or thinning is how large and how many trees to remove, in what spatial pattern (it need not be uniform), and at what cost (harvesting larger trees with merchantable value can offset the net cost of treating the small, unmerchantable trees)?

Some have raised concerns regarding economic utilization of biomass, that the raw material supply demands of sawmills and power plants will dominate the biomass thinning planning and lead to unsustainable harvesting practices, harvest levels detrimental to wildlife habitat, watershed function, and soil productivity. Commercial utilization opportunities would bias the forest management decisions. Others argue that getting some economic return for biomass utilization would stretch funds available for fuel reduction and forest restoration, allowing more acres to be treated.

Utilization of forest biomass:

In addition to small diameter logs for timber, wood chips have value as fuel for electric power plants. There are technologies for utilizing small logs and wood chips for composite wood products (oriented strand board (OSB), particle board, plywood) and chemicals (ethanol, plastics, the same carbon based chemistry products that are made from petroleum). (Shelly. 2003). The major obstacle to utilizing these technologies for forest biomass is the capital investment in the facilities and competing, lower priced feed stock (natural gas and petroleum for electric energy; subsidized corn for ethanol). Wood fueled power plants were built in California in the 1980s in response to the 1978 Public Utilities Regulatory Policy Act (PURPA) which created financial incentives for renewable energy production – solar, wind, geothermal, and biomass. The guarantee of stable prices for 10 years made the investments in the power plants feasible. Those incentives have since ended and biomass fueled electric power is now only marginally profitable. Proponents of biomass utilization cite reduced fire hazard, reduced emissions from wildfire, reduced dependence on fossil fuels, and improvement in forest health as non-market benefits that society should provide incentives for.

The northern California situation:

The proximity of biomass power plants and small log sawmills to the forests in northern California has created a currently unique opportunity to economically conduct biomass thinning projects. For low value products like small diameter logs and biomass chips, the cost of hauling is the major variable cost that will economically make or break a project. Thus, an infrastructure to utilize small logs and chips must be in close proximity to the forest.

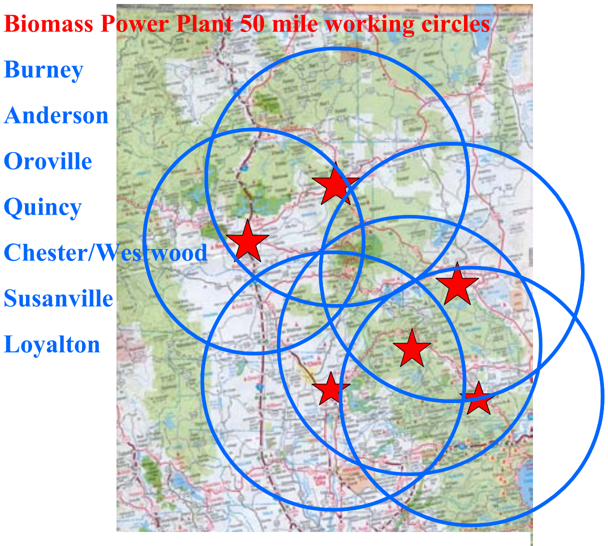

Figure 2—N. California biomass powerplant distribution and fuel supply areas

(Figure 2).

Biomass harvesting considerations:

Forest surface fuels comprised of needles, leaves, branches, logging slash are the most important fuel to treat, as they drive overall fire behavior. Ladder fuels comprised of small trees, large brush, and lower branches of overstory trees will carry surface fires into the crowns of trees under some conditions. In California, crown fires are usually supported by the surface and ladder fuel complex, not crown fuel levels.

Forest biomass harvesting of ladder fuels became feasible with the advent of mechanical harvesting equipment and systems. Manually cutting hundreds of small diameter (2 to 4 in. DBH) trees per acre, and lopping and scattering them can be done for a few hundred dollars per acre, but merely changes ladder to surface fuels, negating some of the fuel reduction value of the treatment. Removal of the biomass to a pile for burning or a chipper to produce chips will cost a few hundred more dollars per acre. Trees 4 to 10 in. DBH would probably not be thinned to waste in this

Figure 3—Initial stand (top), immediately following biomass harvesting, and 8 years after treatment.

manner, thus leaving the unthinned stand in an overstocked, high competition, high fuel condition. (Figure 3).

Biomass harvesting consists of tree shears/ saws (feller-buncher) traveling to the tree, severing the stem, holding onto the stem, traveling to the next tree, severing the stem, bunching that stem with the first, and so on until the gathering arms are full, then depositing the bunched stems in a pile or bunch, called a doodle. (Figure 4).

The gathering of stems and creation of piles of stems is the primary advantage of mechanical harvesting and is what makes biomass harvesting economically feasible. It is not economically efficient to handle individual small diameter, low biomass, low value trees.

Once in a bundle however, the small trees can be efficiently yarded to and fed into a chipper. (Figure 4). Similarly, trees suitable for small logs are bunched, yarded to a log processor which delimbs the trees and cuts them into logs, and places them in piles for loading on

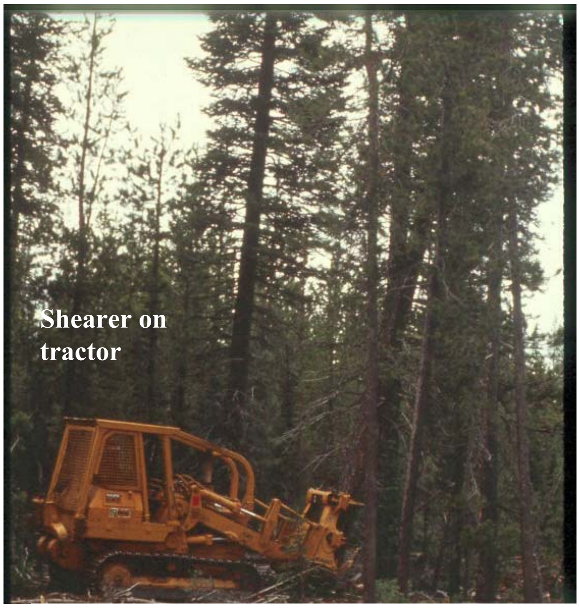

Figure 4—tree shearer felling and bunching trees

Figure 5—whole-tree chipping

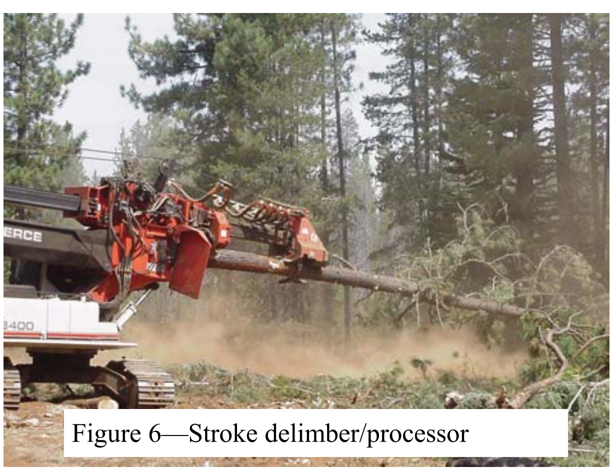

Figure 6—Stroke delimber/processor

trucks to the sawmill. (Figure 5). Again, it would not be economically efficient to yard individual small trees, manually delimb them and buck them into logs.

The dependence upon mechanical methods restricts biomass harvesting to flat to gentle slopes. Harvesting equipment can operate on 35 % + slopes but efficiency and economics suffer at steeper slopes. Most biomass harvesting has occurred on flat, 0 to 20 percent, slopes. Thus, extensive areas of eastside pine and mixed conifer on the volcanic terrains of NE California have been biomass harvested. Much of this flat forestland is also privately owned and highly productive, further justifying the practice and cost of thinning it for tree growth as well as fuel and fire hazard reduction. The steeper grounds of the Klamath Mountains, coast range, and the westside Sierra Nevada will be more difficult and expensive to biomass harvest. Biomass harvesting may be restricted to road rights-of-way, ridgelines, and the flatter topographies creating shaded fuel breaks or defensible fuel profile zones.

The fuel conditions created with biomass harvesting are not expected to be firebreaks which will stop wildfires by themselves. Crown fires are expected to drop from the crowns to the ground at a defensible fuel profile zone (DFPZ). A DFPZ is an area that has fuels modified in amount and form such than a crown fire will drop to the ground where firefighters can suppress it, where fire retardant drops will fall on the surface fuels driving the fire and not be hung up in the canopy. Without ground suppression crews using the DFPZ to control a surface fire, a fire can just burn along the ground and come out the other side of the DFPZ and resume as a crown fire.

Small log sawmills:

Small diameter logs, 4 to 20 inches in diameter and 8 to 32 feet in length, are economically processed in highly mechanized, computerized sawmills. Most sawmills in northern California have converted to efficiently handle small logs. Again, the proximity of these small log sawmills to the forests in northern California has made biomass harvesting economically feasible.

Surface fuels can be removed with prescribed burning, machine or hand piling and burning or reduced to a less flammable form by mastication or chipping and spreading.

Effect of biomass harvesting on wildlife habitat, soils:

Biomass harvesting is simply timber harvesting in the sense that green, live trees are being harvested; the same equipment and techniques are used; the same rules and regulations apply. Biomass harvesting focuses on the understory or smaller trees in a stand. Biomass harvesting thus has the impacts of timber harvesting on wildlife habitat and must be evaluated based upon what trees are being retained and the wildlife habitat that represents, immediately following treatment and over time as the forest regrows. (See Figure 3).

Because biomass harvesting is dependent upon mechanical harvesting, the impacts on the soils might be different than that of conventional timber harvesting, though these days mechanical harvesting equipment and methods are being utilized more and more in conventional timber harvesting of trees up to 20 inches DBH. Mechanical harvesting of many small diameter trees per acre requires machine traffic over much of the area. In one study on loam textured soils, about 1/3 of the harvested area was highly disturbed, 1/3 moderately disturbed, and 1/3 relatively undisturbed. Moderate and high disturbance did measurably increase soil bulk density and soil strength, but it is not clear yet what impact if any that increase will have on tree or plant growth, soil erosion, watershed function. Preliminary results from the long-term soil productivity study (Powers, 2003) indicates soil compaction increased bulk density and soil strength on loam soils but had only slight effects on biomass productivity over 10 years. Compaction of sandy textured soils in the SE US increased biomass productivity over uncompacted soils, possibly by increasing soil micropore volume and soil moisture retention.

Concern is sometimes raised about the effects of tree harvest, particularly whole tree harvest, on fertility, because most of a tree's nutrients are contained in its foliage. In temperate forest ecosystems, only 5-10% of the ecosystem's nitrogen or calcium is in the above ground biomass or vegetation (Figure 7), the bulk of the nutrients being stored in the soil. Thinning trees or biomass harvesting would remove only part of this above ground biomass, so the nutrient effects would be minimal except on soils with special fertility problems like serpentine soils deficient in calcium. Nitrogen, usually the most limiting nutrient, is added to the forest annually in the precipitation. Polluted air, nitrous oxides, can increase the average nitrogen increment of 2 lbs N/ac/yr.

TABLE 1. Nutrient pools–mixed conifer forest ecosystem

	Tree biomass	Tree nutrients lb/ac	
	10^3 lb/ac	Nitrogen	Calcium
	% of total appears in ( )		
Foliage	36 (8)	339 (5)	134 (1)
Branches	36 (8)	71 (1)	134 (1)
Bark	36 (8)	71 (1)	143 (1)
Stem wood	161 (33)	161 (3)	250 (3)
Tree total (above ground)	268 (57)	642 (10)	660 (6)
Forest floor	71 (15)	535 (8)	303 (3)
Soil (to 3 ft)	134 (28)	5,442 (82)	10,082 (91)
System total	473 (100)	6,620 (100)	11,045(100)

Source: Cole, D.W. and D. Johnson, 1979. *In Forest Soils of the Douglas Fir Region.* Heilman, P.E., H.W. Anderson, and D.M. Baumgartner, eds. Washington State Univ., Pullman, WA.
Powers, R.F. and K. Van Cleve, 1991. Long-term Ecological Research in Temperate and Boreal Forest Ecosystems. *Agron.* J. 83:11–24.
Gessel, S.P. et al., eds., 1980. *Forest Fertilization Conference, Proceedings.* Univ. of Wash., Inst. of Fores Resources. Contrib. No. 40.
Allardice, W.R. et al., 1983. *Laboratory data and descriptions for some typical pedons of California soils.* Vol. I – Central and Southern Sierra Nevadas.

Figure 7—Forest nutrient pools.

Effect of biomass harvesting on fuels and wildfire behavior:

The 1992 Fountain Fire (Roseburg Resources), 1999 Megram Fire (Six Rivers, Shasta-Trinity NF), 2001 Stream Fire (Antelope Lake), 2002 Cone Fire (Blacks Mt.) are examples of the effect of biomass fuel reduction treatments on wildfire behavior.

Figure 8—Biomass harvesting for site preparation at 1992 Fountain Fire

The 1992 **Fountain Fire** occurred under severe fire conditions following 6 years of drought and 22 days of 100 degree weather, and with 25 mph winds driving the fire. Some biomass thinning had just been completed on Roseburg Resources land, a thinning from below to improve the condition of the reserved overstory trees by removing competition. This thinning was done about 5 miles east of the origin of the Fountain Fire. Pushed by 25 mph winds, the fire had a lot of momentum when it entered the biomass thinning and burned through it, continuing on to the east. A crown fire when it entered the biomass thinned area, it appears to have dropped to the ground in the thinned area because the crowns of the overstory trees were scorched (and the trees killed) but not consumed by the fire. The thinned area was at most 600 ft wide in the direction of the fire, and maybe only 300 ft. wide, so it is not clear that a back fire or ground crews could have safely fought the fire here under the prevailing fire and wind conditions.

Also supporting the idea that the crown fire dropped to the ground is the fact that the cones on the ponderosa pine trees in the thinned area were not consumed or killed and cast their seed following the fire, naturally regenerating the 1000 acre biomass thinned area.

Thus the biomass thinned area in the Fountain Fire did bring the crown fire down to the ground. However, the biomass thinned area was insufficient to stop the fire by itself and it is not clear that fire crews could have safely utilized it to suppress the fire under the prevailing fire conditions, high winds.

The 1999 **Megram Fire** burned half of its 60,000 acres (on the Six Rivers NF) with moderate to high severity, killing 40 to 60% of the canopy (moderate severity) to > 70% of the canopy (high severity). (Horse Linto, Mill and Tish Tang Creek Watershed Analysis, March 2000). The Ridge Fire Reduction Project had been partially completed at the time of the Megram Fire. It was designed to create a DFPZ to serve as a primary control area for fire suppression, while maintaining northern spotted owl habitat conditions, most notably

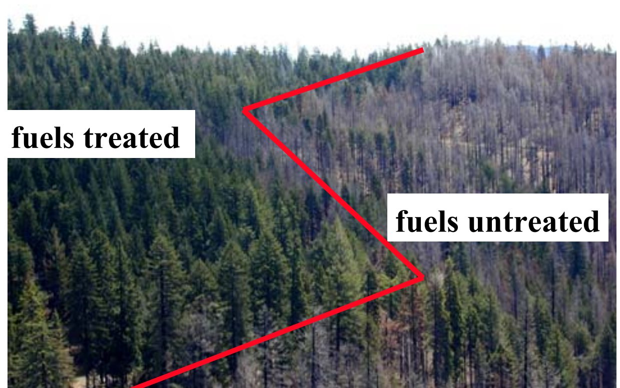

Figure 9—Megram Fire, Lone Pine Ridge

retention of at least 40% crown closure. Many units which had dead and downed trees removed and subsequently prescribe burned to reduce surface fuels had less than 40% mortality even without fire suppression assistance (Figure 9). On the other hand, a number of units which had only their large woody debris removed (Ridge and Onion Fire Reduction Projects were removing downed trees from a 1996 blowdown event) and surface fuels piled and burned sustained >40% mortality in the fire. The variation in fire behavior and severity in the DFPZ was attributed to treatment unit size and width, unit orientation to the fire, wind speed and weather conditions, time of day the fire burned through, date the fuel treatment was accomplished, the fact that DFPZs are not expected to stop fires without fire suppression assistance.

The 2000 **Goat Fire** burned into commercially thinned private industrial forestland (Roseburg Resources) which brought the crown fire to the ground and enabled the fire suppression crews to stop the fire. In addition to enabling ground crews to fight the fire, bringing the fire out of the crowns to the ground also made the fire retardant drops more effective. The commercial thinning occurred in 1990, 10 years before the Goat Fire, and consisted of mechanical shearing of small diameter trees (2 – 6 in. DBH) and harvest of commercial size sawtimber, producing a shaded fuel break even though a fuel break was not the primary objective of the harvest. (Figs 10,11, 12).

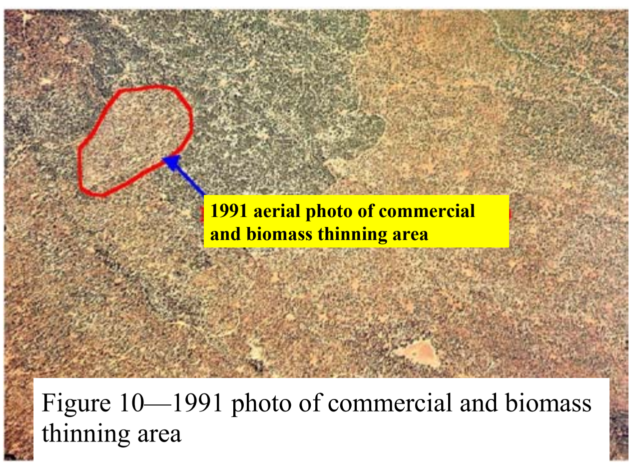

Figure 10—1991 photo of commercial and biomass thinning area

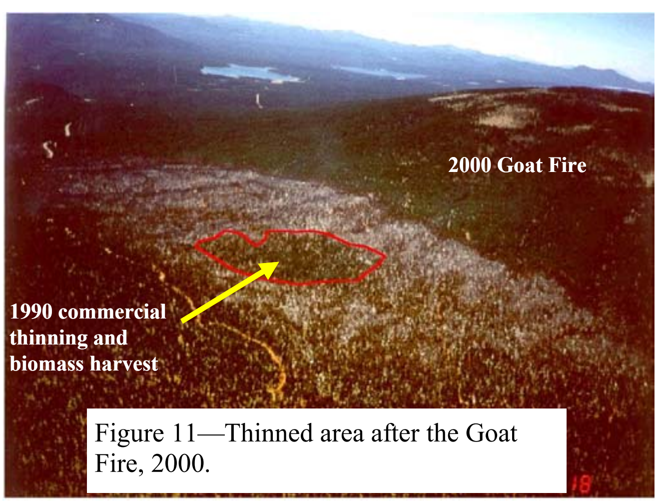

Figure 11—Thinned area after the Goat Fire, 2000.

Figure 12—Inside the thinned area following the Goat Fire

A shaded fuel break or defensible fuel profile zone (DFPZ) was installed west of Antelope Lake, Plumas National Forest. Small diameter trees were thinned out but it is not clear what, if any, surface fuel treatment was applied – piling and burning, prescribed fire. The August 2001 **Stream Fire** (or Stream Incident) burned 3500 acres, 2200 acres severely. The DFPZ burned moderately severely and appears to have been used by the fire fighters to stop the fire. (Figs. 13, 14).

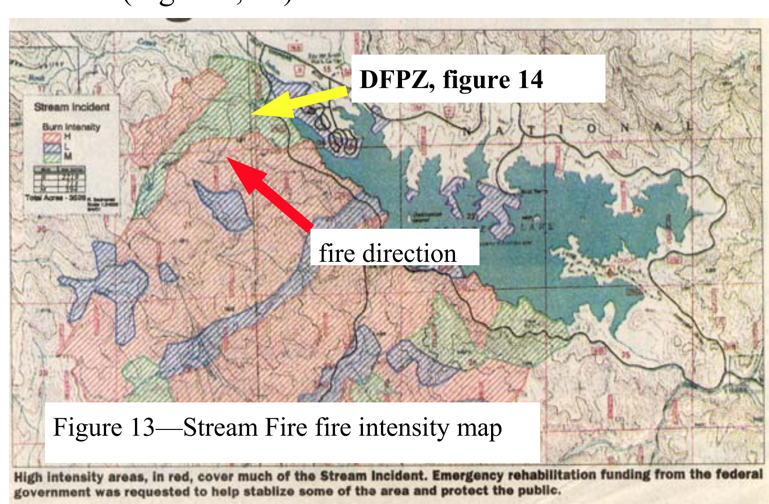

Figure 13—Stream Fire fire intensity map

Figure 14—Stream Fire, DFPZ. Fire burned on ground, scorching but not killing trees.

The 2002 **Cone Fire**, Lassen National Forest, occurred under very severe fire conditions of low humidity, very low fuel moistures, and 10 – 20 mph winds, following a long, dry period. It burned into the Blacks Mountain Experimental Forest which had received a series of thinning and prescribed burning treatments designed to study the ecological effects of creating very different stand structures. Fuel reduction and fire hazard reduction were secondary objectives of the treatments. Nonetheless, the crown fire in the untreated forest dropped to the ground and went out when it entered a unit which had been biomass thinned and subsequently prescribe burned to remove surface fuels. Where the thinning alone had been done without prescribe burning the surface fuels, the crown fire dropped to the ground and continued to burn as a surface fire which fire suppression crews could put out. The Cone Fire at Blacks Mountain Experimental Forest represents the best documented example of the effect of biomass harvesting and prescribed burning to treat fuels and modify wildfire behavior.

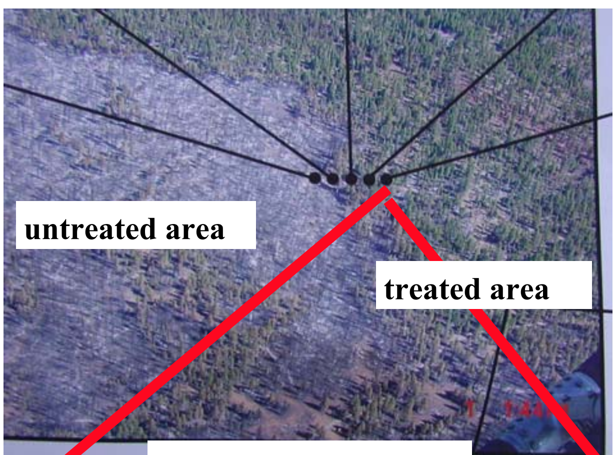

Figure 15—2002 Cone Fire

Figure 16—Cone Fire, biomass harvested with prescribed burn.

For more information on these fires:

Megram Fire – August and September 1999. http://www.cnr.berkeley.edu/forestry/curr_proj/megram/megram.html

Cone Fire – August 2002. http://groups.ucanr.org/forest/Cone_Fire_Tests_Fuel_Reduction_Treatment_Effectiveness/

Stream Fire or Stream Incident, Plumas National Forest, July 2001. Burned-Area Evaluation Report (BAER) .

Fountain Fire, August 1992, Round Mountain, CA. Primarily on industrial private forestlands. Evaluation of fire severity and pre-fire fuel conditions was not well documented.

References:

Powers, R. F. 2003. North American long-term soil productivity study. Presentation at the

Summer 2003 California Forest Soils Council field trip. July 24-25, 2003.

Shelly, J. R. 2003. Utilization of small logs, biomass. Presentation at the Biomass Thinning for Fuel Reduction and Forest Restoration field trip, July 17-18, 2003. Redding, CA.

Photo credits:
Figure 1—Allen Taylor, Pennsylvania State University

Figures 2, 7, 9, 12, 14, 16—Gary Nakamura, University of California Cooperative Extension

Figure 3—Stephen Jolley, Wheelabrator Shasta Energy.

Figures 4, 5, 6, 10, 11, 12 —California Dept. of Forestry and Fire Protection

Figure 8—Jeff Webster, Roseburg Resources

Figure 13— Plumas County, Bulletin, Progressive, Record, Reporter newspaper. Wednesday August 22, 2001

Figure 15— Lassen National Forest

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