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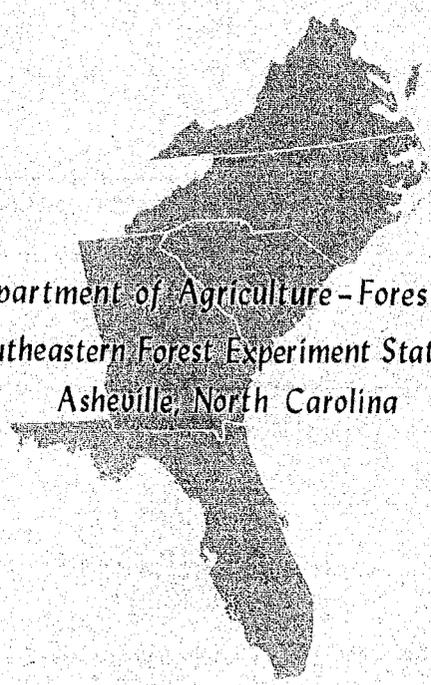
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*Fuel and Weather Influence Wildfires
in Sand Pine Forests*

by

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INTRODUCTION

Sand pine (*Pinus clausa* (Chapm.) Vasey) has a very limited range and, in general, low economic value. The largest concentration is a block of about 280,000 acres on the Ocala National Forest in north-central Florida (5, pp. 447-450); this block provides pulpwood for the local economy.

Sand pine is known as a fire species. The existence of even-aged, dense natural stands can usually be traced to large wildfires. The cones persist for years and open only when subjected to high temperatures. Because the trees often grow in dense stands, wildfires crown rather easily and spread rapidly. Estimated spread rates of 5 m.p.h. and higher have been reported (6).

Records of fires occurring from 1927 to 1952 in sand pine stands on the Ocala National Forest show that 80 percent of all wildfires larger than 10 acres in size occurred between February and June. Thirty-one percent of these fires occurred in the month of May (3). Rainfall deficiencies and dry fuel conditions can be as severe at other times of the year, but large fires occur only during the spring.

The ignitability and flammability of forest fuels are influenced primarily by fuel and weather conditions. The moisture content of green fuel is an important factor, and the influence of foliage moisture on crown fires has been mentioned by others (7, 12, 14).

The amount of inorganic material contained in plant tissue has been found to have an influence on the combustion process (10). Some components are inert and have little effect. Phosphorus, however, is one of the elements that can act as a retardant and show the burning rate of a fuel (2). Seasonal changes in phosphorus content, therefore, may have an effect on fuel flammability.

The material that can be extracted from pine needles with ether is insoluble in water and is composed of resins, waxes, oils, and fats. These materials have very high energy contents and, because they are easily vaporized, may be more available to combustion than are the non-extractable materials (11). If so, fuels with high amounts of such extractives may ignite easily (9) and burn intensely.

During the spring of the year, sand pine needles shine with exuded resinous material (referred to locally as "varnish"), which is suspected of being responsible for past conflagrations. A cooperative study between the Southern Forest Fire Laboratory and the Ocala National Forest was made in 1969-71 to evaluate the effect of fuel variables (including resin content) and weather factors on the occurrence of large fires in stands of sand pine.

METHODS

Wildfires

Fire records were summarized to show the acreage burned and the number of fires by months for each year in the period 1961-70. These data were supplied by the Ocala National Forest and include all sizes of fires occurring on the forest in the sand pine type. Only two fires exceeded 100 acres in size within this 10-year period.

Weather

Complete weather records were not available for Ocala, Florida; therefore, climatological data from Orlando, 35 miles south of the National Forest, were analyzed (13). The weather conditions on days when large wildfires occurred were obtained from surface observations made at Ocala airport and supplied by the National Weather Records Center.

Fuels

Samples of live sand pine needles were collected on the National Forest bimonthly between January and June and at monthly intervals from July to December in 1969 and 1970. Additional samples were collected at monthly intervals from January to June and also in October 1971.

These samples were separated into new and old needles in the field. New needles were from the branch tips and ranged in age from 0 to 10 months, whereas old needles were from the base of the branches and ranged from 9 to 18 months old. New needles initiated in April were probably included as part of the old sample in January of the next year. With several growth flushes in a single year, it was difficult to tell the exact age of the needles.

In 1969, needles were collected from the lower branches of trees about 25 to 30 feet tall in a naturally regenerated stand. In 1970 and 1971, trees in this stand were again sampled, as were younger trees 10 to 15 feet tall from a plantation about 1 mile away.

All samples were mailed to the Southern Forest Fire Laboratory, oven-dried at 85° C., and ground in a Wiley mill. Moisture and energy contents and amount of benzene-alcohol extractives were measured for all samples. The samples collected in 1969 were subjected to ignition tests in a muffle furnace at 232° C. Those collected in 1971 were tested for amounts of ether extractives and inorganic elements (including P, Ca, K, Mg, Mn, Al, and Na).

RESULTS

Weather and Wildfires

The variations in the number of fires and acreage burned from 1961 through 1970 were correlated, in a general way, with average monthly precipitation for the same period (fig. 1). The relationship was strongest in spring and summer and weakest in the fall. Although a small secondary peak in number of fires did coincide with the low amounts of precipitation in the fall, it is apparent that very little acreage is lost in the normally dry months of October through January. This small acreage loss is explained in part by less severe fire weather: fewer days with low humidities (40 percent or less) and high windspeeds (9 m.p.h. or more) occur during these months. Also, airmasses are generally more stable in the fall and winter.

The fire data also showed that fire occurrence may be relatively high in a month with normal or high rainfall if there are periods of 4 to 7 days between rains. Light, fine ground fuels dry in this length of time and will ignite; however, the fires spread slowly and are easily controlled. Heavy rains of short duration do little to restore fuel moisture that has been lowered by drought (4). The excess water will run off the fuel and quickly drain through the sandy soils. Thus, heavy but infrequent showers will not reduce the fire hazard for long.

Weather conditions associated with three large fires in the sand pine type were compared. The fires occurred on February 19, 1950 (200 acres), on March 29, 1962 (285 acres), and on April 18, 1970 (130 acres). There seemed to be a general weather pattern associated with these fires:

(1) Rainfall deficiencies occurred during the fall before the fire and continued into the spring fire season. For example, rainfall was 6.0 inches below normal from September through December 1961 and 1.8 inches below normal from January through March 1962.

(2) On the days when large fires occurred, relative humidity tended to be low (23 to 35 percent) and windspeeds high (9 to 20 m.p.h.). Visibility was very good (12 to 15 miles), indicating frontal passage or an unstable airmass.

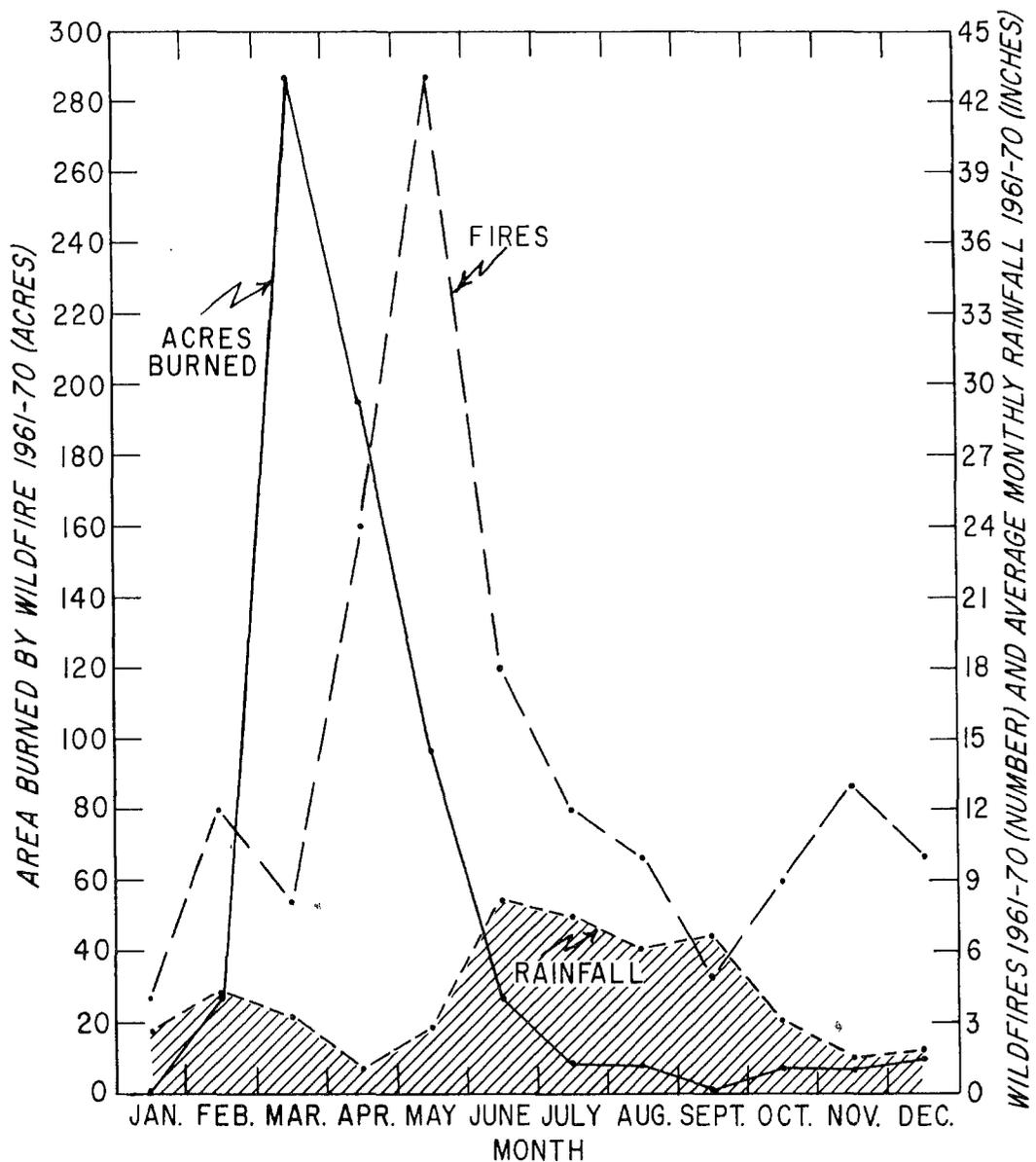


Figure 1. --Total number of wildfires and acreage burned each month in sand pine stands on the Ocala National Forest and average monthly rainfall at Orlando, Florida, from 1961 through 1970.

Fuels and Wildfires

None of the fuel characteristics measured during this study could be used by itself to predict the occurrence of a large wildfire in sand pine stands. Three variables did, however, exhibit annual trends that help account for the occasional spring conflagration:

- (1) Moisture content. --A low point in the seasonal variation in moisture content of new and old needles occurred in March (fig. 2). Moisture content of old needles increased through the summer and

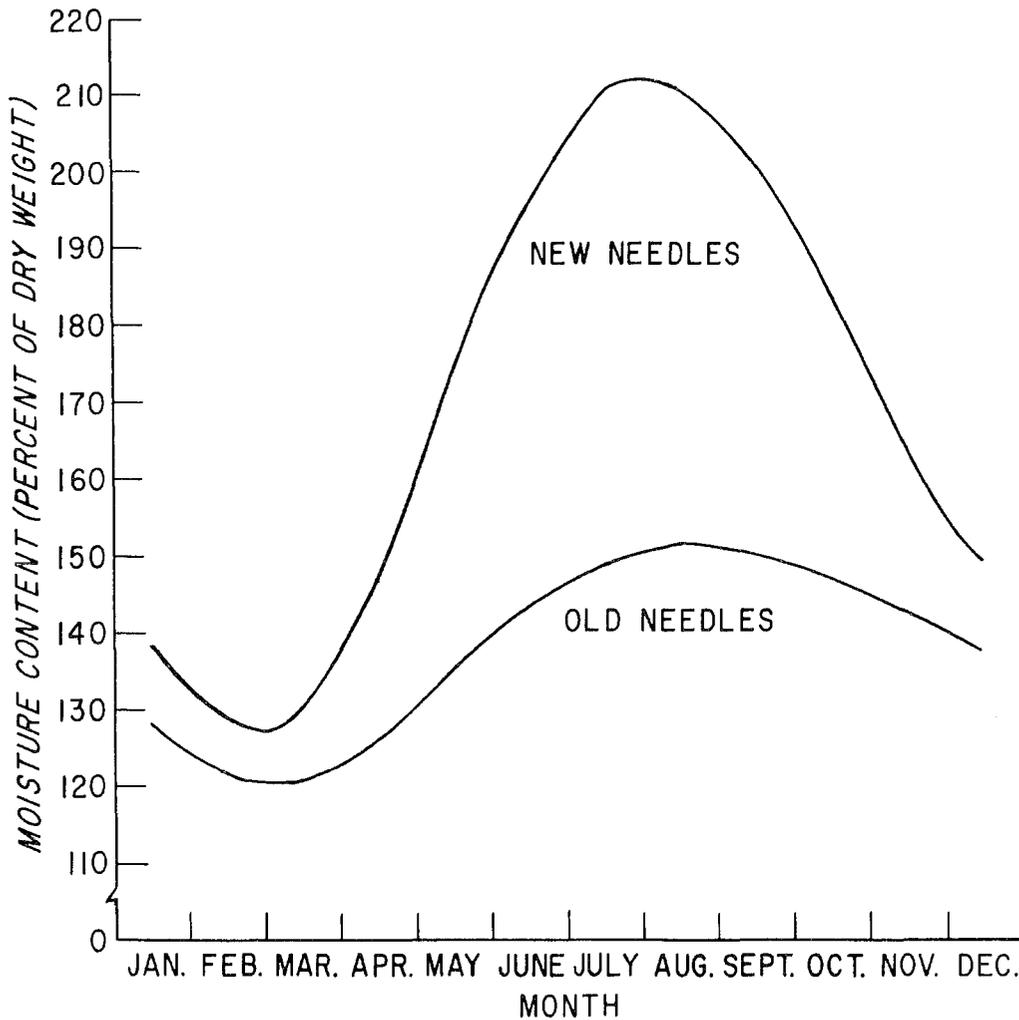


Figure 2.--Seasonal variation in moisture content of new and old needles (smoothed curve through data points for both areas and all years) and phenology of sand pine trees: (Jan.) flowers are developed and vegetative buds swell; (Feb.) buds break dormancy; (Mar.) shoots elongate; (Apr.) at the beginning of the month shoots are 1 to 2 inches long and needles are visible; by the end of the month shoots are 3 to 6 inches long and needles are $\frac{1}{4}$ to $\frac{1}{2}$ inch long; (May) shoots are 6 to 8 inches long and needles are $\frac{1}{2}$ to 1 inch long; by the end of the month, new vegetative buds are formed; (June) needles are 1 to $1\frac{1}{2}$ inches long and another growth flush develops; (July) needles are $1\frac{1}{2}$ to 2 inches long; by the end of the month, some old needles are yellowing; (Aug.) needles approach full size; (Sept.) main needle fall begins; (Oct.) another growth flush begins; (Nov.) April needles reach full size; (Dec.) vegetative buds change color and flower buds start growth.

reached its highest values in August and September. Moisture content of new needles rose sharply to very high values in June and July and decreased through the rest of the year. These high values resulted from initiation of new growth.

(2) Ether extractives. --The content of ether extractives in old needles was at a very high level throughout the year and rose to a slight peak in March (fig. 3). The content of ether extractives in new needles also reached a peak in March, then dropped sharply as the spring growth flush occurred, and reached a low in June. The extractive content rose through the rest of the year as the new needles matured, but the values remained consistently lower than those found in old needles. Seasonal trends similar to the curves for extractive content were also evident in energy content of sand pine needles. This similarity was not surprising because heat value and extractive content of these needles were found to be directly related. Ether extractives and energy values for sand pine are generally higher than those for most other pines, and they compare with the high values reported for California brush species (9).

(3) Phosphorus content. --The phosphorus contents of new and old needles were about the same at the start of the year, and both decreased until March (fig. 3). Old needles continued to lose phosphorus until June, but their phosphorus content then increased through the rest of the year. As shoots elongated and needle growth began, phosphorus content increased sharply in new needles, reaching a peak in April. Phosphorus in new needles decreased through the summer months but remained higher than the content of old needles. Similar changes in phosphorus content have been reported for loblolly pine (16).

Benzene-alcohol extractives were not strongly correlated with trends in fire occurrence or acreage burned. The alcohol fraction extracted sugars and other readily soluble compounds from the live material; this fraction confounded the results by masking the changes in resin content.

Results of tests in the muffle furnace were variable but indicated that old needles ignited much more frequently than new needles. These tests also showed that no ignition occurred in any of the new needles collected between mid-May and August, the period during which needles had high moisture and phosphorus contents and low ether extractives.

DISCUSSION

The variation in acreage burned cannot be fully explained by weather factors, indicating that fuels also have an influence on the behavior of crown fires in sand pine stands. The seasonal trends in the fuel characteristics followed in this study indicate that crown fires have the highest probability of occurring in late February or early March. This is the period during which both new and old needles have the lowest moisture and the highest ether extractive contents. Phosphorus content of new needles is also lowest at this time, whereas phosphorus content of old needles is low but not at its minimum value until June.

Although fuels would have their greatest influence on crown fire at this time, it must be remembered that the major portion of the tree crown will remain highly flammable through May or June. It is not until the new needles make up a significant part of the total crown that

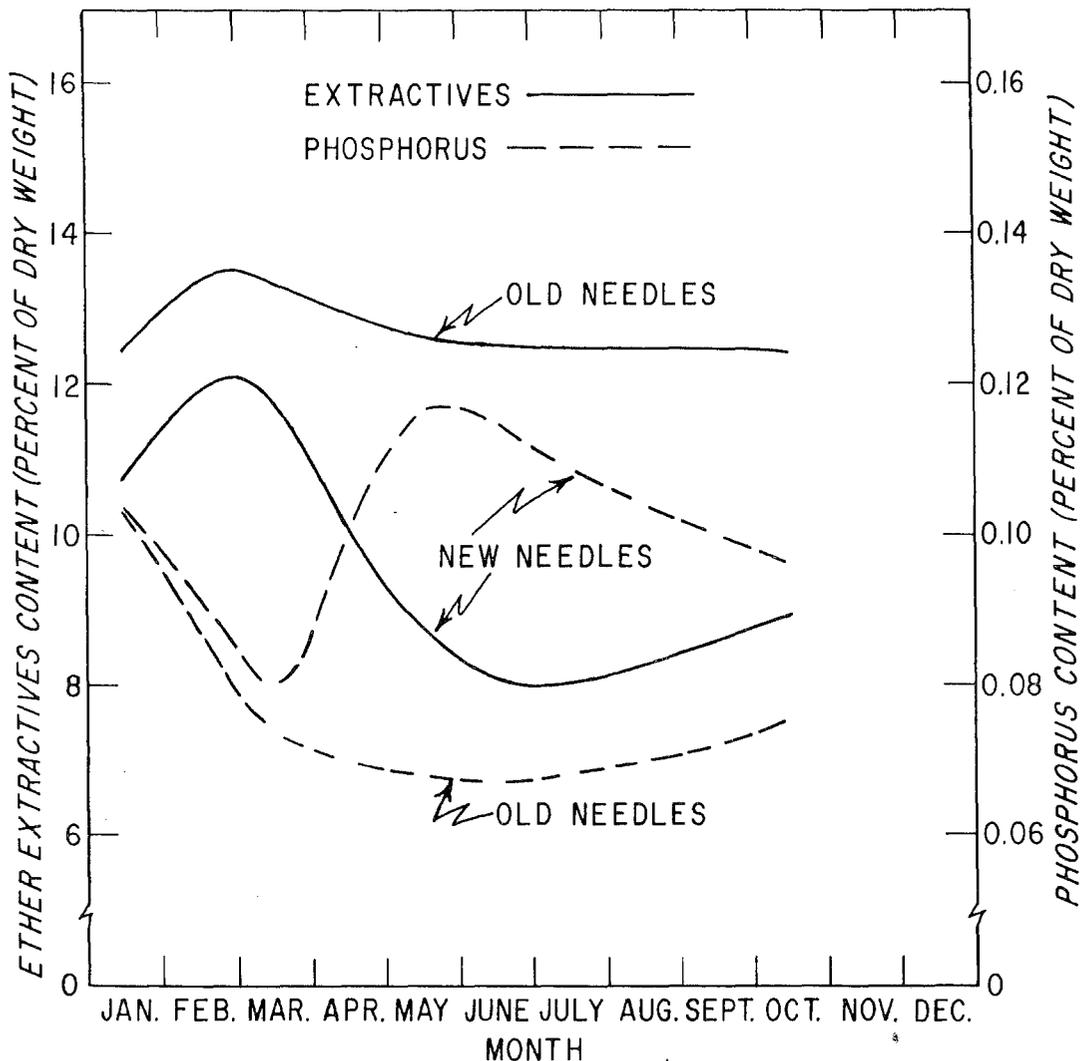


Figure 3. --Seasonal variation in content of ether extractives and phosphorus in new and old needles of sand pine (smoothed curves through data points for both areas in 1971).

their high moisture content and low extractive content will influence fire behavior.

The occurrence of maximum or minimum values in these fuel factors coincides closely with the break in bud dormancy and the start of shoot elongation (fig. 2). Low moisture content of older needles at this time of the year has been reported in many other species (1, 8, 14) and appears fairly typical of the pines. At the time of shoot elongation, moisture and phosphorus may be translocated from the older plant parts to the active growth centers to satisfy the requirements of the developing tissue. This is an important factor in drought years because soil moisture is not readily available and there is a greater demand on the older needles. Thus, the moisture in old needles may be even lower, resulting in easier ignition and faster spread of crown fires.

Crowning in sand pine takes place after the start of a surface fire. Normally, ignition occurs in the litter layer or cured vegetation and is influenced primarily by the moisture content of the dead fuel. The number of fires, therefore, depends upon the number of ignition sources (risk) and the relative humidity. The energy released as the dead fuels burn may involve the understory vegetation, which may then carry the fire into the tree crowns. Obviously, young stands with low branches increase the chance that the surface fire will reach the crowns. In older stands, the understory vegetation would play a major role in getting the fire into the overstory. It is reasonable to assume that understory plants also have cycles in moisture, mineral, and extractive contents. Preliminary tests show these fuels have trends similar to those in sand pine crowns, reinforcing the fact that spring fires are likely to be more intense than fall fires.

Most crown fires are supported by the surface fire and cannot advance ahead of it (15). In dense stands of sand pine, crown fires can burn independently once flame from the surface fire ignites the tree crowns. The forward progress of the crown fire is controlled by the very delicate balance between fuel arrangement, windspeed, energy release, and energy transfer. If crowns are widely spaced or windspeed drops below 4 or 5 m.p.h., the fire will not crown because of the reduced amount of energy transferred to the unburned fuels. If moisture content of the foliage is high, combustion efficiency is reduced and greater amounts of energy are required to bring the needles to ignition temperatures. This is undoubtedly the reason for less crowning in the fall when needle moisture is high. The effectiveness of aerial water drops in knocking down the head of crown fires in sand pine stands is a simple matter of adding water to the surface of the needles, thereby decreasing their flammability. Water drops that were allowed to dry for 24 hours had no effect on the spread of crown fires (6).

The influence of windspeed on the spread of crown fires through sand pine was observed on small test fires conducted in May 1964 and May 1965 on the Ocala National Forest. Winds in 1964 were steady in speed and direction, and hot crown fires developed. In 1965, fuels were much dryer but winds were weak and variable in direction. Fires crowned only in spots and then dropped back into the understory fuel.

CONCLUSIONS

The results of this study indicate that both weather and fuel variables have an influence on the occurrence of large fires (over 100 acres) in sand pine forests. The weather and fuel factors that influence fire behavior reach critical levels in the spring of the year. Moisture content of the needles was found to be the most important fuel variable, and the appearance of new shoot growth can be used as an indicator of the start of the critical fire period. Fuel variables become important, however, only when accompanied by certain weather patterns. Weather conditions associated with large fires during the spring include

- (1) Extended deficiencies of rainfall over several months
(especially the fall and winter before a spring fire season)
- (2) Frontal movement through the area (especially if associated
with low humidities and high winds)
- (3) Low-level instability (0 to 5,000 feet) of the airmass
(especially if absolutely unstable conditions prevail).

These are indicators of increased potential for the development of large fires and erratic fire behavior, and control agencies should be alert to their occurrence.

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A complex combination of fuel and weather factors accounts for the dangerous fires that often develop during the spring in sand pine forests of Florida. Moisture content of live needles is lowest in March, and resin and energy contents reach their yearly highs during the 4-month period from February through May. These fuel properties become critical, however, only when they are accompanied by rainfall deficiencies that begin in the fall and winter and continue through the spring and by unstable airmasses with low relative humidities and high winds.

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