Moisture in Living Fuels Affects Fire Behavior

Clive M. Countryman

"Last year at this time, we got our shirttails burned trying to keep the fire within bounds when we burned the block next to this one. Now it won't burn worth a damn. Everything is the same as before —temperature, relative humidity, and wind. Even the fuel stick reads the same. I don't understand it!"

These were the comments of a fire boss in despair as he watched his crew vainly attempt to get a 40-acre prescribed burn going in a stand of southern California chaparral one afternoon in late March 1973.

But everything wasn't the same. Both winter and early spring of 1973 had above normal precipitation, with the rain coming in small, well-spaced storms that kept the amount of moisture in the ground high. The chaparral responded by starting to grow early, and by putting out large amounts of lush new growth with a high moisture content. In contrast, 1972 was deficient in rainfall—so much so that by the spring growing season the first foot of ground had virtually no moisture. The shrubs produced little new growth, some not at all. Thus, the fire boss had overlooked one factor in an otherwise well-planned burn—the moisture content of the living fuel.

Moisture Content Overlooked

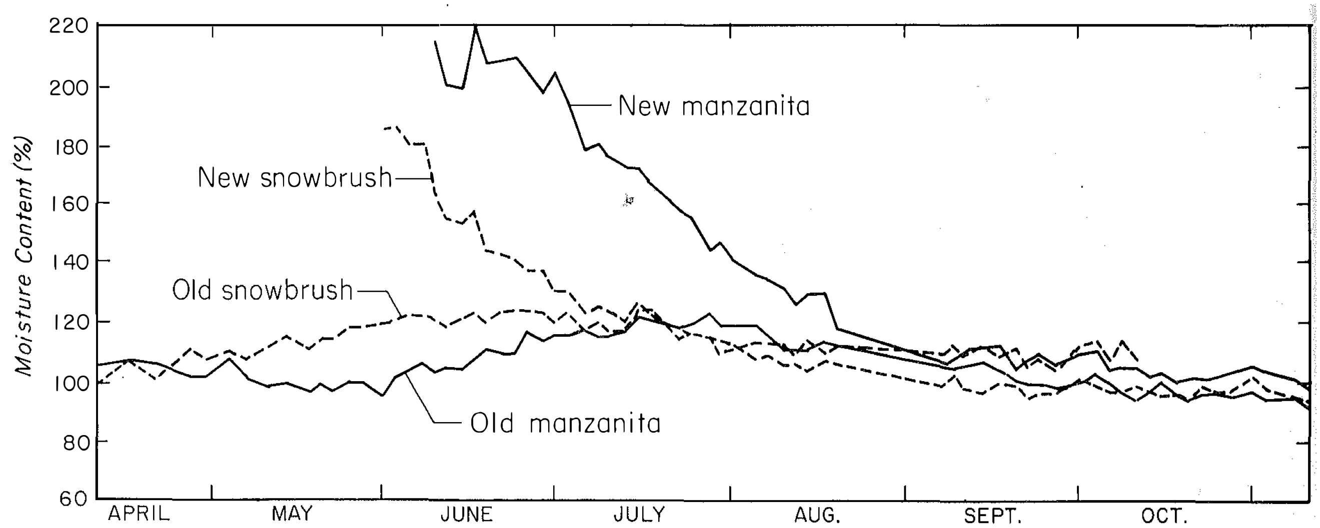
The effects of moisture content in living fuel is often overlooked in the behavior of fire—not only in prescribed burning but in wildland fire control as well. In fuel types where the spread of fire depends largely on crowns, such as in much of the chaparral and brush of the Southwest, the moisture in living fuel is a major factor in the fire behavior produced. It may sometimes determine whether a fire will burn at all.

Usually 65 to 85 percent of the total standing fuel in a mature chaparral stand is living material. Uniformly distributed through this living fuel is dead material. Some species produce little litter, while others may develop a layer of litter and duff of moderate depth, but one that seldom burns rapidly because of its compactness. Some soft chaparral, such as California sage and buckwheat, does neither. When dormant, chaparral stands in which these species predominate can have large amounts of dead fuel and loosely arranged litter. But during the growing season, these species also tend to have the most moisture in the living material.

Although chaparral often appears so dense as to be impenetrable, it contains little fuel compared to the space it occupies. For example, the amount of standing living fuel in a typical 6-foot-tall chamise stand with 25 percent dead material equals a layer of solid fuel less than 1/8-inch thick, and the dead material a layer about 1/32-inch thick. The total volume of fuel is about the same as in a 5-inch-deep layer of ponderosa pine needles.

Because of its high moisture content, living fuel will seldom burn by itself. Heat from burning dead fuel is needed to dry the living material

Figure 1. Moisture contents of manzanita and snowbrush foliage.



to a point where it will burn and add to the heat output of the fire. Since the relatively small amount of dead fuel is distributed throughout the fuel bed, it also does not burn well by itself - the spacing between the dead fuel pieces is too great to produce an intense fire. For a hot fire to develop in chaparral, a large part of the living material must burn along with the dead fuel.

Thus, fire behavior in chaparral depends largely on the amount of dead fuel and moisture content of the living material. When the living fuel is too moist for the available burning dead fuel to dry it quickly, the fire spreads slowly if at all.

Pattern of Moisture Content

The moisture content of living chaparral follows a distinctive pattern during the year (fig. 1). When growth starts in spring, the moisture content of the new material reaches a peak, often near 200 percent of its dry weight, and for some species greater than 300 percent. During this period, the moisture content of the older parts of the shrub increases too, but to a lesser degree than that of the new growth.

As the season progresses and the long, rainless season sets in, the moisture content of the shrub decreases and reaches a minimum when the plants become dormant in fall. The moisture content then remains more or less constant until growth resumes in spring. Low moisture content of the shrubs during winter is one of the chief reasons that areas exposed to periodic dry weather in winter, such as southern California, can have on large chaparral-fires.

The moisture content in living chaparral usually follows the same general pattern each year, but important differences exist from year

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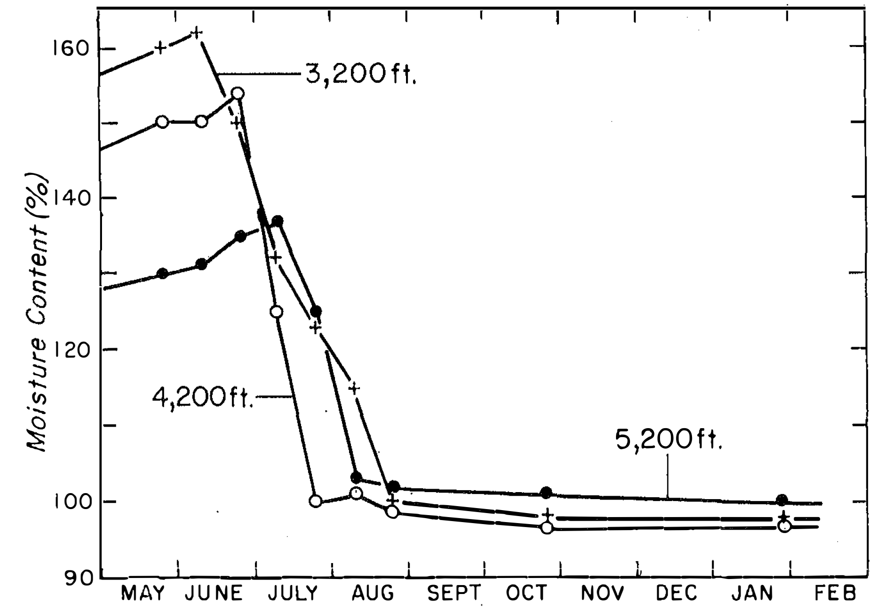

Figure 2. Moisture content of manzanita foliage, by elevation May 1962 - February 1963 (Philpot 1963).

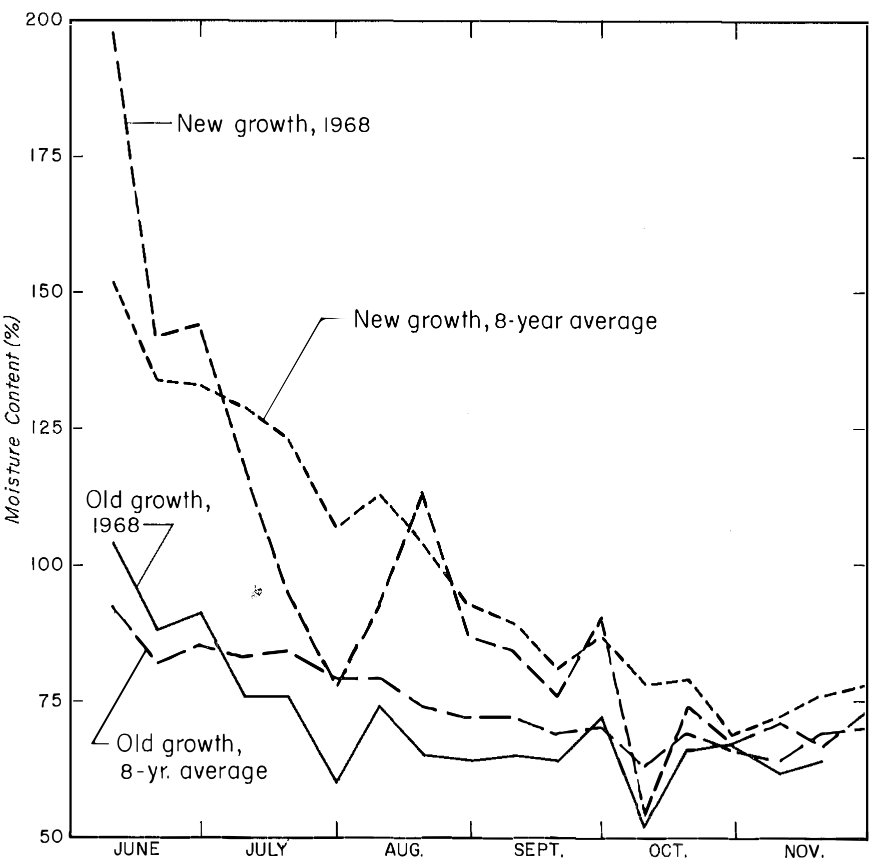

Figure 3. Moisture content of living fuels in chamise, Angeles National Forest, Southern California.

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to year. These differences affect fire behavior and should affect decisions in fire control and prescribed burning.

Changes in moisture content are due to the physiological activity of the shrubs, and this activity is controlled largely by soil moisture and the weather—chiefly temperature. If precipitation is deficient, plants remain dormant or grow slowly.

Their moisture content will increase less in spring than at other seasons when soil moisture is plentiful. If the deficiency presists through summer, the moisture content in living fuel drops quickly.

It will be lower in fall than at other seasons when conditions are normal. Temperature affects the time new plant growth will start. If the weather in late winter and spring is warm, moisture content will increase more quickly than if it is cold, and it will reach a higher level if soil moisture is adequate. Elevation affects temperature; therefore, the altitude at which shrubs are growing markedly affects the amount of fuel moisture and when peak moisture is reached (fig. 2).

Direct Measurement—Best Way

How can land managers determine the moisture content of living fuels when it is so variable? Visual indicators are few—the amount of new growth is about the only readily perceptible one. No analog devices are yet available for estimating living fuel moisture such as the fuel moisture indicator sticks commonly used for dead fuels. Thus, to determine the moisture content of living fuel, we must usually resort to direct measurement.

In California, fire protection agencies collect samples of predominant chaparral species every 10 days from selected areas and send them to the Pacific Southwest Forest and Range Experiment Station's Forest Fire Laboratory for moisture determination. The moisture contents are plotted in graphical form (fig. 3), and graphs are sent to all fire control agencies statewide at 10-day intervals during the fire season, along with other fire danger and weather information.

This procedure has been carried on long enough to permit us to say what the average conditions are for the sample areas and to compare current conditions with the average and with conditions in other years. Only a few areas and species are sampled; hence, the fuel moisture given in the 10-day reports provides only general guidelines for fire control and prescribed burning decisions.

Determining Fuel Moisture

The laboratory procedures used in accurate fuel moisture determination require trained personnel and expensive equipment. However, precise measurement of living-fuel moisture is not needed for general field application, and "do-it-yourself" techniques are quite simple and require little equipment. With reasonable care, adequate and consistent results can be obtained.

One piece of equipment required is a laboratory balance capable of weighing up to 1,000 grams to the nearest 0.1 gram. The beam type balance frequently used in high school chemistry and physics laboratories is adequate and relatively inexpensive. Sample bottles for collecting the fuel samples will be needed; wide-mouth quart Mason jars with screw type caps do very well. Each bottle and cap should be labeled with an identifying number and weight.

The final piece of essential equipment is a drying oven capable of maintaining a temperature of 200° to 205° F. (See microwave oven article, p. 22.) The oven in a kitchen range can be used, but in the interests of domestic tranquility, it is not recommended that the fuel moisture determination be done in the home—some plants produce a strong persistent odor when drying. A better solution is to purchase a drying oven from a laboratory supply house, or have one fabricated in the shop of your organization.

The fuel sampling procedure is also quite simple, but must be carefully followed if consistent and reliable results are to be obtained. To determine the trend of fuel moisture over the fire season, select a sampling area representative of the general area in elevation, aspect, and species. The area should cover 3 to 5 acres, and it should be used each year. Since most moisture variation takes place in the fine material, a good indication of the moisture conditions can be obtained by collecting foliage and small twigs less than 1/8 inch in diameter. Obtain material from all parts of the plant and from as many plants in the sampling area as possible. Remove all dead material from the sample because even a small amount can drastically affect the results. Sample old-growth separately from the new as long as the material can be visually separated, and sample different species separately.

Collect at least two samples of each type of fuel—three samples of each would be better. Each sample should contain 100 to 150 grams of material. This is about the amount that can be loosely packed in a quart jar; it is not necessary to weigh the sample in the field. Cap the sample bottle immediately after taking the sample. Best results are obtained if sampling is done during the same time of day for each sampling period, preferably between noon and 3 p.m. Do not collect samples when the foliage is wet from rain or dew.

At headquarters, weigh each sample, (still capped) to the nearest 0.1 gram and record the weight. Then uncap the samples and place them in the drying oven set at a temperature of 200° to 205° F. Usually a 24-hour drying period is sufficient, although material with a very high moisture may require a longer time. Weigh the samples after 20 hours and again after 24 hours. Don't forget to add the caps when weighing. If the weight change in the 4-hour period is less than 0.2

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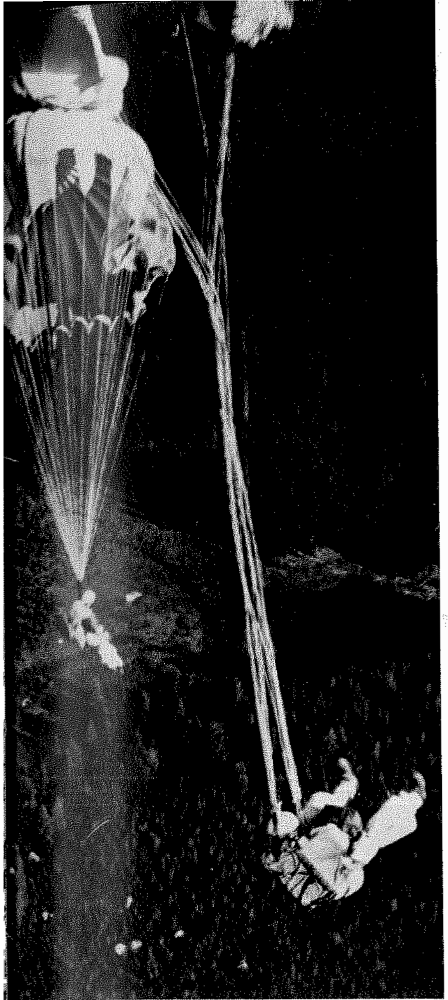

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gram, the samples are sufficiently dry. But if the weight change is greater than 0.2 gram, the drying should be continued until the weight change in a 4-hour period is 0.2 gram or less.

The sample moisture content in percent is determined from the equation:

$$\text{Moistuie Content} = \frac{\text{Wet Weight-Dry Weight}}{\text{Dry Weight}} \times 100$$

To find the wet weight of the sample, subtract the weight of theesample bottle from the weight of the sample and bottle that was obtained when the sample was brought to headquarters. The dry sample weight is the weight of the bottle subtracted from the sample and bottle weight at the end of the drying period.e

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Smoke Jumping . . .
An Expanding, Varied Role

William D. Moody

Since 1940 smoke jumpers have been an important part of the fire suppression team. The smoke-jumper, through his versatility, equipment improvements, and progressive management, continues to play an important but changing role in forest fire suppression.

An Important Role

The overall area covered by smokejumpers and the number of fire jumps has increased. Growing from a squad of 14 men in 1940, today's force of over 400 jumpers has made as many as 4,500 fire jumps to 1,200 fires a single year. Once restricted to use in the inaccessible mountainous areas of the Pacific Northwest and Intermountain Region, today's highly mobile aerial fire fighters combat fires in the Alaskan interior, the entire Western United States and, since 1971, in the Southern Region, Forest Service.

Forest Service smokejumpers give assistance to State and other Federal agencies upon request.

Smokejumpers' New Role

Originally conceived as a force to combat small backcountry fires, smokejumpers now have an expanded role. Smokejumpers help meet today's fire control objectives, whether it be to reinforce helitack or other initial attack forces or to perform as an organized suppression crew on project fires—in heavily roaded or accessible areas. Their specialized training with chainsaws and one-man mechanical fireline trenchers enables smokejumpers to serve as line cutting, snag felling, or mechanical fireline construction crews. On project fires, they jump to spot fires and reinforce ground crews when hot spots flare up along the main fire perimeter. Crews of jumpers are dropped at selected points on the fire perimeter to construct helispots and heliports.

In addition to fire suppression, jumpers had other roles. With an ever increasing recreation use of back-country areas, smokejumpers are used for emergency para-rescue missions. Parachuting project crews perform a variety of jobs such as telephone line maintenance or removal, helispot construction, timber inventory, and trail maintenance.

Better Equipment

To meet the needs of the 1970's equipment continues to be improved to do the job better, faster and safer. Jumpers today are attired in fireproof Nomex jump suits and the latest in head protection gear.

Maneuverable parachutes enable jumpers to jump safely under adverse conditions in rugged mountainous terrain.

Improved Aircraft

The most important advancement in smokejumping is the aircraft used to carry out the smokejumper mission. Modern, fast aircraft help meet initial attack objectives. A modern, fast, turbine powered aircraft used during 1972 season reduced smokejumper manning time by 50 percent. Aircraft capable of 270 to + 300 mi/h will replace the 165 mi/h Twin Beeches and DC-3's used for many years.

Infrared fire spotting equipment mounted on jumper aircraft help the smokejumper spotter locate fires

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difficult to detect visually. Once on the ground, jumpers use chainsaws, mechanical fireline trenchers, and other modern fire suppression equipment. As soon as the fire is out or the jumpers are released, helicopters are often used to retrieve the jumpers and quickly return them to their base for another fire call.

Automatic Dispatch System

Speed of initial attack is a paramount fire control objective. Progressive fire managers have taken steps to speed manning of fires. In the Pacific Northwest Region, two smokejumper bases operate on an automatic dispatch system. The smokejumper base dispatcher, upon monitoring an emergency fire call, automatically dispatches jumpers to the fire. Used for 6 years on the Okanogan National Forest in North Central Washington, this system has been a significant factor in meeting critical initial attack manning objectives and reducing fire losses.

Smokejumpers on Patrol

When lightning storms are in progress, smokejumper aircraft patrol behind the storm and man fires as soon as they are detected. Routine smokejumper patrols have also proven valuable in areas of lightning "sleepers" and high man-caused risk. On an experimental basis, small smokejumper aircraft, with two or four jumpers aboard, have replaced single engine aerial detection aircraft on routine daily patrols. Once limited to operating from large permanent bases, jumper crews in some regions now operate from satellite bases located in or adjacent to areas of high risk or extreme fire danger. Often these satellite bases are manned on a daily basis with the crew returning to the home base each night.

It is apparent to foresters who have used automatic dispatch, jumper patrols and decentralization of smokejumper forces that they are much better able to meet their initial attack objectives through these management practices.

The Future

The smokejumper program can continue to play an important role in meeting fire attack objectives. The future of smokejumping depends upon how fire managers will use this resource. Through utilization of their versatile skills, continued technological advancement, and progressive management practices smokejumpers will continue to be an integral part of the fire suppression team in the 1970's.

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For example, suppose the sample bottle weighs 393.8 grams. When the bottle is filled with the fresh sample it weighs 494.8 grams, and after the drying period, 448.9 grams. The wet sample weight will be $494.8 - 393.8 = 101.0$ grams. The dry sample weight is $448.9 - 393.8 = 55.1$ grams. The moisture content of the samples is $\frac{101.0 - 55.1}{55.1} \times 100 - 83.3$ percent. Duplicate samples of the same material should be averaged.

Measurement for Prescribed Burning

To obtain measurements of living-fuel moisture for use in prescribed burning, follow the same basic procedures, but collect the samples in the area of particular interest. If the burn area is large, covers a wide range in elevation, or is on more than one aspect, more than one sampling area with separate samples will be needed for a good evaluation of living fuel moisture conditions. Since living-fuel moisture changes slowly, the sampling may be done several days before the planned date of the burn, thus providing information that can be useful in deciding whether to burn or not. By relating living fuel moisture to fire intensity and burn effectiveness over a period of time, a backlog of information can be built up that will help in planning prescribed burns.

Most experimental work and practical application of data in living fuel moisture to fire control and fire use activities has been in chaparral and brush fuels. But other fuel types also have moisture variations that can significantly affect fire behavior, although the moisture patterns may be different than fore chaparral. For example, the moisture content of the needles of some conifers varies enough during the fire season to affect the potential for crown fires. By sampling living fuels at regular intervals, the moisture patterns and current conditions can be established. This information can help the fire boss in his decisions about fire control and firee use.e

Reference: Philpot, C. W. 1963. The moisture content of ponderosa and whiteleaf manzanita foliage in the central Sierra Nevada. U.S. Forest Serv. Res. Note PSW-39 Pacific Southwest Forest and Range Experiment Station, Berkely, Calif. 7 p.

Electronic Fire Marker Being Tested in Canada

Fires producing little or intermittent smoke are frequently spotted and reported from patrol aircraft, but they cannot be readily relocated by initial attack crews travelling on the ground or via helicopter.

To assist relocation from both ground and air, an electronic fire marker has been developed at the Northern Forest Research Center in Edmonton, Alberta. It will be used operationally in Alberta during the 1974 fire season. Other provinces are currently evaluating the system.

The transmitter was designed and built to the receiving specifications of the common fireline radio. It operates on the frequency 26.920 MHz and is activated by installing a 9-volt