FUEL TYPE MAPPING IN REGION ONE

By L. G. HORNBY

Northern Rocky Mountain Forest and Range Experiment Station

The mapping of a fuel is simply the identification of the place where a specific kind of fire behavior and difficulty, or expense, of control are expected. The article presents, in abbreviated form, instructions issued to fuel mappers in northern Idaho and western Montana. Under this method, which was developed incidental to fire control and transportation planning, fifteen million acres of national forest fuels have been mapped to date.

THE reason for making a fuel map is to know, before a fire occurs, under a given degree of weather danger, what speed and strength of attack will be required.

The rate at which a fire will spread determines how many chains of fire line will be produced per hour. The difficulty of firefighting caused by slope and soil, together with amount, size, arrangement and species of fuel along the perimeter of the fire, determines how many man-hours of work will be required for each chain of fire line. Evidently the man-hours per chain multiplied by the number of chains to be worked gives the firefighting job to be done. Fuel maps will show, according to the mapping legend, the probable *rate of spread* and the *resistance to control.*

The first use of this map will be in making preparations for fires that may occur, stationing firemen for detection, and stationing one or several of them within permissible travel-time distances as necessitated by fuels. The most frequent use will be by dispatchers sending men to fires.

Firemen and their expensive improvements, including roads, must be located in relation to fuels and cannot be moved annually. Mappers are expected to rate fuels as they will be five years after examination. Estimates of such known changes as result from burns, blowdowns, epidemics and cutting operations are required.

Ratings will assume conditions after a month of continuous mid-summer drouth has prevailed.

Consideration will be limited to the first few hours after a fire is large enough to be discoverable, i.e., to the elapsed time required for travel and firefighting.

The scale one inch to the mile will be standard for present field mapping. For planning purposes field maps will be reduced to half-inch scale.

This method omits a detailed inventory on the assumption that the best conclusions can be drawn by men looking at the amount, arrangement and continuity of fine fuels and their exposure to sun and wind. It is adapted to refinement as usable data on combined influences become available. It states concisely what planners and dispatchers need to know. Fine fuels consist of such materials as branches of trees less than one inch in diameter, shrubs and herbaceous plants, loose, rotten wood and bark, frayed, broken trunks, open rotten checks, moss and dead needles on snags and windfalls, and needles, leaves, duff, weeds, grass and moss on the forest floor.

Rate of Spread

Four classes are recognized. The mapper should endeavor to visualize all the different rates of spread that have occurred. He should divide these into three equal parts called *low, medium,* and *high,* and assign each fuel he encounters to

TABLE 1

DIFFERENCES IN MOISTURE CONDITIONS IN STANDS OF VARYING DENSITY

Timber density	At 9:00 A.M. per cent moisture[1]	At 4:30 P.M. contents per cent
Clear-cut area	5.3	2.4
Half-cut area	6.0	4.4
Full-timbered area	8.7	6.1

[1]Moisture is in percentage of oven dry weight of cylinders.

one of these classes. A fourth class, *extreme*, has been specified. It is considered an exclusive part of the highest class reserved for the worst parts of blowdowns, cut-over areas and single burns. Grass is eliminated.

Where large fires are observed to have stopped naturally, the influences of precipitation, high humidity, change of wind and night cooling, working singly or in combination, have frequently been the cause rather than the fuel.

Reliable guides to probable rate of spread are available in consistent data collected at widely separated forest experiment stations.

EFFECT OF DENSITY OF CANOPY

At Priest River, Northern Rocky Mountain Experiment Station, U.S.F.S.—H. T. Gisborne has established three weather stations about 500 feet apart in a line approximately parallel to the prevailing wind direction. All are on a flat that originally bore a dense stand of overmature white pine-hemlock type. The wind and sun have full access to the station farthest south, where the timber was clear-cut. Northward, with the wind, the next station is in timber whose canopy was half-cut. Around the third station the natural forest was untouched. It is protected from wind by about 500 feet of half-cut plus 300 feet of virgin timber.

The week August 10-16, 1931, was selected for study of differences at these stations because it satisfied the requirement to have no rain and to be in mid-fire-season of a disastrous year. Extreme burning conditions had been demonstrated on opposite sides of this set of weather instruments. For any factor seven daily records were averaged for each hour of the day to obtain a representative day.

It was found that between 7:00 A.M. to 4:30 P.M. temperature was high and humidity low, according to openness of the stand.

Half-inch wood cylinders, ten inches above ground, showed the record given in Table 1.

Wind influences rate of spread in two very different ways. In places exposed to dry, prevailing winds, fuels are being dried and prepared for more rapid spread than in sheltered places. After ignition, wind increases the rate of spread by supplying oxygen for combustion. Varying with the steepness of slope, rising hot air currents prepare fuels up the slope ahead of a fire for rapid combustion, while the cooler air, coming in below, provides oxygen.

It will be noted that tree crowns and trunks cut the afternoon wind velocity of the open down to about one-twentieth in the full-timber, at nine feet above ground. Undoubtedly the wind was moving as fast above the tree crowns as it was at the clear-cut station, and fine dead fuels in the crowns would exhibit the same tendencies toward fast spread except that evaporation would modify it. Small changes in humidity exert a much greater influ-

TABLE 2

THE AVERAGE DAILY RECORD OF WIND AT GISBORNE'S THREE WEATHER STATIONS.

Timber density	Wind in miles per hour, average From 5:00 P.M. to 9:00 A.M.	From 9:00 A.M. to 5:00 P.M.
Clear-cut area	1.2	3.8
Half-cut area	0.6	2.3
Full-timbered area	0.1	0.2

ence on inflammability than small changes in temperature.

At Northeast Forest Experiment Station, U.S.F.S.—Data from Massachusetts were published by Paul W. Stickel in *Pulp and Paper in Canada,* January, 1933. Comparisons of inflammability were presented for four degrees of thinning. The conclusions agree with the data from Priest River.

Effect of Topographic Shelter

In Region 1 the prevailing wind direction is from southwest to northeast and only rarely are fires or fuels influenced by general winds moving in any other direction.

Shade is simply absence of sunlight. Whatever causes it reduces the amount of radiation received from the sun.

Obviously, slopes bombarded all day and tilted so as to be perpendicular to the sun at its highest midday position will receive the greatest possibly quantity of solar radiation.

Effects of Cover and Topography

At Fremont Experiment Station, U.S.F.S., Colorado.—The following information is obtained from Carlos G. Bates' article "The Transect of a Mountain Valley," *Ecology,* January, 1923.

For fuel mappers the important contribution is a correlation of species as well as density of stands with the inflammability factors, temperature, moisture and exposure. The topography involved is a valley 700 feet wide with axis east-west.

South exposure.—"All of the south exposure is subjected to direct insolation at some time during the day and during the entire year. As a result, high maximum temperatures (150° F.) are recorded at the surface of the soil (60° above the coolest neighboring site)."

Near the foot of the south exposure only scattered trees of ponderosa pine are able to exist.

The extreme top portion of the south exposure, where Douglas fir is invading ponderosa pine, shows almost as thorough drying of the surface soil as any other portion, but appreciably lower temperatures.

North exposure.—"From the bottom of the valley to almost the top of the north exposure relatively moderate temperatures are experienced, both on account of the angle of incidence of the sun's rays and the completeness of the cover. On the lowest and also steepest portion, the evaporation rate is lowest, the soil temperatures are lowest, the accumulation of moisture is greatest, and the drying of the soil is most gradual. So far as these are the results of steep slope, the conditions would probably exist in a degree if all cover were removed."

Spruce, almost pure, occupies the lower part of the north exposure.

"The upper portion becomes progressively warmer and drier. Here, evidently, are encountered about the mean temperature conditions which are favorable to Douglas fir. But it should be noted on all similar exposures, once the Douglas fir forest is established, there is a marked tendency for Engelmann spruce to invade and supersede fir."

Table 3

FIRES JUNE 21-SEPT. 10 OF 1926 AND 1929 COMBINED. ORIGINS IN UNCUT GREEN FORESTS, ATTACKED 0-24 HOURS AFTER IGNITION.

Exposure	Number of fires	Origin to arrival hours av.	Av. size when reached acres	Av. rate of spread acres per hour
NE[1]	397	7.1	0.52	0.07
SW[1]	414	7.0	0.62	0.09

[1]Each direction includes a half circle.

The evidence seems to permit the conclusion that any density of stand, by obstructing wind and sun, makes possible a greater density, accompanied by reduction of inflammability, until a climax is reached.

Fuel mappers are warned against the assumption that all north exposures are moist and cold. West of north-south divides they are dried more by wind than east of those divides. At junctions of valleys north slope vegetation frequently is typical of moderately dry sites.

As the drouth of fire season continues the moisture contents of protected and exposed fuels become more alike. However, analysis of fires that occurred in mid-season of the two worst years out of ten shows that differences still exist.

Fire in Relation to Fuel Type

Green Stands, Uncut, Pole Size and Larger.—From an exhaustive study of rates of spread that occurred 1921-30, it was found that the standard types lined up in the following descending order:

1. Brush-grass
2. Ponderosa pine
3. Larch-fir
4. Douglas fir and lodgepole pine
5. White pine and cedar-hemlock
6. Subalpine
7. White fir and spruce

This order is approximately the same as density of stand and is consistent with Bates' data from Colorado. The same relative order was found for any severity in burning conditions.

Unfortunately, the mere presence of a particular timber type does not determine

Table 4

EXAMPLE OF FIRE SPREAD AND RESISTANCE RATINGS FOR VARIOUS KINDS OF FUEL

Example no.	Description of fuel E=extreme, H=high, M=medium, L=low	Rate of spread	Resistance to control
1	Ponderosa pine, mature stands on SW slopes with reproduction scattered or absent	H	L
2	With reproduction moderately dense	H	M
3	Spruce, white fir or cedar-hemlock mature, normally dense in protected bottoms. If rough snags are conspicuously present and green trees are limby, connecting fuels on ground to mossy crowns	L	H
4	If snags are smooth and thinly scattered while green trees are clean of moss and brushy limbs	L	L
5	White pine, larch-fir, Douglas fir or lodgepole pine, normally dense stands, windfall and snags almost absent, ground vegetation conspicuously low shrubs; on protected flats and NE exposures	L	L
6	On exposed flats and gentle SW exposures with usual increased openness and prevalence of grass, with snags and windfall moderate but not continuous	M	M
7	Any species except ponderosa pine; mature dense stands, 80 per cent + killed by ground fire or epidemic, leaving all dead foliage on trees; half or more of dead trees down and not completely shaded by reproduction. On exposed SW slopes	E	E
8	On protected NE slopes	H	E
9	If same stands burned hot enough to consume fine fuels. On exposed SW slopes	H	H
10	On protected NE slopes	M	H

the probable rate of fire spread or resistance to control at a specific spot. It simply indicates the degree to which part of the influences are present. The age of a stand, in combination with the amount and condition of older or younger intermixed dead and green trees, means much.

Burns, Cut-over Areas, Blowdowns, Snags, Moss.—As burns produce openness of stand it might be expected that rates of spread there would be faster than in green timber of the same type. This tendency was only slightly exhibited by the 1,536 fires recorded as originating there. The condition commonly called burn has included large areas of brush and reproduction up to 30 years old. This growth is performing the same functions of shelter as mature stands to the degree that fine fuels are being shaded and air movement around them prevented. Between burned areas and unburned clear-cut areas, bare ground is frequent in the former and rare in the latter.

Cutting operations, in general, have produced a high degree of openness in stands. It was found that rates of spread conformed more to a completeness of slash disposal than to timber type. Under all severities of weather, rates of spread were much faster in cut-over areas than in uncut, green forests or in single burns.

The complete blowdown of a dense stand, fully exposed to sun and wind, must be given the highest possible rating.

Initial ignitions are not likely to spread aerially between snags that are more than 75 feet apart. Examination of the fuel on the ground at the foot of snags and between them is necessary to known the probability of fire running there.

Fuel mappers will recognize moss only in conjunction with other fuels. The most important association is with loose, dead bark and dead crowns.

Resistance to Control

Resistance to control is the intensity of firefighting difficulty. It is the amount of work per chain, or other unit, of perimeter length.

The degrees of resistance to be mapped are designated in the same terms as used for rates of spread—low, medium, and high—with a fourth class, extreme, to be used for conspicuously difficult fuels.

The important factors that determine resistance are:

Fuel conditions	*Existing in*
Amount	Standing green timber
Arrangement	Snags
Size	Windfall and slash
Species	Brush, reproduction and grass
Decay	Duff and roots

Trenching and Dirt-Smothering Chance

Roots, soil, rocks, slopes.—The fuel mapper will assume the method of attack to be by ordinary hand work, using the most suitable tools. In rating resistance, he is to judge only the work required to corral fires and to hold them through the midday burning period. He should endeavor to visualize an efficient fireman, doing whatever work exists at the spot under consideration.

Ratings for Typical R-1 Conditions

At five training camps for fuel mappers 90 men, representing 10 national forests, agreed on 42 ratings to be assigned to typical fuels of Region 1. From them the examples in Table 4 are given as guides to the reasons for increasing ratings as fuel dangers increase.

The production of a map, showing the location of each class of fuel, is simply a step toward providing protection proportional to the need for it. Analysis has shown what rates of spread to expect and what progress different numbers of men can make. From this information an allowable travel time has been derived for each fuel class.

Another necessity satisfied by the fuel map is in making total danger ratings for forest areas that differ in the three essential considerations, fuel danger, values at stake and frequency of occurrence. By adding together the dangers of small areas the total amount covered by different detectors, smokechasers, roads and trails, per dollar of annual expense has been determined.

"The independent effort of an individual may be but a feeble gesture . . . . But when he joins in mass formation with his neighbors the same effort becomes an irresistible and mighty force. *Cornellian Council Bulletin,* Oct., 1934.