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Fuels Management—Looking Back in Time

Fire Management *today*

Fire Management Today is published by the Forest Service, an agency in the U.S. Department of Agriculture, Washington, DC. The purpose of *Fire Management Today* is to share information related to wildland fire management for the benefit of the wildland fire community. *Fire Management Today* is available online at *https://www.fs.usda.gov/managing-land/fire/fire-management-today.*

Trade Names

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On the Cover:

Roy Headley (1879–1951), circa 1942. Headley joined the Forest Service in 1907 and served as the agency's first Chief of the Division of Fire Control from 1935 to 1942. According to an obituary in the April 1951 issue of the Journal of Forestry, *"Roy Headley was considered an executive and organizer of exceptional ability. An exponent of accountability and responsibility in all public transactions, his influence was felt throughout the Forest Service organization." Among his many accomplishments, Headley was instrumental in creating and developing* Fire Control Notes, *the forerunner of* Fire Management Today. *Photo: USDA Forest Service.*

IN THIS ISSUE

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Firefighter and public safety is our first priority.

GUIDELINES for Contributors

Learning From the Past

By Vicki Christiansen
Former Chief, USDA Forest Service

> **We need to focus on the factors in the system that we can control, such as the quality of our relationships.**

Our wildland fire system is changing before our eyes. In the short term, the coronavirus disease of 2019 (COVID-19) challenged the way we manage wildland fire last year. We learned as we went, adapting our management accordingly, with lessons learned for fire years to come.

COVID-19 compounded a very difficult fire year based on changes to our wildland fire system over the last 20 years. The 2017 and 2018 fire years in California exemplified some of these changes, which we saw again in 2020.

Last year, we had extreme fire weather across much of the West—record-shattering heat, tinder-dry fuels, stalled weather fronts, hot and dry winds, and dry lightning busts in unprecedented places. All of it combined to start thousands of fires with phenomenal rates of spread. We had record megafires and record rates of spread from the West Coast to the Central Rockies. Megafires roared across vast landscapes and through the wildland-urban interface (WUI). Areas normally too wet to burn went up in flames, like in the Westside Cascades.

These changes to our wildland fire system are rooted in extraordinary drought, in legacy fuel buildups compounded by climate change, in homes spreading into fire-prone landscapes—and, as we have seen in recent years, in the volatility of WUI fuels themselves. Think of the 2018 Camp Fire in California, where thousands of homes burned.

Yet through it all, there are things we can do. We need to focus on the factors in the system that we *can* control, such as the quality of our relationships. Under our National Cohesive Strategy for Wildland Fire Management, the entire wildland fire community has come together to pursue three overarching goals:

1. To accelerate the treatment of forested landscapes for greater health and resilience;
2. To help communities and homeowners become more fire adapted; and
3. To develop a shared risk-based response to wildfire, even in a pandemic.

Fuels management is central to achieving all three goals. Fire plays an important role in many ecosystems; managing fire for fuels, where appropriate, is a central part of risk-based response to wildfire. Firewise and related approaches to protecting homes and communities from wildfire are based on eliminating fuels in the WUI or reducing their flammability and vulnerability. Managing fire-adapted landscapes for health and resilience involves using prescribed fire and other techniques to keep fuels at optimal levels.

Continual learning and adaptation are key to keeping pace with the rising complexity of the wildland fire system. We know that our fuels and forest health treatments work when applied in the right ways in the right places at the right scale. The wildland fire community has a century of experience to draw on in finding and applying the right fuels management techniques, many of them captured in the pages of *Fire Management Today* and its predecessors. The articles in this issue offer wildland fire managers some of the most relevant past experience for managing fuels today.

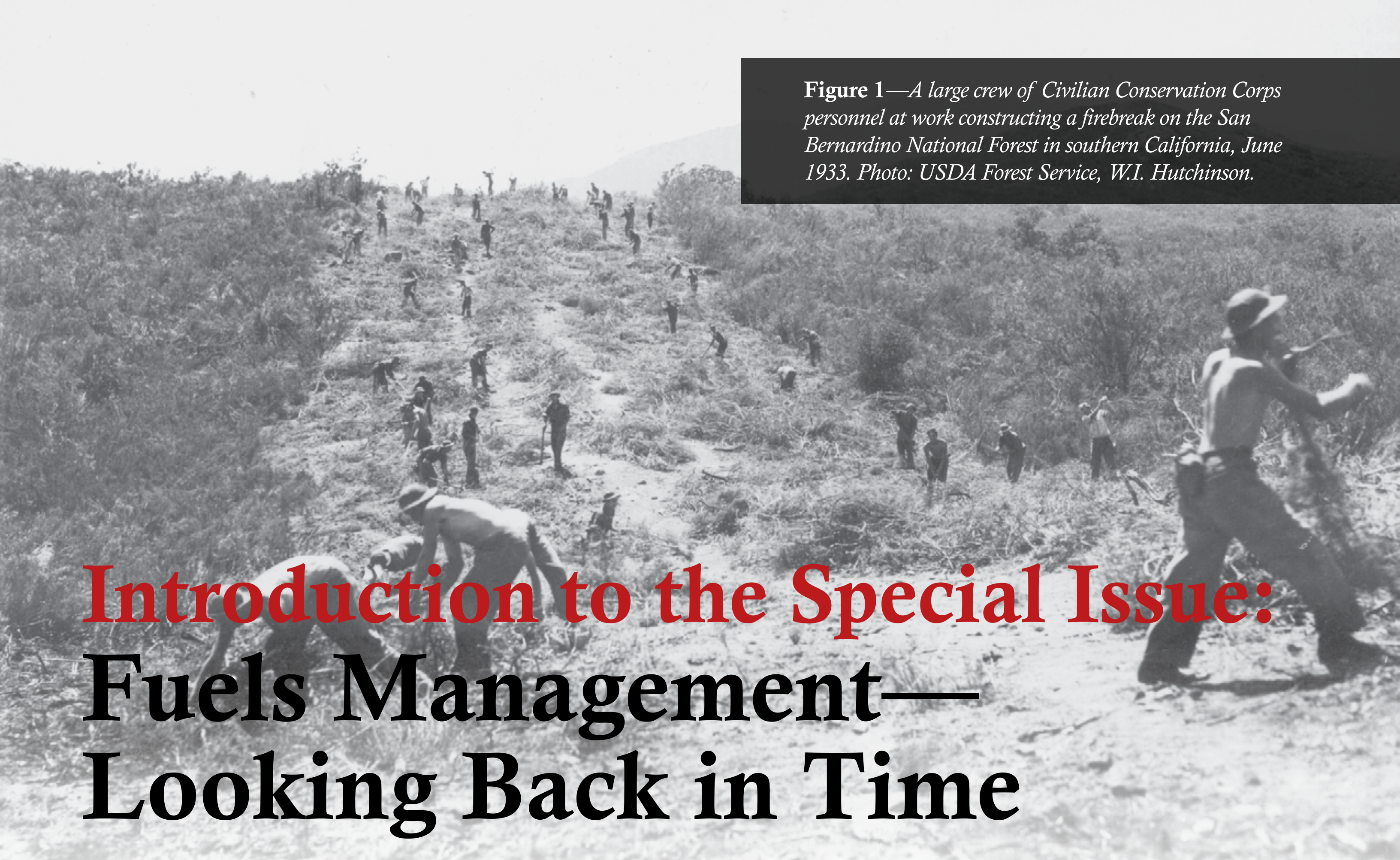

Figure 1—*A large crew of Civilian Conservation Corps personnel at work constructing a firebreak on the San Bernardino National Forest in southern California, June 1933. Photo: USDA Forest Service, W.I. Hutchinson.*

Introduction to the Special Issue: Fuels Management—Looking Back in Time

Martin E. Alexander and Hutch Brown

Simply put, fuels management is the planned manipulation of wildland vegetation to modify the behavior of unwanted wildfires and reduce their impacts (Omi 2015), thereby increasing the safety and efficiency of fire suppression efforts. There are four broad methods of fuels management:

1. Reduction (removing fuels from a site by burning, full-tree harvesting, livestock grazing, or other means);
2. Manipulation (rearranging the fuel complex structure, such as by hand pruning, thinning with chainsaws, or mechanical means);
3. Conversion (physically changing the vegetative cover type to a less flammable state); and
4. Isolation (creating firebreaks and fuelbreaks).

Very often, these fuel treatments are done in combination. For example, clearcut harvesting of a conifer forest followed by broadcast burning of the slash debris might be used to create a deciduous fuelbreak (Bickford 1972).

Fuels management is by no means a new concept. Both firebreaks and fuelbreaks (fig. 1), for example, were constructed in California beginning in the early 1900s (Green 1977). One of the most extraordinary accomplishments in this regard was the creation of the "Ponderosa Way," a fuelbreak/road system that ran nearly the entire length of the montane region of the Sierra Nevada, from Redding in the north to Bakersfield in the south, a distance of some 650 miles (1,050 km) (Avery 1935; Price 1934).

Prescribed fire has been used in a variety of fuel complexes over the course of many years in various regions around the globe (Kayll 1974). Fuel hazard reduction has in turn been accomplished, either directly or indirectly, as an objective (Romamcier 1960; Sweeney and Biswell 1961).

GENESIS OF THIS SPECIAL ISSUE

For 85 years, *Fire Control Notes* and its successors, *Fire Management*, *Fire*

Marty Alexander is the proprietor of Wild Rose Fire Behaviour, Leduc County, AB, Canada; he has been a contributor to Fire Management Today *(FMT) and its predecessors since 1974 and has served as issue coordinator for six special issues, including this one. Hutch Brown is the editor of FMT and a program specialist for the Forest Service's Office of Communication, Washington Office, Washington, DC.*

Management Notes, and *Fire Management Today*, have published articles on all aspects of wildland fire management (Brown 2021b), including fuels management (fig. 2). This fulfills the journal's original purpose of serving as a medium for exchange of information and ideas between all groups and individuals who are engaged in doing creative work related to wildland fires (Headley 1936). This intention lives on to this day (Brown 2021a).

Alexander (2007) published a bibliography comprising 117 articles on fuels management in *Fire Management Today* and its predecessors, along with an index with 12 subject areas dating from 1939 to 2006. Two articles were later found missing (Alexander 2008, 2019). An additional 23 articles on fuels management appeared in *Fire Management Today* from 2007 to 2020 (fig. 2). They are listed in the accompanying sidebar.

RELEVANT ARTICLES FROM THE PAST

Many of the 119 articles dealing with fuels management published prior to 2007 are still of value in meeting current challenges. This issue of *Fire Management Today* reprints 22 of the most pertinent articles about various aspects of fuels management, including hazardous fuels situations requiring abatement, from issues of *Fire Control Notes*, *Fire Management*, and *Fire Management Notes* dating from 1941 to 1984. Included is Countryman (1956) in the version that appeared in *Fire Control Notes*.

Although the articles were reformatted to fit today's online version of *Fire Management Today*, the text is reprinted largely verbatim and therefore reflects the style and usage of the time. Minor wording changes were made for clarity. The occasional quotation pull was made

Fuels Management Bibliography, 2007–20

The following articles update the bibliography of articles on fuels management published in *Fire Management Today* and its predecessors from 1936 to 2006 (Alexander 2007, 2008, 2019).

Alexander, M.E. 2007a. Simple question; difficult answer: How much fuel is acceptable? *Fire Management Today*. 67(3): 6–11.

Alexander, M.E. 2007b. How much fuel is in that pile or windrow? *Fire Management Today*. 67(3): 12, 27.

Alexander, M.E. 2007c. Software can assess fuel treatment effectiveness on crown fire behavior. *Fire Management Today*. 67(3): 30.

Alexander, M.E. 2009. Are we abusing our use of models and modeling in wildland fire and fuel management? *Fire Management Today*. 69(4): 23–26.

Briggs, R.D.; Cook-Patton, S.C. 2018. Conifer mortality in California: fire risk and dead tree management. *Fire Management Today*. 76(3): 5–12.

Evans, A.M.; Wright, C.S. 2017. Unplanned wildfire in areas with slash piles. *Fire Management Today*. 75(2): 25–29.

Fitzhenry, R. "Fitz." 2012. National Fire Plan funds support Maine's defensible space chipping program. *Fire Management Today*. 72(3): 26.

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Garlough, E.C.; Keyes, C.R. 2010. Pitching theories from the duff mound. *Fire Management Today*. 70(3): 5–7.

Gavin, D.G.; Flower, A.; Cohn, G.M.; Parsons, R.A.; Heyerdahl, E.K. 2017. Western spruce budworm and wildfire: Is there a connection? *Fire Management Today*. 75(2): 12–16.

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Johnson, M.; Peterson, D.L.; Raymond, C. 2009. Fuel treatment guidebook: illustrating treatment effects on fire hazard. *Fire Management Today*. 69(2): 29–33.

Krake, H. 2019a. Fuel breaks work in Colorado. *Fire Management Today*. 77(3): 46–47.

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McCaffrey, S. 2009. Crucial factors influencing public acceptance of fuels treatments. *Fire Management Today*. 69(1): 8–12.

Meyer, K.E.; Dwire, K.A.; Champ, P.A.; Ryan, S.E.; Riegel, G.M.; Burton, T.A. 2012. Burning questions for managers: fuels management practices in riparian areas. *Fire Management Today*. 72(2): 16–23.

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Romero, F.; Menakis, J. 2013. Fire season 2012: the impact of fuel treatments on wildfire outcomes. *Fire Management Today*. 73(2): 15–24.

Thompson, M.P.; Vaillant, N.M.; Haas, J.R.; Gebert, K.M.; Stockmann, K.D. 2013. Quantifying the potential impacts of fuel treatments on wildfire suppression costs. *Fire Management Today*. 73(2): 5–10.

Varner, J.M.; Keyes, C.R. 2009. Fuels treatment and fire models: errors and corrections. *Fire Management Today*. 69(3): 47–50.

Wright, C.S.; Eagle, P.C.; Balog, C.S. 2010. Characterizing hand-piled fuels. *Fire Management Today*. 70(3): 16–18.

and metric unit conversions included where needed. Paragraphs were broken up and sidebars used to improve readability. Almost all illustrations were taken from the original articles. The articles are presented in chronological order of publication.

LOOKING AHEAD

Fire Management Today will continue to provide a service to the wildland fire community in the future. Three articles related to fuels management, for example, were published in volume 79(1), the first issue in 2021.

ACKNOWLEDGMENTS

The authors appreciate the assistance of Dave Stack (Museum of Forest Service History), Pamela Sikkink (Forest Service, Missoula Fire Sciences Laboratory), and Eben Lehman (Forest History Society) in preparing this issue of *Fire Management Today.*

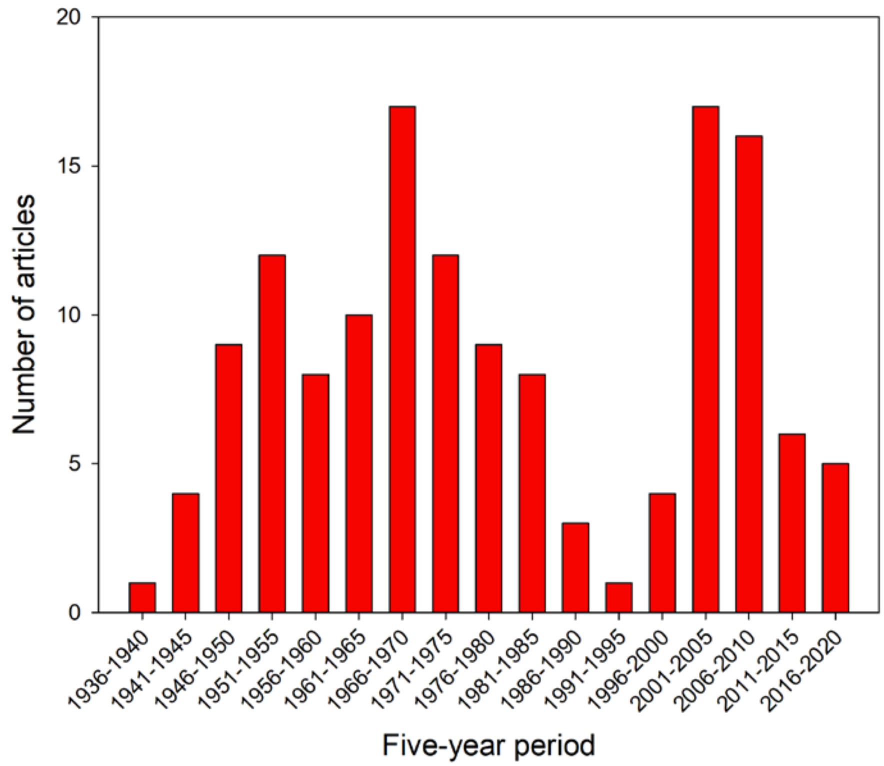

Figure 2—*Number of articles on fuels management published in* Fire Management Today *and its predecessors from 1936 to 2020, by 5-year intervals.*

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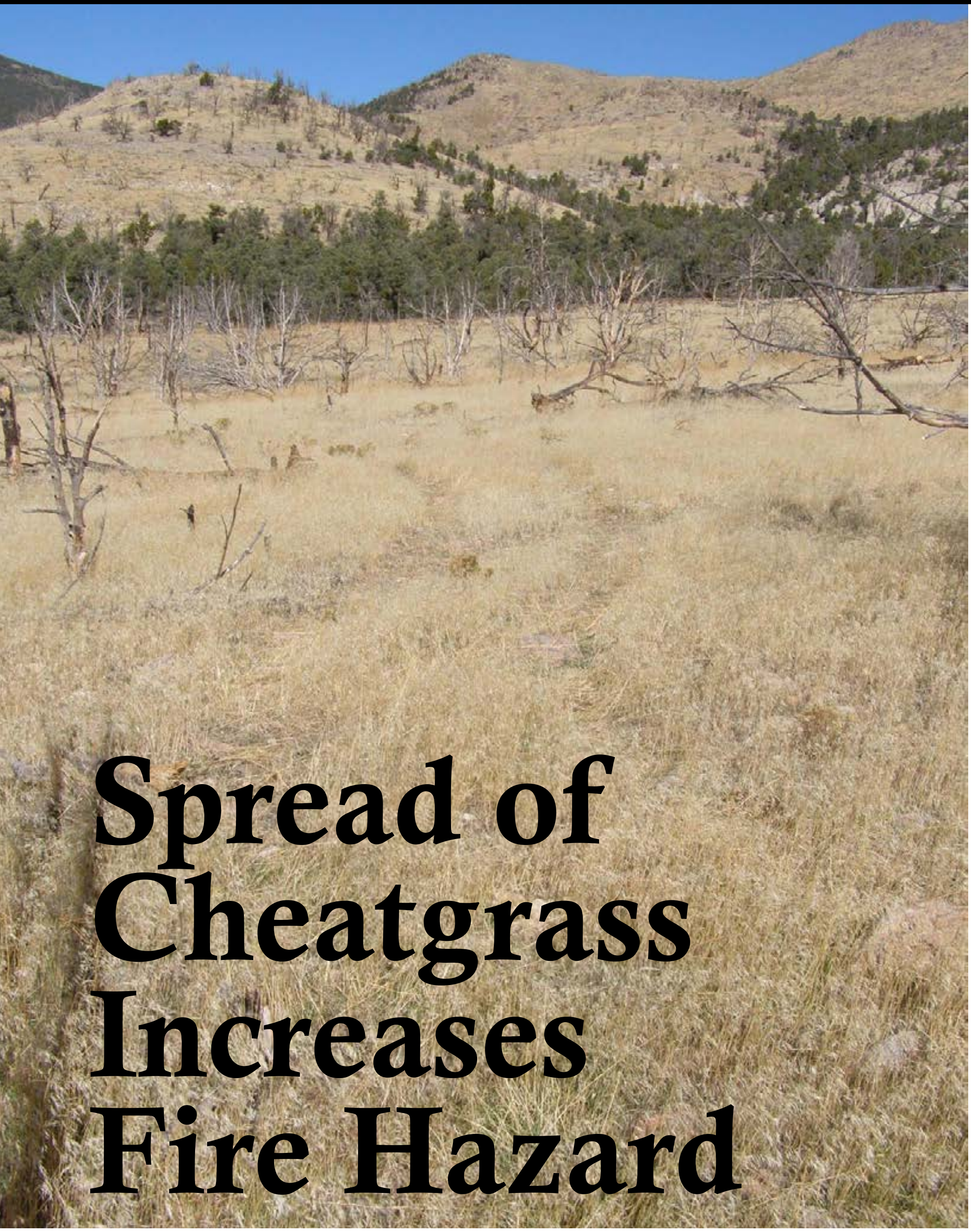

Cheatgrass infestation on the Parsnip Peak Wilderness in southeastern Nevada. Photo: Bonnie Million, Bureau of Land Management, Bugwood.org.

Spread of Cheatgrass Increases Fire Hazard

> **"Today the honey-colored hills that flank the northwestern mountains derive their hue not from the rich and useful bunchgrass and wheatgrass which once covered them, but from the inferior cheat which has replaced these native grasses."**
>
> **–Aldo Leopold,** "Cheat Takes Over" *(A Sand County Almanac, 1949)*

D.S. Nordwall

During the last 10 years, downy chess (*Bromus tectorum*), also known as cheatgrass, has extended its range perceptibly on and adjacent to the Holy Cross National Forest. Overgrazed areas in the lower to moderate ranges of elevation and roadside zones have in many places reverted almost solidly to cheatgrass.

In normal years, the spread of cheatgrass would cause little concern from a fire standpoint. However, during the last few years, the dry seasons have forced consideration of this plant as a serious fire menace. It is understood that Region 1 rates cheatgrass as one of the flashiest of fuel types, and this rating is well substantiated in the few fires that have occurred in this fuel type on the Holy Cross. Because of relatively heavy human use, the roadside strips present the greatest hazard.

Heretofore restricted in intensity by elevation, a limited range, and an abundance of moisture, the cheatgrass fire hazard must now be given a high rating in fire planning.

The article is adapted from Fire Control Notes *5(3) (July 1941), page 143. The author was the assistant forest supervisor for the Holy Cross National Forest, now the White River National Forest, Glenwood Springs, CO.*

Firebreak Prevents Larger Fires

A.J. Wagstaff

If fires could be checked before reaching the steeper part of the mountain, then large fires would be prevented.

In the spring of 1935, an addition was made to the Uinta National Forest—a new area extending from the valley floor above cultivated fields at an elevation of about 5,000 feet (1,500 m) to higher country some 3 miles (5 km) distant at elevations of 8,500 to 11,000 feet (2,600–3,400 m). The vegetative cover consisted of a belt of cheatgrass (*Bromus tectorum*) at the lower elevations, gradually merging into oak brush, with aspen and small patches of alpine fir and Douglas-fir at the higher elevations.

The cheatgrass belt at the base of the mountain presented a new fire problem, which was accentuated after the area was added to the forest. Watershed protection was of first importance, so the land previously grazed was given total protection, which resulted in the growth of rank vegetation.

The cheatgrass belt remains very inflammable from the time the grass seeds start to ripen in early June until late October, depending upon the amount and frequency of precipitation. The annual normal rainfall over this area is 4.82 inches (12.24 cm) from June through October.

There are no data available to show the number and size of fires prior to 1935, although fires were common. During the 5-year period from 1935 to 1939, however, 25 fires occurred in the area under discussion, which burned over 1,222 acres (495 ha) of important watershed land, costing $1,080 to suppress and causing an estimated damage of $1,222.

During this time, a Civilian Conservation Corps (CCC) camp was located near the area, and most of the suppression was done with CCC labor. Otherwise, the suppression costs would have been much higher. Also, it is reasonable to assume that the CCC crew put the fires under control faster than a crew of civilians could have done, considering time in recruiting and previous training, which all resulted in smaller fires.

Under extremely dry conditions, these fires spread very fast. Some of them have actually traveled half a mile (0.8 km) in 10 minutes. It was observed that trails and small openings in the grass, if they occurred before the fire reached the brush type, often controlled the bounds of the fires.

Figure 1—*A section of the firebreak located at the base of the steeper part of the mountain.*

Most of this area is near U.S. Route 91, with its heavy travel load. Also, the cities of Provo and Springville, UT, with a population of about 25,000, are adjacent to the area. The human element of fire hazard is therefore high, and all fires have been human caused.

The article is adapted from Fire Control Notes *6(3) (July 1942), pages 114–15, 127.*

The author was the assistant forest supervisor for the Uinta National Forest, now part of the Uinta-Wasatch-Cache National Forest, South Jordan, UT.

The firebreak has been a great help in limiting the size of fires, resulting in lower suppression costs and less damage.

It was thought that if fires could be checked before reaching the steeper part of the mountain, then large fires would be prevented. With this in mind, it was decided to build a firebreak, which was done in the early spring of 1940.

The firebreak was located as near as possible around the old Bonneville Lake terrace, which forms a small bench and makes construction less difficult (fig. 1). This location is generally at the foot of the steeper mountain but above the areas where the fires ordinarily start. A caterpillar tractor with bulldozer and a grader were used, and the cost amounted to approximately $20 per mile ($12/km). The width of the break is 8 to 9 feet (2.4–2.7 m), or just wide enough for the tractor. Ten miles (16 km) of this type of break were constructed. No car travel is permitted over the break. Maintenance is not difficult and requires but one annual trip, before the cheatgrass starts to ripen. The cost runs from $2 to $3 per mile ($1.2–2/km).

Although the break has been in use for only 2 years—one of which was the most favorable known in terms of precipitation—it is believed that the break was a good, sound investment. During the 2 years of operation, 10 fires have occurred, burning 24 acres (10 ha) with a suppression cost of $90 and a damage estimate of $50. The number of fires in the last 2 years has averaged the same as in the previous 5-year period, with the average acreage burned one-twentieth of the 5-year average. The 5-year suppression cost average is slightly higher than the total construction cost of $200. The savings over suppression costs in the past 2 years have paid for the break nearly twice. The damage costs are likewise low compared with the 5-year average. Table 1 shows a direct comparison. In other words, during the past 2 years, there has been a direct savings of 464 acres (188 ha) in area burned, $340 in suppression costs, and $438 in estimated damages.

It is not expected that this firebreak is going to stop all fires in the area, nor has it solved all fire problems; but, so far, no fires have crossed it. The evidence is that, thus far, the firebreak has been a great help in limiting the size of fires, resulting in lower suppression costs and less damage. Its value will be better appraised in the future.

Table 1—*Suppression and damage costs, compared with cost of constructing new firebreak.*

Factor	Number of fires	Acres (ha) burned	Suppression costs	Damage estimates
5 years (1935–39)	25	1,222 (495)	$1,078	$1,222
Average per year	5	244 (99)	215	244
2 years (1940–41) [a]	10	24 (10)	90	50
Average per year	5	12 (5)	45	25

a. After firebreak construction.

On the Optimal Width of Firebreaks in Grasslands

Early on, George M. Byram offered a rough guide for estimating the desired width of a firebreak needed to stop (or slow down) a fire of any expected intensity, provided that severe spotting had not begun (Byram 1959). He assumed that the width of a firebreak needed to be 1.5 times the expected flame length.

More recently, Andrew A.G. Wilson developed a logistic equation relating the probability of firebreak breaching in relation to firebreak width and fireline intensity based on 113 outdoor experimental fires (Wilson 1988). In turn, Steve Davidson wrote an interpretive article on this study (Davidson 1988).

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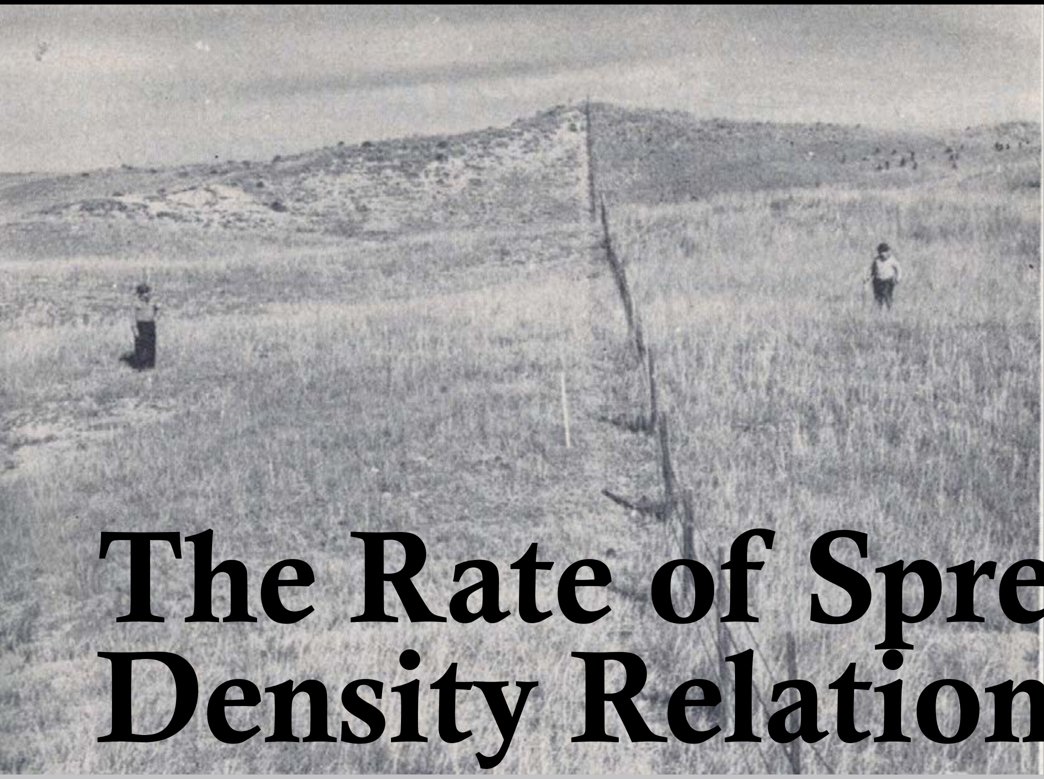

Figure 1—*Portion of test area. Utilization: heavily grazed (about 0.6 animal months per acre (0.24/ha)) on the left and lightly grazed (about 0.3 animal months per acre (0.12/ha)) on the right.*

The Rate of Spread/Fuel Density Relationship

Wilfred S. Davis

All tests showed conclusively that the reduction of fuel density has a marked effect on both the rate of spread and the intensity of grass fires.

During a recent consideration of the value of fuel reduction as a fire control tool in the Rocky Mountain Region, a question was raised as to whether the density of fuel had any effect on the rate of spread of grass fires. The relationship between the rate of spread and factors such as wind, fuel moisture, relative humidity, and topography has, of course, been reasonably well established by earlier experiments; but no data could be found covering the problem in question.

Casual observations of the behavior of prairie fires had created in some the belief that a fire would roll through sparse grass with the same velocity it attained in denser stands, although admittedly with a lesser intensity; whereas others held that a reduction in fire intensity would also lead to a lower rate of spread. To settle this interesting difference of opinion, it was decided to conduct some controlled burning on the Nebraska National Forest, where the rolling sandhill grasslands provide a good continuity of forage conditions.

Possibly, the reason for the lack of data on the relationship between fuel density and the rate of fire spread lies in the fact that there is no convenient yardstick for measuring fuel density. In the Nebraska experiment, it was decided to use the forage utilization of variously stocked range allotments as such a yardstick.

Two adjacent grazing allotments were then selected in gently rolling terrain. One showed an average forage utilization of 0.6 animal months per acre; the other was stocked only half as heavily. These two allotments were separated by a drift fence, and a marked change in vegetation density was indicated on the fence line (fig. 1).

The forage consisted of a well-cured mixture of the following:

- Turkeyfoot (sandhill bunchgrass) (*Andropoyon hallii*);
- Dropseeds (*Sporobolus* spp.);
- Prairie sandgrass (sand reed grass) (*Calamovilfa longifolia*);
- Lovegrass (*Eragrostis trichodes*);
- Sedges (*Carex* spp.); and
- Hairy grama (*Bouteloua hirsuta*).

Parallel plots, 500 feet (150 m) in length and 100 feet (30 m) wide, were established on each side of the fence and surrounded by adequate firebreaks.

The test was conducted in November. Some variance in temperature and relative humidity was noted, but the wind held at a steady 16 miles per hour (26 km/h) throughout. The fires were allowed to run with the wind and were

The article is adapted from Fire Control Notes *10(4) (April 1949), pages 8–9. The author was a forester for the USDA Forest Service's Rocky Mountain Region, now headquartered in Lakewood, CO.*

The result of the test is further proof that the principle of fuel reduction is sound, from a suppression standpoint.

set so that the lightly grazed and heavily grazed plots burned simultaneously, affording a good comparison. Stopwatch readings were taken for the rate of advance of the head of the fire in each plot. Since thermocouples were not available, the intensity of the fire was gauged by measuring the average height of the flames. Finally, the fire was allowed to run with the wind from the lightly grazed to the heavily grazed area in order to discover whether a rolling fire would be affected by thinner fuel.

All tests showed conclusively that the reduction of fuel density has a marked effect on both the rate of spread and the intensity of grass fires. Table 1 shows the average results.

Under the test conditions, the residual density of grass as represented by a utilization of 0.3 animal months per acre will allow potential fires to advance three times as fast and with five times the intensity of fires in areas that have been grazed twice as heavily. The result of the test is further proof that the principle of fuel reduction is sound, from a suppression standpoint. This finding, of course, does not alter established Forest Service policy of managing the range primarily in accordance with the needs of the soil and vegetation rather than as a means of reducing fuel hazards.

Table 1—*Fire behavior in lightly and heavily grazed areas, by rate of spread and intensity.*

Area	Frontal advance of fire (ft/sec (m/sec))	Intensity of fire (average flame height, ft(m))
Lightly grazed	1.56 (0.48)	5 (1.5)
Heavily grazed	0.53 (0.16)	1 (0.3)

For the latest summary on grassland fire behavior knowledge, see:

Cheney, P.; Sullivan, A. 2008. Grassfires: fuel, weather and fire behaviour. 2nd ed. Collingwood, Victoria, Australia: CSIRO Publishing. 150 p.

Nebraska Firebreaks

Wilfred S. Davis

The Nebraska National Forest has kept up a system of firebreaks since 1910.

Firebreak building was a fairly popular work project in the days of the Civilian Conservation Corps (CCC). It enabled the employment of great numbers CCC recruits with hand tools and created swaths from which fire suppression forces could make a stand. But lack of maintenance funds made it difficult to keep up these barriers when the CCC was disbanded, and most of the firebreak systems are today abandoned and overgrown.

The Nebraska National Forest, however, is keeping up a system of firebreaks that has been maintained since 1910. Without such a system, it is doubtful whether the forest could survive.

This national forest is located in the vast sea of grass-covered dunes known as the Nebraska sandhills. Every tree on some 20,000 acres (8,100 ha) has been planted. It is a successful attempt to show that a forest can be grown under the somewhat adverse conditions in the sand prairie, and it represents one of the largest single afforestation projects in the world (fig. 1).

The article is adapted from Fire Control Notes *12(1) (January 1951), pages 40–43. The author was a forester for the USDA Forest Service's Rocky Mountain Region, now headquartered in Lakewood, CO.*

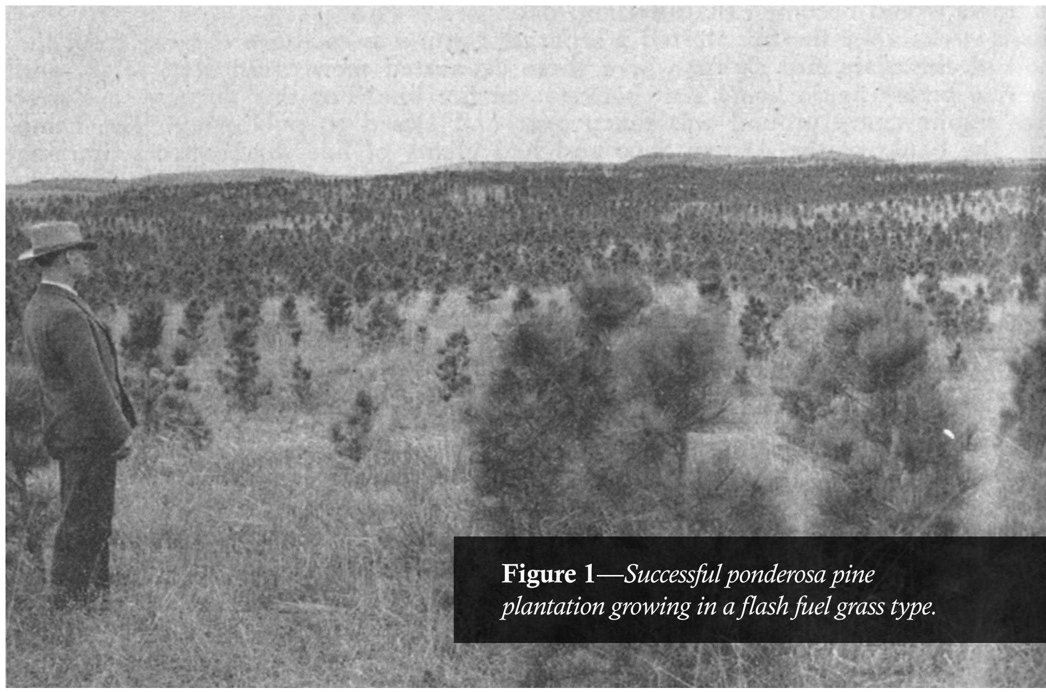

Figure 1—*Successful ponderosa pine plantation growing in a flash fuel grass type.*

Lightning and man for centuries have caused vast prairie fires to sweep across the sandhills. The chemicals in the ashes gravitated into the major depressions and created potash deposits, which were recovered during World War I and used in the manufacture of explosives. The repeated fires that caused this potash accumulation probably prevented the buildup of surface litter for more than a few years at a time.

When the plantation project was initiated, it was of course necessary to check periodic prairie fires in the afforested area. This soon caused an increase in the grass density between the trees and an accumulation of dry litter, which made it extremely difficult to check fires sweeping in from the outside (fig. 2). Consequently, a system of permanent firebreaks was devised.

Figure 2—*Dense prairie grass on the edge of a plantation. There is enough litter on the ground to carry fire even when the grass is green. When the grass is cured, it will support fire of high intensity and rate of spread.*

The annual burning of firebreaks takes place in the fall, usually after the first frost has killed the annual growth of grass.

The basic concept of the firebreak system was:

- To provide protection from outside fires, and
- To divide the planted areas into units of less than a square mile (2.6 km^2) so as to make interior fires easier to handle.

Some of the first firebreaks were made relatively narrow; these proved ineffective in high winds, and wide standards were adopted. The major exterior firebreaks consist of three plowed and disked 20-foot (6-m) sand strips separated by strips of grass at least 150 feet (46 m) wide. The sand strips are disked annually to prevent vegetation from creeping in, and one of the grass strips is burned annually; two years' growth of grass is required for a clean burn. The interior firebreaks are single lanes of grass edged by disked strips (fig. 3). The grass cover is burned off every other year.

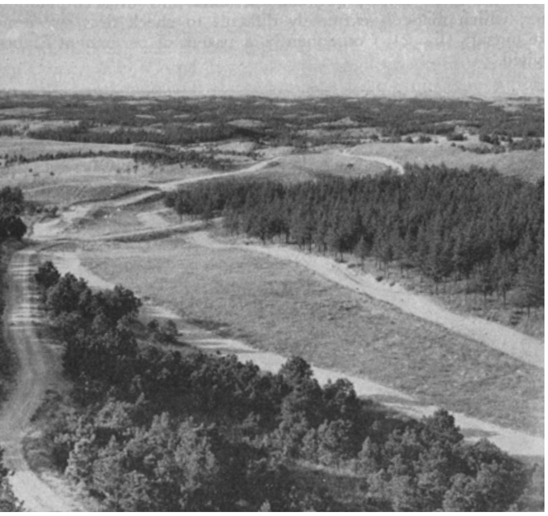

Figure 3—*Typical interior firebreak*

The annual burning of firebreaks takes place in the fall, usually after the first frost has killed the annual growth of grass (fig. 4). A typical burning crew consists of three firefighters with torches, two guards, one tanker or tractor driver, and two firefighters for mopup. The fire in grass goes out quickly, but mopup is required for smoldering cow chips and burning soapweed (yucca) plants. The crew soon becomes adept in the use of fire and learns to employ terrain and wind to the best advantage. Three to five miles (4.8–8 km) can be burned each day when the humidity is sufficiently low (less than 30 percent). The maintenance of the Nebraska firebreak system is a considerable task involving the disking of 594 miles (956 km) and the burning of 61-1/2 miles (99 km) of grass lane annually.

Figure 4—*Burning an exterior firebreak in the fall of the year.*

Virtually all of the planted acreage of the Nebraska project was wiped out in the spring of 1910, when a disastrous prairie fire swept through the area. Since the establishment of the firebreak system in that year, however, plantation losses to fire have been small, despite the fact that there have been a number of large "outside" fires. These advance with considerable rapidity; in one instance, a frontal spread of 6 miles (10 km) in 40 minutes was clocked. However, the planted areas have remained relatively free from fire invasion. Today, some of the older trees are approaching sawlog size, and natural reproduction is beginning to come in. Thanks to the protection system, of which the firebreak network is a vital part, an afforestation effort extending over nearly half a century is beginning to bear fruit. ■

For a brief history of the Nebraska National Forest, see: Hunt, J.C. 1965. The forest that man made. American Forests. 71(12): 32–35, 48–50.

For further information on the management of grassland firebreaks in Nebraska, see: https://climatechange.lta.org/wp-content/uploads/cct/2015/12/Firebreak-Management-Brochure.pdf

Firefighters in 1940 with portable flame thrower (stretcher style) in chaparral on the Los Padres National Forest in California. Photo: Neil L. Perkins, USDA Forest Service.

Flammability of Chaparral Lands Depends on How It Grows

Charles C. Buck

The normal state of affairs has been upset since 1945, the beginning of the present southern California drought.

Southern California chaparral has long been noted for its flammability, which is usually ascribed to the general character of the vegetation, steep slopes, and severe weather conditions. Probably not enough emphasis has been given to changes in the vegetation itself that affect its fuel qualities.

All evergreen California chaparral species normally grow new twigs and leaves in the spring and drop a portion of the older leaves in the summer and fall. For the canopy to reach full development after this type of vegetation is first established usually requires 8 to 12 years, during which time little dead wood or litter is produced and fire presents no particular problem.

When the site becomes fully occupied, annual production of new twigs and leaves is balanced by the death of older branches and leaves. In normal years, there is a seasonal cycle in flammability caused by an increase in number of leaves with high moisture content in the spring, then a decrease in number and decline in leaf moisture in summer and fall. Normally, this annual cycle of balanced growth and death causes a gradual buildup of dead fuels. But flammability is usually kept within reasonable, though seasonally variable, limits by the slow compacting and decay of accumulated litter and by the overstory of green leaves which shields against sun, wind, and desiccation.

This normal state of affairs has been upset since 1945, the beginning of the present southern California drought. By 1948, the shortage of rainfall began showing its effects through the appearance of individual dead bushes scattered over the landscape.

By the beginning of the 1950 fire season, the topsoil was powder dry. In some areas, there was little if any growth of new leaves; more old leaves, too, had fallen. Instead of full-bodied dense crowns, thin, transparent, drab-colored foliage met the eye. By midsummer, the chaparral looked and felt parched. That it could be so dry and still be alive was unbelievable. The canopy over large areas was punctured with stark, dead branches, and many more than the usual number of dead shrubs could be seen.

This marked change in growth—or lack of it—meant a much higher than normal ratio of dead to green fuel, extremely flammable foliage, higher fuel temperatures from increased exposure to the sun, and more freedom of air movement—meaning more wind close to the ground.

Years of drought are often characterized by low humidities and high temperatures. These occurred often in the summer of 1950. The lack of moisture in soil and vegetation also held the pickup of humidity and fuel moisture at night to a minimum, resulting in extra long daily burning periods.

The combination of deteriorated cover and severe weather had, by 1950, reached the point of near-maximum conflagration potential. By May, the southern end of the State had received only half or less of its normal seasonal rainfall, and very little more was expected. The outlook for the 1951 southern California fire season is thus for more thinning and dying out of shrubs, with a consequent increase in flammability beyond anything yet experienced in our time. ■

The article is adapted from Fire Control Notes *12(4) (October 1951), page 27. The author worked for the USDA Forest Service in the Division of Fire Research, California Forest and Range Experiment Station, Berkeley, CA.*

Roofing Slash Piles Can Save—Or Lose—You Dollars

George R. Fahnestock

In 1951, Ash (1951) reported that slash piles could be burned much more expeditiously in wet fall weather if they were covered with waterproof paper. Results of a November 1953 experiment on the Coeur d'Alene National Forest in northern Idaho show that the use of paper roofs should greatly reduce the labor and incidental costs required for burning slash. Whether the overall cost of burning piles is reduced depends on the price of paper and on the speed with which unroofed piles can be ignited.

The 1953 experiment was undertaken to obtain a reliable comparison between burning roofed and unroofed slash piles. A small national forest crew established the experiment in the course of the season's slash disposal job. Early in July, the crew spent 1 day making piles without roofs, one day making piles with 2-foot-by-2-foot (0.6-m-by-0.6-m) roofs, and 1 day making piles with 4-foot-by-4-foot (1.2-m-by-1.2-m) roofs. The roofing material was a duplex-type waterproof building paper. Piles to be roofed were built up to about three-fourths of their final height, the roof was put on, and then the pile was completed. No special pains were taken beyond seeing that the top of the pile before roofing was rather evenly convex. Roofing the piles involved no additional labor cost because the foreman cut and distributed roofs incidental to supervision. The only extra expense was the cost of the paper.

A statistical test showed odds of 99 to 1 that roofing would always prove similarly advantageous in comparable situations.

The slash was chiefly Douglas-fir and grand fir, with some ponderosa pine and western redcedar and a very small amount of western white pine and western larch. All of it was from trees cut early in 1953. Needles were still attached except on the larch.

The plan was to defer burning as long as possible in order that heavy rainfall would make burning conditions completely safe and would so saturate the slash that the advantage of roofing, if any, would show up clearly. Unfortunately, an exceptionally warm, dry fall left the country considerably drier than normal by November 25, when the slash was burned, just before the first heavy snowfall. Precipitation for September and October at the weather station nearest the slash experiment was only 1.34 inches (3.40 cm), approximately one-fourth of normal. The first 24 days of November brought 3.92 inches (10.0 cm) of moisture, mostly in the form of rain; and rain fell intermittently on the 25th. The woods were wet enough that slash fires could not possibly spread, but piled slash was not nearly so wet as it would normally be so late in the fall.

The slash was ignited by three workers equipped with propane torches.

Table 1—*Time required to ignite roofed and unroofed slash piles, Coeur d'Alene National Forest, November 1953.*

Burner	Time required to light 10 piles that had—		
	No roof	2-foot-by-2-foot roof	4-foot-by-4-foot roof
		Minutes	
Number 1	13.2	8.6	5.8
	13.6	11.5	9.0 [a,b]
Number 2	14.5a	10.7	6.8
	12.8	4.5	6.1
Number 3	10.5	7.3	10.0 [a]
Average	12.92	8.52	7.54

a. Exceptionally long walking time.

b. Ran out of propane; two piles lighted by burner number 2.

The article is adapted from Fire Control Notes *15(3) (July 1954), page 22–25. The author was a forester for the Forest Service, Northern Rocky Mountain Forest and Range Experiment Station, Missoula, MT.*

About 70 percent more roofed than unroofed piles can be burned in a given period of time.

With inspection for composition or compactness, 50 piles for each roof classification were selected for burning. On signal, each burner lit 10 piles and called out when finished. Time for lighting 10 piles was recorded in minutes and tenths. Fires that went out after they appeared to be established were not rekindled. A tally was made of piles that did not burn, and all other piles were inspected to see whether they had burned clean.

Table 1 summarizes the results of the experiment. It is apparent that the roofed piles were ignited much more rapidly than the unroofed. The surprising thing was that the little 2-foot-by-2-foot (0.6-m-by-0.6-m) roofs proved almost as beneficial as those that covered four times the area. Probably the explanation lay in the relative accessibility of the different classes of piles. Walking time between piles was noticeably less in the 2-foot-by-2-foot (0.6-m-by-0.6-m) pile area than in the other two areas because of the gentle slope, short distance between piles, and proximity of all piles to a road.

The first attempt at ignition was much more successful for roofed piles than for unroofed. Twelve unroofed piles out of 50 failed to burn after the first ignition effort, against 2 piles with 2-foot-by-2-foot (0.6-m-by-0.6-m) roofs and 1 with a 4-foot-by-4-foot (1.2-m-by-1.2-m) roof. The latter pile failed to burn only because the person lighting it was in too much hurry: it burned well when the torch was reapplied, without any change in the pile itself. The burners complained that many of the unroofed piles were poorly made, but the same complaint might have been made about a number of roofed piles that were ignited without difficulty. In fact, one burner reported lighting a 4-foot-by-4-foot (1.2-m-by-1.2-m) roofed pile that he would have passed by as unburnable had it not been roofed. It appeared that the "poor" unroofed piles were most often simply those that lacked a natural roof of closely packed needle-bearing branches.

All piles that were ignited satisfactorily burned clean. The time required for them to burn out was not measured. Differences in burning time appeared to vary more in proportion to the amount of fine material in the piles than in relation to the presence or absence of roofs.

A statistical test showed odds of 99 to 1 that roofing would always prove similarly advantageous in comparable situations. The test showed no difference in effect between 2-foot-by-2-foot (0.6-m-by-0.6-m) and 4-foot-by-4-foot (1.2-m-by-1.2-m) roofs. The cost analysis and subsequent discussion are based on the larger sized roof in order to be ultraconservative in estimating savings and to avoid the possibility that the apparent effect of the small roofs was due largely to accessibility.

In the experiment, a given number of slash piles with 4-foot-by-4-foot (1.2-m-by-1.2-m) roofs were burned in 58 percent of the time required for burning the same number of unroofed piles. Put another way, this means that about 70 percent more roofed than unroofed piles can be burned in a given length of time. For practical purposes, the actual time per pile determined in the experiment means nothing. The burners were ready at their first piles when the order to start was given, and they quite obviously worked at top speed. The percentage figures can, however, be applied to an average day's accomplishment in burning unroofed piles to get a rough idea of possible savings due to roofing.

The slash-burning crew had worked on the same logging chance on the preceding day, under almost identical weather conditions, burning unroofed piles only. Accomplishment for the day was 235

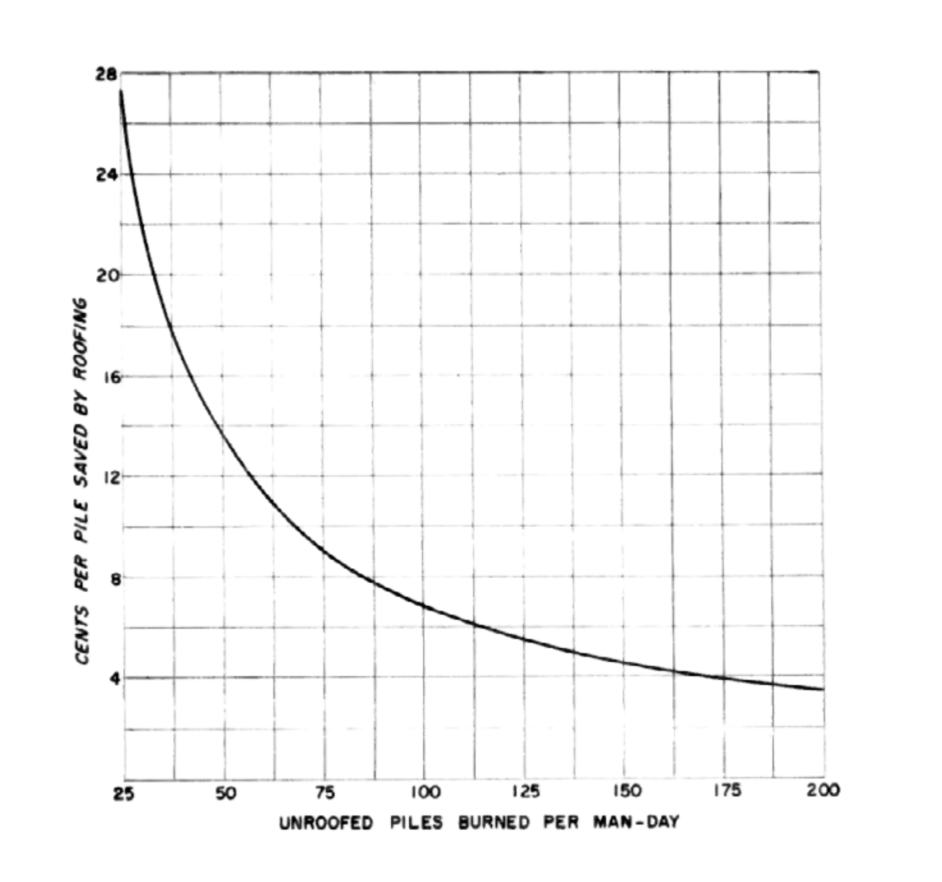

Figure 1—*Savings per pile roofed in relation to unroofed piles that can be burned per person-day.*

piles, more or less. A conservative estimate of the cost of keeping such a crew on the job in 1953 is $50 per day; this includes wages, transportation, propane, and incidentals. The cost per pile was therefore, 21.3 cents. A 70-percent increase would bring the number of piles per day to 400, at an average burning cost of 12.5 cents. The straight cash-on-the-barrelhead advantage of using 4-foot-by-4-foot (1.2-m-by-1.2-m) roofs would be 8.8 cents a pile, from which the cost of paper must be deducted.

It is apparent that the saving per pile varies inversely with the number of piles that can be burned in a day. Thus, if the crew in question could burn an average of only 100 unroofed piles per day, the cost per pile would be 50 cents; the cost of burning 170 roofed piles, about 30 cents each; and the savings per pile, 20 cents. By the same line of reasoning, if the crew could burn 500 unroofed piles a day, roofing would reduce burning costs by only 4 cents a pile.

If the savings are greater than the cost of paper, an overall cash advantage is realized from roofing slash piles and vice versa. The current cost of 48-inch (122-cm) Kraft 30-30-30 Vulcan waterproof paper f. o. b. Spokane, WA, is 0.45 cents per square foot or 7.2 cents for a 4-foot-by-4-foot (1.2-m-by-1.2-m) roof, leaving a cash saving of 1.6 cents per pile. But the paper used in the experiment was Kraft 30-30-30 Leatherback, which cost 19.2 cents per 4-foot-by-4-foot (1.2-m-by-1.2-m) roof, so a net loss of 10.4 cents a pile was incurred. Figure 1 shows the savings per pile, prior to deducting the cost of paper, effected by roofing in relation to number of unroofed piles that can be burned per person-day. Although production would vary a little according to crew size, the figure affords a rough guide to the margin available for purchasing paper and also for putting it in the piles if this involves extra cost.

Cash savings are not the only reason why roofing slash piles is good business. An even better reason is the certainty that roofed slash can be burned expeditiously when there is no longer any danger that slash fires will spread. No dollar value can be placed on this factor; seasons and situations vary too much. But many thousands or probably millions of dollars have been spent over the years in checking slash fires and in extinguishing those that got away because they were started in too dry weather or hung over into a dry period. As a consequence of diverting money to firefighting, the overall slash-disposal program has suffered. The diversion of manpower to firefighting has set back other activities. This waste of money and manpower—this handicap to constructive work—would be greatly reduced if the burning of piled slash could always be accomplished rapidly after the fire threat is definitely over.

Probably the greatest benefit derived from roofing slash piles is the ability to burn efficiently when the danger of wildfire is past.

This experiment dealt with hand-piled slash, most of which had the needles attached, the easiest kind of slash to burn. Roofing should have a greater advantage if the needles have been lost, as in the case of old slash and hemlock and spruce slash of any age. The same principles should apply to machine-piled slash. Rather delicate timing is required to burn dozer piles, and the danger of hangover fires is great because of the large amount of heavy material. Further study is planned to get definite information on the value of roofing dozer piles and hand-piled slash that has lost its needles.

There is nothing magical about the 4-foot-by-4-foot (1.2-m-by-1.2-m) roof. A somewhat smaller or differently shaped one may be just as effective. In this experiment, the apparent advantage of the 2-foot-by-2-foot (0.6-m-by-0.6-m) roofs was heavily discounted for two reasons:

1. The piles were more accessible than those in the other two classifications, and
2. The piles were exceptionally well constructed and contained plenty of fine material.

A disadvantage of the small roofs is that they cannot be seen after the pile has been completed. Time may be lost in searching for the dry spot in the pile. Where larger roofs were used, an edge or corner of the paper could usually be found without much looking. It seems reasonable to believe that a substantial part of the pile should be kept dry if a complete burn is to result after the unroofed part is saturated. Savings will be increased, however, to the extent that smaller roofs can be used without a corresponding reduction in efficiency.

The experiment described in this article was too small to provide a completely dependable dollars-and-cents estimate of how roofing slash piles affects slash-burning costs. Certain generalizations appear to be well supported, however:

1. About 70 percent more roofed than unroofed piles can be burned in a given period of time.
2. Under the right conditions, an appreciable cash saving can be effected or a loss can be sustained.
3. The factors that govern the amount of saving or loss are the cost of paper and the ease of burning unroofed piles.
4. The financial advantage of roofing should be greatest if the slash has lost its needles.
5. Probably the greatest benefit derived from roofing slash piles is the ability to burn efficiently when the danger of wildfire is past. The cash value of this ability is great over the years but cannot be estimated accurately.
6. It appears that money almost certainly will be lost unless roofs are put on as part of the piling job.

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Old-Growth Conversion Also Converts the Fire Climate

C.M. Countryman

The term "fire climate" designates the environmental conditions of weather and fuel moisture that affect fire behavior.

Converting an old-growth forest presents problems that have long challenged foresters, engineers, and economists. Road location, method of cutting, fire control, and slash disposal are all critical jobs. In terms of fire control, the forest manager has been concerned primarily with slash disposal and fire suppression in slash areas. The manager has frequently observed the great difference in fire behavior between slash and uncut areas, quite naturally associating this difference with the obviously different fuel conditions.

Although the general relations between weather factors, fuel moisture, and fire behavior are fairly well known, the importance of these changes following conversion and their combined effect on fire behavior and control are not generally recognized. The term "fire climate," as used here, designates the environmental conditions of weather and fuel moisture that affect fire behavior. It does not consider fuel created by slash because, regardless of what forest managers do with slash, they still have to deal with the new fire climate. In fact, the changes in wind, temperature, humidity, air structure, and fuel moisture may result in greater changes in fire behavior and the size of the control job than does the addition of more fuel in the form of slash.

Conversion that opens up the canopy by removal of trees permits freer air movement and more sunlight to reach the ground. The increased solar radiation in turn results in higher temperatures, lower humidity, and lower fuel moisture. The magnitude of these changes can be illustrated by comparing the fire climate in the open with that in a dense stand. It is the same kind of difference that occurs when a closed, mature stand is clearcut.

In the open, solar radiation impinges directly on the Earth's surface. Because both the Earth and the air above it are poor conductors, heat is concentrated at the surface and in the layer of air next to it. Ground fuels can thus become superheated. In full sun at midday, it is not uncommon for surface temperatures to reach 165 °F (74 °C) or more, based on unpublished data on file at the California Forest and Range Experiment Station in Berkeley, CA (see also Geiger 1950; Kittredge 1948). At the same time, air temperatures measured at the standard height of 4-1/2 feet (1.4 m) in an instrument shelter may not exceed 85 or 90 °F (29–32 °C). Temperatures in the lower layers of air in the open decrease rapidly with height above the ground. In a typical temperature profile in northern California, for example, the temperature was 135 °F (57 °C) at the surface and decreased to 77 °F (25 °C) at 5 feet (1.5 m) (fig. 1).

Relative humidity will vary inversely to the temperature of the air as long as the amount of water vapor remains constant. A relative humidity profile, then, can be expected to be the inverse of the temperature profile; and, in the open, relative humidity near the surface

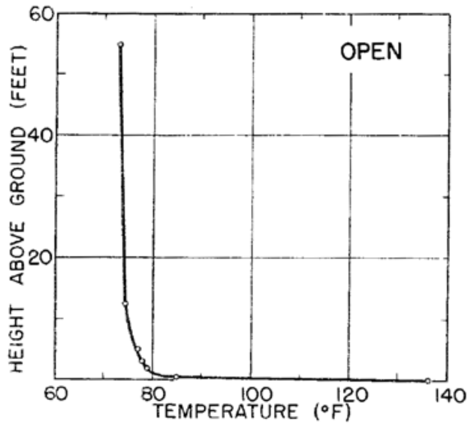

Figure 1—*Typical temperature profile over bare ground in the open. (Data taken at 12 a.m., September 16, 1943, Shasta Experimental Forest.)*

The article is adapted from Fire Control Notes *17(4) (October 1956), page 15–19. It was first published in the Society of American Foresters meeting proceedings in 1955. The author was a forester for the USDA Forest Service at the California Forest and Range Experiment Station, Berkeley, CA.*

Firebrands that do not contain enough heat to start a fire in a closed stand may readily start one in the open.

is much lower than that at the standard 4-1/2 feet (1.4 m).

These temperature and humidity relations have an important influence on fuel moisture. In the absence of precipitation, the moisture content of dead fuel decreases as humidity decreases and as temperature increases. Surface fuels can thus be expected to be materially lower in moisture content than fuels a short distance above the ground and exposed to the cooling effect of wind. Measurements of standard half-inch (1.3-cm) fuel-moisture indicator sticks at the California Forest and Range Experiment Station have shown that the minimum daily moisture content of surface fuels averages only about half that of fuels 10 inches (25 cm) above ground.

A mature, closed stand has a fire climate strikingly different from that in the open. Here, nearly all of the solar radiation is intercepted by the crowns. Some is reflected back into space, and the rest is converted to heat and distributed in depth through the crowns. Air within the stand is warmed by contact with the crowns, and the ground fuels are in turn warmed only by contact with the air. The temperature of fuels on the ground thus usually approximates air temperature within the stand.

Temperature profiles in a dense mixed-conifer stand illustrate this process (fig. 2). By 8 a.m., air within the crowns had warmed to 68 °F (20 °C). Air temperature near the ground was only 50 °F (10 °C). By 10:00 a.m., temperatures within the crowns had reached 82 °F (28 °C) and, although the heat had penetrated to lower levels, air near the surface, at 77 °F (25 °C), was still cooler than at any other level. At 2:00 p.m., air temperature within the stand had become virtually uniform at 87 °F (31 °C). In the open less than one-half mile (0.8 km) away, however, the temperature at the surface of pine litter reached 153 °F (67 °C) at 2:00 p.m.

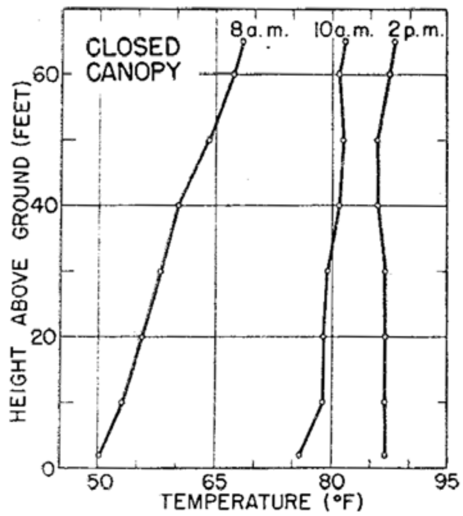

Figure 2—*Temperature profiles in a dense mixed-conifer stand in northern California, showing the progressive downward transfer of heat into the stand from the crowns. (Data taken September 22, 1943.)*

Clearcutting can change the fire climate so that fires start more easily, spread faster, and burn hotter.

Because of the lower temperature and higher humidity, fuels within the closed stand are moister than those in the open under ordinary weather conditions. Typically, when moisture content is 3 percent in the open, 8 percent can be expected in the stand.

Moisture and temperature differences between open and closed stands have a great effect on both the inception and the behavior of fire. For example, fine fuel at 8-percent moisture content will require nearly one-third more heat for ignition than will the same fuel at 3-percent moisture content. Thus, firebrands that do not contain enough heat to start a fire in a closed stand may readily start one in the open.

Fires starting in the open also burn more intensely and build up to conflagration proportions more quickly since less of the heat produced by the fire is used in evaporating water from the drier fuels. Strong convection columns that can carry burning material aloft develop rapidly; these columns and the relative ease of ignition in the open are largely responsible for one of the major fire control problems in clearcut slash areas—that of spread of fire by spotting.

Another very important difference between fire climate in a closed stand and fire climate in the open is in air movement. In general, wind direction and velocity 2,000 feet (600 m) or more above the surface are the result of widespread pressure differences and general weather conditions. In the layer of air below 2,000 feet (600 m), surface friction and local landscape features have an increasingly important effect on air movement. Consequently, over an extensive closed stand, wind velocity decreases only slightly above the crowns. Within the stand, however, air movement is much restricted, seldom exceeding 3 or 4 miles per hour (4.8–6.4 km/h) even with velocities of 25 to 30 miles per hour (40–48 km/h) above the canopy or in the open (fig. 3) (Fons 1940; Gisborne 1941; Kittredge 1948;).

Since the rate of forward spread of fire is largely dependent upon wind velocity, a much faster rate can be expected in the open, at least in the initial stages of the fire. For example, under moderate conditions of fuel moisture and temperature, a wind velocity of 25 miles per hour (40 km/h) will result in a rate of spread more than 5 times as great in the open as in a closed stand because of wind differences alone. Clearcutting, then, can change the fire climate so that fires start more easily, spread faster, and burn hotter. The effect of these changes on the fire control problem is extremely important. When a standard fire weather station in the open indicates a temperature of 85 °F (29 °C), fuel moisture of 4 percent, and a wind velocity of 15 miles per hour (24 km/h)—not unusual burning conditions in the West—then a fire starting on a moderate slope will spread 4.5 times as

A mature, closed stand has a fire climate strikingly different from that in the open.

fast in the open as in a closed stand. The size of the suppression job, however, increases even more drastically.

Greater rate of spread and intensity of burning require control lines farther from the actual fire, increasing the length of fireline. Line width also must be increased to contain the hotter fire. Less production per firefighter and delays in getting additional crews complicate the control problem on a fast-moving fire. It has been estimated that the size of the suppression job increases nearly as the square of the rate of forward spread. Thus, a fire in the open will require 20 times more suppression effort. In other words, for each firefighter required to control a surface fire in a mature stand burning under these conditions, 20 firefighters will be required if the area is clearcut.

Methods other than clearcutting, of course, may bring a less drastic change in fire climate. Nevertheless, the change resulting from partial cutting can have important effects on fire. The moderating effect that a dense stand has on the fire climate usually results in slow-burning fires. Ordinarily, in dense timber, only a few days a year have the extreme burning conditions under which surface fires produce heat rapidly enough to carry the fire into the crowns. Partial cutting can increase the severity of the fire climate enough to materially increase the number of days when disastrous crown fires can occur.

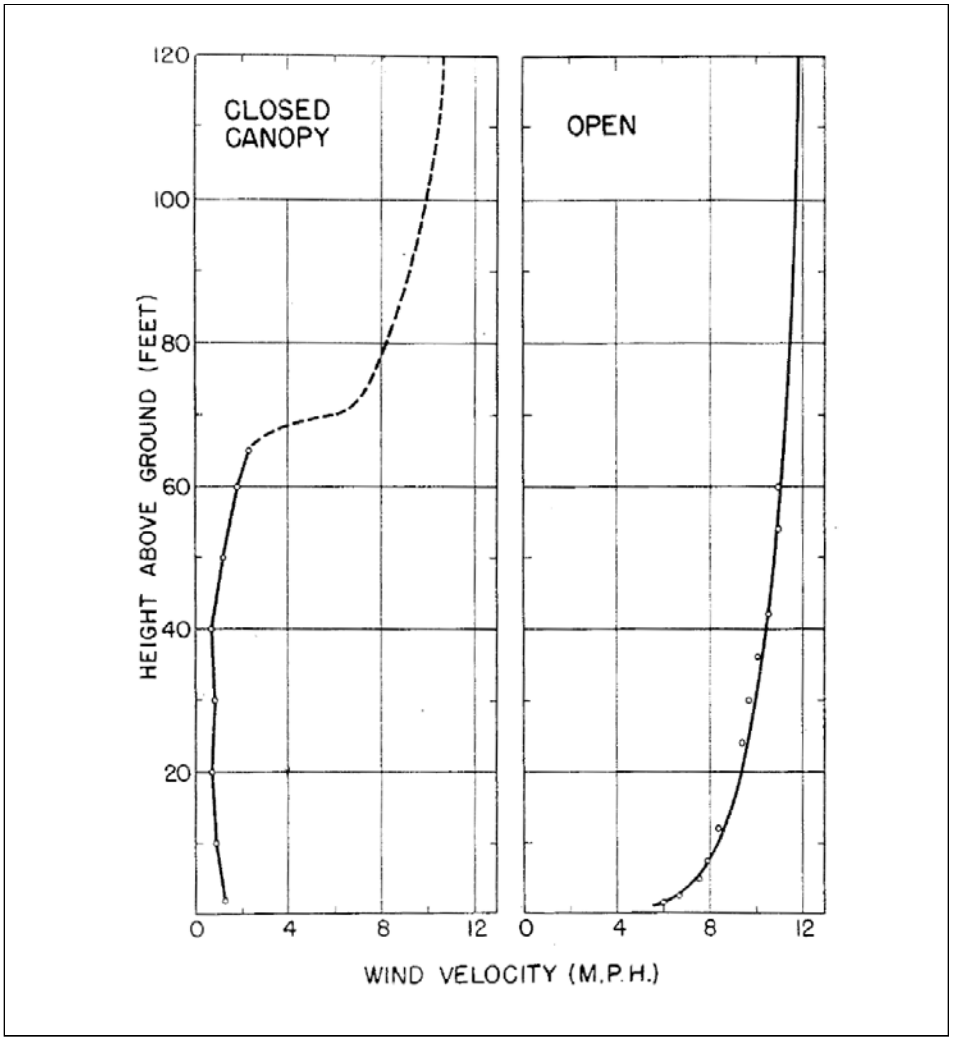

Figure 3—*Left, typical daytime wind profile in and over dense conifer stand; right, typical daytime wind profile over level ground in the open.*

Forest management is impossible without adequate fire control, and it is axiomatic that fire control planning is a vital part of timberland management. It is important to recognize that, besides creating additional fire hazard in the form of slash, stand conversion can alter the fire climate for many years. Therefore, the effect of silvicultural practices on fire climate must be given major consideration in the management plan for the forest. Protection must be adequate to compensate for the changes in fire climate as well as for slash. This is the only way to ensure that we convert our old-growth forests to managed stands and not to wasteland.

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Fire Hazard Resulting From Jack Pine Slash

D.E. Williams

In cutover areas where slash had been piled and burned, the hazard was substantially lower than in areas where the slash had been left unburned.

The accumulation of slash during logging operations introduces a serious problem to those concerned with fire control. Fires are more likely to start in slash areas; and, once ignited, they have a greater resistance to control and often do more damage than fires burning in an uncut forest. Slash is treated in a number of ways, usually depending on the cutting method. Essentially, there are two main treatments:

1. Leaving the slash on the cutover area, and
2. Removing it by burning.

Furthermore, the manner in which the slash is left has an effect on the subsequent fire hazard.

The comparative fire hazard of areas of burned and unburned slash was investigated by Munger and Matthews (1941), who concluded that unburned slash in western Washington and Oregon is one-third more hazardous than burned slash 10 years after logging. Cheyney (1939), on the other hand, writes in the *Journal of Forestry*: "It would be a conservative statement to say that no slash is a special fire hazard in the Lake States for more than 5 years after it is cut." There appears to be no doubt, however, that an accumulation of slash in a cutover forest will increase the fire hazard of the area for a considerable period after cutting operations have been completed. Furthermore, it is evident that, in any locality, the increase of hazard brought about by the presence of slash will vary somewhat with the method of slash treatment employed and with the number of years that have elapsed since cutting took place.

Canada's Federal Forestry Branch, in cooperation with the Manitoba Forest Service, conducted a series of large-scale test fires in slash areas in the Sandilands Forest Reserve. The object of the study was to determine experimentally:

1. The comparative fire hazard in jack pine in similar cutover areas where different slash treatments had been employed, and
2. The variations in hazard that occur as slash ages.

The term "slash age" refers to the number of years since logging.

This study also provided an opportunity for an investigation of the effect of slash disposal methods on jack pine regeneration. The results of this investigation are described by H. J. Johnson (1955) in a current publication of the Federal Forestry Branch.

DESCRIPTION OF AREA

The Sandilands Forest Reserve lies near the southeast corner of Manitoba at the western extremity of Halliday's (1937) Great Lakes-St. Lawrence Forest Region. The topography is flat and the soil is sandy. Stands of jack pine (*Pinus banksiana* Lamb.), the most important commercial species in the area, are typically very open; and consequent heavy branching results in moderate to heavy slash accumulation during logging operations. High underbrush is very scattered and other vegetation is moderate, with bearberry (*Arctostaphylos uva-ursi*), blueberry (*Vaccinium* spp.), and caribou moss (*Cladonia* spp.) as the main components, along with a considerable amount of grass.

The area in which the study was made is adjacent to agricultural land and subject to fires started by land-clearing operations. Owing to the lack of natural water supplies and to the nature of the soil, fire suppression is best effected by hand tools and pumper-tankers.

The cutting methods employed were mainly medium to heavy selection cuts and a few clearcuts.

The article is adapted from Fire Control Notes *17(4) (October 1956), page 15–19. It was first published in the Society of American Foresters meeting proceedings in 1955. The author was a forester for the USDA Forest Service at the California Forest and Range Experiment Station, Berkeley, CA.*

Differences in hazard owing to the use of different treatments of unburned slash were found to be small and of little significance.

METHOD OF STUDY

Examples of six different slash treatments were available in the Sandilands area, and areas representing four stages of slash deterioration were located. Duplicate test fire plots were placed within each slash age class for each type of disposal method, wherever it was possible. Table 1 shows the distribution of the plots that were available and on which the conclusion of this study was based. In addition to the plots listed, two control plots were located in a representative uncut jack pine stand.

The sample plots were square, 100 feet (30 m) to the side. Two single furrows were plowed around the perimeter of each plot as a fireguard; where slash was particularly heavy, an additional fireguard was plowed approximately 20 feet (6 m) outside the first. A Manitoba Forest Service fire ranger and five or more firefighters were present at all tests. When the plots had been burned, hand tools and pack tanks were used to extinguish the fires.

Four-foot (1.2-m) stakes were set at 20-foot (6-m) intervals throughout the plot, providing a grid that greatly facilitated the plotting of the fire perimeter as burning progressed. Just before burning, each plot was inspected and a complete plot description was recorded on specially prepared forms. Particular attention was paid to the height of the slash; ground vegetation; the kind, amount, and depth of the duff; and the thickness of the humus layer. The number of pieces and sizes of the heavier fuels (3 inches (7.6 cm) or more at the large end) were recorded.

Air temperature and relative humidity were measured with a sling psychrometer, and other weather conditions were noted. The wind velocity at the time of the fire was measured with a portable anemometer, and its direction was estimated with the aid of a box compass. The amount of dew that formed the previous night was measured by the method developed by the Federal Forestry Branch and recorded in the field notes (Potvin 1949).

Various sizes of branches, duff, and other fuels were sampled and their moisture content determined by laboratory methods.

Immediately after igniting each test fire, an observer and an assistant began plotting the position of the fire perimeter at 1- or 2-minute intervals, depending on the rapidity of spread. Observers worked independently on the leeward and windward sides of the starting point and were able to keep accurate records of the fire's progress with the aid of stopwatches and guide stakes. Notes were made also on the height of flame, vigor, smoldering, and depth of ash.

When the fire was out, further notes on the severity of the burn were made. Estimates were made of the percentage of the area left unburned as well as the percentages of each type of unburned fuel.

The careful plotting of the fire perimeter at regular intervals gave a very comprehensive picture of the fire's progress and a measure of its rate of spread. The grids were planimetered, and the proportionate area burned during each 5-minute interval of the fire's progress was determined.

A numerical hazard index was computed for each test fire using much the same method as that employed regularly by the Forestry Branch in rating small-scale test fires (MacLeod 1948). In calculating this hazard index, the factors used and the relative weights given to each were as follows:

1. Rate of spread, 30 percent;
2. Total area burned, 20 percent;
3. Vigor, 20 percent;
4. Height of flame, 10 percent;
5. Smoldering, 10 percent; and
6. Depth of ash, 10 percent.

These factors, with the exception of vigor and smoldering, can be measured directly, with the result that errors owing to personal judgment are kept to a minimum.

Following the described procedure, all test fire plots shown in table 1 were burned during the summer periods of 1949, 1951, and 1952. A fire weather station was set up in the area and the danger index was calculated daily throughout the periods of the tests from the Midwest Fire Danger Tables (Beall 1948). All tests were made when this local danger index was in the range 7 to 12; the average for all tests was found to be 9.

Table 1—*Distribution of test fire plots according to slash treatment and slash age class.*

Slash treatment	Number of plots burned, by slash age class			
	1–2 years	3–5 years	6–9 years	10–12 years
Left as cut (untreated)	2	2	2	1
Piled and left unburned	1	2	2	2
Piled and burned (100 percent)	1	2	2	2
Tops only (standard with clear-boled trees)	1	2	2	0
Lopped and scattered (maximum depth 18 inches (46 cm))	1	2	2	2
Windrows (1 chain (20 m) apart, unburned)[a]	0	2	0	0

a. This treatment dropped from the study because of insufficient data.

Each test fire was given a hazard rating as determined by the six performance factors listed above. An adjustment of one hazard index unit was made to the rated hazard for the tests made on days when the local danger index differed from the mean by two units or more. For example, one plot was burned on a day when the local danger index was 7. To adjust for the lower fire danger conditions on this day, the rated hazard index for that test fire, calculated to be 11, was increased by one unit to 12.

It should be noted here that the local danger index refers to the average fire danger in all fuel types in the area, whereas the rated hazard index is a measure of the fire hazard as indicated by the individual test fires in the fuel concerned.

ANALYSIS OF DATA

Burned Slash. Analysis of test fire behavior in cutover areas where slash had been piled and burned indicated that the hazard is substantially lower than in areas where the slash had been left unburned. Moreover, it was found that when slash is burned after cutting operations, the fire hazard can be expected either to be similar to that before the area was cut or slightly higher because of increased insolation. Other investigators have found that, under full insolation, fuel temperatures approaching 150 °F (66 °C) are not uncommon.

The conclusions drawn here will hold true only if the slash burning operations have been thoroughly carried out, in which case all the slash in the piles will have been destroyed. It is to be expected, however, that in some instances the original duff and litter will be left unburned between the piles.

Of the test plots burned in this group, one was not included in the analysis. The plot description indicates that there was an 85-percent coverage of jack pine duff and litter on the plot, as opposed to an average of less than 10 percent on the remaining six plots representing this treatment. The depth of litter and humus on that was double the average of the other plots. This was no doubt a result of the unusually high density of the residual stand. Observations made on this plot, therefore, were excluded from the analysis on the basis that fuel conditions were not typical.

Figure 1 shows the comparative hazard to be expected with each type of slash treatment studied and with slash age. The curve for piled and burned slash (fig. 1) describes the hazard of burned slash over the years since it was cut. This curve shows that, if slash burning is done thoroughly, the hazard will be almost nonexistent immediately afterward and will increase, within a period influenced by the density of the residual stand and the growth of new vegetation, to a value comparable to that in the uncut stand.

Unburned Slash. The analyses of tests on unburned slash showed that fire hazard will remain comparatively high, regardless of treatment, for at least 10 years after the cut. Figure 1 shows the percent of worst possible hazard to be expected with each disposal method ("worst possible" meaning the highest hazard rating based on the danger index scale of 0 to 16). These methods are listed in decreasing hazard potential at a slash age of approximately 2 years:

- Lopped and scattered,
- Piled and not burned,
- Left as cut, and
- Tops only.

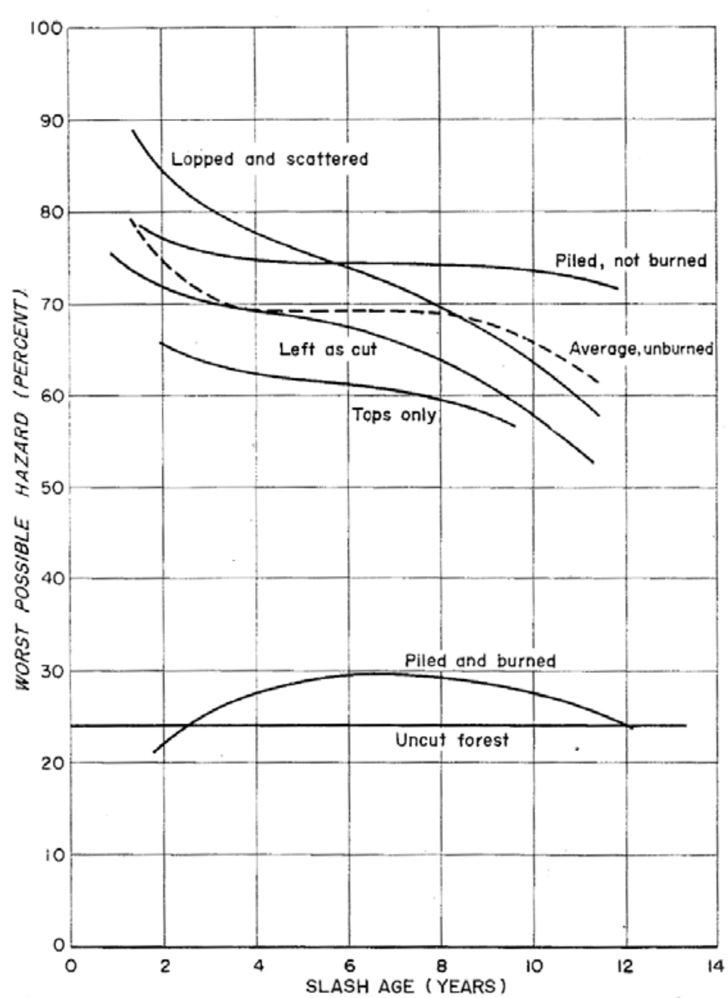

Figure 1—*Variation in hazard with age of slash.*

Differences in hazard owing to the use of different treatments of unburned slash, however, were found to be small and of little significance. Of somewhat greater significance is the fact that slash that has been lopped and scattered or left as cut deteriorates more rapidly over the years than that which has been piled and left. Thus, the hazard in cutover areas where the slash has been scattered or left strewn about, although initially high, falls off with age at a relatively rapid rate.

In areas where tops only have been left after cutting, the hazard is lower than when other treatments have been employed, and the reduction in hazard over the years parallels closely that for piled slash. It should be borne in mind, however, that in the Sandilands area stands are typically open, and this type of slash consists mainly of scattered tops. Where this treatment is used in heavy stands, the tops are more or less contiguous and the slash resembles that left as cut.

Of the test fires made in slash that had been piled and left, only six of the seven fires were considered to be truly representative of normal conditions. A changing wind direction during the course of the burning of one plot prevented the fire from burning consistently on any one front. Also, there were more bare patches on this plot than were normally encountered on the remaining six plots. In consequence, observations made on that plot were not included in the analysis.

The average height of the piled slash was 3 feet (0.9 m), and when the test fire was in progress, sufficient heat was produced by the burning pile of slash to promote the rapid spread of the fire between the piles. This was normally a distance of 20 feet (6 m). Under the piles, all duff and organic matter were completely burned to mineral soil, whereas between piles, the burn was light. There was less falling off of hazard with slash age than occurred when the lopped-and-scattered or left-as-cut methods were employed.

In almost all areas of piled slash and tops only, there were sufficient surface fuels to allow the fire to run from pile to pile or from top to top.

CONCLUSIONS

In the region and season in which these tests were made, the burning of jack pine slash, when thoroughly carried out, will reduce the fire hazard to a level comparable to that of the uncut forest and to about one-third of that of unburned slash. Therefore, where hazard reduction is of primary importance, serious consideration should be given to slash burning after cutting operations. This is the only commonly used slash disposal method that is effective in reducing the fire hazard.

The hazard resulting from unburned slash is comparatively high for at least 10 years after it has been cut—about three times as great as the hazard of the uncut forest. Some further effects regarding unburned slash were noted in this study:

- The hazard is highest immediately following the cut when the dead foliage is still clinging to the twigs.
- The hazard diminishes gradually as the needles dry and fall—that is, until approximately 4 years after the slash has been cut.
- From this point until the slash is 8 or 9 years old, the hazard decreases slowly as the debris weathers and compacts.
- After this time, the slash has been reduced by weathering and other action to a point where it is overgrown by an increasing abundance of vegetation.

With this increased shade, the slash receives less ventilation and solar radiation and, as a result, the rate of moisture loss is reduced, thus further lessening the hazard.

An illustration of this process is given in figure 2. The two curves show the

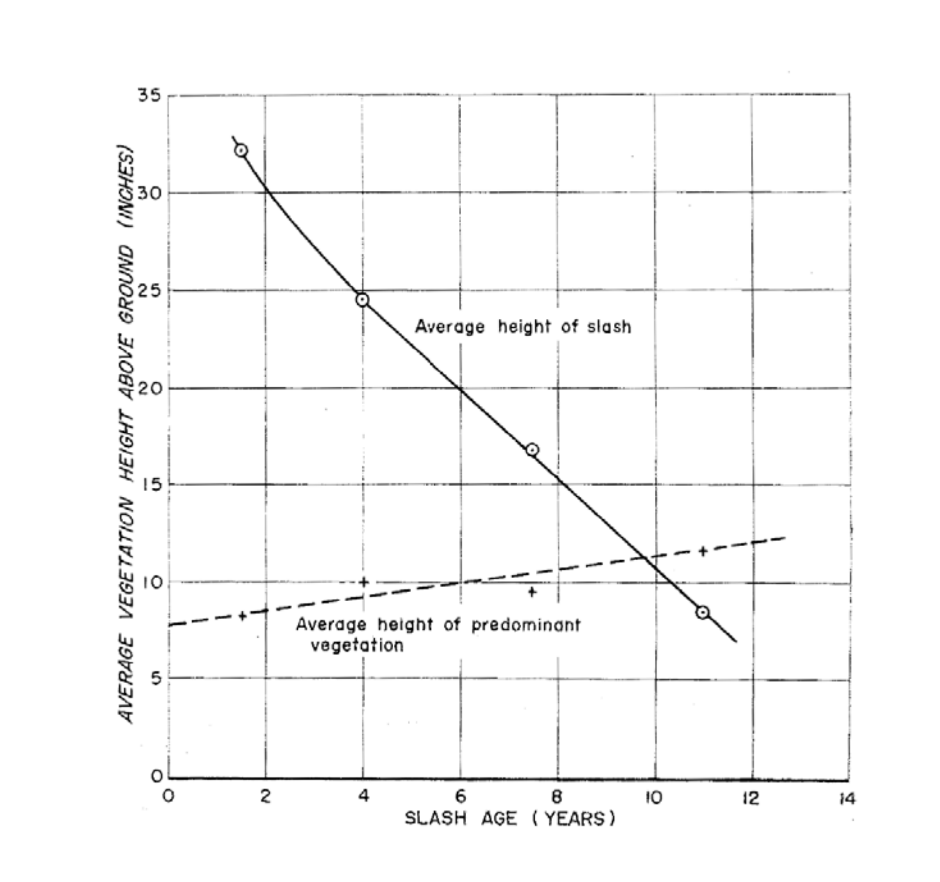

Figure 2—*Deterioration of unburned slash with age and growth of ground vegetation after cut.*

relationship between average height of slash and height of ground vegetation during the first 12 years following the cut. From this graph, it appears that green vegetation begins to overtop the slash 10 years after the cut. Figure 1 shows a general falling off of fire hazard at approximately this same point. It may be expected that, where environmental conditions differ from those of the area under study, the rate of slash deterioration and vegetative growth may also be different.

The small differences in hazard resulting from the use of the four different treatments of unburned slash are more or less of academic interest only. The choice of one method over another will depend a great deal on the chooser's point of view. For example, it may be felt that the high initial hazard of slash that has been lopped and scattered or left strewn over an area is offset by the relatively rapid rate of hazard decrease with increasing slash age. Others may argue that this high initial hazard is too risky to tolerate under any circumstance.

Although Johnson (1955) found that the poorest regeneration resulted from piling and burning, no slash treatment studied gave a satisfactory stocking of seedlings. Thus, because it results in the lowest hazard, the piling and burning of jack pine slash should be carried out whenever it is economical to do so.

Head fire advancing in 1-year-old jack pine logging slash under moderate fire danger conditions. Photo: B.J. Stocks, Canadian Forest Service, Sault Ste. Marie, ON.

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Aftermath of a clearcut on the Six Rivers National Forest in 1959. Slash disposal was needed to prevent a new kind of fire problem from emerging in the cutover Douglas-fir forests of northern California. Photo: Kenneth N. Boe, USDA Forest Service.

Slash Disposal by Burning on the Klamath

Lee Morford

Beginning with the World War II years, the cost of slash disposal increased to such an extent that disposal and hazard reduction became less common on forest lands. Personnel on the national forests of California began searching for a cheaper method to accomplish the desired results from both a fire hazard and silvicultural standpoint. When the logging industry moved into the Douglas-fir area of northwestern California, a new fire problem faced the protection agencies. In the Douglas-fir timber, a cull volume ranging from 20 to 50 percent of the total volume was left on the ground following logging. This created a very heavy accumulation of both large and small fuels. Fires occurring in these fuels were extremely difficult to control, particularly when fire dangers were above the low range.

Late in 1952, a study was made of the fires occurring in the Douglas-fir type slash areas of northern California. This study indicated that, if protection goals were to be met, some method of slash disposal would have to be instituted, in spite of the heavy costs.

The Klamath National Forest took the lead in attempting to devise ways of disposing of the heavy accumulation of fuel so that fires in the slash areas could be controlled. The Happy Camp District

The article is adapted from Fire Control Notes *19(4) (October 1958), page 141–43. The author was a forest dispatcher for the USDA Forest Service, Klamath National Forest.*

If slash burning was to be done safely and economically, all district managers would need established guidelines.

was designated as an experimental area. Fred Wilder, who has an excellent knowledge of fire behavior, was assigned to the project. He treated the areas in several different ways and kept cost records on the treatments. It soon became apparent that if slash burning was to be done safely and economically, all district managers would need established guidelines. The costs could be prohibitive if burning was tried when fuels were too wet; and burning was unsafe when fuels were too dry.

The problem had been discussed with the California Forest and Range Experiment Station in Berkeley, CA, and the fire weather section of the Weather Bureau. It was decided to set up a series of weather observation stations to get a representative measure of weather conditions in the timbered belt. By correlating their observations with the burning being done under the supervision of Fred Wilder—and through trial and error in other slash burning projects—it was possible to establish a set of preliminary guidelines to slash burning for use by all districts on the forest.

During the fall of 1956, the new guidelines were put into full use forestwide. Weather observations were taken at the Humbug Fireman Station and the Scott Bar Mountain, Slater Butte, and Blue Ridge Lookouts. The lookout stations were at the upper edge of the timbered areas in which the slash was being burned, and the Humbug Fireman Station at the lower edge.

These observations were correlated with the burning projects on the Happy Camp District to serve as a basis for revising and improving the preliminary guidelines, for which burning indexes had been computed from our Fire Danger Rating System. The revised system was used again in 1957, and a record was kept of the intensity with which the slash burned. Using this record and correlating it with the observed weather conditions and the previously established indexes, we again broadened and improved the guidelines.

The procedure under the guidelines is as follows: observations are taken from selected stations prior to the beginning of the slash burning. Weather forecasts are received twice daily during the month of October and once each day thereafter. From these weather forecasts and from the computed indexes of the day before, the burning index is predicted for the next day. This predicted index is then given to all districts engaged in or planning slash burning.

The fire overhead stated that only because of the previously burned slash were they able to construct and hold firelines.

No burning is done prior to October 1, and then not until at least 1/2 inch (1.3 cm) of rain has fallen. The guidelines and the indexes are used to determine where and when the slash can be burned safely and where and when the slash can be burned without too great a cost. In other words, when the burning index is zero, it is a waste of manpower and money to try to burn the lighter fuels. Heavy fuels that have been piled with some type of protection from weather can be burned at any time when there is no danger of spread.

To take advantage of every day of good burning conditions, it is advisable that work crews have a staggered tour of duty. It is also best to have men available to check areas that have been previously burned under favorable conditions whenever the increasing burning indexes indicate that there is danger of spread.

This system does not entirely eliminate all risk in burning slash since weather predictions are not always dependable and very often the weather prediction is not representative of small isolated areas. Either one of two methods is recommended for overcoming these deficiencies:

1. Place a person in charge of the burning operations who has a good understanding of fire behavior and a background of experience in slash burning, or
2. Have a portable weather station available at a selected site near the burning project where observations may be taken during selected periods throughout the day.

Either of these two methods work satisfactorily and prevent unpredicted severe burning conditions from trapping the burning crews or catching them with fires that they may be unable to contain and that may become costly.

TYPICAL SLASH BURNING GUIDELINES

1. Slash burning will not be permitted until after October 1 and then not until the following conditions are present and requirements met.
2. Trends of the fire danger for area 8 must be available for at least 5 days prior to burning, except that burning may be started immediately after at least 1/2 inch (1.3 cm) of rain has fallen.
3. Slash may be burned in these situations after 1/2 inch (1.3 cm) of rain and the area 8 index trends are as indicated:
   - In shaded canyon bottom—index below 17.
   - North exposure, about 6,000 feet (1,800 m) elevation—index below 15.
   - North exposure, fir type, 3,500 to 6,000 feet (1,100–1,800 m) elevation—index below 12.
   - North exposure, pine or mixed conifer type, 3,500 to 5,000 feet

We believe that, by using these guidelines for reduction of hazard, we will be able to meet the objective of both fire protection and silvicultural management of cutover areas.

(1,100–1,500 m) elevation—index below 10.

» Piled slash along lower side of roadbed or slash piled and lined with firebreaks, fir and Douglas-fir types—index below 10.

» East, south, and west exposures, Douglas-fir slash, 2,500 to 6,000 feet (800–1,800 m) elevation—index below 10.

» East, south, and west exposures, mixed conifer and pine, below 5,000 feet (1,500 m)—index below 7.

» Ridgetops and exposed points, pine and mixed conifer—index 3; Douglas-fir and fir—index 5.

CONCLUSIONS

The hazard reduction done on the Klamath since 1950 has not been fully evaluated. However, in 1955, during one of the most severe fire seasons in the history of the forest, an incendiary fire was started in unburned slash. It spread to an area in which the slash had been burned. This fire was controlled during the first burning period after spreading over approximately 800 acres (320 ha). The fire overhead stated that only because of the previously burned slash were they able to construct and hold firelines. This fire was one of 28 that started on the forest between September 1 and September 5. Several of these 28 fires were disastrous, and a total of approximately 64,000 acres (25,900 ha) of timberland were burned over in the first 10 days of September.

The Klamath is crossed by a very large lightning belt and no part of the entire forest is exempt from lightning storms. It is not uncommon for 30 to 70 fires to be started from a single thunderstorm. With the cutover area increasing at the rate of 5,000 to 10,000 acres (2,000–4,000 ha) per year, the risk of lightning fires and the potential disaster resulting from them is continually increasing. This situation alone makes it imperative that adequate hazard reduction be employed. We believe that, by using these guidelines for reduction of hazard, we will be able to meet the objective of both fire protection and silvicultural management of cutover areas. ■

SUCCESS STORIES WANTED

We'd like to know how your work has been going!

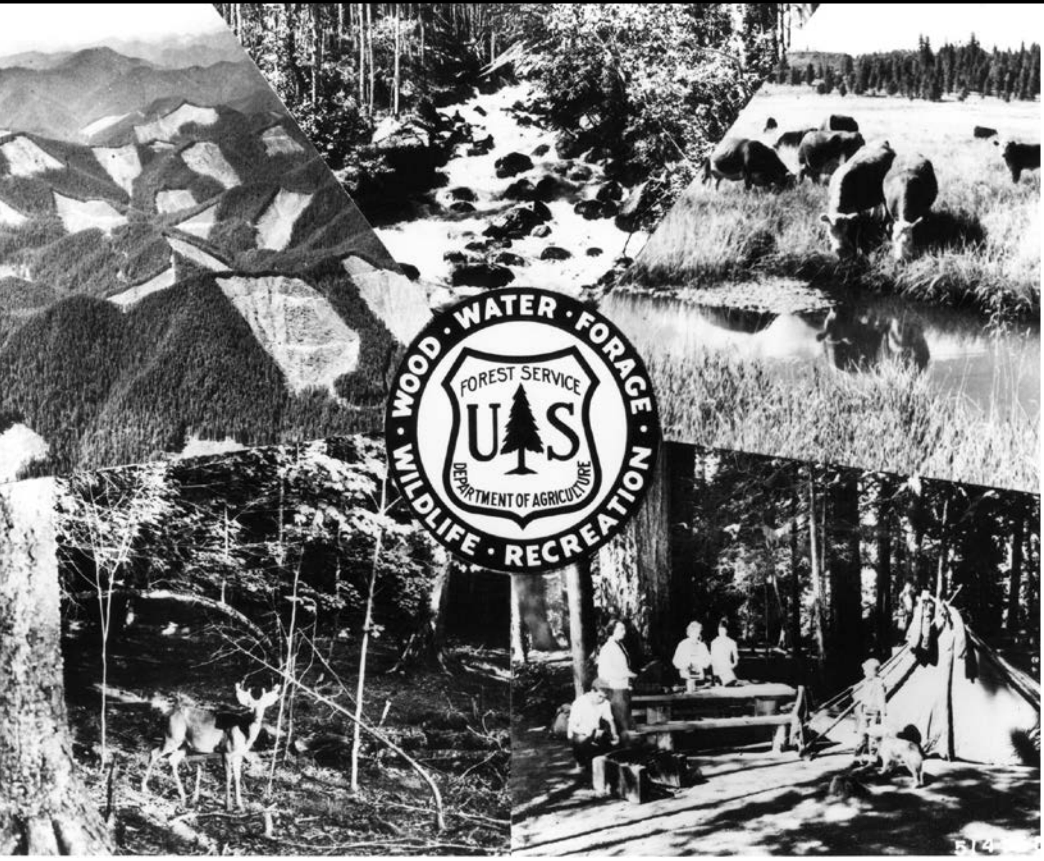
Let us share your success stories from your State fire program or your individual fire department. Let us know how your State Fire Assistance, Volunteer Fire Assistance, Federal Excess Personal Property, or Firefighter Property program has benefited your community. Make your piece as short as 100 words or longer than 2,000 words, whatever it takes to tell your story!

Submit your stories and photographs by email or traditional mail to:

USDA Forest Service
Fire Management Today
201 14th Street, SW
Washington, DC 20250

If you have questions about your submission, you can contact our FMT staff at the email address below.

SM.FS.FireMgtToday@usda.gov



Composite photo illustrating the five major uses of the national forests enshrined in the Multiple Use-Sustained Yield Act of 1960 (wood, water, forage, wildlife and fish, and outdoor recreation). The article discusses the need for fuels management to help sustain the uses, all prominent on the Stanislaus National Forest in California.

Management Designs for Conflagration Control, Duckwall Test Unit

R.W. Bower

Many wildland management areas in California contain extensive continuous stands of highly flammable vegetation. These areas have a high frequency of very high to extreme fire danger days each season. Use is high, with peaks of intensive use during the fire season. The combination of fuel, use, and fire danger results in conflagration-type fires that quickly overwhelm the normal initial-attack organization, cause extensive loss of resources, and require high suppression expenditures, as illustrated in California by the extensive timber losses of 1955, 1959, and 1960.

The article is adapted from Fire Control Notes *24(3) (July 1963), pages 51–55. The concept and program for the test unit were prepared by a management team from the California Region's Pacific Southwest Forest and Range Experiment Station and Stanislaus National Forest. The author was a forester for the USDA Forest Service, Division of Fire Control, California Region (now Pacific Southwest Region).*

The cost of maintaining a fire control organization to meet these conditions would be prohibitive; therefore, the problem must be attacked by doing something about the fuels on the ground.

The concept was to integrate fuel treatment with multiple-use management programs in high-hazard areas in a complete area management plan.

FUEL TREATMENT

The size, complexity, and cost of a direct fuel treatment program are also prohibitive. Slash disposal on timber sales, firebreaks, prescribed burning, and brush clearing for forage production are some of the programs being effected piecemeal. To secure the desired results, the concept of integrating fuel treatment with all of the multiple-use management programs in these high-hazard areas on a complete area management plan basis was developed. This concept was titled "Management Designs for Conflagration Control." It could also be called Integrating Fuel Management with Multiple-Use Management.

Every multiple-use operation that could contribute to this high-priority program was examined and, if feasible, scheduled for early start.

THE DUCKWALL TEST UNIT

To determine how this concept could best be carried out, a test area was selected. The Duckwall Unit on the Stanislaus National Forest met the criteria for an active multiple-use program, high-hazard fuels, and a history of severe conflagrations. Extensive high-value timber stands and recreation areas lie within and contiguous to the area. The Duckwall Unit consists of about 40,000 acres (16,000 ha) clearly defined by the middle fork of the Tuolumne River on the south, Clavey River on the east, Duckwall Ridge on the north, and the north fork of the Tuolumne on the west. Elevations vary from 900 feet (270 m) in the canyons to 5,800 feet (1,800 m) on Duckwall Ridge.

Cover types consist of annual grass on the lower river slopes and woodland/grass on the upper canyon slopes and lower spur ridges, with dense brushfields taking over nearer the timber belt. Timber types range from young pure ponderosa pine stands to mixed conifer in the intermediate elevations and to some sugar pine/fir areas at higher elevations. Some small patches of oak are interspersed with the conifers.

Soils include Bandarita, which has a low vegetative capability (annual grass and light brush); Mariposa, with a capability for hardwoods, heavy brush, and some pockets of conifers in the deeper soil areas; and Josephine, with a high capability for coniferous timber.

Precipitation amounts to 20–25 inches (51–64 cm) of rain annually, normally occurring from November to April. There is some snowpack at the upper elevations. The summer climate is hot and dry. Temperatures often exceeds 100 °F (38 °C), and humidities fall to 5 percent. Daytime winds are normally strong enough to result in many days of high to extreme fire danger.

About 20 percent of the unit is in private ownership. Most is commercial timberland, some tracts are patented mines, and some are small homesteads.

Management history shows two grazing allotments with some range revegetation done on both Government and private land, three public campgrounds, and some wildlife habitat improvement on the winter deer range. Most of the private timber has been cut over. There have been some small sales of national forest timber. Fire history indicates that, since 1910, about 83 percent of the Duckwall Unit has burned at least once, 25 percent has burned twice, and 10 percent has burned three times.

The fuelbreak stopped the head of the fire and made the suppression job much easier.

CONFLAGRATION CONTROL PROGRAM PROCEDURE

The first step in the program was to have a complete pre-attack survey and plan made for the area. The completed pre-attack plan shows the firelines, fuelbreaks, and other facilities needed by suppression forces for an adequate, safe place to make a stand on any fire that escapes initial attack on a high-fire-danger day. The general guide for the layout was to break the area into about 2,500-acre (1,000-ha) blocks with continuous firelines and fuelbreaks or natura1 barriers. All available resource inventory and multiple-use maps were used as references.

The next step was to overlay the area pre-attack plan with maps of current management operations and operations planned for the immediate future, such as the 5-year timber operating plan. Highest priority went to a major continuous fuelbreak and fireline at the general line of demarcation between the heavy brush on the steep river slopes and the high-value timber on the gentler topography of the ridges and basins above the river. A soil survey was made of this area.

Every multiple-use operation that could contribute to this high-priority program was examined and, if feasible, was scheduled for early start. Areas where the multiple-use program could not contribute were identified and the work scheduled as direct construction out of fuel treatment funds.

The following programs were used in first unit development:

1. *Range revegetation.* Conversion of brush areas to perennial grasses. One unit on national forest land and one on private land were already done. These were tied into the plan, and the new work on both private and national forest land are designed to extend the fuelbreak as far as possible.
2. *Wildlife habitat.* Some work had been done on deer browseways in the winter feed areas on the river slope and spur ridge brushfields. This work was tied in and new work programmed to contribute to the high-priority fuelbreak.
3. *Recreation.* Rehabilitation of one campground adjacent to the general fuelbreak location includes a fuel reduction plan for fire prevention.
4. *Timber sales.* A 3-million-board-foot (7,080-m^3) timber sale included about 1 mile (1.6 km) of the primary fuelbreak location. The portion of the sale area included in the fuelbreak was designated as a "fuelbreak cut unit." Marking was modified to remove a large portion of the mature overstory and thin out the intermediate-size class in order to get proper spacing of the trees on the fuelbreak and still maintain shade on the low ground cover. All slash is disposed of on the fuelbreak cut unit.

5. *Stand improvement.* Stand improvement funds are used to thin the material under merchantable size up to the point justified for silvicultural practice. Additional work needed for fuelbreak purposes is paid out of fuel treatment funds. All trees on the fuelbreak are pruned so as to completely eliminate the continuous vertical distribution of fuels. All stand improvement slash is eliminated by chipping or piling and burning.
6. *Timber plantations.* On good timber soils, there is a regular program of stripping brush for planting of commercial trees. One such unit is contributing to the primary fuelbreak. Current work is underway on the proper plantation design to get nearly full production on the timber soil and yet maintain the efficiency of the fuelbreak.
7. *Fire control/fuel treatment.* Handlines on the steep canyon slopes have been put in by fuel treatment funds in order to effectively tie the fuelbreak into unit boundary natural barriers. Helispots and water source improvements are being carried out concurrently with the fuel work.
8. *Watershed management.* All work is checked for erosion control, such as waterbreaks on firelines and surface ground cover to be maintained on fuelbreaks.
9. *Other activities.* There will not be any major engineering projects in this test unit. Management designs for conflagration control are needed in connection with major highway construction, powerline locations, reservoir clearing, and similar projects.

PRIVATE LAND

The Duckwall area landownership pattern requires work to be done on the private lands to make the program totally effective. The area plan and purpose of the program were explained to the landowners, county officials, and adjacent communities. Complete endorsement of the program resulted. In one case, the private landowner was interested enough to do all the work at his own expense with the advice of the project leader. This included 1/2 mile (0.8 km) of main fuelbreak, one helispot, and 1/2 mile (0.8 km) of secondary fuelbreak on a spur ridge.

Other landowners doing work for range conservation were able to qualify for financial aid under the Agricultural Conservation Practice Program for brush conversion and firebreak practices

Figure 1—*Some 450 acres (180 ha) of fuelbreak were cleared along the Paper Cabin Ridge. The brush from the cleared break was burned. The brush-cleared areas were planted to perennial grass. Groups of oak and pine were thinned and pruned.*

authorized by the State and county conservation committees. One mineral land patent owner having no interest in the surface values, which were low, gave the Forest Service an easement to do the work across his property.

A problem yet to be explored is how far commercial timber landowners whose lands are now cutover can go in participating in the plans.

COOPERATION WITH RESEARCH

Research personnel from the Pacific Southwest Forest and Range Experiment Station have been on the management team and have been delegated the major responsibility for physical and economic evaluation of the work. They are working on such aspects of the program as determining the volume of fuels before and after treatment, the effect of the treatment on the microclimate on the fuelbreak, the effect of the fuelbreaks on fire behavior under various weather conditions, best types of low ground cover to maintain on the fuelbreaks, and best methods of disposal of fuels to be removed.

The findings from these investigations will make it possible to prepare more complete specific management guidelines for the application of the conflagration control concept to the multiple-use management programs throughout the Region.

PROGRESS TO DATE

Figure 1 illustrates work on the ground. Work was started on the pre-attack plan in January 1962. By January 1963, the following had been accomplished:

- Pre-attack plan for the 40,000-acre (16,000-ha) Duckwall Unit completed.
- Fourteen miles and 1,056 acres (427 ha) of major fuelbreak completed, including:
  - Two miles (3.2 km) by timber sale and plantation preparation,
  - Two miles (3.2 km) on private land by owners,
  - Two miles (3.2 km) on private land by the Forest Service under easement,
  - Six miles (9.7 km) by range revegetation and wildlife browseway work supplemented by fire funds, and
  - Two miles (3.2 km) of handline out of fuel treatment funds.
- About 3,000 snags felled in and adjacent to the fuelbreaks.

FIRST FIRE TEST

On July 3, 1962, a fire on a very high-danger day built up too fast for initial attack to handle, crowned upslope, and hit the Paper Cabin Ridge fuelbreak. The fuelbreak stopped the head of the fire and made the suppression job much easier. A conservative estimate places the suppression cost savings at $25,000, which is about double what has been spent on the Paper Cabin Ridge fuelbreak.

SUMMARY

Progress to date indicates that it is feasible to integrate fuels management into the multiple-use management program on an area plan basis.

Some modification of treatment may be necessary on specific fuelbreak areas. This can be done with a small increase in costs and without reducing the productive capacity of the land.

Multiple-use management measures must be supplemented by fuel treatment funds to make the program fully effective.

For further information on the Duckwall Conflagration Control Project, see:

Murphy, J.L 1964. Conflagration barriers—a new concept. In: People's Stake in Forest Fires—The Proceedings of the 1963 Annual Meeting of Western Forest Fire Committee, 9 December 1963. San Francisco, CA/Portland, OR: Western Forestry and Conservation Association: 10–12.

Murphy, J.L. 1965. An analysis of the economic efficiency of an experiment in conflagration control on the Stanislaus National Forest, California. Ph.D. Diss. Ann Arbor, MI: University of Michigan. 275 p.

Figure 1—*Lodgepole pine high hazard area showing the heavy ground fuel accumulation.*

Fire Hazard Management

John Morrison

Fires such as the Sleeping Child Fire are very costly to control.

About 100 years before Lewis and Clark passed through western Montana in 1805, a large fire or series of large fires burned about 1 million acres (400,000 ha) on what later became portions of the Bitterroot, Deerlodge, and Beaverhead National Forests. In this burn, a lodgepole pine forest became established and eventually flourished. The stand became overmature and, in the late 1920s, was struck by a bark beetle epidemic that killed between 65 and 90 percent of the stems. Most of the snags fell in subsequent years (fig. 1).

The article is adapted from Fire Control Notes *25(2) (1964), pages 13–15. John Morrison was a forester for the Forest Service, Bitterroot National Forest, Missoula, MT.*

When the snags were standing and for the first few years that they were on the ground, the fire hazard was not greatly increased. However, in recent years, their decomposition has greatly increased their combustibility. A tangle of reproduction, mostly alpine fir, became established under the open stands (fig. 2). This was the setting for the Sleeping Child Fire, which started from a dry lightning storm on August 4, 1961. In spite of rapid initial attack, the fire enveloped 145 acres (59 ha) in 2 hours and spread to 9,000 acres (3,600 ha) in 24 hours (fig. 3). The fire continued to spread until August 13, when it was controlled at 28,000 acres (11,300 ha).

Fires such as the Sleeping Child Fire are very costly to control. However, a conflagration-type fire such as this must be controlled as quickly as possible because of its destructive potential to forest resources and improvements. Such a conflagration in these fuels could spread with force to hundreds of thousands of acres and destroy all that is on them. Reduction or elimination of these fuels, at the cost of controlling one conflagration, would reduce the hazard on an area many times the size of the conflagration. The Sleeping Child and Saddle Mountain Fires reemphasized the need.

There are still over 200,000 acres (80,000 ha) of these high-hazard fuels on the Bitterroot National Forest. This area is producing little or no valuable timber owing to dwarf mistletoe in the lodgepole pine understory and the poor potential and low quality of the alpine fir. It has not been developed because of its present low value, and roads generally stop on its perimeter.

In the fall of 1962, the Bitterroot National Forest started development of a hazard management plan for these areas. Objectives of the plan include:

1. Minimize the possibility of conflagration-type fires;
2. Salvage all available merchantable material;
3. reduce the fire hazard; and
4. bring timber production to or near full potential.

Before field work was started on the plan, work maps were made of the general high-hazard area. Two-inch-to-the-mile timber management maps were used. The lodgepole pine and sawtimber types were shaded on the plats so that they could be readily checked in the field. Ridges were also shown. Two observers field-checked the area by helicopter. The heavy fuel types were readily discernible. The aerial base timber plats were invaluable in delineating the high-hazard areas, which, along with possible helicopter spots and natural firebreaks, were recorded on the maps.

Figure 2—*High hazard area. Trees killed by bark beetle infestation in the late 1920s are mostly on the ground.*

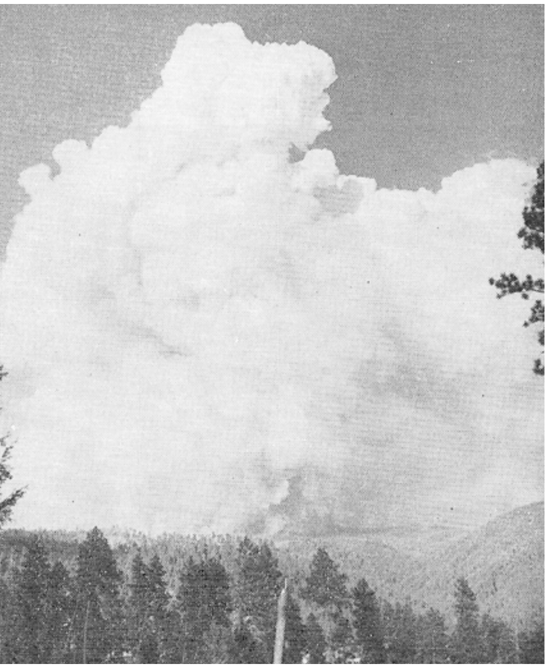


Figure 3—*Sleeping Child Fire, August 9, 1961.*

After the field check, boundaries of the high-hazard areas were outlined on a ½-inch (1.27-cm) forest map. They were then subdivided into 16 units, where drainages or natural firebreaks were used as unit boundaries. These units varied in size from 5,000 to 26,000 acres (2,000–10,500-ha). Two-inch-to-the-mile base maps were prepared for each unit showing hazard and major timber types. An improvement overlay was made for each unit showing:

- Planned roads,
- Planned helispots, and
- Planned firebreaks.

A written section was made for each unit showing:

- Estimated volume of commercial timber by species, and
- Estimated cost of proposed roads, helispots, and firebreak construction.

The units are further broken into blocks that are being used as work units and for which intensive on-the-ground plans will be made.

In implementing the plan, first consideration is given to a transportation system of roads and helispots needed to provide better protection until fuels reduction can be accomplished. Helispots in very heavy fuel areas are given highest priority. These will be used by helitack to speed up initial action on fires. Roads are also assigned construction priorities. Second consideration is given to harvesting merchantable timber, and third to reduction of the fire hazard and establishment of a new timber stand. Establishment of a new timber stand

Figure 4—*Area proposed for burning. The seed trees will be killed when the area is burned.*

will, in most cases, be accomplished by leaving seed trees on the areas prepared for prescribed burning.

A start was made in 1963 toward implementing the plan. Fifteen helispots were constructed, and a construction contract was let for 5 miles (8 km) of the highest priority road. In addition, three areas (totaling 160 acres (65 ha)) where merchantable timber had been salvaged were prepared for prescribed burning. In preparing the areas, from 10 to 20 lodgepole pine seed trees per acre (25–50/ha) were left to help establish a new timber stand. The remaining trees and snags were felled to provide flash fuels to carry the fire and ignite the heavier fuels. The seed trees will be killed by the fire, but their cones will open and reseed the areas to lodgepole pine.

Preparation of the areas was accomplished by the interregional fire suppression crew stationed on the Bitterroot Forest at Trapper Creek. The flash fuels had not dried sufficiently to ignite and carry fire in the fall of 1963. Plans are to burn the areas in the fall of 1964 (fig. 4).

The areas to be burned were selected for their potential to serve as firebreaks or barriers to keep wildfires from becoming conflagrations. Eventually, the hazard on the entire area should be reduced to a level that will not be conducive to large fires. This will be done in conjunction with intensive resource management.

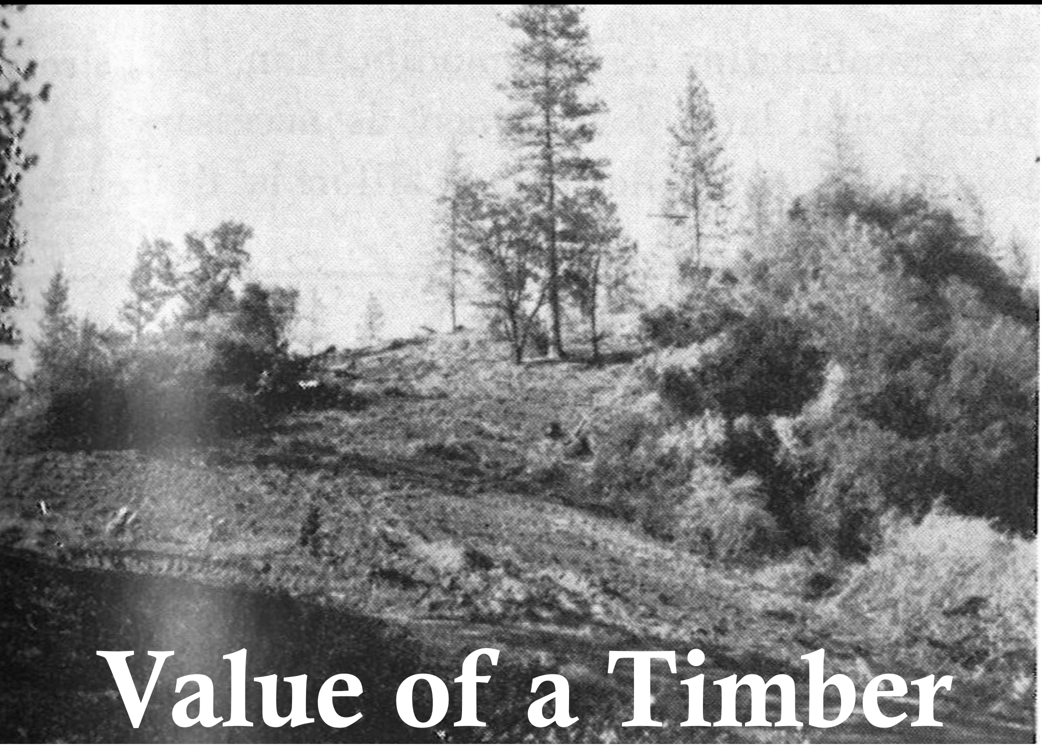


Figure 1—*A planned fuelbreak, cleared as part of the Duckwall Conflagration Control Project, extended along the ridge at the head of the canyon where the fire was located.*

Value of a Timber Fuelbreak—the Wet Meadow Fire

Eugene E. Murphy and James L. Murphy

Without the fuelbreak, the fire would have crossed the ridge into heavy brush and burned at least 60 more acres.

How effective are fuelbreaks in northern California timber country? On July 5, 1962, a fuelbreak on the Stanislaus National Forest (fig. 1) helped stop the Wet Meadow Fire at 23 acres (9 ha). Although not a conflagration, it was the first sizable fire on the 40,000-acre (16,000-ha) Duckwall Conflagration Control Unit. Here, Stanislaus National Forest personnel and fire researchers from the Pacific Southwest Forest and Range Experiment Station are studying the prevention and control of conflagrations by fuel modification through integrated land management.

Value of a Fuelbreak

Nine miles (14 km) of fuelbreak constructed along the main ridge stopped the Wet Meadow Fire at 23 acres (9 ha). Without the fuelbreak, the fire would have crossed the ridge into heavy brush and burned at least 60 more acres (24 ha) (fig. 2). About $18,000 in suppression costs may also have been saved. Thus: the $10,300 expenditure for constructing the fuelbreak was justified.

Engineering Fuelbreaks

Local weather as well as topography resulted in a "pull and push" of the Wet Meadow Fire toward a prominent knob and a saddle. The inertia of the fire caused it to "lick over" the fuelbreak and to throw spot fires at these two points. The fire burned fiercely although it was only a high fire danger day (fig. 2). Erratic local winds were an important cause of the fire's behavior. Fuelbreaks in timber must be widened at critical pressure points. Stocking may have to be reduced in timber country because the flames tend to flash through crowns at the edge of a fuelbreak.

An old cabin on private land was in the path of the Wet Meadow Fire. Though it was within the fuelbreak system, brush and debris had not been cleared. Ten men took nearly one-half hour to build a fireline around the cabin. During extreme fire danger, the fire would have burned the cabin and swept across the ridge.

During the summer following the fire, private property owners on the Duckwall Unit were contacted. They were encouraged to help complete the fire-barrier system (with partial Federal financing through the Agricultural Conservation Program, if desired) or to grant the Forest Service a fuelbreak

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The article is adapted from Fire Control Notes *26(4) (October 1965), pages 3–4. The authors were, respectively, district ranger for the Mi-Wok Ranger District, Stanislaus National Forest, CA; and a research forester for the Forest Service, Pacific Southwest Forest and Range Experiment Station, Berkeley, CA.*

Figure 2—*The fire burned fiercely in the thick brush as it started up the steep slope and headed for the ridge where the fuelbreak was located.*

Fuelbreaks must be maintained to remain effective.

easement. The fire helped show landowners the importance of fuel modification, and they participated wholeheartedly the first year. The cabin incident also stressed the need for hazard reduction at other critical points, such as at campgrounds and along roads.

MAINTENANCE OF FUELBREAKS

Fuelbreaks must be maintained to remain effective. The Pacific Southwest Station researchers have begun a series of studies to determine the cost and effectiveness of various herbicides for control of undesirable regrowth and of soil sterilants for maintaining firelines within fuelbreaks. Optimum rotation and cutting cycles for timbered fuelbreaks and costs and schedules of TSI work are also being studied.

FUELBREAKS NEED FAST, STRONG ATTACK

The Wet Meadow Fire showed that fuel modification must be combined with fast, strong attack by an efficient fire control organization experienced in constructing firelines. Under severe burning conditions, the fire would have hit the ridge in 15 minutes. Quick reconnaissance, probably by aircraft, would have been needed to positively locate the fire and to report its condition.

Airtanker attack with 15-minute travel time would have been required to help keep the fire from crossing the fuelbreak. Quick followup by ground crews would have been necessary. Travel time for the nearest ground crews was 40 minutes. Hence, access roads must be improved, and attack crews and equipment may have to be relocated during high fire danger.

LAND DEVELOPMENT

Water developments to supplement the many miles of grass-covered fuelbreaks would help utilization by livestock. They would also furnish water for fire control. Road and trail construction and maintenance would also facilitate access.

SUMMARY

A combination of fuel modification, fast and strong fire attack, and land development is necessary to control conflagrations in northern California timber country.

For more on maintaining timber or shaded fuelbreaks, see:

Green, L.R. 1977. Fuelbreaks and other fuel modification for wildland fire control. Agric. Handb. 499. Washington, DC: USDA. 79 p.

Green, L.R.; Newell, L.A. 1982. Using goats to control brush regrowth on fuelbreaks. Gen. Tech. Rep. PSW-59. Berkeley, CA: USDA Forest Service, Pacific Southwest Forest and Range Experiment Station. 13 p.

Schimke, H.E.; Green, L.R. 1970. Prescribed fire for maintaining fuel-breaks in the central Sierra Nevada. Berkeley, CA: USDA Forest Service, Pacific Southwest Forest and Range Experimentation Station. 9 p.

Figure 1—*This self-propelled chipper is being used on windrowed brush piles.*

Slash Disposal by Chippers

Wayne R. Cook

For disposal of logging or thinning slash, chipping has many advantages over piling and burning or broadcast burning.

Chipping can be done throughout the year. Best results are obtained when the material is green, but frozen or dry slash can be chipped.

Chipping slash can reduce the potential rate of spread and resistance to control of fire in recently logged-over areas. Chipping also eliminates the need for costly piling and waiting for proper burning conditions.

The article is adapted from Fire Control Notes *27(2) (April 1966), page 7. The author was a forester for the USDA Forest Service, Black Hills National Forest, SD.*

Chipping does not reduce and can enhance aesthetic values, which is vital along highways and near recreation areas. It is the only practical method for concurrent slash proposal and cutting. Also, chips decompose faster than normal slash.

CREW SELECTION

Crews must be well organized, trained, and supervised. Crew size depends on the distance the material must be hauled and on the capacity of the machine. A three- or four-person crew can usually keep the chipper working at capacity in ponderosa pine slash. For safety, only one person at a time should feed the chipper.

WORK PLANNING

Best results are obtained when cutting methods are determined and routes laid out and mapped prior to commercial timber stand improvement. All trees are felled in one direction so that butts point one way and less handling is required. Windrowed material can be fed to the chipper continuously (fig. 1).

SELECTING CHIPPERS

In choosing a chipper, the size of the material to be chipped must be considered. Most chippers can handle material with diameters of up to 4-1/2 inches (11.4 cm) and some up to 8 inches (20 cm).

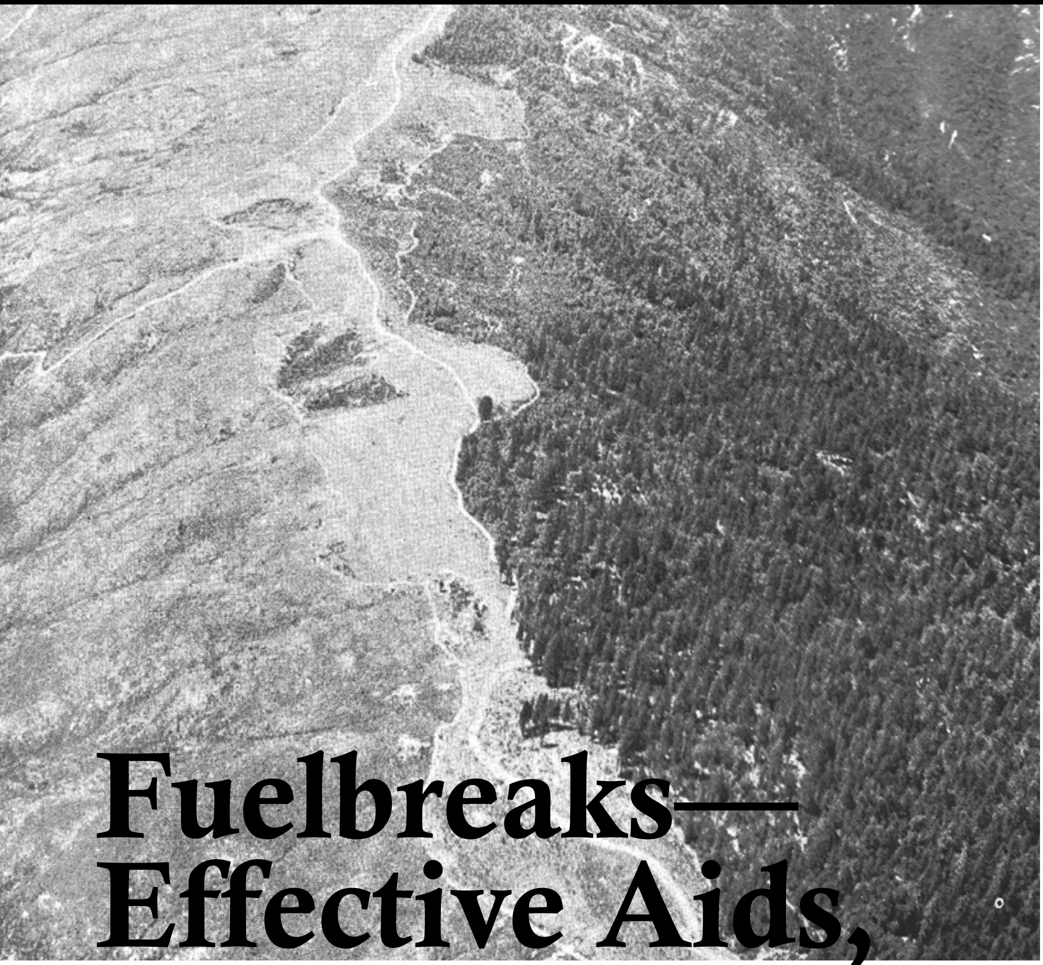
For economy, the chipper should have enough horsepower and torque to handle material continuously. Sufficient power on a weighted flywheel enables the cutting head to rotate uniformly. To reduce blade damage, a series of small blades staggered on the cutting head, rather than one large blade, should be used.

The unit should have an adjustable bonnet on the chip exhaust head. The bonnet adjustment should allow for 180-degree rotation and for some change in elevation. Thus, the distribution of chips can be controlled from the chipper to ensure an even coverage over the ground or for side or end loading onto trucks.

The Black Hills National Forest operates seven chippers. Five of these are mounted on trailers and towed behind conventional or four-wheel-drive pickups or small tractors, depending on terrain and ground condition. The other two units are self-propelled—the chipping heads have been incorporated into modified four-wheel-drive vehicles.

COST

The cost per acre, based on a commercial cut of 2,500 board feet (5.9 m^3) per acre, averages \$60 and ranges from \$34 to \$120.



The fuelbreak shown stopped the Horse Fire on the Mendocino National Forest in California.

Fuelbreaks—Effective Aids, Not Cure-Alls

James L. Murphy, Lisle R. Green, and Jay R. Bentley

Fuelbreaks, while furnishing relatively safe access and attack points, can lure a crew into a false sense of security.

"This fire hit the ridge and kept right on going—it didn't even know the fuelbreak was there."

"That fuelbreak sure didn't do what it was built for—we wasted a lot of money and time building it."

"Fire will spread faster in tall grass on a fuelbreak than in the brush."

"We don't need to worry about that side of the fire—there's a fuelbreak up there."

Such remarks have long been made and will continue to be made. Obviously, all firefighters do not understand the purposes and limitations of fuelbreaks, but strategically placed fuelbreaks help reduce the conflagration or fire disaster problem.

DEFINITION OF A FUELBREAK

A fuelbreak is a strip of land on which the primary fuel, usually brush (fig. 1) or timber (fig. 2), has been permanently converted to a lighter, less dense fuel type to facilitate fire control. As prescribed by an interagency committee ([Anonymous] 1963), fuelbreaks—typically on ridgetops, in valleys, along roads, and on wide benches—are at least 200 feet (60 m) wide. A firebreak—a road or other strip with exposed mineral soil—is often within the fuelbreak.

A fuelbreak might be built to help protect a single campground or community; a connected network might be constructed to safeguard large wildland areas.

PURPOSE OF FUELBREAKS

Fuelbreaks break up the continuity of heavy fuels, and if the fuelbreak system is dense enough, they help firefighters prevent fires from reaching and maintaining high-energy output levels. Resistance to control is less on fuelbreaks, and retardants dropped from aerial tankers may be more effective.

The article is adapted from Fire Control Notes *28(1) (January 1967), pages 4–5.*

James Murphy was a research forester and Lisle Green and Jay Bentley were range conservationists for the USDA Forest Service, Pacific Southwest Forest and Range Experiment Station.

Fuelbreaks must be planned and constructed as part of the total management program.

Fuelbreaks are permanent preattack installations, and when they are well located and constructed, they are effective in firefighting. They provide access for crews, ground tankers, and other vehicles. Thus, a fireman can backfire while he is the "boss"—not when the fire is.

Fuelbreak systems provide defense in depth. The first objective of an attack is to stop the fire in place. Subsequent strategy is directed by current fuel and fire behavior, but the fuelbreak becomes important in fire suppression strategy. If the fire jumps, fire control forces can be regrouped and redeployed until the fire can be held. Meanwhile, under most burning conditions, the flanks and rear of fires can be held at fuelbreaks. Because fuelbreak systems improve the chances of fire control forces controlling fires during the first burning period, "control by 10 a.m." becomes a realistic objective, even for conflagration fires.

Fuelbreaks used as line locations tend to reduce mopup and patrol costs after a fire is controlled. They provide safer access for firefighters. And the lighter fuels on the breaks do not hold fire tenaciously or as long. Consequently, the problem of high costs due to slow, tedious mopup and long, intensive patrols can be alleviated.

USE OF FUELBREAKS

Fuelbreaks alone are not expected to stop a hot, fast-moving fire. They are designed for offensive tactics, such as backfiring, and must be manned—usually the sooner, the better. They must be further cleared to serve as control lines, but with their reduced resistance to line construction, a wide defense line can be established fairly quickly.

Fuelbreaks provide some security to the firefighter. You can better estimate your safety and your opportunity for attacking successfully when you have an opened ridge or canyon bottom from which to reconnoiter and work.

However, fuelbreaks, while furnishing *relatively* safe access and attack points, can lure a crew into a false sense of security. The ground cover may be flashy fuel with a rate of spread greater than that of adjacent fuels in which the fire is burning. Firefighters should not be placed far out on a fuelbreak unless larger, standard safety zones are at about quarter-mile (0.4-km) intervals, as recommended in guidelines.

Experienced crews must quickly fire out the flashy ground fuel at the right time. Enough time is needed to plan and safely execute the firing. It is preferable not to fire when a high-intensity fire is "making a run" at the break. Wind and heat generated by a big fire close to a grass-covered break can cause many spot fires in annual grass and dry perennial grass that spread rapidly and imperil firefighters on the line. Also, firing out can be risky in dry grass during adverse winds because of the rapid spread of the fire and the high proportion of spots that "take." The situation may not be so critical on timbered fuelbreaks, where low-growing perennials such as bearclover—which are not as flashy as grass—provide fuelbreak ground cover.

BENEFITS OF VEGETATION ON FUELBREAKS

Vegetation on fuelbreaks limits their effectiveness as barriers to fire spread. Firefighters know that dry herbaceous ground cover—specifically, tall grass—is a flashy fuel that burns with much heat. However, to reduce soil erosion, such vegetation must be left on fuelbreaks or new ground cover must be established.

A dense cover of grass or forest litter is fairly stable and can be maintained free of brush quite inexpensively. However, it is first necessary to kill all brush sprouts and seedlings, preferably by chemical spraying. Killing may require 3 to 5 years, and fuelbreaks should not be started unless funds will be available to complete

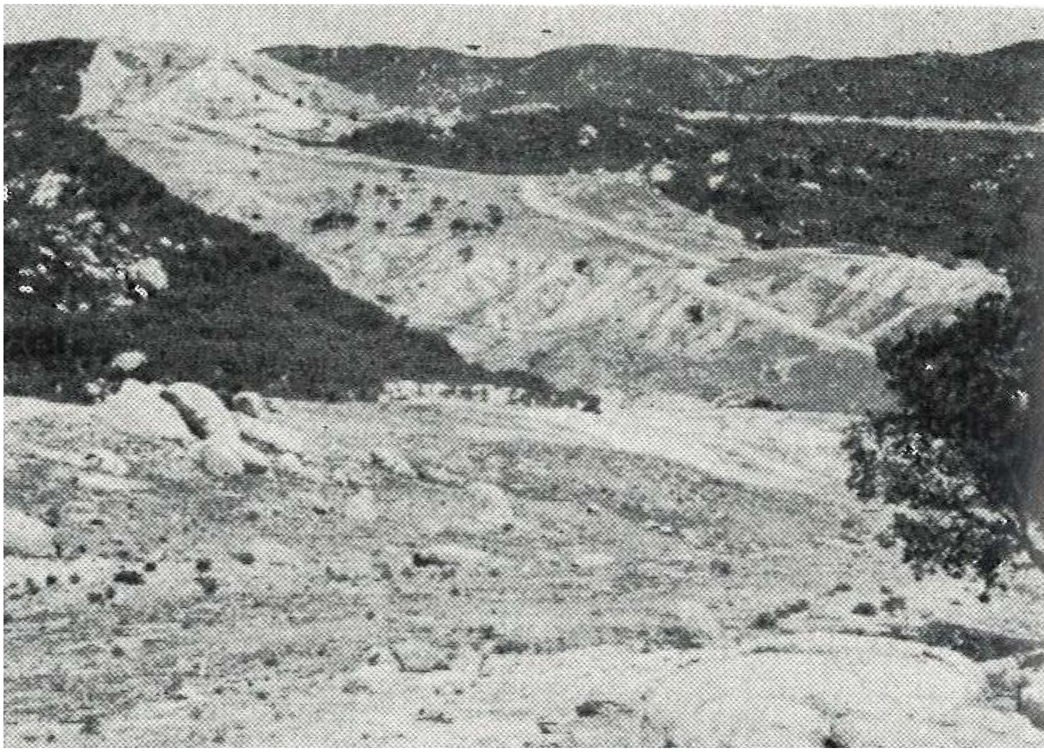


Figure 1—*Fuelbreak in southern California brush.*

the job. Eventually, grass or litter will usually choke out new brush seedlings and make maintenance fairly easy.

Although a grass cover may be needed on a fuelbreak, all grass need not be left as hazardous dry fuel. The excess can be removed by grazing, mowing, or burning. Grass species that remain green for long periods are desirable. Techniques for management of the current vegetation growth can be developed after the heavy fuels have been modified during fuelbreak construction.

A mixture of grass or litter and brush is unstable; attempts to maintain it usually fail, or else only a small acreage can be maintained because of high costs. Also, a mixture of grass or litter and low-growing brush can burn hotter than grass alone. Brush clumps, when left on fuelbreaks, may flare up from sparks and burning embers during firing operations.

Vegetation on fuelbreaks can do more than reduce erosion and stabilize ground cover. Forage grass or timber can be grown on areas formerly covered by dense brush. However, a thinned timber stand left after fuelbreak construction might produce less than a natural stand and thus add to the costs rather than benefits of fuelbreak construction.

MULTIPLE USE AND FUELBREAKS

Fuelbreaks must be planned and constructed as part of the total management program. Specific guidelines for fuelbreak planning, engineering, and construction are usually formulated and approved by fire control specialists and timber or other resource management specialists working together under the concept of multiple-use management. The guidelines help ensure that fuelbreaks are compatible with good land management. Thus, the very factors that make fuelbreaks valuable in fire control also make them valuable from a total management standpoint. Brush areas can be converted to forage grass or to timber production. Slash and other debris are cleaned off the forest floor in timber areas. Trees are thinned and pruned. The wildlife habitat is improved. Live ground cover maintained on fuelbreaks reduces erosion. The net effect of fuel modification should be higher production in both timberlands and brushlands.

CONCLUSIONS

Fuelbreaks are not cure-alls—they are prebuilt firelines that provide safer access to otherwise dangerous areas; they give firefighters a better chance of controlling fires. And, like other fire tools, they must be used for a specific purpose, in a specific place, and at a specific time.

LITERATURE CITED

[Anonymous]. 1963. Guidelines for fuel-breaks in southern California. Fuel-Break Rep. 9. Berkeley, CA: USDA Forest Service, Pacific Southwest Forest and Range Experiment Station. 25 p.

Fuelbreaks are not cure-alls—they are prebuilt firelines that provide safer access to otherwise dangerous areas; they give firefighters a better chance of controlling fires.

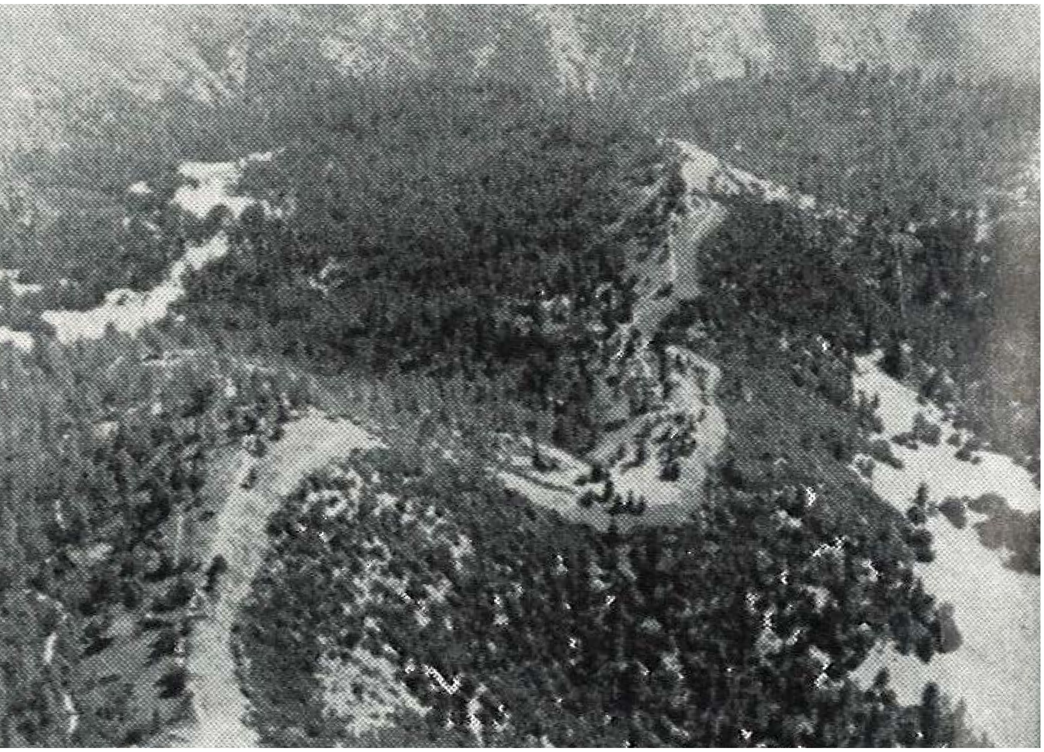


Figure 2—*Fuelbreak in Sierra Nevada mixed conifer in central California.*

Figure 1—*Untreated area ready to burn.*

Fire Hazard Management on the Bitterroot—A Further Report

John Morrison

In the fall of 1962, the Bitterroot National Forest started developing a hazard management plan for 200,000 acres (80,000 ha) of high-hazard, overmature, and insect-killed lodgepole pine stands. Objectives of the plan are to:

- Minimize the possibility of conflagrations;
- Salvage available merchantable timber;
- Reduce the fire hazard; and
- Return the area to timber production (Morrison 1964).

The plan was initially implemented in 1963, when 15 helispots and 5 miles (8 km) of access road were constructed. Three fuelbreak areas totaling 160 acres (65 ha) were prepared for burning. Merchantable timber was salvaged, with 10 to 20 lodgepole pine seed trees left per acre. Unmerchantable trees and snags were felled. Burning of these areas in 1964 resulted in a good clean burn with minimum control problems. But there is now insufficient natural regeneration to stock the areas, even though seed trees with serotinous cones were left.

Because of the high cost of preparing the areas and the failure to quickly establish a satisfactory stocking of seedlings, a search was begun for other methods of establishing fuelbreaks in the high-hazard, heavy-fuel areas.

THE NEW PLAN

Plans were made to develop strip fuelbreaks at two of the largest and most hazardous blocks on the forest: along the Meadow-Tolan Creeks divide and the Sleeping Child-Skalkaho Creek divide. Each of these planned fuelbreaks consists of a continuous strip 1/4 to 3/4 mile (0.4–1.2 km) wide on which all the readily burnable fuels are to be consumed and a young stand of timber reestablished. When the young trees reach a height sufficient to shade the ground and close their canopy, the area will become virtually fireproof.

On the merchantable timber types, all salable material will be removed by commercial sale and the residual burned. Nonmerchantable areas will be lined and burned to make the break continuous.

Access roads have been built by the timber operators and the Hazard Management Project. The Meadow-Tolan fuelbreak will be 7 miles (11 km) long, and the Sleeping Child-Skalkaho break will be 8 miles (13 km) long. Others are being planned.

FOUR METHODS TRIED

In an effort to find an economical way to build the fuelbreaks and reforest them naturally, four methods were tried in 1967:

1. In July, half of the standing material on two blocks was laid down using a D–8 dozer working on the contour.

The article is adapted from Fire Control Notes *29(3) (July 1968), pages 3, 16. The author was a forester for the USDA Forest Service, Bitterroot National Forest, MT.*

Figure 2—*Same area as figure 1, firing completed 10 p.m., September 20, 1967.*

Figure 3—*Same area as figures 1 and 2, firing completed 10 p.m., September 21, 1967.*

No treatment other than control lines is necessary to establish satisfactory fuelbreaks in our high-hazard fuels.

2. On one block, all standing material was laid down.
3. One block was helicopter-sprayed with one part 2–4–D (4 pounds (1.8 kg) acid equivalent) to nine parts diesel, at the rate of 10 gallons per acre (94 L/ha).
4. Two other blocks were left in their natural state except for control lines.

Exterior firelines approximately 1 chain (20 m) wide were constructed with a D–8 dozer. Lines between blocks were one dozer wide. The access road was used for the bottom line on all blocks. Snags that would fall across the road were cut before burning. The treated blocks were burned on September 18, 1967, and the untreated blocks on September 20 (figs. 1–3). All blocks ignited readily and burned well. The sprayed block burned somewhat violently, possibly because flash fuels were supplied by the low shrubs killed by spraying.

SEEDFALL IS ADEQUATE

The day after firing, seed traps were placed in all blocks except in the 100-percent laydown block. The traps were checked on November 13 with the following results:

- 50-percent laydown blocks: 58 million seeds per acre (23.4 million seeds/ha)
- Spray block: 50 million seeds per acre (20.2 million seeds/ha)
- Natural area: 134 million seeds per acre (54.2 million seeds/ha)

The traps were left in position for checking in the spring to determine later seedfall. The seedfall to date appears sufficient to establish a new, fully stocked stand.

Because the untreated areas cleaned up as well as the treated ones, we believe that no treatment other than control lines is necessary to establish satisfactory fuelbreaks in our high-hazard fuels.

In merchantable stands, the salable material will be removed and the residual burned. The slash from the cut material will make ignition easier here. Standing stems will be killed by the fire and will furnish shade for the new seedlings.

Strategically located fuelbreaks for controlling potential conflagrations are being given first priority as roads are developed through high-hazard units. They will be rehabilitated to develop full timber production potential as well as to fireproof them.

LITERATURE CITED

Morrison, J. 1964. Fire hazard management. Fire Control Notes. 25(2): 13–15.

Thinning as an Aid to Fire Control

Robert H. Cron

The fire crossed this stand as a crown fire, but when it hit an adjacent thinned stand, it dropped to the ground.

Foresters and fire control people have often debated whether the slash created by thinning dense young stands of conifers poses a greater threat to controlling fires than the original stand. Many have felt that the volume of dry fuel created by thinning would accentuate the control problem.

During August of the very severe season of 1967 in northern Idaho, northeastern Washington, and all of Montana, several thinned stands were burned by wildfire. On at least three fires, thinned stands aided in controlling fast-spreading fires under extreme burning conditions.

A large fire in Glacier Park, across the North Fork of the Flathead River from the Flathead National Forest, crowned rapidly through dense pole stands of lodgepole, larch, and Douglas-fir. At a bend in the river, it spotted across onto the Flathead into an unthinned lodgepole/larch stand (fig. 1). It crossed this stand as a crown fire, but when it hit an adjacent thinned stand, it dropped to the ground. Although the surface fire was hot, the spread was much slower and the fire was checked by dozers and backfire at 50 acres (20 ha) (fig. 2). The aspect in both the thinned and unthinned stands was flat to rolling.

Again, on the Miller Creek Fire on the Flathead National Forest, thinned stands aided control actions. The north flank of this 800-acre (320-ha) fire crossed Keith Mountain Ridge, crowning rapidly through a sapling and pole stand until it hit a thinned area. At this point, the fire dropped to the ground and spread much more slowly, enabling dozers and crews to complete lines on that sector during the night. Again, the aspect or topography was no different on the thinned and unthinned stands.

Green brush (mostly alder) was growing heavily as an understory beneath the thinned larch.

The Cotter Bar Fire burned 7,100 acres (2,900 ha) on the Nezperce National Forest. On the second day, it reached a series of clearcut blocks and a thinned area of ponderosa pine. Although the clearcuts and planted areas checked the fire and ultimately contributed to its control, it did burn between and over some of the plantations. Crews were able to backfire from the thinned area. The backfire burned hot but did not crown rapidly in adjacent unthinned areas, and it became one anchor point of the final control line.

In all three of the cases cited, the thinning slash was left on the ground. All areas had been thinned since 1962.

The article is adapted from Fire Control Notes *30(1) (Winter 1969), pages 3, 16. The author was the Assistant Regional Forester for the USDA Forest Service, Division of Timber Management, Northern Region, Missoula, MT.*

Figure 1—*Typical conditions in the unthinned stand through which the fire burned.*

Figure 2—*Thinned stand where the fire was stopped. Cleared area on the left was dozer piled and burned after the wildfire.*

Figure 1—*Ponderosa pine thinning slash.*

Thinning Slash and Fire Control

Robert W. Appleby

The factors that determine the rate of spread of a fire and the resistance to control are complex, variable, and interrelated.

As Robert Cron's article in *Fire Control Notes* points out, there have been many debates regarding the relationship of thinning slash to fire control. I do not believe Cron's article really deals with the thinning slash problem in itself but simply compares observations of fire actions in a pole-and-sapling stand and a stand that was thinned. Most people would agree that it is easier to build a dozer line through a 2- or 3-year-old thinned stand than through a green, uncut stand, all other things being equal. This is simply a matter of mechanics.

In many situations, I am sure that fire control experts would rather burn out from a line in thinning slash than they would in some pole-and-sapling stands. Here again, each situation is different.

Determination of fire behavior in any particular situation is not unlike determining a stumpage price through the appraisal system. There must be a complete analysis of the data affecting all the factors of the operation before the proper decision can be made.

WHAT WE NEED TO KNOW

Here are some of the facts we need to know in making a true comparison of fire control in thinned and unthinned stands:

1. What was the weather situation at the time of each burn situation?
2. What diurnal weather changes were involved? The burning index drops off sharply after the middle of the day, and 30 minutes could make a considerable difference in burning conditions. Because the thinned-area burns, as pointed out in Cron's article, were evidently later than the unthinned stands, this could have been a factor (Barrows 1951).
3. What was the topography in front of and behind each fire situation?
4. What were the fuel conditions in each area burned?

The article is adapted from Fire Control Notes *31(1) (Winter 1970), pages 8–10. The article is in response to the article by Robert Cron in this issue on thinning and its effects on fire control. The author was the Branch Chief for the USDA Forest Service, Prevention and Hazard Reduction, Fire Control, Pacific Northwest, Portland, OR.*

Risk can be lowered at a reasonable cost by treating the slash in order to give us a rate of spread and resistance to control in which a fire can be controlled.

5. What temperature, wind, and humidity occurred during the two situations?
6. What tonnage of fuel was on the ground below the pole-and-sapling stand (fig. 1)?
7. What were the age, species composition, average diameter, number of stems per acre, and ground cover in each situation? Rate of spread and resistance to control depend on these elements (Fahnestock 1968).
8. What was the fuel moisture content in each situation? In a season such as 1967, the moisture content in evergreen foliage is considerably reduced (Davis 1959; Intermountain Forest and Range Experiment Station 1934).
9. What was the temperature of the fuel in each burning situation? Cron points out in one instance that green brush (mostly alder) was growing heavily as an understory beneath the thinned larch. This could change the thinning slash combustion characteristics if the facts were known.
10. What were the fuel type ratings in each situation? Fire control action is principally based on two elements: rate of spread and resistance to control.

The factors that determine the rate of spread of a fire and the resistance to control are complex, variable, and interrelated. Most observations, whether they favor thinned or unthinned stands, are related to large-fire control.

Controlling a large project fire and controlling a small fire have entirely different management considerations (Davis 1959). While thinning slash may not be a serious problem in building a fireline a mile away from the fire front with a D–9 dozer, it will have a serious effect on the ability of two firefighters with axes and shovels to construct a line. The rate-of-spread factor of fuel is more a matter of logistics in the case of a large fire, but when a high or extreme rate of spread is present on a small fire and a few firefighters are involved, it is a matter of immediate concern and dictates whether the fire is able to be controlled within standards.

POLICY

It is Forest Service policy to attack a fire when it is small and control it while it is small. In pole stands, this usually means a ground fire or an occasional flareup in a thicket when ground fuels are heavy. I would not say that the Forest Service will have this policy forever, but until the basic fire factors of fuel and weather can be better controlled, it would not seem prudent to let the small fires become large and attempt to control all of our fires after they become large.

Assuming, then, that we are going to attempt to control fires when they are small, let us look at the basic change in fuel and environmental factors caused by saw thinning. Let us try to visualize 10 acres (4 ha) of ponderosa pine (saplings); flat ground; 4,000 stems to the acre (1,600 stems/ha); and no fuel on the ground except for light needle and duff cover. Table 1 lets us compare just the conditions we change by the act of thinning. The factors show that a fire will start much more readily in dry slash. Therefore, the risk of fire increases considerably. In looking at the rate-of-spread factors, I think most foresters would agree that dry fuels burn better than green fuel, that the compacted position permits greater fire intensity, and that ignition is more rapid and the fire burns hotter in an environment where higher temperatures and wind are permitted.

The resistance-to-control factors are based on fighting a small fire, and the jackstraw position of the thinned material creates a difficult job in constructing a line by hand, even with a power saw. Constructing a handline through a pole stand with the fire on the ground is much faster and easier.

A SHORTCOMING

A serious shortcoming, in my opinion, in making decisions related to slash disposal has been the constant reference to the relationship of the new hazard to the old hazard. You continually hear the argument made that the stand was a serious fire hazard before the silvicultural operation, so why are fire people worried about the new hazard? This philosophy is comparable to the fellow who buys a house full of termites and, because they have been there for years, he doesn't believe it is necessary to eliminate them now. A common question asked is: Would you rather fight fire in a doghair thicket or in a thinned stand? The question is academic. My answer is that I would rather not have to fight fire in either situation. It seems to me that it ought to be national forest management's objective to take steps to ensure the lowest calculated risk of having serious large fires in stands where we have invested many dollars per acre.

Table 1—*Thinned and unthinned stands, by factor related to rate of fire spread.*

Factor	Thinned stands	Unthinned stands
Fuel moisture content	Dry	Green
Fuel density	More compact	More spread out
Fuel temperature	Higher	Lower
Wind	Less restricted	More restricted
Air temperature	Higher	Lower

This risk can be lowered at a reasonable cost by treating the slash in order to give us a rate of spread and resistance to control in which a fire can be controlled within policy standards. Figure 2 shows the results of one slash treatment method (Dell and Ward 1969). Chemical thinning and machine swamper burning are other ways in which to reduce the hazard.

I think we should consider what problems develop and base our decision on the situation as it exists. If a Region is considering thinning 50,000 to a 100,000 acres (20,000–40,000 ha) or more, the created fuel types of HH rating or above cannot be reasonably protected. The labor, equipment needs, and costs to control fires in these fuel types within present standards would be exorbitant. At the same time, the risk of losing these stands would be very high.

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Figure 2—*Area treated with mechanical brush cutter.*

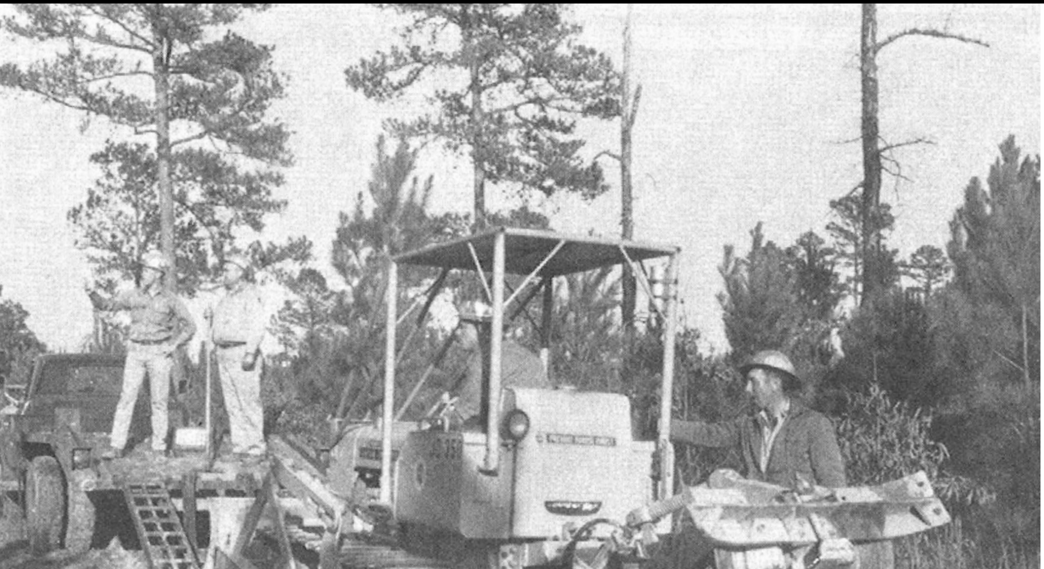

Figure 1—*Firebreaks have made many areas that could be reached only on foot accessible to fire crews.*

Firebreaks of Many Uses

Hamlin L. Williston and R.M. Canarro

Building firebreaks has been a cooperative effort among the landowners and several government agencies.

Permanent forest firebreaks that facilitate travel are necessary for forest fire prevention and suppression on the Yazoo-Little Tallahatchie Flood Prevention Project in northern Mississippi.

During the last 4 years, 1,207 miles (1,942 km) of firebreaks have been built to help protect the 500,000 acres (200,000 ha) of highly flammable, privately owned pine plantations established by the project. They won't stop a "hot" forest fire without firefighter assistance, but they do provide:

- Quick access for fire suppression (fig. 1),
- A base for backfiring,
- A green barrier to slow winter fires,
- Ways for harvesting forest products,
- Ways for multiple-use management of the forested property, and
- Winter game food where conditions permit it to grow.

COOPERATIVE EFFORT

Building firebreaks has been a cooperative effort among the landowners and several government agencies within the project area, and other organizations can benefit from our experience and guidelines. The landowner must want firebreaks enough to cooperate in their maintenance and to permit the Mississippi Forestry Commission to use them in controlling fires on the landowner's or adjoining land. The Soil Conservation Service helps in planning, seeding, and fertilizing. The Forest Service helps in the planning, flags out the rights-of-way, finances some of the land clearing cost, and supervises their construction. The Agricultural Stabilization and Conservation Service provides partial financing, generally about 50 cents per 100 linear feet (30 m). The Mississippi Forestry Commission will contract with the landowner to do disking, light clearing, and some ditching.

The effectiveness of a firebreak system depends upon thorough planning. Our plans cover not only an entire ownership but also several adjoining ownerships. (We have firebreaks that extend 6 miles (9.7 km) across 17 ownerships.) Planners concentrate on a system that is economical to construct and to maintain and yet is completely serviceable. Good use is made of the old woods roads that abound on the ridgetops in this area. Often, rights-of-way for power, pipe, and telephone lines—provided that written permission can be secured—are utilized.

In planning, due weight is given to past fire records, management needs, direction of the prevailing winds, topography, and access roads to the system and property. In scouting the route selected from aerial photos, the terrain, condition of the soil, forest canopy, on-the-ground flammable material, and other fire hazards, logical timber harvesting routes, recreational

The article is adapted from Fire Control Notes *31(1) (Winter 1970), pages 11–13. Hamlin Williston was an assistant project manager for the USDA Forest Service, Yazoo-Little Tallahatchie Flood Control Project; and R.M. Canarro was a forestry consultant, Mississippi Forestry Commission.*

The effectiveness of a firebreak system depends upon thorough planning.

possibilities, potential wildlife openings, natural manmade barriers, and fences are all considered. Routes are chosen to avoid cutting pole-size or large timber and to avoid installing ditches and cross drainages. Steep grades, sharp curves, bogs or marshes, and live stream crossings are avoided. Truck and tractor turnaround space is provided at dead ends and at about onehalf mile (0.8-km) intervals along the break.

COST SHARING

To qualify for cost sharing under the local ACP Program, the area protected must have a stocking of at least 50-percent desirable stems and the firebreaks must be located to contribute directly to the protection of the area. Breaks should be 15 feet (4.6 m) wide. No part of the breaks will be less than 10 feet (3.0 m) wide. The breaks may be located along property lines and throughout the area, but no more than 5 percent of the woodland area may be in firebreaks. The firebreaks must accommodate truck traffic. Lead-off ditches and water bars must be constructed where erosion hazards are created.

Where side ditches are needed, their required space is in addition to the designed traveled width. Where cross-drainage is required, the firebreak is widened slightly for a distance of about 20 feet (6 m) on the high side to provide better protection for the cross-drainage entrance.

Firebreak clearing in stands of trees 3 inches (7.6 cm) and larger in diameter is generally done in the summer using a D–6 (or equivalent) tractor and blade. This clearing job can usually be contracted at less cost than hand operations. The maximum distance between surface drainage should be 500 feet (150 m) where the grade is 2–5 percent and 300 feet (90 m) where the grade is 6–10 percent. Grades up to 15 percent may be used if their length does not exceed 100 feet (30 m). A lateral grade of 3–5 percent is best. Avoid areas with no lateral grade or with lateral slopes of over 10 percent.

Build side ditches only where necessary to drain permanent seeps. Use cross-drainage to prevent water from rushing on or across the firebreak. For cross-drainage, install an open ditch with rounded edges at an angle of 60 degrees to the center line of the road. This prevents both front or both rear vehicle wheels from being in the low or high part of the cross-drainage at the same time.

SOIL COVER

To be effective, a firebreak should provide, in addition to a travelway, a soil cover that will be green and nonburning during the winter forest fire months, October 15 to May 15. Seedbed preparation—disking, liming where needed, and fertilizing—should be started in the summer and completed by September 1. Wait at least 30 days before seeding, longer if the weather remains dry. Complete the seeding not later than October 15.

Kentucky fescue (*Festuca elatior* var. *arundinacea*) is one of the main winter plants sown, but it needs renovating after 3 or 4 years. It is a heavy user of nitrogen, phosphate, and potash and requires a pH of 6.0–6.8. White clover (*Trifolium repens*) or winter peas (*Lathyrus hirsutus*) can be grown in combination with fescue. Fescue needs a moist, well-drained soil and some sunlight for good establishment and growth.

Rye grass (*Lolium multiflorum*) is an annual that will quickly protect the soil. Rye should be used in combination with small grains such as winter wheat (*Triticum aestivum*) and winter peas or with crimson clover (*Trifolium incarnatum*). The seedbed should be cultipacked after seeding. It generally requires two tons of lime per acre (360 kg/ha). Rye grass combinations need a light soil disturbance each summer if permitted to go to seed.

Common Bermuda grass (*Cynadon dactylon*) is widely used in open areas in Mississippi. Only firebreaks constructed

Figure 2—*Quail hunting is excellent along many of the firebreaks.*

in areas open to grazing and not shaded should be seeded to Bermuda. Common Bermuda will produce better growth if it is mixed with legumes such as crimson clover, white clover, or winter peas.

GAME MANAGEMENT

Many landowners are interested in managing for game as well as timber. Game food plots, not to exceed one-half acre (0.2 ha), can be located along firebreaks and sown with the same cover. A scattering of foodbearing plants, if available, should be left on the plots. Mast-bearing trees surrounding the plots should be stimulated to produce bumper food crops by fertilizer applications. A fringe of common lespedezas, reseeding cowpeas, and wild soybeans can be seeded on the plots. Browse plots for deer can be located on the poorer timber sites. Such sites should be cleared of standing trees, with the principal objective being to grow a heavy stand of fast-growing sprouts.

Increased accessibility to their property alone has more than compensated most landowners for their investment.

Many legumes may be found growing wild near firebreak locations. They provide winter food for quail. Legumes such as rattlebox, wild sweetpea, butterfly pea, and Japanese clover will grow under some shade and may be seeded outside the edges of the firebreak to provide winter food. Blackberries and mulberries are favored quail food and can be grown under partial shade (fig. 2). Common lespedezas, reseeding cowpeas, and wild soybeans provide excellent quail food and are easily established.

COST

The cost of firebreak construction has run from $60 to $250 per mile, averaging about $90. Increased accessibility to their property alone has more than compensated most landowners for their investment. Started in order to protect young flood-control pine plantations, this practice has fitted effectively into a multiple-use land management program. Firebreaks have stopped many slow winter fires and have enabled the State fire crews to quickly get into the "backcountry" to suppress hot fires. Firebreaks are also being used for pulpwood operations, hunting, access to lake sites, and motorbike and horseback riding trails.

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Shaded Fuelbreaks: Fire Control and Timber Both Benefit

Ernest V. Andersen, Jr.

A fuelbreak is defined as "a wide strip or block of land on which the native vegetation has been permanently modified so that fires burning into it can be more readily controlled. There may not be a preconstructed fireline within the fuelbreak" (Stanislaus National Forest 1967).

In weighing the desirability of constructing fuelbreaks, the land manager must consider Value Classes (USDA Forest Service, n.d.) of the area to be protected as well as the impact on all the resources, including the visual resource within the fuelbreak itself. The land manager must also weigh effectiveness and construction and maintenance costs of the planned fuelbreak against the cost of fire protection alternatives. Once the decision that a fuelbreak is desirable has been made, the manager must determine construction standards (Stanislaus National Forest 1967).

FUELBREAK FRUSTRATION

As selective logging of conifer stands in California has progressed, it has become increasingly apparent that fire presuppression activity in that area must include selective fuel manipulation. Due to both the impracticability, in some cases, of physical disposal of the slash resulting from selective cutting and the costs related to physical disposal, the concept of the shaded fuelbreak has been developed.

The article is adapted from Fire Control Notes *32(2) (Spring 1971), pages 11–12. The author was the district ranger for the USDA Forest Service, Red River Ranger District, Nezperce National Forest, ID.*

The shaded fuelbreak has many advantages in the timbered area of northern California (and probably elsewhere).

SHADED FUELBREAKS

The shaded fuelbreak has many advantages in the timbered area of northern California (and probably elsewhere) over a completely cleared strip or fireline as a presuppression activity. The area of a shaded fuelbreak remains in production of timber (frequently increasing its quality and quantity) as well as forage and browse; visual qualities are maintained or even enhanced; and erosion potential is lower, as are maintenance costs.

TIMBER SALES

Timber sales can be used to accomplish much of the work needed to establish a shaded fuelbreak system. Appropriated money might be needed in areas ineligible for cutting, in nonstocked areas, and in noncommercial areas. Nearly every commercial timber sale offers an opportunity to begin, improve, or maintain the fuelbreak system.

A timber sale called the Ice Cream Sale in central Trinity County, CA, was begun by the Hayfork Ranger District on the Shasta-Trinity National Forest in 1970. The purpose of the sale is to selectively remove timber before creating a shaded fuelbreak. The fuelbreak in this location is high priority because it separates an area of high and extreme probability rates of fire spread and high resistance to control from an area of high human-caused fire risk (fig. 1).

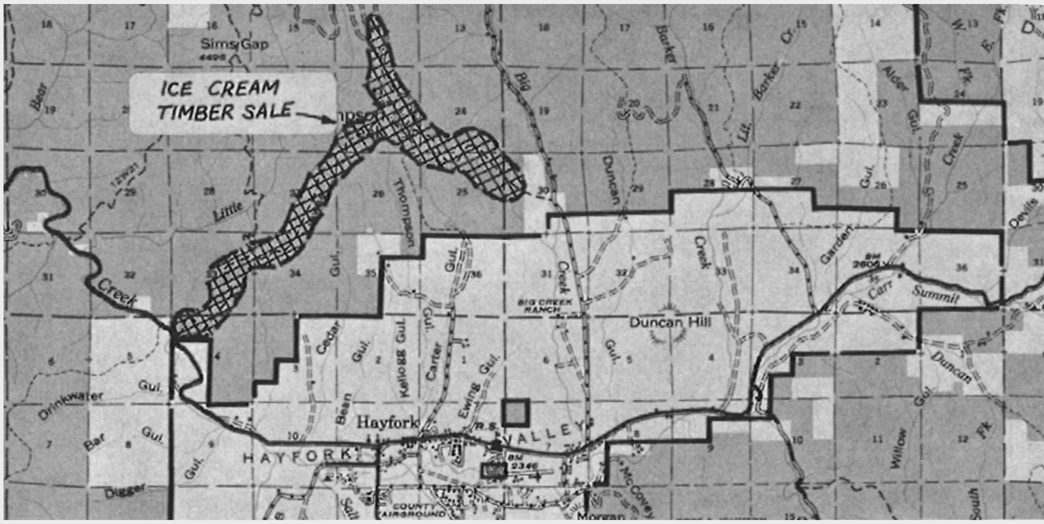

Figure 1—*Map showing Ice Cream Timber Sale location. Note how the completed fuelbreak will separate the high-fire-risk area north of Hayfork from the large undeveloped area north of the fuelbreak.*

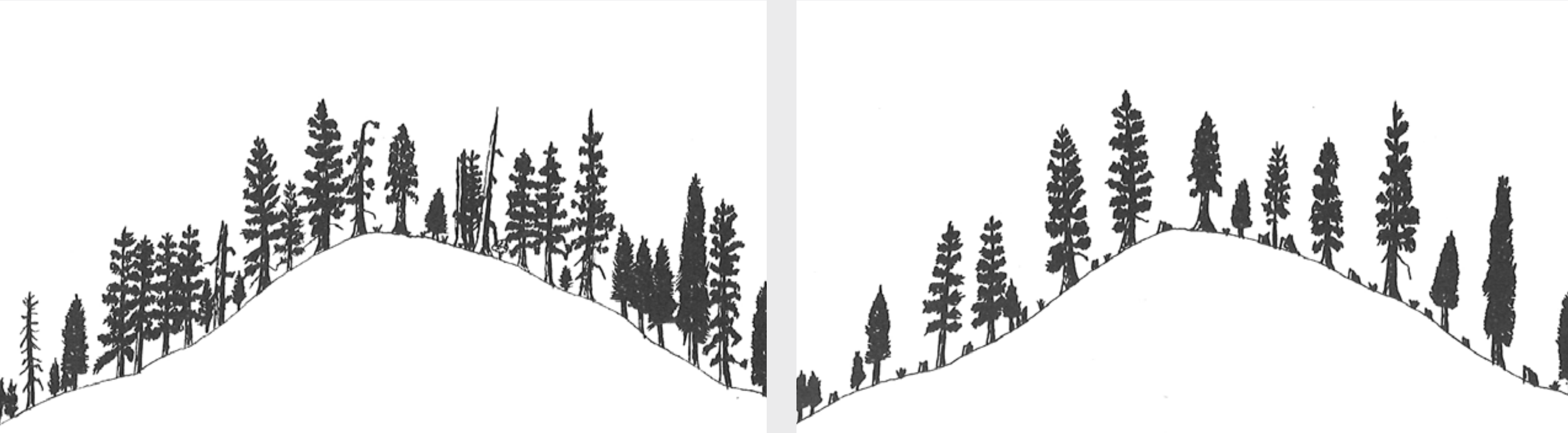

Figure 2—*Left: Typical cross-section view of mixed-conifer stand before treatment for a shaded fuelbreak. Right: Same stand after logging and slash treatment.*

The entire sale was premarked. The required logging method is to use a mobile yarder on the part of the sale where slopes average 60 percent and slopes of 100 percent or more are common. In order to capitalize fully on this opportunity to develop a fuelbreak, an 8-inch (20-cm) diameter inside bark top utilization is required.

The stand is cut to separate tree crowns to a degree that crown fires burning into the completed fuelbreak will drop to the ground (fig. 2). However, enough large trees and/or groups of smaller trees are left to shade the ground and to discourage the establishment and growth of understory vegetation. This balance in stocking is essential to keep maintenance costs at a minimum. It is expected that helitack crews, ground crews, all-wheel drive tanker crews, and air tankers would be able to control fires burning into the fuelbreak.

In a sale like this, special timber sale contract requirements are necessary.

Nearly every commercial timber sale offers an opportunity to begin, improve, or maintain the fuelbreak system.

Special care to protect the trees planned for leave must be exercised and intense slash cleanup and disposal is also necessary. Well-planned cutting and slash disposal result in helispot sites where they are needed to meet hour-control standards along the fuelbreak.

A collection from the purchaser is being made by the Forest Service to dispose of cull logs, tops, limbs, and other logging debris consistent with current policy. Cultural work in precommercial-sized portions of the stand will require slash disposal measures appropriate to the primary purpose of the sale.

FLEXIBILITY FOR LAND MANAGERS

In other timber sale areas, the same measures are being taken on portions of the sale where a fuelbreak system is planned. Developing shaded fuelbreaks as an integral part of timber sales provides another option for land managers. To date, a total of 41 miles (66 km) of shaded fuelbreak cutting on the Shasta-Trinity National Forest has been included.

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Large accumulations of fuel caused by insect epidemics can result in intense burns.

Developing a Long-Range Fuel Program

John Maupin

In the last decade, a mountain pine beetle epidemic has destroyed as much as 90 percent of the lodgepole pine on 500,000 acres (200,000 ha) of the Targhee National Forest in southeastern Idaho. Of some 3 billion board feet (7 million m^3) of merchantable lodgepole, approximately 2 billion board feet (5 million m^3) are now deadwood.

The article is adapted from Fire Management Notes *40(1) (Winter 1979), pages 3–5. The author was the fuel management officer for the USDA Forest Service, Targhee National Forest, ID.*

During the next few years, these bug-killed trees will fall and convert the forest floor into a sea of jackstrawed timber (fig. 1). Downed woody fuel volumes may exceed 90 tons per acre (202 t/ha). Douglas-fir and alpine fir regeneration will create a ladder effect between surface fuels and remaining overstory. As the forest canopy opens, solar insolation and surface windspeed will increase while relative humidity and fuel moisture will decrease. Fire rate of spread and resistance to control will be high for 40 to 60 years, until the tree canopy closes and the heavy fuel settles to the ground.

In 1976, the Targhee management team realized that the forest was facing a fuel crisis unprecedented in its history.

CRISIS REALIZED

In 1976, the Targhee management team realized that the forest was facing a fuel crisis unprecedented in its history. The pine stands were nearing the peak of the 150- to 200-year lodgepole flammability cycle (fig. 2). Historically, at this point such bug-killed stands have been visited by large, stand-destructive crown fires such as the Sleeping Child Fire, which swept through 28,000 acres (11,000 ha) of bug-killed lodgepole on the Bitterroot National Forest in 1961.

The management team concluded that unless an aggressive, long-term fuel management program was implemented, the alternative would be to contend with a large area of high-hazard fuel for many years. An extensive recreation complex in the epidemic area—consisting of resorts, campgrounds, and several hundred summer homes—made the alternative unacceptable.

OBSTACLES

Two obstacles impeded implementing a major fuel management program. The first was the absence of fuel management expertise at the forest and district levels. A fuel management specialist was added at the forest level, and fuel management officers were added to the two most critical ranger districts. The second obstacle, an extensive lack of funds, was overcome when existing programs were adjusted to assist in accomplishing the fuel management task.

POTENTIAL OPPORTUNITIES

Fortunately, the forest at the time had three potential fuel management opportunities:

- An extensive salvage program to harvest deadwood was just beginning.
- Spurred by the national energy crisis, an explosion of free-use firewood cutters began visiting the forest.
- Simultaneously, several youth corps programs were being implemented that used labor-intensive projects.

FUEL PLAN DEVELOPED

In 1977, a long-range fuel plan was developed for the forest, with the goal of mitigating the hazard over a 5-year period. It combined a system of fuelbreaks with strategic-area fuel reduction to break large expanses of high-hazard fuels into smaller blocks that are more easily handled under conflagration conditions. The first step of the plan involved hazard inventory and classification. Although most of the dead trees were still standing and the hazard was consequently low, the inventory was made as if all trees were down.

During the second step, the forest was divided into fuelbreak blocks similar to preattack blocks. Block boundaries were drawn along existing or proposed roads. Minimum fuelbreak widths, varying from 20 to 200 feet (6–60 m), were specified based on adjacent hazard classification and natural barriers. Meadows, clearcuts, and other barriers next to roads were considered when evaluating effective fuelbreak width.

After the forest was divided into blocks, priorities were set for completion of fuelbreaks. The final step was to marshal resources available for the job.

Figure 1—*Bug-killed lodgepole stands can contain up to 90 tons per acre (202 t/ha) of downed woody fuel.*

TIMBER SALES

Forest guidelines were written to require timber sales to be placed near block boundaries so that roads would be incorporated into the fuelbreak system. The guidelines also specified that timber sale fuel treatment plans consider the total fuel situation of the area.

FIREWOOD CUTTERS

Free-use firewood cutters provided the next fuel management opportunity. Prior to 1977, people were allowed to cut firewood by permit any place on the forest. After extensive use of the media

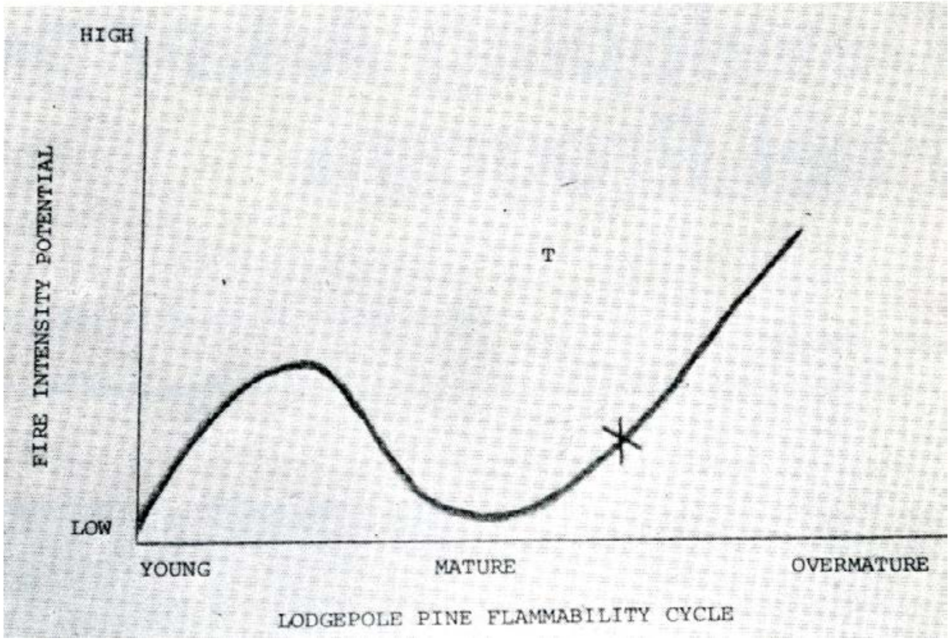

Figure 2—*Many lodgepole pine stands have flammability cycles. The "T" indicates the position of Targhee National Forest lodgepole stands in the flammability cycle.*

Spurred by the national energy crisis, an explosion of free-use firewood cutters began visiting the forest.

to inform the public of the problem, firewood cutters have been sent to cutting areas along roads designated as high priority for fuelbreak construction. There, they are allowed to fell dead lodgepole and are required to pile their slash (fig. 3). Only enough permittees are funneled into an area to ensure adequate cleanup. Additional permittees are directed to other areas.

Public reaction to the firewood program has been excellent. Individuals have stated that they were glad to help the forest while harvesting a product useful to themselves. In 1978, over 12,000 permittees removed an estimated 40 million board feet (9,400 m^3) of deadwood and created 900 acres (360 ha) of fuelbreaks. This program also improved roadside aesthetics. Initial-attack success along high-risk roads increased too.

YOUTH CORPS CREWS AVAILABLE

Crews from the Young Adult Conservation Corps, Youth Conservation Corps, and Comprehensive Employment and Training Act burn the slash piles from the firewood program. Five- to eight-person crews from the programs are also used for fuelbreak construction along short sections of high-priority fuelbreak or for hazard reduction work around high-value improvements.

Suppression crews and prevention employees on the Targhee are involved in the fuels reduction program, as time permits. As part of their regular duties, prevention people monitor the firewood program to ensure that fire requirements are followed. Snag felling and bucking are done by suppression crews in these areas for training and to maintain skill proficiency.

The Targhee National Forest still has a few years before the fuel situation becomes acute. We are hopeful that our long-range fuel program will enable us to ride out the notorious lodgepole flammability cycle without a catastrophic fire.

Figure 3—*Slash piles are made by free-use firewood cutters along designated fuelbreaks.*

For further information on the general topic discussed in this article, see:

Brown, J.K. 1975. Fire cycles and community dynamics in lodgepole pine forests. In: Baumgartner, D.M., ed. Management of Lodgepole Pine Ecosystems Symposium Proceedings, 9–11 October 1973. Pullman, WA: Pullman, WA: Washington State University, Cooperative Extension Service: 429–456.

Lotan, J.E.; Brown, J.K.; Neuenschwander, L.F. 1985. Role of fire in lodgepole pine forests. In: Baumgartner, D.M.; Krebill, R.G.; Arnott, J.T.; Weetman, G.F., eds. Lodgepole Pine: The Species and its Management Symposium Proceedings, 8–10 May 1984 and 14–16 May 1984. Spokane, WA/Vancouver, BC/Pullman, WA: Washington State University, Office of Conferences and Institutes: 133–152.

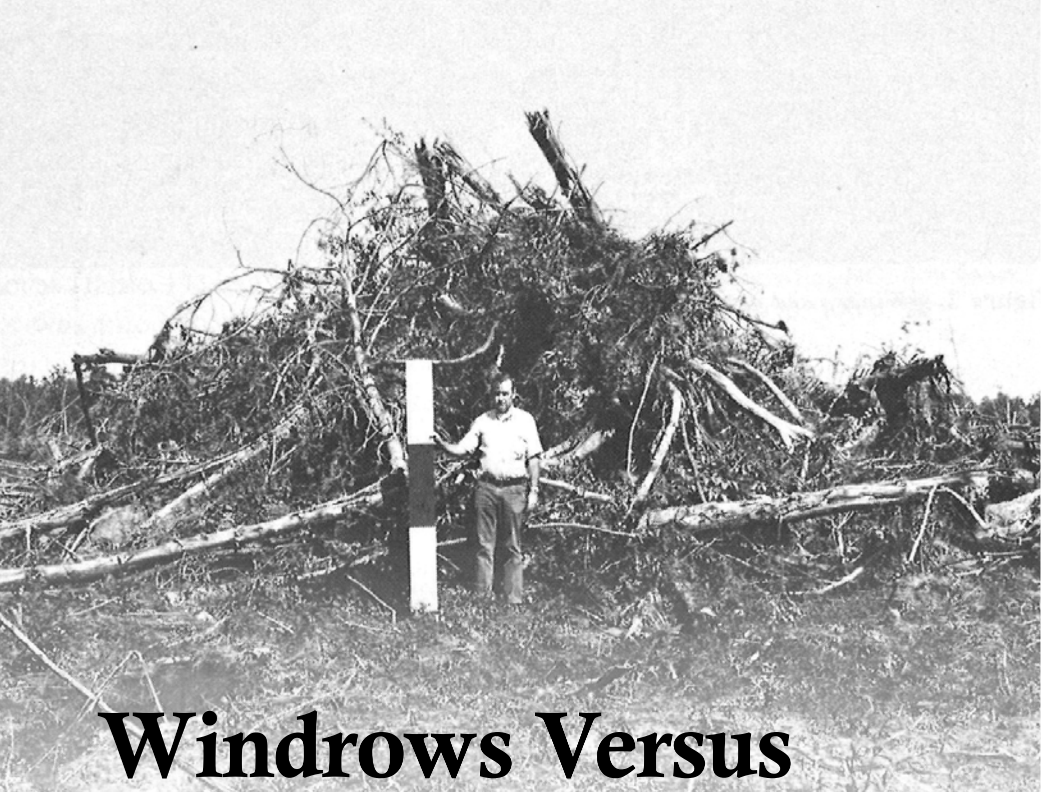

Figure 1—*Small haystack-like piles of debris.*

Windrows Versus Small Piles for Forest Debris Disposal

Ragnar W. Johansen

Film records show a more rapid combustion rate of debris in small piles.

After a timber stand is harvested, debris left over from the harvest must be removed. If material is small, a broadcast burn is usually effective. Unfortunately, broadcast burning will not dispose of material over 2 inches (5 cm) in diameter. The short burning time of such fires does not permit ignition and sustained combustion of the larger material.

The article is adapted from Fire Management Notes *42(2) (Spring 1981), pages 7–9. The author was a research forester for the USDA Forest Service, Southern Forest Fire Laboratory, Southeastern Forest Experiment Station, Macon, GA.*

One way in which larger material can be burned is to pile it in mixture with the smaller size fuel. The reinforcing radiation of burning particles nearby will allow more complete combustion of the large material.

Slash piles are generally constructed in one of two ways:

1. As round, haystack-like piles (fig. 1); or
2. As long windrow piles that extend the length of a clearcut area (fig. 2).

Spacing of piles and windrows depends on the amount of slash and the carry distance for piling equipment. Windrows are most common in the South, but small piles offer some advantages that make them worth considering.

SMALL PILES BURN FASTER

There appear to be good reasons for expecting that haystack-like piles would burn faster than windrows. When woody material flames, it is in the gas evolution phase of combustion. Individual particles, usually not exceeding one-half inch (1.3 cm) in diameter, will sustain flame at the particle surface as long as the gases from pyrolysis continue to be evolved and the resulting air/gas mixture is combustible. Groups of particles gathered into a pile behave much the same way, except that flaming takes place at the outer pile surface once the pile is enveloped in flames. At this stage of combustion, oxygen is usually not available to particles inside the pile, but those particles provide the combustible gases that combine with oxygen in the air at the pile surface in flaming combustion. If more air can be supplied to the combustible gases, the combustion rate will increase proportionately.

A windrow, however, has less surface area per volume of wood than does the same debris gathered into many small piles. Thus, fuel in small piles has more air for combustion. If one envisions small piles as short pieces of a long windrow, the additional surface area created by using small piles instead of windrows then becomes obvious (fig. 3).

Film records also show a more rapid combustion rate of debris in small piles. Two time-lapse cameras were pointed at:

- A 600-foot (180-m) row of small piles, and
- An adjacent 500-foot (150-m) windrow on a clearcut area.

Fuel weight was similar per unit length of row for each, but small piles were slightly higher (not exceeding 5.5 feet (1.7 m)) and pile bases were wider. Flaming burnout time for small piles was over three times faster than for windrows, and maximum flame length was over twice as high (fig. 4). This is a single case observation, and conditions for fuel consumption were optimal. Piling was done when the soil was dry so that soil inclusion in the piles was minimal. At the time of burning, the area was suffering severe drought, with the Keetch-Byram Drought Index at 652 (Keetch and Byram 1968), and relative humidity lows of under 20 percent were recorded for the 2 days preceding the low of 15 percent on the day of the burn. The fuel could not have become much drier.

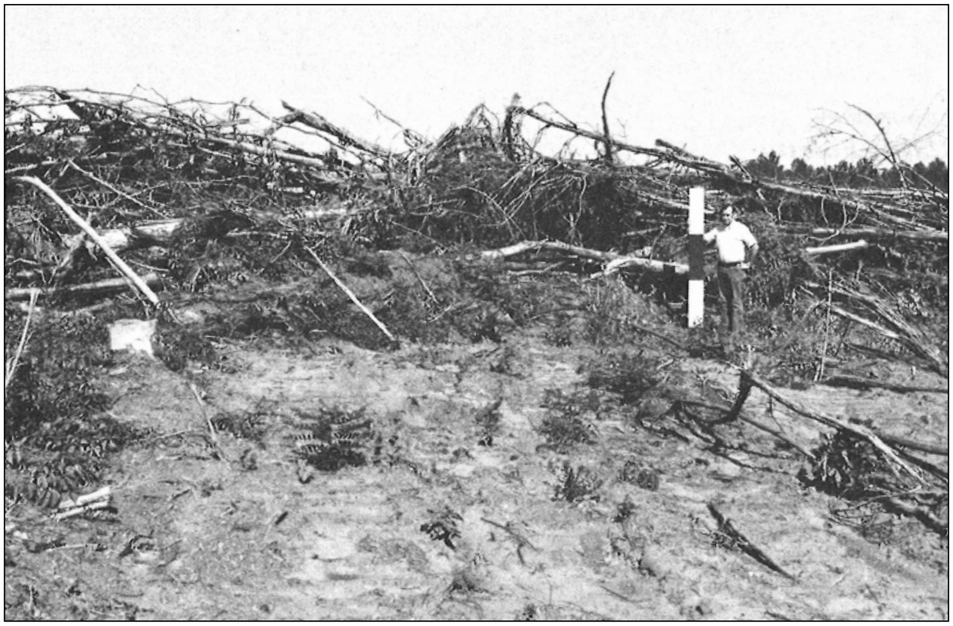

Figure 2—*Windrowed debris.*

SMALL PILES PRODUCE LESS SMOKE

One basic approach to reducing particulate matter production from prescription burning is to maximize the flaming combustion stage of burning, thus minimizing the smoldering stage (Southern Forest Fire Laboratory Staff 1976). The reason is clear. Smoldering combustion has a much higher emission factor (pounds of particulate matter produced per ton of fuel consumed) than flaming combustion, and burning takes much longer. By virtue of the higher combustion rate, small piles favor the flaming combustion stage of burning; thus, they minimize not only flaming combustion time but also smoldering combustion. This would shorten the total burning time and emission period.

A higher combustion rate has the second advantage of lofting the smoke higher over the burning site. Higher lofting allows for greater smoke dispersion downwind before the smoke reaches the ground.

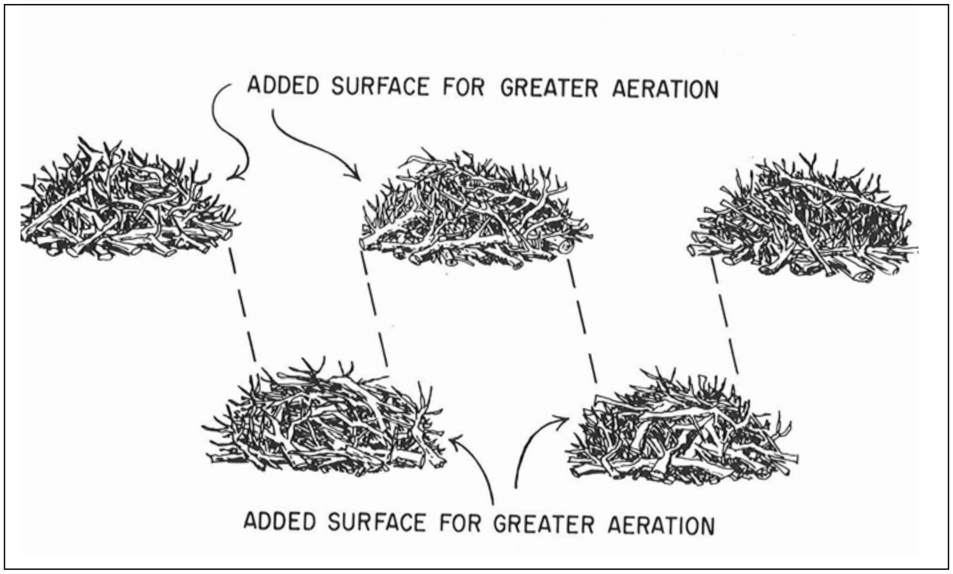

Figure 3—*Removal of sections of a windrow pile illustrates why more surface area is exposed to air when small piles are constructed instead of windrows.*

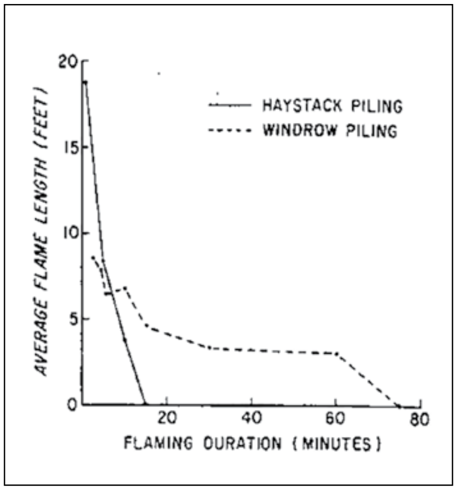

Figure 4—*Fire behavior in the course of flaming combustion in piled debris in Toombs County, GA.*

Gathering forest debris into small piles can be accomplished almost as quickly as windrow piling using the same equipment.

Two other necessary means for reducing smoke are:

- Working only under site conditions that will minimize soil in the piles, and
- Burning piles only when the fuel is dry enough to get rapid consumption.

Emission factors are believed to increase as fuel moisture increases.

SMALL PILES IMPROVE ACCESS TO THE AREA

Small piles have some decided physical advantages over windrows. If the debris cannot be burned before planting, access within the area would be relatively unobstructed because of the open spaces between piles. Unburned or poorly burned windrows physically obstruct movement of people and machines except in the direction parallel to the windrow. Mobility is especially important in the event that future fire control effort is necessary in the area. Wildlife mobility is also unrestricted when small piles are used.

PILING COSTS ARE COMPARABLE FOR SMALL PILES

Before anyone would change from windrow piling to another type of piling, he or she should consider the costs of small piles and windrows. Three preliminary time studies on the two methods of piling were conducted by Union-Camp Corporation in Georgia (Bunker 1978). Two studies were on Union-Camp's Satilla Forest in Glynn County, and one was on its Oconee Forest in Toombs County. In the Satilla-1 test area, two Caterpillar tractors with root rakes were worked together for windrow piling on 10 acres (4 ha) and then together for small piling on an adjacent 10 acres (4 ha). Both operators were experienced in making windrows but had done little haystack-style piling.

The Satilla-2 tests were conducted with the same tractors and operators as in the Satilla-1 area. Again, the tractors worked together to complete all the windrowing on 15.4 acres (6.2 ha) before making small piles on 13.1 acres (5.3 ha).

On the Oconee Forest test, a single D–6 Caterpillar tractor with operator was used to make both types of piles. Although experienced in windrow piling, this operator was inexperienced in making small piles. During the course of 1 day, he windrowed 3.4 acres (1.4 ha) and small-piled 5.4 acres (2.2 ha) (table 1). In two instances, debris was piled from 12 to 16 percent faster in windrows than in small piles. In one test, small piles were constructed slightly faster. Since the tractor operator was not experienced in small-pile construction, the disparity in construction times may have been exaggerated. Gathering forest debris into small piles can be accomplished almost as quickly as windrow piling using the same equipment.

Table 1—*Time study on use of D–6 tractors to windrow and to make small piles of debris after slash pine clearcut logging operations.*

Test	Windrow piling		Small piling		Comparisons
	Acres (hectares) treated	Minutes/acre (hectare)	Acres (hectares) treated	Minutes/acre (hectare)	
Satilla 1	10 (4)	55.2 (136.4)	10 (4)	61.7 (152.4)	Windrow production 11.8% greater per unit time
Satilla 2	15.4 (6.2)	57.6 (142.3)	13.1 (5.3)	57.2 (141.3)	Small-pile production 0.7% greater per unit time
Oconee 1	3.4 (1.4)	55.3 (136.6)	5.4 (2.2)	63.9 (157.9)	Windrow production 15.6% greater per unit time

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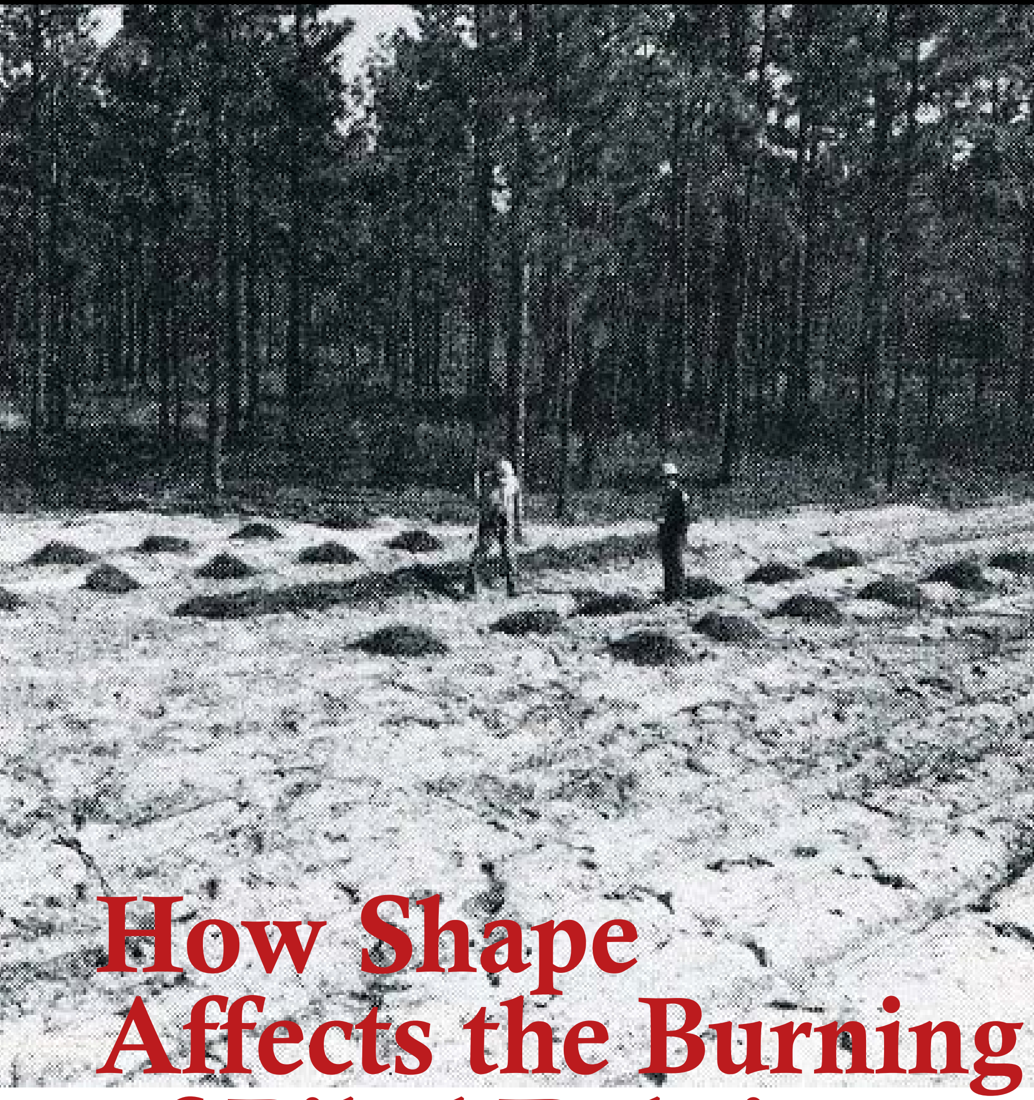

Figure 1—*Scaled tests of round and cylindrical piles pine litter with equal loading at 24:1.*

How Shape Affects the Burning of Piled Debris

Von J. Johnson

Debris created during harvesting or clearing forest land is usually disposed of by chopping, chipping, burying, or burning. Slash for burning may be scattered or broadcast over the cleared area or it may be concentrated into piles. Burning broadcast slash is preferable when the slash is evenly distributed and is of sufficient quantity to carry fire.

The article is adapted from Fire Control Notes *45(3) (Summer 1984), pages 12–15. The author was a project leader for the Forest Service, Southeastern Forest Experiment Station, Dry Branch, GA.*

Broadcast burning is also preferable when slash consists mostly of small pieces that are not compacted or when postburn residue will not interfere with subsequent land use.

Piling slash before burning is the best alternative when the volume of slash is not sufficient to sustain a broadcast bum or when the material to be disposed of is large and bulky. Piling slash is also preferable when the fuel moisture content is high or woody material is mixed with large quantities of organic or mineral soil. In this article, I describe the results of a test to determine whether the shape of a pile affects the burnout time of piled logging residue.

Burnout time of brush piles does not appear to be influenced by the shape of pile.

Piles are usually shaped indiscriminately at the discretion and convenience of the equipment operator. Forms may range from long windrows to round piles. According to Johansen (1981), the shape of the piles when burned influences the rate of fuel consumption. If this idea is correct, then the shape of piles has important implications for managing emissions produced from burning piles. The combustion rate is directly proportional to intensity, and the amount of emissions produced per unit weight of fuel is inversely proportional to intensity (Sandberg 1974). An increase in the fuel consumption rate would shorten burnout time and the consequent duration of emissions. The experimental work on pile shape and burnout time was performed at the Bladen Lakes State Forest in North Carolina and involved both small-scale tests and full-scale validation.

SMALL-SCALE TESTS

In these tests, piles of longleaf pine needles that were ambiently conditioned and mixed for 2 weeks were constructed at a ratio of 0.133 times the size of the slash piles that would be burned later. Shapes were truncated and nontruncated windrows and circular piles (fig. 1). Because surface area and loading are critical for determining fire intensity (Rothermel 1972), the tests were stratified to isolate any influence these characteristics might impose on shape. Round and truncated configurations, stratified by equal

With more area that can be ignited, an increase in combustion rate of the pile is often incorrectly attributed to shape.

surface area and equal loading, were each replicated 3 times, for a total of 12 tests. The scaled windrows were equal to the combined surface area of loading of the counterpart circular piles, all of which had the same basic dimensions (fig. 2). In all, 17 circular and 11 truncated piles were required for surface/area tests and 24 round and 17 truncated piles for loading tests. The piles were ignited by a centrally placed aerial ignition device in each circular pile and a corresponding number of the devices equally spaced in the windrows. The plastic-encased potassium permanganate aerial ignition devices were handcharged with 1 milliliter of 50-percent ethylene glycol solution for a delay of about 30 seconds (Sain 1979). Ignition form, timing, and placement were uniform for each windrow/hemisphere replication. Immediately before ignition, eight fuel moisture samples were taken randomly—four from the circular piles and four from sections of the windrows. Burnout times—the periods from ignition to cessation of flaming and to cessation of visible emission—were estimated by three observers.

Although the level of moisture was high, averaging about 22 percent (table 1), the piles burned briskly. Windspeed averaged less than 3 miles per hour (4.8 km/h), with a few isolated gusts reaching 5 miles per hour (8 km/h). All burning was in full sunlight. The estimated times from completion of ignition to the last visible flame or the last visible smoke did not vary appreciably (less than 10 percent) between the three independent observers. A t-test disclosed no significant difference (P < 0.05) in average burnout times between windrows and hemispheres,

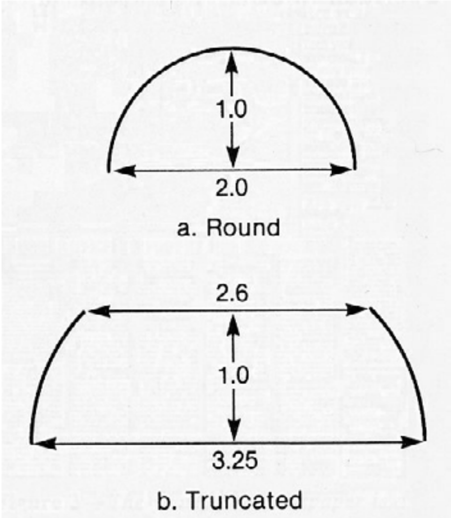

Figure 2—*Cross-sectional dimensions (in feet) of round (a) and truncated (b) scaled piles of pine litter.*

whether round or truncated. An F-test revealed that no differences (P < 0.05) in burnout times could be attributed to shape, loading, or surface area. Burnout times for the truncated series averaged about 40 percent longer than the round series. Average fuel moisture contents of the 12 replications ranged from 14.8 to 26.2 percent. Linear correlation between burnout time and moisture content was negligible ($r^2 = 0.017$), with a slope not significantly different from zero. Correlation was only marginally improved by an exponential transformation ($r^2 = 0.059$ for $Y = ax^b$). These results strongly suggest that the shape has little influence on the combustion rate of piled fuel consisting of uniform-size particles. The added implication that fuel moisture of 15 to 27 percent does not substantially affect the burnout rate of piled pine needles was also noted by Blackmarr (1972).

FULL-SCALE VALIDATION

A full-scale validation of the equal loading, round series, was conducted in 1-year-old mixed-hardwood and softwood logging slash. The windrow, about 7 feet (2 m) high by 15 feet (5 m) wide by 246 feet (75 m) long, was constructed on a 3.87-acre (1.57-ha) clearcut tract. Nearby, 24 randomly spaced piles, 7 feet (2 m) high by 15 feet (5 m) wide, were constructed in three contiguous tracts totaling 3.68 acres (1.49 ha) (fig. 3). Before piling, the broadcast slash was inventoried by the planar intersect technique described by Brown (1974). Loading of piled material was reestimated twice, following methods suggested by McNab (1980) and Mohler (1977). To verify these methods, loading was again estimated in the windrow by removing and weighing two randomly selected 2-foot (0.6-m) transverse slices (fig. 4).

There was no significant difference between the total net loading in the

Table 1—*Moisture content and burnout time of scaled piles of pine litter.*

Pile shape	Mean percent moisture (N = 24)	Mean burnout time (minutes) [a]					
		Hemispheres (N = 9)			Windrows (N = 9)		
		IF	IS	FS	IF	IS	FS
Round							
Equal loading	17.9	6.0	10.1	4.1	5.5	11.8	6.2
Equal surface area	23.0	8.0	16.5	8.5	12.7	17.0	4.3
Truncated							
Equal loading	24.3	11.5	20.8	9.2	11.1	20.8	9.6
Equal surface area	21.35	13.6	24.0	10.4	16.3	24.9	8.6
Mean	21.6	9.8	17.8	8.1	11.4	18.6	7.2
Standard deviation	3.33	3.3	6.5	4.1	5.6	6.3	4.3
Total number of samples	96	36	36	36	36	36	36

a. IF = ignition to flameout; IS = ignition to smokeout; FS = flameout to smokeout.

Figure 3—*Round piles, about 7 feet (2 m) high by 15 feet (5 m) wide, of mixed-hardwood/softwood slash used in pilot test.*

Figure 4—*Material from a transverse 2-foot (0.6-m) section of the windrow was removed, separated into size classes, and weighed.*

windrows and piles or between the windrow loading estimated by the planar intersect and the weighed sections (table 2). However, the variation in size class distribution between the windrow and pile sites and estimating methods is apparent. About 13 percent of the windrow consisted of duff or organic soil and over half the loading was 3 inches (8 cm) in diameter or larger. Applying various weight estimation methods to the piled material gives a range in total loading of 60.3 to 107.7 tons (54.7–97.7 t) (table 3). There is little apparent difference between the total weight as projected from the transverse samples and the weight derived by McNab's (1980) method. The total loading, estimated from the transverse sections, is based on an average solid density of 7.5 pounds of wood per cubic foot of pile (120.1 kg/m^3). This density, which is influenced by size and species of residue and compactness of the pile, ranged from 7.0 to 8.0 pounds per cubic foot (112.1–128.1 kg/m^3).

Unless the intensity of ignition is directly proportional to the size (that is, volume) of the pile, burnout time will increase with size.

Total tractor time required to prepare the windrow was 17 hours; building the 24 piles required 21-1/2 hours; thus, the same operator required about 25 percent more time to construct the round piles.

Table 2—*Estimated fuel loading in windrows and round piles.*

Fuel size class (inches [cm])	Planar intercept (tons/acre [t/ha])						Weighed sections—windrow (tons/acre [t/ha])
	Before piling [a]		After piling [a]		Net		
	Windrow	Piles	Windrow	Piles	Windrow	Piles	
Duff	5.0 (11.2)	5.0 (11.2)	3.7 (8.3)	3.0 (6.7)	1.3 (2.9)	2.0 (4.5)	2.04 (4.57)
< 1/4 (0.6)	0.48 (1.07)	1.04 (2.33)	0.23 (0.52)	0.21 (0.47)	0.25 (0.56)	0.83 (1.86)	0.04 (0.09)
1/4–< 1 (0.6–< 2.5)	3.67 (8.23)	7.09 (15.89)	1.70 (3.81)	1.87 (4.19)	1.97 (4.42)	5.23 (11.72)	0.37 (0.83)
> 1–< 3 (> 2.5–< 7.6)	2.44 (5.47)	3.30 (7.40)	1.28 (2.87)	1.08 (2.42)	1.16 (2.60)	2.22 (4.98)	5.50 (12.33)
> 3 (> 7.6)	16.08 (36.05)	11.22 (25.15)	4.09 (9.17)	3.87 (8.68)	11.99 (26.88)	7.35 (16.48)	7.93 (17.78)
Total	27.67 (62.02)	27.65 (61.98)	11.00 (24.66)	10.03 (22.48)	16.67 (37.37)	17.63 (39.52)	15.88 (35.60)

a. Estimated from depth—McNab and others (1978); Albrecht and Mattson (1977).

Table 3—*Estimated total weight of fuel in windrow and piles.*

Method	Basis (lb/ft^3)[kg/m^3]	Fuel weight (tons [t])	
		Windrow	Piles (N = 24)
Planar intercept	33.0 (528.6) [a]		
	30.5 (488.6) [a]	64.5 (58.5)	64.9 (58.9)
Weighed sections			
Softwoods	7.0 (112.1) [b]		
Hardwoods	7.4 (118.5) [b]	61.4 (55.7)	--
McNab (1980)	5.2 (83.3) [b]	60.3 (54.7)	64.9 (58.9)
Mohler (1977)	6.5 (104.1) [b]	107.7 (97.7)	129.6 (117.6)

a. Solid wood × particles.

b. Includes interstices in pile not occupied by wood.

The piles and windrows were ignited concurrently with fuel boosters, consisting of 16 ounces (0.47 L) of alumina-gel-thickened gasoline in plastic bags. These were centrally placed in each pile and at 14.75-foot (4.50-m) intervals in the windrow. The boosters were ignited at 30-second intervals with a hand-held fuse, completing the ignition of the windrow and all piles in about 12 minutes. Average moisture of fuels less than 1/4 inch (0.6 cm) in diameter at the time of ignition was 8.7 percent. Ambient weather conditions were:

- Temperature: 90 °F (32 °C)
- Relative humidity: 42 percent
- Wind 2–5 miles per hour (3–8 km/h)
- Precipitation: 6 days since 1.0 inches (2.5 cm)

Maximum flame lengths of 40 feet (12 m) were observed in the burning windrows 30 minutes after ignition. Maximums of 35 feet (11 m) were observed in the piles 40 minutes after ignition. The windrow began to collapse about 1 hour after ignition; individual piles required 6 to 10 minutes longer to collapse. The differences in flame lengths and times from ignition to collapse may have been due to the distance between piles, which exceeded the 15-foot (5-m) intervals between ignition points in the windrow. As ignition progressed along the windrow. the combustion rate may have been reinforced by heat transfer from previously lighted points. Very little unburned material remained 24 hours after ignition, and few emissions were visible from either the windrows or piles. However, hot embers remained in all piles.

CONCLUSIONS

Burnout time of brush piles does not appear to be influenced by the shape of pile. The combined surface area of many small piles is often greater than that for a comparable volume in windrows; and with more area that can be ignited, an increase in combustion rate of the pile is often incorrectly attributed to shape. Unless the intensity of ignition is directly proportional to the size (that is, volume) of the pile, burnout time will increase with size. With proportional ignition, larger piles should burn hotter with a lower emission rate per unit of fuel. The burnout time of brush piles may vary because of differences in:

- the maximum size of fuel particles;
- porosity of the pile (the ratio of void volume to fuel volume); and
- the distribution or blend of sizes of component fuel particles.

But, surprisingly, moisture content in a range that allows ignitions to propagate has no more than a modest effect on burnout time. Large piles, whether round, elongated, or in windrows, afford less flexibility for discontinuing burning during marginal days. Once a debris pile is successfully ignited, extinguishing prior to burnout is difficult.

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Fire Management today

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