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Flagstaff's wildfire fuels treatments: prescriptions for community involvement and a source of bioenergy

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Abstract

Flagstaff, Arizona, is a high elevation urban area in north-central Arizona surrounded by a dense ponderosa pine (*Pinus ponderosa*) forest. The annual wildland fire ignitions in and near to the urban area average over 200/year. Over the past 5 years, National Forest and city fire managers in the Wildland–Urban Interface (WUI) have developed a system of socially-welcomed fuel reduction treatments to reduce the wildfire threat to the community. These treatments have proven effective in reducing fire hazard, improving probability for successful initial attack on wildfires, maintaining and enhancing vegetative diversity, initiating improvement of overall forest health, and providing a local source of bioenergy. The long-term objective of the program is to facilitate socially acceptable stewardship of forested properties within the WUI. The Flagstaff WUI treatment prescription incorporates not only forestry and fire science, but also community and neighborhood input as vital components in successfully developing, implementing, and maintaining the treatments. Throughout the entire effort, project managers must maintain contact with and gather input from adjacent property owners and the community as a whole. Although current commercial markets are poor, there has been a great deal of success in utilizing bioenergy by designating free-use firewood areas. These events typically draw 200+ people who will remove 362 m^3 of wood in half a day. With over 1000 ha now treated, other benefits and lessons have been noted as well.
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1. Introduction

1.1. Background

After a series of large wildfires, a partnership of federal, state, local, and private organizations began a fire risk reduction program in 1997 for restoring 97,500 ha of overstocked conifer forests around the Flagstaff, Arizona, wildland–urban interface (WUI) zone [1–3]. Flagstaff lies within the largest contiguous portion of the 16.2 million ha of ponderosa pine (*Pinus ponderosa*) forest in North America.

Prior to European settlement in the 1860s, the ponderosa pine forest consisted of relatively open stands of large-diameter ponderosa pine with a significant grass-forb understory. Tree numbers

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averaged 75–125 trees/ha, with these trees arranged in small groups. Light surface fires occurred on the landscape at an average interval of 2–7 years. These low-severity fires consumed forest floor material, burned most of the young regeneration, and promoted growth of a dense, grassy understory. Catastrophic crown fires were rare due to the lack of ladder fuels, and the clumpy widely spaced ponderosa pine canopy [4,5].

Heavy sheep and cattle grazing and then modern forest fire control for most of the 20th century resulted in the development of dense, overstocked stands. Tree numbers range from 500 to 5000/ha. Canopy closures typically range from 50% to 70% but often approach 100%. An occasional juniper (*Juniperus* spp.), pinyon pine (*P. edulis*}, Douglas fir (*Pseudotsuga menziesii*), white fir (*Abies concolor*), Gambel oak (*Quercus gambelii*), limber pine (*P. flexilis*) or aspen (*Populus tremuloides*) are scattered among the pine stands. Insect and disease problems include dwarf mistletoe (*Arceuthobium* spp.) and periodic episodes of various bark beetles. Forest floor fuel loads that were 0.4–4.5 Mg/ha prior to 1870 increased by nearly two orders of magnitude to an average of 49 Mg/ha with some stands accumulating up to 112 Mg/ha [6]. Many ponderosa pine stands reached a critical ecological point late in the 20th century so that wildfires frequently consume four times the area that they did in the period from 1910 to 1990 [7].

1.2. Flagstaff WUI

Flagstaff, Arizona is a high elevation (2133 m) urban area located in north-central Arizona surrounded by a dense ponderosa pine forest. The population is currently 53,000 within the Flagstaff city limits and another 10,000 in the unincorporated urban fringe. The city has an outstanding history of citizen participation in community efforts via Northern Arizona University, the Grand Canyon Trust, numerous environment-oriented groups, cultural organizations, and numerous volunteer activities. The annual number of wildland fire starts in and immediately adjacent to the interface area averages over 200/year with some years recording over 300 fires. Based upon existing hazard and values-at-risk, wildfire is the primary fire threat to the community.

In the early 1990s, the US Forest Service began treating high-risk areas adjacent to and within the Flagstaff corporate boundary with the goal of reducing the fire threat to the southwest side of Flagstaff, including historic landmarks such as Lowell Observatory. The City of Flagstaff Fire Department began a fuel management program after the severe 1996-wildfire season. The Ponderosa Fire Advisory Council, a consortium of Fire Departments and land-management agencies from the greater Flagstaff area, has also supported and recently initiated fuel reduction projects. Since the program was started, over 1000 ha have been successfully treated with overwhelming public support.

Completed fuel treatments compliment the area's fire suppression system. With six staffed fire lookout towers that oversee the north end of the Coconino National Forest (including Flagstaff), early wildfire detection is usually possible. Once a report is received, the Coconino National Forest dispatch office, which provides wildfire dispatch service to all area fire agencies, can rapidly dispatch initial attack units. An extensive road system usually enables initial attack forces to arrive on the fire scene within 15–30 min from the time of the initial report.

Forest stands are best represented by Fire Behavior Prediction System (FBPS) Fuel Model Number 9 (closed-canopy pine stand with needle understory). In the few open areas, the ground cover is a mix of grasses and forbs. Heavy logging slash from the early 1900s, such as pitchy high stumps and cull trees, contribute to the fire hazard and fuel ladder potential.

1.3. Objectives

One aspect of the Flagstaff fire risk reduction project is to harvest and utilize large fuels that have created high fire risks by harvesting and utilizing large amounts of small diameter (<40 cm) ponderosa pine. Fire risk reduction cannot be accomplished by simply introducing fire back into forests that have had fire excluded for nearly 120 years [6]. This paper documents efforts to facilitate proper resource-stewardship of all forested properties within the urban interface area. Individual stands or parcels, regardless of ownership, are considered valuable components of the overall ecosystem.

Table 1
Tree thinning criteria for the Flagstaff, Arizona, WUI fuels treatments

Tree condition criterion	Thinning action if criterion met	
	Yes	No
1. Creates a ladder fuel effect into the overstory canopy.	Cut	Leave
2. Tree is suppressed or is suppressing otherwise healthy trees.	Cut	Leave
3. Tree shows signs of poor vigor.	Cut	Leave
4. Tree is damaged or deformed and contributes to fire potential.	Cut	Leave

Specifically, the goals of the Flagstaff fire risk reduction effort are to:

1. Reduce the wildfire hazard through a combination of thinning, brush disposal and prescribed fire.
2. Maintain and enhance vegetative species and the structural diversity of the interface.
3. Improve overall forest ecosystem health.
4. Obtain the support of individual property owners, and the community in general, in the effort.

2. Silvicultural prescriptions

2.1. General considerations

The Flagstaff area is a true wildland/urban interface forest. Therefore, the silvicultural prescription is fairly basic. Selective thinning of the pine overstory "from below" is preferred. Target basal areas for mistletoe-free stands are 2.3–2.8 m^2/ha. If possible, retained trees (leave-trees) are left in a clumpy pattern rather than evenly spaced. This benefits certain wildlife species, as well as avoids a uniform appearance. Trees designated for removal are those that meet the criteria listed in Table 1.

Stands with high levels of dwarf mistletoe (rating greater than 3), are thinned to reduce crowning potential during the inevitable wildfire [8]. Small isolated pockets of mistletoe < 0.1 ha are either isolated from non-infected trees by a barrier of 15.2 m to reduce further spread of the disease, or totally eliminated.

Old growth and large diameter "blackjack" pines are protected by removing thickets of younger trees from around their bases [3]. Oaks and other infrequent species can also be highlighted by removing some or all of the encroaching ponderosa pines. Other unique features, such as geologic protrusions, scenic vistas or uncommon ground vegetation, can be enhanced as well.

The cutting of old growth, large diameter "blackjack" pines, or standing snags, is almost never required to implement this prescription. The only reason for removing these trees would be if they pose a threat to public safety or improvements. Examples might include trees leaning over homes, play areas, powerlines, roads and hiking trails, and trees that are weakened or damaged from a variety of disturbances. This approach is considered a moderate-to-heavy modification of the existing stand. Typically, these thinnings involve removal of 50–75% of mostly small diameter in the treatment area.

2.2. Designating trees for removal

Simple guidelines, issued by the project manager either verbally or in writing to the thinning crew, have worked well. These guidelines are very important because of the sensitivities of environmental groups and the general public to tree cutting. Where possible, a cutter selection method is preferred. If necessary, a sample cut can be designated and reviewed by the thinning crew. Where designating trees with paint is necessary, a cut-tree mark, as opposed to a leave-tree mark is preferred. Marking cut-trees eliminates the long term visual appearance of a leave-tree mark. However, one method being considered in areas scheduled for follow-up underburning involves placing only one paint mark on the leave tree as close to the ground as possible. The scorch from the underburn should hide or eliminate the paint.

When designating trees for removal, the existing stand is used as a "template" for a desired outcome. In doing so, personnel must be aware of fire behavior alignments such as prevailing wind direction, shading, slope, fuel arrangement and continuity, and potential fireline locations. Careful consideration also needs to be given to the type of fuel model conversion that may result from the treatment. Converting a stand from a FBPS Fuel Model 9 to a FBPS Fuel Model 2

(open pine stand with grass understory) may be more appropriate directly adjacent to a control feature such as a road, trail or natural barrier.

2.3. Cutting techniques

The type of mechanized operation should be seriously considered when cutting in the interface. A traditional harvesting operation may not be suitable in some areas, while in others it is the preferred method. Although traditional timber-harvesting equipment has been used in the past, and will be utilized again where conditions warrant, the preferred approach is to use a "micro" harvesting techniques. Trees are cut either using hand-crews with power saws, or by a hydraulic shear blade. Cut up stems are moved out of thinning areas using a four-wheeled All-Terrain-Vehicle (ATV). The ATVs used are equipped with wide, low-impact tires and small wood-transport trailers. This equipment system is not as intimidating to many area residents as would be the case with larger, conventional harvesting equipment. It allows curious residents to readily and safely approach thinning crews to learn about the operation. This is encouraged rather than discouraged in order to give nearby residents a better understanding of the operations and process. In addition, smaller equipment with low tire-pressure loadings reduces site disturbance by minimizing soil compaction and the amount of soil exposed for noxious weed and other exotic plant establishment.

Restricting hours of operation is another local twist to foster public support. If thinning operations are immediately adjacent to homes or a neighborhood, treatments are typically restricted to those hours when most people are not home.

Stumps should be cut as low to the ground and as level as possible. This not only improves post-treatment visual quality, but facilitates wood removal and subsequent fire management needs by allowing easier access. Daily removals of slash are incorporated into thinning operations. Leaving untreated slash—even for a few days—invites criticism and neighborhood concern.

2.4. Wood utilization for bioenergy

To the maximum extent possible, wood produced from thinning operations is removed and utilized. Although current commercial markets are poor for many of the products produced, a great deal of success has been achieved by designating accessible areas as free-use firewood areas. Each fall, the Flagstaff Fire Department's free wood Saturdays typically draw 200+ people who will remove 362 m^3 of firewood in half a day. Fire Department staff supervise the loading and transport of the free firewood to prevent further site disturbance and to ensure safe operations. To facilitate removal, firewood must be cut into 0.6–1 m lengths, and poles into 3 m lengths. Access through neighborhoods for any wood removal needs to be discussed with adjacent homeowners during the initial planning stages, not after cutting is underway.

At the present time, a proposal has been submitted for funding of a bioenergy electrical production facility to utilize the small-diameter thinnings from Flagstaff. Similar efforts are underway or planned elsewhere in the western USA. In light of the energy distribution and generation capacity crisis on the west coast of the USA in recent years, support for alternative renewable energy endeavours may be forthcoming.

Without a market for small diameter thinnings, or in areas where wood removal is not practical, project managers must carefully consider the size and number of the trees designated for cutting on any one site. More than one cutting cycle may be required so as to not overload the ability to treat the resulting slash in a timely manner.

2.5. Slash treatment

Currently there is no market for slash material in Arizona or the Southwest USA, so this biomass must be treated on-site to reduce forest fuel loads. While piles can be burned in the period from late fall to early spring, they are problematic in that high fire temperatures can adversely affect the soil beneath the piles.

Hand piles. These piles should be constructed in teepee-shaped piles a minimum of 1.8 to 2.0 m tall and wide. Pile placement needs to be carefully considered. Piles should be situated in openings to avoid scorching leave trees when the piles are later burned. Likewise, building piles on top of old stumps or logs should be avoided so that both the amount of smoke and the chance for "creep" (an escaped controlled burn) is reduced when the piles are burned later. To the public,

a scorched tree appears to be worse than a cut tree, and "creep" is definitely a fear on everyone's mind.

Machine piles. This slash treatment is sometimes used in more open areas since smoke production and chance of escape are reduced. The most success has occurred with a windrow piling method perfected on the Mormon Lake Ranger District. This method requires directional falling into a windrow that can then be pushed into large piles by a bulldozer during a single pass. Because the bulldozer is not constantly spinning and turning, few ruts are made. The larger piles result in fewer piles per hectare, speed production by an estimated 30%, and improve ignition under snowier or wetter conditions than traditional hand piles. At first, some managers were skeptical of this method, but once the process and results have been observed, comments have been favorable. Whole tree skidding has also been used quite successfully.

Chip or grind. Occasionally this technique is used, but unfortunately this approach is comparatively expensive and chips decompose slowly due to the semi-arid conditions around Flagstaff. If future underburning is scheduled for the site, chips may add to smoke management problems. The material can, however, be used for mulch or decorative landscaping. Hauling chips to a disposal site such as a landfill is expensive because of transportation costs and landfill fees. At the present time there is no market for chipped slash, but bio-fuels could be a potential one in the future.

Lop-and-scatter. This method should receive careful thought. If the amount of slash is light, and the manager can complete a broadcast burn soon after cutting, it may work. However, this approach has not been used much in the Flagstaff WUI. Due to the increased hazard fire, dried lopped-and-scattered slash should never be left in-place adjacent to homes.

2.6. Pile burning

When burning, air quality is the primary concern, not the area treated per day. This is the case regardless if the material is hand or machine piled.

Hand piles. As a standard practice, hand pile ignition is delayed until either an adequate snow cover exists or an extended wet weather episode arrives. On burn day, the crew will ignite a reasonable number of piles. As they burn-down, the crew goes back through the area and consolidates each pile 2–3 times to ensure complete, and timely consumption. The work pace is governed by the intent to have all piles burned-down by nightfall.

Machine piles. Burning of this larger type of slash pile is typically delayed until snow is on the ground. As the piles are burned, a small bulldozer is typically on-hand to shape up the piles and landings. While the bulldozer is working, seed can be spread and worked into the ground. This type of operation results in faster site recovery, less likelihood of noxious weeds becoming established, and reduced visual impact.

Dead and downed woody debris. Because broadcast burning is planned for most, if not all the fuel reduction areas, some of the existing dead-and-downed material may be piled. These piles are then burned when the thinning activity slash piles are burned. Doing so prior to broadcast burning is an important smoke management technique.

Piles should be burned only when the consumption of the woody material in a prescribed fire will be greater than 90%. Otherwise too much unsightly residue is left and it may interfere with herbaceous plant and grass re-growth. A test pile may need to be ignited to ensure this is achievable. All pile burns should be conducted under conditions intended to reduce scorch, minimize smoke issues, and lessen potential control problems.

2.7. Broadcast burning

Treating ground fuels is a critical component of our effort. Once an area has been thinned and the activity slash has been treated, the site should be broadcast burned. Since the prevailing wind is from the southwest, burn blocks, where possible, are burned starting in the northeast and working toward the southwest. Firelines are usually constructed by hand or with a drag pulled by an ATV.

As a standard practice, standing dead trees over 30 cm diameter or those that could threaten the line if ignited, are either hand lined or excluded from the burn block. The same is true for cultural or archaeological sites, or any other feature important to land managers, that might be degraded by fire.

In addition, once ignited, deep duff and needle accumulation at the base of the larger older trees will often smolder for days. This essentially bakes the

cambium layer. Death can occur 1–2 years, or more, after the burn. To avoid damaging these trees, this material is routinely raked away from high-risk trees. Usually raking to a distance of 30 cm from the bole is sufficient as long as the material is well-scattered and large litter "doughnuts" are not left around the stems of these trees. The same procedure is used for downed or partially decayed logs that need to be retained for wildlife cover diversity.

The preferred season for broadcast burning is normally during breaks in the summer monsoon season, during the transition from the monsoon season to drier fall weather or during the fall and early winter. While spring burning is sometimes used, it must be balanced against resource availability, training commitments, and the normally escalating fire danger indices found at this time of year. However, if the planned burn is small, of short duration, and is anchored in to a recent burn or fuel break, spring burning can be done.

The ultimate intent of the program is to move some burns into the summer months to mimic fires of historical times. This will become easier once a site has been previously burned one or two times to remove excessive accumulations of fuel.

The underburning prescription generally calls for strip-head fires along with a combination of backing fires (used at starting points and on steep slopes) with target flame lengths of 0.3–1.0 m. Ignition by hand with drip torches or with ATV-mounted torches is preferred. Ignition usually begins mid-morning following break-up of the nightly inversion and the establishment of the daily wind pattern. Every effort is made to complete ignition by early afternoon. Burn blocks are generally kept small to achieve this objective.

Although each burn block may have specific objectives, there are generally two constant objectives for each site. The first is to reduce 1- and 10-h fuels by a minimum of 60%. One, 10-, 100-, and 1000-h fuels refer to the time-lag between atmospheric moisture changes and fuel moisture adjustment. One-hour fuels are less than 6 mm in diameter and 10-h fuels are 6–25 mm in diameter [9]. The second objective is to keep residual tree mortality to less than 5% of the existing stand.

Intense public notification is an essential element of the program. This is achieved through area signing, news releases, and in many cases, door-to-door contact through nearby neighborhoods. Any concerns receive immediate attention, either by a phone call or personal visit. If concerns arise on the day the site is being burned, the project manager or a fire crew-member visits the people involved while the fire is still underway.

Experience has clearly shown that a previously notified neighborhood is willing to tolerate smoke for a day and night, but after 2–3 days, patience wears thin. A particular log, stump, or site within a burn unit may be extinguished the first night if it becomes a major concern to a nearby resident.

Fuels treatment projects are designed so they can be dispersed throughout the community, thereby not constantly impacting the same neighborhoods. The Flagstaff Fire Department has offered to relocate smoke sensitive people: to-date, however, this has seldom been necessary. Neighborhood air sheds, indicated by diurnal smoke flows, are routinely mapped so future smoke management efforts can be well-planned.

2.8. Maintenance

Once the thinning, slash treatment, and first entry underburning have been completed, the treated area is considered an effective fuelbreak for at least the next 3–4 years. Follow-up thinning and maintenance burns are scheduled as necessary to ensure long-term attainment of the project's ultimate goal, to reduce the risk of destructive fire. Typically, thinning is rescheduled every 10–15 years, while follow-up prescribed fires are planned on a 3–7 year cycle. Smoke management concerns are much less during these subsequent maintenance burns because of fuel removal.

3. Community involvement

Throughout the entire effort, the project manager must maintain contact with adjacent property owners. The procedure followed is to routinely gather neighborhood input, consider their concerns and beliefs, and where possible, incorporate their desires into the overall effort. Project managers commonly go door to door to each residence that borders the project to explain the project proposal and gather comments. Follow-up visits are paid to those people who have questions or

Table 2
Realized benefits from the Flagstaff, Arizona, WUI fuels treatment program

Benefit from WUI fuels treatments	Importance
1. Improved access for fire fighters and apparatus.	High
2. Increased ability to utilize barriers when locating and constructing fireline.	High
3. Spot fires are easier to locate and suppress.	High
4. Decreased mop-up.	Medium
5. Less tree torching and mortality.	Medium
6. Options for a modified suppression response are expanded.	Medium
7. Improved public safety.	High

concerns. If necessary, a "case-officer" is assigned so the resident deals with the same person from the start of a project to the end.

Some might believe that most people would prefer their privacy and ask for no or limited treatments next to their property line. This is rarely the case. In fact, most often the opposite is true: property owners want the work carried onto their land, or onto other adjacent or nearby property. The occurrence of wildfires within or adjacent to the Flagstaff WUI in the past 5 years, as well as on-going public education efforts on the wildfire risks from over-stocked forests, has produced a lot of public support for fuels treatments.

There has been a concerted effort on the part of city and Federal fire managers to involve local businesses in the fuels cutting efforts. Prior to 1998, no more than 10 contracts per year were issued. Since 1998, approximately 60 have been issued each year. Although it takes considerable time and commitment, this one-on-one community involvement is essential for the success of the Flagstaff WUI fuels program.

3.1. Benefits

Wildfires have occurred in several of the fuels-treated areas since the program began. A number of distinct benefits have been noticed because of the forest fuels treatment program (Table 2). In addition, trash accumulation in the WUI has been reduced through elimination of hiding cover necessary for transient camps and party spots.

3.2. Lessons learned

A number of important community involvement lessons have been learned so far by the Flagstaff WUI fuels reduction program. The first is to involve those impacted or affected from the very beginning. Once the project is started, it is important to commit to complete the project in a timely manner. The use signs and news releases to update people on the status of the project are valuable and effective communications tools. When mistakes happen, it is very important to immediately notify each adjacent owner, explain what happened and why, and assure them of what is being done to correct the situation. Project managers should assume full-responsibility and allow on-site personnel to make commitments to rectify problems. Documentation of actions and follow-up on special concerns or small items that may be extremely important to a concerned individual are crucial factors in the success of this program. Personal customer service is an absolute necessity. All project personnel must always strive to maintain the professionalism, integrity and credibility that has already been established. It is important to stay focused on the ultimate objective. Reduction of fire risk produces stumps and smoke. If we are not doing that, we are not successful. However, it should also be recognized that some sectors of the public will not be happy with this result.

Finally, success leads to success. Many landowners throughout the community have viewed the ongoing and completed treatments and have since implemented similar treatments on their land.

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