Station Paper No. 144 July 1962

Surplus

Forest Fuels on Organic and Associated Soils in the Coastal Plain of North Carolina

by

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Local, accepted common, and scientific names of the principal species of vegetation in organic and associated soil fuel types

LOCAL	ACCEPTED COMMON NAME	SCIENTIFIC NAME
	Blackberry	Rubus sp.
	Common Sweetleaf	Symplocos tinctoria (L.) L'Her.
	Loblolly-Bay	Gordonia lasianthus (L.) Ellis
	Leatherleaf	Chamaedaphne calyculata
Swamp Maple	Red Maple	Acer rubrum L.
	American Holly	Ilex opaca Ait.
Sweet Pepperbush	Summersweet Clethra	Clethra alnifolia
Winged Sumac	Shining Sumac	Rhus copallina L.
	Smooth Sumac	Rhus glabra L.
Myrtle Dahoon	Dahoon	Ilex cassine L.
Tall Gallberry	Large Gallberry	Ilex coriacea (Pursh) Chapm.
Common Gallberry	Inkberry	Ilex glabra
Wild Raisin	Witherod Viburnum	Viburnum cassinoides
	Swamp Cyrilla	Cyrilla racemiflora L.
	Dangleberry	Gaylussacia frondosa
Sheep Laurel	Lambkill	Kalmia angustifolia
	Fetterbush	Lyonia lucida
	Pinxterbloom Azalea	Rhododendron nudiflorum
Trailing Blueberry	Creeping Blueberry	Vaccinium crassifolium
Honeycup	Dusty Zenobia	Zenobia pulverulenta
	Redbay	Persea borbonia (L.) Spreng.
Greenbrier	Laurel Greenbrier	Smilax laurifolia
Greenbrier	Common Greenbrier	Smilax rotundifolia
	Carolina Jessamine	Gelsemium sempervirens
White Bay	Sweetbay	Magnolia virginiana L.
Myrtle	Southern Bayberry	Myrica cerifera L.
Blackgum	Black Tupelo	Nyssa sylvatica Marsh.
	Sweetgum	Liquidambar styraciflua L.
	Chokeberry	Aronia arbutifolia
Reed	Switch Cane	Arundinaria tecta (Walt.) Muhl.
	Bracken Fern	Pteridium aquilinum
	Pond Pine	Pinus serotina Michx.
	Loblolly Pine	Pinus taeda L.
	Longleaf Pine	Pinus palustris Mill.
Wire Grass	Pineland Three-awn	Aristida stricta Michx.
	Bluestem Grasses	Andropogon spp.
	Beakrushes	Rhynchospora spp.
	Panicums	Panicum spp.
	Honeysuckle	Lonicera spp.

ACKNOWLEDGMENTS

Our sincere thanks to Jim Huff, Forest Supervisor for Halifax Paper Company on Hofmann Forest, and his staff, and to I. F. Trew and D. M. Crutchfield, of West Virginia Pulp and Paper Company, for their wholehearted cooperation and assistance in the field phases of this study. District Ranger O. T. Jamison helped locate plots on the Croatan District, North Carolina National Forests. T. H. Ellis, formerly with the Southeastern Station, assisted with the field work.

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INTRODUCTION

The fire problem in the organic soil (pocosin) areas of eastern North Carolina centers around the frequent and costly blowup[1/] wildfires occurring there and the use of fire as a management tool. Under certain combinations of fuel and weather, low intensity fires will suddenly and often unexpectedly multiply their rate of energy output many times. In almost all instances these fires have been virtually uncontrollable until the weather has moderated or the fire has run out of fuel. Efforts at control are often greatly hampered by inaccessibility and the poor soil trafficability in much of the area.

Prescribed fire appears to be a potentially valuable tool in the management of pond pine by promoting seed fall from the serotinous cones and in preparing the seedbed. Fires of sufficient intensity to achieve these results, however, are usually difficult to control and tend to burn deeply into the organic soil. The problem has become more acute in the past 10 years because of the increased commercial importance of the pocosins as pulpwood and timber producing areas. A better understanding of the behavior of fires in the pocosins, especially of the factors that favor the occurrence of major fires, could contribute much to the economy of this particular region as well as to the general fund of basic fire behavior knowledge.

1/ "Sudden increase in fire intensity or rate of spread sufficient to preclude direct control or to upset existing control plans. Often accompanied by violent convection and may have other characteristics of fire storm" (17).

Fuels and Extreme Fire Behavior

One of the most important factors contributing to the blowup fire potential is the quantity of live and dead understory and overstory fuel that constitutes a fire's basic source of energy. An additional source of energy of fires in the pocosins is the flammable organic soil.

During periods of drought, soils of high organic matter content have been consumed to depths of 2 or 3 feet. In very high intensity fires practically all of the brush and litter as well as the overstory foliage and light branchwood can be consumed. Usually there is spotting for considerable distances ahead of the main fire front. In order to provide presuppression measures to reduce the probability of blowup fires, better ways for recognizing the potential for extreme fire behavior are required. A system for rating fuels in terms of fire behavior would be an important first step in accomplishing this objective. Although eastern North Carolina is used as the study area, it should be pointed out that the main concepts in this paper are of a basic nature and should apply anywhere.

Previous Fuel Classifications

The literature contains several fuel classification systems. Fire researchers generally agree that fuel size, quantity, arrangement, and moisture content are the most important fuel variables that determine rate of fire spread and resistance to control (5, 6, 7). As a result, many of the present classifications, although mainly based on cover types, incorporate these variables and rate the cover types as to their relative rate of fire spread and resistance to control (8, 9). Much of the past work included some actual measurements, particularly of rate of spread and fuel weights (1), but most of the results are expressed only qualitatively. Only limited work has been done on the quantitative fire behavior significance of factors such as fuel energy content and rate of energy release.

Fire control people in eastern North Carolina recognize four general fuel types on organic soils; i.e., low pocosin, high pocosin, open cane, and overstoried cane, but no detailed descriptions have been written for these types. A more detailed fuel classification based on species composition, density, height, and age of rough[2/] would have more utility than the broad classification now in use. Because of the frequency and unpredictable behavior of large pocosin fires in the past, a classification based on the fuel-fire behavior relationships embodied in this paper will be even more useful.

2/ Years since last disturbance.

DESCRIPTION OF STUDY AND RESULTS

The objectives of the study were: (1) to type pocosin fuels based on species composition, height, and density; and (2) to determine the total weight per unit area of each of the types including vegetation and litter, group them into total weight classes, and rate each class for extreme fire behavior in terms of its blowup potential.[3/]

In general, pocosins may be described as those areas, including swamps and bays, with soils having 20 percent or more organic matter content, fair to poor internal drainage, and supporting stands of pond pine (19). Also, these areas have a medium to heavy density understory composed principally of woody shrubs and reeds. The pocosins constitute roughly 2 million acres in coastal North Carolina, principally in the Dare-Tyrrell-Hyde County area in the northeast part of the State and in the several counties surrounding New Bern in the central coastal plain. Other isolated pocosins are found in the vicinity of Wilmington and Elizabeth City, North Carolina (fig. 1). Individual pocosins range from a few thousand acres in size to many thousands of acres and, until recently, were not very accessible. Large-scale drainage and development programs on many pocosins have hastened the drying of soils and made the area more accessible, but have increased the fire hazard.

General Fuel Types Selected

A preliminary reconnaissance of the various pocosins indicated that most of the fuel types, as well as the different organic soils, in the North Carolina coastal plain were represented on or in the vicinity of Hofmann Forest in Jones and Onslow Counties, North Carolina. As a result, the bulk of the sampling was done on Hofmann Forest. Other types which did not occur there were sampled on industry lands in Tyrrell County, and on the Croatan National Forest.

An extensive reconnaissance of Hofmann Forest was made and areas similar in species composition, apparent density, and height were identified as distinct fuel types. The pine overstory, if present, was not considered in identifying fuel types, although most types appeared to have a characteristic overstory. In all, 14 types were identified, described, and photographed. Fuels also were designated as brush, switch cane, or grass types, depending on the proportion of brush species, switch cane, and grasses in the composition.

Brush types are composed mainly of common gallberry, tall gallberry, white bay, redbay, loblolly-bay, swamp cyrilla, and fetterbush. Switch cane types are composed principally of reeds and minor amounts of common gallberry, common greenbrier, redbay, and white bay. Only one grass type, composed mostly of wire grass, was identified.

3/ The blowup potential is defined in terms of the ember lifting power of the convection column over a high intensity fire and is thus closely related to the capacity of such a fire to spot. Numerically, the blowup potential is equal to the quantity $(w/w_o)^2$, where w is the weight of the fuel and w_o is a reference fuel weight. In this study, which assumes the worst possible burning conditions, w is the total weight of the fuel. Under severe conditions all of the fuel is consumed and the maximum amount of energy released. A more detailed account of these concepts is given in a later section.

Is it not essential that w_o be approximately the mean of the fuels being rated

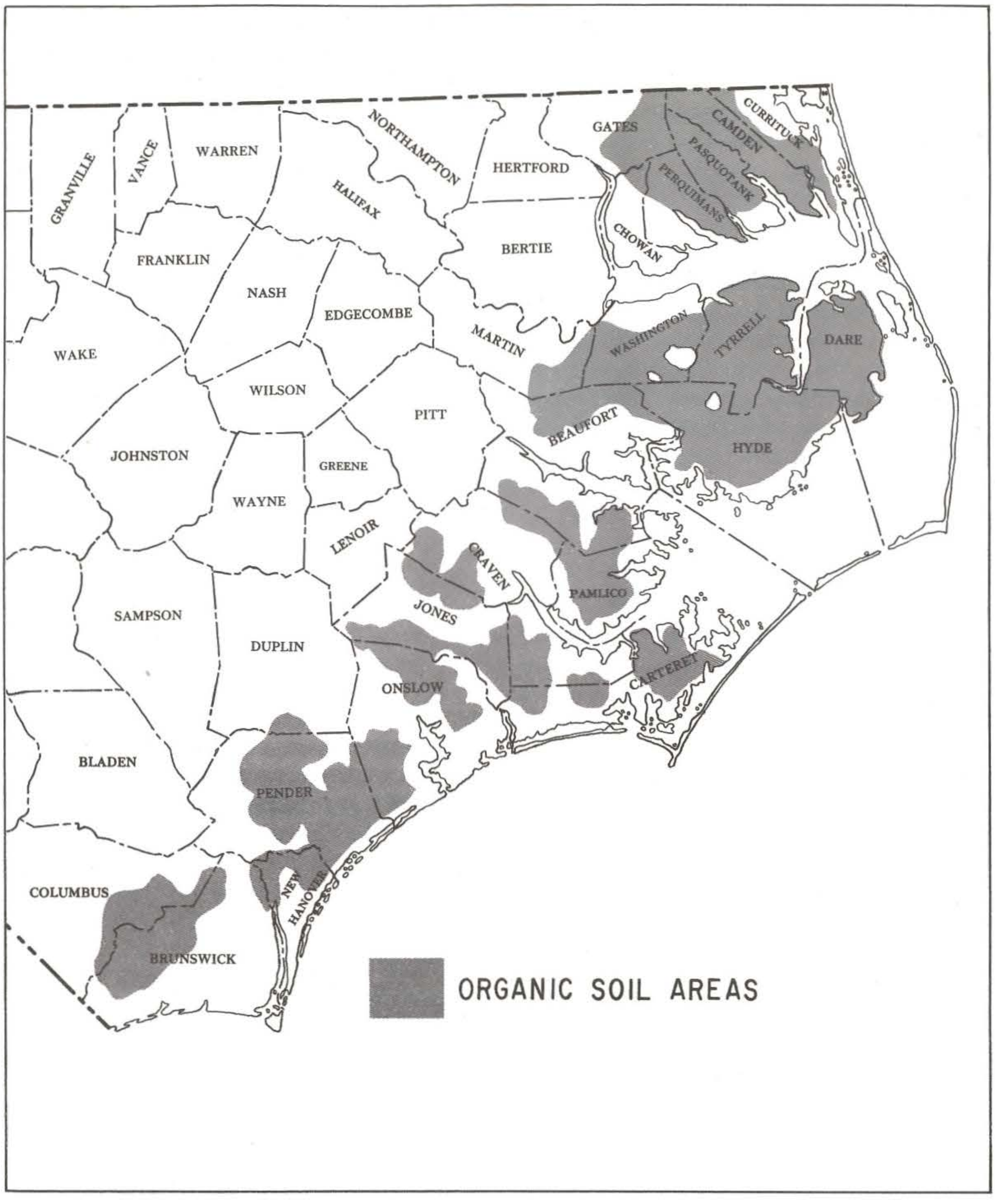


Figure 1.--Locations of principal organic soil areas in eastern North Carolina.

The understory species on pocosins, particularly the shrubs, generally grow in clumps, probably because of recurrent fires. Intense surface fires and brush crown fires, although hot and consuming, do not often kill the plant roots. As a result, the shrubs sprout prolifically. The clumps may vary in size from about 8 inches in diameter at the ground to 3 feet or more, as in the case of loblolly-bay. The area covered by brush clump crowns may vary from about 1 square foot to 60 or more square feet. Except for swamp cyrilla and honeycup, most of the more common species of pocosin vegetation are evergreen. The foliage of reeds cures on the canes in the winter.

Sampling the Understory Vegetation and Litter

Fuel weights were obtained from three 1/100-acre square plots and two 1-milacre plots laid out in each type, the latter to determine the feasibility of using smaller plots in future sampling. These smaller plots were only slightly larger than individual brush clumps. Average weights of the large plots and the small plots were very little different so all plots were combined for the analysis.

The vegetation was cut 1 inch above ground level, separated by species, and weighed. Pond pines no taller than the brush and the few dead standing plants were included with the understory. A sample of each species, usually a whole bush, was taken at the time of weighing for moisture content determination. A milacre plot of litter[4] was collected and weighed from each of the 1/100-acre plots after the vegetation was removed. Fresh weights of each species and the litter were converted to ovendry weight in tons per acre by the following formula:

$$W_d = \frac{W_g}{20(100+m)A}$$

$W_d = \frac{W_g}{(1+m)A}$ = Pounds per acre

where W_d is the ovendry weight of the fuel component in tons per acre, W_g is the green weight of the fuel component on the plot in pounds, m is the moisture content in percent of ovendry weight determined by ovendrying a randomly selected small sample at 102° C., and A is the plot area in acres. The total fuel weight in tons per acre ovendry was obtained by adding up the individual species weights and the weight of the litter. Average weights of the 5 plot replications were used in the analysis.

Sampling the Overstory

Most of the fuel types appeared to have a characteristic pine overstory or no overstory, probably the reflection of site. However, pond pine stands of different diameters and densities were observed to occur occasionally over all understory fuel types. This seemed to rule out sampling the overstory on a plot basis along with the understory. A simple method of estimating the contributions of the pine crowns to total fuel weights was devised.

4/ Includes both the litter layer and the duff layer, defined by the U. S. Forest Service respectively as, "the top layer of the forest floor, composed of loose debris of dead sticks, branches, twigs, and recently fallen leaves or needles, little altered in structure by decomposition," and "the partly decomposed organic material of the forest floor beneath the litter of freshly fallen twigs, needles, and leaves" (17).

A companion study (18) provided the basis for table 1; the contribution of the pine foliage can be estimated readily from average stem diameter and degree of stocking. The technique of estimating tree crown weights from stem dimensions is well established (10, 11, 15, 16). During very intense fires, twig ends are consumed in addition to the foliage, but as a rule, the contribution of the branchwood to total fuel weight consumed is small and can be ignored. Also, there is a compensating effect in that brush stems larger than 1 inch in diameter were weighed with the understory vegetation but are not always totally consumed in blowup fires.

Crown weight studies were not made for longleaf pine or loblolly pine because in only 3 of the 14 fuel types are either of these species important components of the overstory. In only one of these three types is longleaf pine usually present. The needles seldom burn because the understory wire grass fuel usually is not heavy enough to cause crowning. Table 1 can be used to estimate the foliage contribution of all three species to total fuel weight with good accuracy.

Table 1.--Ovendry foliage weight of pond pine by stem diameter and stocking

D.b.h. (inches)	Number of trees per acre									
	10	20	30	40	50	60	70	80	90	100
	Tons per acre									
2	--	--	--	--	--	--	--	--	--	0.1
3	--	--	--	--	--	--	0.1	0.1	0.1	.2
4	--	--	--	0.1	0.1	0.2	.2	.2	.2	.3
5	--	--	0.1	.2	.2	.2	.3	.3	.3	.4
6	--	0.1	.2	.2	.3	.3	.3	.4	.5	.5
7	--	.1	.2	.3	.3	.4	.5	.5	.6	.7
8	--	.2	.3	.3	.4	.5	.6	.7	.8	.9
9	0.1	.2	.3	.4	.5	.6	.7	.8	.9	1.0
10	.1	.3	.4	.5	.6	.8	.9	1.0	1.1	1.3
11	.1	.3	.4	.5	.7	.8	.9	1.1	1.2	1.4
12	.2	.3	.5	.6	.8	.9	1.1	1.2	1.4	1.5
13	.2	.4	.5	.7	.9	1.1	1.2	1.4	1.6	1.8
14	.2	.4	.6	.8	1.0	1.2	1.4	1.6	1.8	2.0
15	.2	.5	.7	.9	1.1	1.4	1.6	1.8	2.0	2.3

Total Weight Classes and Blowup Potential

The final steps in rating the 14 fuel types are expressed in tables 2 and 3. Table 2 expresses basic physical relationships and does not depend on any given fuel type. The first column in this table shows fuel weight classes set up in a convenient but arbitrary physical breakdown. The weight range within a class bears an approximately constant ratio to the midpoint weight of the class. The blowup potential is defined by the dimensionless ratio $(w/w_o)^2$, where w is fuel weight and w_o an arbitrary reference weight which can be assigned any convenient value. A value of w_o of 6 tons per acre was chosen because the probability of blowup fires decreases rapidly when w_o is less than 6 tons per acre. The class range of $(w/w_o)^2$ corresponding to each fuel weight class is shown in the second column of table 2. Descriptive designations for the blowup potential classes are listed in the third column.

The first, second, and third columns of table 3 give the symbol, name, and total fuel weight, respectively, of the 14 principal fuel types in the organic soils region. The blowup potential $(w/w_o)^2$ is given for each type in numerical form in column 4. Comparing column 3 in table 3 with column 1 in table 2 gives the appropriate descriptive designation of the blowup potential for the different types. These are listed in the fifth column of table 3.

Because the fuel weight classes of table 2 are independent of the different fuels listed in table 3, a specific fuel type does not necessarily have a fixed relationship to a given fuel weight class or its associated blowup potential. For example, a fire could burn over an area and consume some of the fuel, thereby reducing the fuel weight. If the fire was not intense enough to change the type characteristics (species composition, apparent density, and height), then for that particular area the blowup potential for the type might drop from high to medium high or even lower. Values of the blowup potential for the different fuel types in table 3 should, therefore, be regarded as estimates which will change as the quantity of fuel changes.

Table 2.--Blowup potential ratings for various fuel weight classes

Fuel weight classes (tons per acre)	Blowup potential	
	Range of $(w/w_o)^2$ 1/	Description
2.9 - 4.0	0.23 - 0.45	Very Low
4.1 - 5.7	0.46 - 0.91	Low
5.8 - 8.0	0.92 - 1.79	Medium Low
8.1 - 11.0	1.80 - 3.39	Medium
11.1 - 16.0	3.40 - 7.15	Medium High
16.1 - 23.0	7.16 - 14.7	High
23.1 - 32.0	14.8 - 28.4	Very High

1/ Reference weight, w_o, is 6.0 tons per acre.

Table 3.--Estimated blowup potential ratings for various pocosin fuel types

Symbol 1/	Name	Total 2/ fuel weight	Blowup potential	
			$(w/w_o)^2$	Description
		Tons per acre		
G-5	Wiregrass	4.5	0.55	Low
P-5	Low pocosin--open	5.7	.90	Low to Medium Low
GB-7	Grass--low brush	6.4	1.14	Medium Low
RG-7	Low reeds--grass	6.5	1.17	Medium Low
P-10	Low pocosin--dense	8.4	1.99	Medium
B(SR)-10	Brush (sand ridge)	8.6	2.02	Medium
RB-10	Medium reeds--brush	8.8	2.13	Medium
BG(SR)-10	Low brush--grass (sand ridge)	8.8	2.16	Medium
BG-10	Medium brush--grass	9.4	2.43	Medium
R-10	High reeds	3/ 10.1	2.84	Medium
R-14	Very high reeds	3/ 13.2	4.82	Medium High
P-14	High pocosin	3/ 15.0	6.25	Medium High
B-20	High brush	3/ 17.3	8.35	High
B(S)-20	High brush (swamp)	3/ 21.0	12.2	High

1/ G = wiregrass; P = pocosin; B = brush; R = reeds (switch cane); S = swamp; SR = sand ridge; the numerals 5, 7, etc. are the approximate midpoints of the total fuel weight classes in tons per acre as set up in table 2.

2/ Total fuel weights are averages of sampled weights.

3/ If an overstory is present, add to the tabular value a correction for foliage weight from table 1. Check this corrected total weight figure against column 1, table 2, to obtain the appropriate blowup potential.

The weights of the fuel for the different types given in table 3 represent the litter and understory fuel only. Although many high intensity fires crown only sporadically in most of the southern pine types, the highest intensity fires may consume the foliage. Hence, for extreme conditions the estimated foliage weights from table 1 should be added to the total fuel weight in table 3. The correction is relatively small. Also, because extensive crowning is unlikely in the lighter fuels even under severe conditions, the foliage weight could probably be disregarded for litter and understory fuel weights less than 10 tons per acre. One exception would be for dense even-aged reproduction stands 15 to 30 feet in height that will crown readily even if the ground fuel is light. However, this type is not common in the organic soils region of North Carolina.

It should be emphasized that the fuel classes described in this paper are based on one fuel factor, total fuel energy[5/] (and hence total fuel weight), and for this reason apply only to the most severe conditions of fuel dryness. Under these conditions practically all of the fuel burns, releasing the total energy which feeds into the base of the convection column. However, the concept will be applicable under all weather conditions as soon as sufficient information is available on the remaining fuel factors--primarily the combustion rate and the fuel energy available for convection, both of which depend on fuel size, fuel arrangement, and fuel moisture content. In less severe fire weather situations, the fuel weight w would then become the weight of fuel whose energy is available for convection. This might be far less than the total fuel weight. For example, in an area where the total fuel weight is 25 tons per acre it might be possible under some weather conditions to have a fire that would burn only 3 tons per acre in a time short enough for the energy to flow into the convection column (provided a convection column could exist).

5/ The amount of energy released if all of the fuel is consumed by a fire. This and the other five fuel factors are described in greater detail in a later section.

Identification of Fuel Types

The following key, photographs (figures 2 to 15), and accompanying descriptions give a more detailed account of the 14 fuel types and should aid in their identification.

Key for the Identification of Fuel Types[6/]

A. Grass Type. Occurring on mineral soils; a wire grass-common gallberry mixture; average $1\frac{1}{2}$ feet high; generally found in association with the longleaf pine timber type; 4.5 tons per acre.	G-5
A. Switch Cane Types. Generally occur on organic soils having fair internal drainage and 40 to 50 percent organic matter content in the upper 4 inches of soil; species composition 70 to 100 percent reeds in association with varying amounts of greenbrier, common gallberry, white bay and redbay, and a pond pine overstory.	4
A. Brush Types. Occurring on mineral and organic soils, composed principally of low and tall woody shrubs, small hardwood trees, and varying amounts of grass and herbaceous vegetation but with little or no reeds in composition, may have loblolly pine or pond pine overstory.	1
1. Occurring on mineral soils, low sand ridges adjacent to pocosins; composition chiefly a mixture of sweetgum, blackgum, myrtle, and swamp maple, 4 to 6 feet tall, with a lower stratum 1 to 2 feet tall of grasses and herbaceous vegetation; 8.7 tons per acre.	BG(SR)-10, B(SR)-10
1. Occurring on organic soils, pocosins, swamps, or bays; does not include cypress or gum swamps.	2
2. Occurring mostly on the more shallow, poor to fairly well drained organic soils, 6 to 24 inches deep; 30 to 50 percent organic matter content in the upper 4 inches of soil; average height of the understory varies from 4 to 14 feet.	3

6/ Weights given in the key are total fuel weights and are averages of sampled weights.

2. Occurring mostly on deeper, poorly drained organic soils usually 2 feet or more in depth; mostly peats and mucks with more than 80 percent organic matter content.

Composed principally of 60 percent swamp cyrilla, and 40 percent fetterbush, common gallberry, honeycup, leatherleaf, and sheep laurel, in equal amounts; average height of brush 3 feet, open habit of growth; widely scattered, short (10 to 12 feet tall) pond pine overstory; 5.7 tons per acre; open low pocosin. P-5

Chief species in the composition are 35 percent swamp cyrilla, 35 percent honeycup, 25 percent common gallberry and fetterbush, with an occasional large clump of loblolly-bay scattered throughout; average height of brush 4 feet, dense habit of growth; pond pine overstory similar to that in P-5; 8.4 tons per acre; dense low pocosin. P-10

3. Organic soil layer mostly 8 to 24 inches deep; tall shrub understory stratum.

Species composition 50 percent swamp cyrilla, 25 percent loblolly-bay, 15 percent common gallberry, 10 percent greenbrier, white bay, and redbay; good vertical continuity within the understory stratum due to abundant greenbrier and pine needle drape; brush height ranges from 2 to 16 feet with the average about 14 feet; 15.0 tons per acre; high pocosin. P-14

Species composition 50 percent fetterbush, 30 percent tall gallberry, dangleberry, and loblollybay, 20 percent white bay, greenbrier, and swamp cyrilla; a very dense mass due to the closeness of the stems; height range 4 to 12 feet, average about 8 feet; 17.3 tons per acre. B-20

Species composition 85 percent swamp cyrilla, 10 percent blackgum, and 5 percent common gallberry, white bay, and fetterbush; fewer but larger stems permit relatively easy travel through the type; height range of 5 to 14 feet with the average about 13 feet; 21.0 tons per acre. B(S)-20

3. Organic soil layer usually 6 to 8 inches deep; areas supporting these types usually have been logged.

Average height of brush 4 feet; species composition 60 percent grasses and herbaceous vegetation, 20 percent common gallberry, and redbay, 20 percent greenbrier, honeycup, blackgum, and fetterbush; recently logged, logging trails support dense grass stands; 6.4 tons per acre. GB-7

Average height of brush 5 feet; species composition 40 percent swamp cyrilla and redbay, 45 percent common gallberry, blackgum, sweet pepperbush, and greenbrier, 15 percent grasses and herbaceous vegetation; older logging; 9.4 tons per acre. BG-10

4. More than 80 percent switch cane in composition, chief associates are common gallberry and greenbrier; average height of the reed stratum is 10 feet, although many individual stalks may exceed 12 feet; reed stems at soil surface range from 1/2 to 3/4 inch in diameter; 13.2 tons per acre. R-14

4. Approximately 70 to 80 percent reeds in composition, principal associates common gallberry, fetterbush, white bay and redbay; average height of the reed stratum is less than 8 feet.

   5. Reeds less than 5 feet tall.

      Average height of reed 4 feet; species composition 70 percent reed, and grasses, with clumps of common gallberry, fetterbush, white bay, redbay, and grass areas making up the remaining 30 percent; usually the more recent (2 to 3 years) logged or burned reed areas; 6.5 tons per acre. RG-7

      Average height of reed 5 feet; species composition 80 percent reed, 10 percent common gallberry, greenbrier, and miscellaneous shrubs, 10 percent grasses and herbaceous vegetation mostly in old logging trails; shrub clumps are larger and reed stems are closer together than in RG-7; 8.8 tons per acre. RB-10

   5. Average height of reed 7 feet, although individuals may go to 9 feet; species composition 80 percent reed; common gallberry and greenbrier are major associates; 10.1 tons per acre. R-10

Figure 2. - Fuel type G-5 (wiregrass). Low blowup fire potential.

TYPE G-5 (WIREGRASS)

Ovendry weight	Tons per acre
Vegetation	1.54
Litter	2.92
Total	4.46

Fuel type G-5 occurs in association with longleaf pine in eastern North Carolina. These areas are important from the fire standpoint because they are often adjacent to pocosin areas and also because the fast-drying grass fuels can burn vigorously at any time of the year. Fires in this type have been known to occur only a few hours after heavy rains.

The soil is a sand with a very low organic matter content.

The principal species in the understory composition are wire grass, approximately 60 percent; common gallberry, 20 percent; and bracken fern, 20 percent. Scattered throughout the type are an occasional redbay bush and numerous herbaceous species. Bracken fern and common gallberry average $1\frac{1}{2}$ feet tall and the wire grass blades are generally $1\frac{1}{2}$ to 2 feet long. The wire grass appears shorter because the stems bend over and form a loose mat covering the area. The base of the wire grass clumps may average 3 to 4 inches in diameter, but these are usually not visible until after a fire.

During the late fall and early spring, wiregrass areas assume a brownish cast because of heavy longleaf pine needle fall and the curing of the wire grass.

The total weight figure represents the growth of the understory vegetation for 2 years. Older roughs may yield an additional 2 or more tons of ovendry material per acre. Generally most of the wiregrass areas are under management and are prescribed burned at 2 to 3 year intervals.

The overstory stands of longleaf pine are open and may contain groups of two or more age classes.

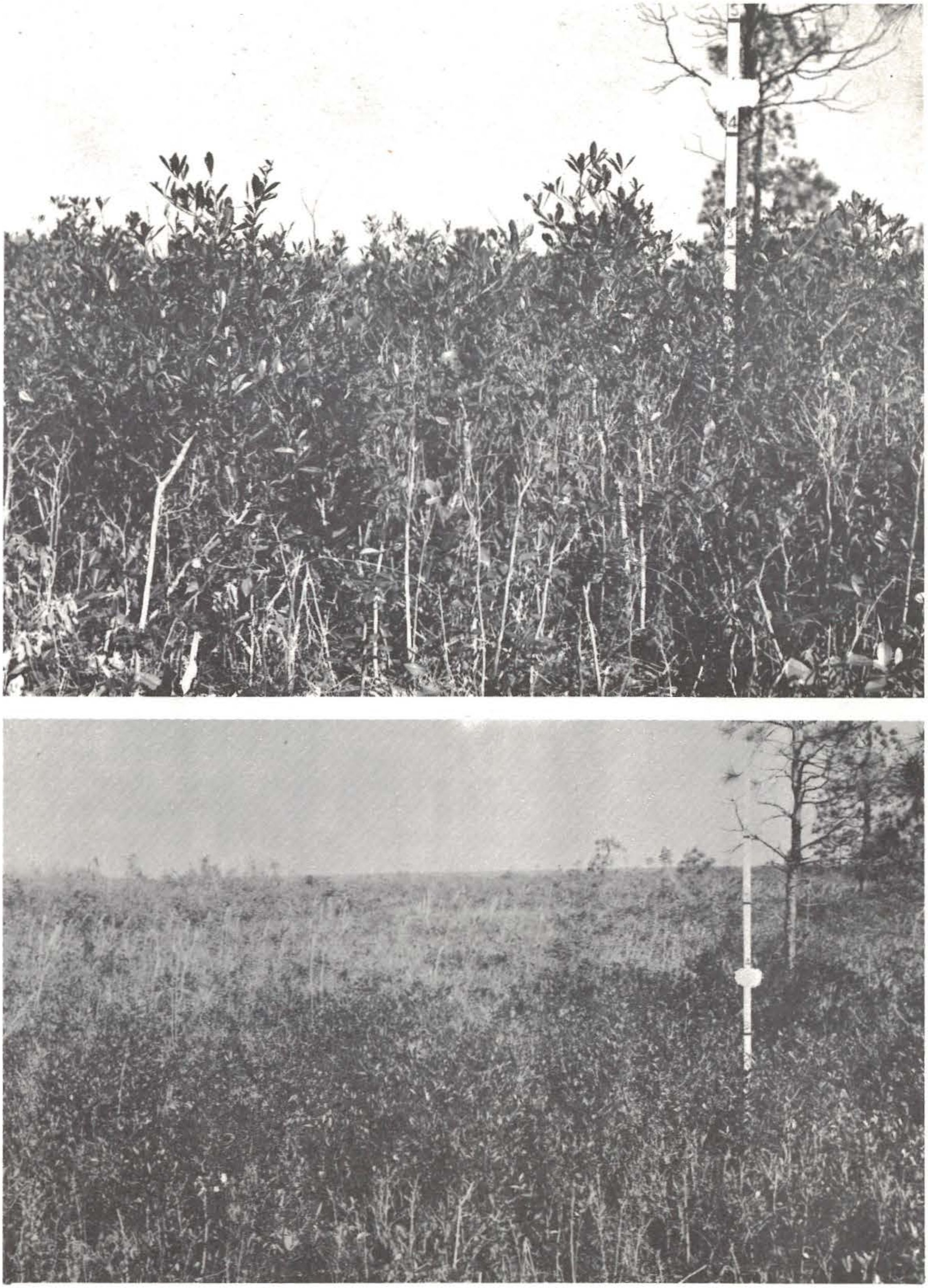


Figure 3.--Fuel type P-5 (low pocosin - open). Low to medium low blowup fire potential.

TYPE P-5 (LOW POCOSIN - OPEN)

Ovendry weight	Tons per acre
Vegetation	2.06
Litter	3.62
Total	5.68

Fuel type P-5 consists mainly of low shrub species that range from 1 to $3\frac{1}{2}$ feet high. P-5 usually occurs on peat or muck soils having an organic matter content of 90 percent or more. The soil organic layer may be 2 feet or more in depth.

Principal species in the composition are swamp cyrilla, 60 percent; fetterbush, 10 percent; common gallberry, 10 percent; and honeycup, 10 percent. The remaining 10 percent consists of greenbrier, leatherleaf, redbay, and pond pine sprouts. The two largest contributors to total ovendry weight are swamp cyrilla and fetterbush which account for 60 percent of the total weight.

The soil surface in the type is characterized by brush hummocks averaging 6 inches high and spaced at approximately $1\frac{1}{2}$-foot intervals. The area between hummocks is soft and does not offer much support to foot or equipment travel. From an over-all view the type appears as an even and homogeneous mixture.

The litter is generally 1 to 2 inches deep and is concentrated for the most part in the depressions between the hummocks.

The overstory consists of widely scattered pond pine of poor form that seldom exceed 15 feet in height. Much of the pine is of sprout origin and the area is considered noncommercial timberland.

The low and scattered nature of the shrub clumps makes this type very easy to walk in. It represents a brush growth and litter accumulation of 3 years.

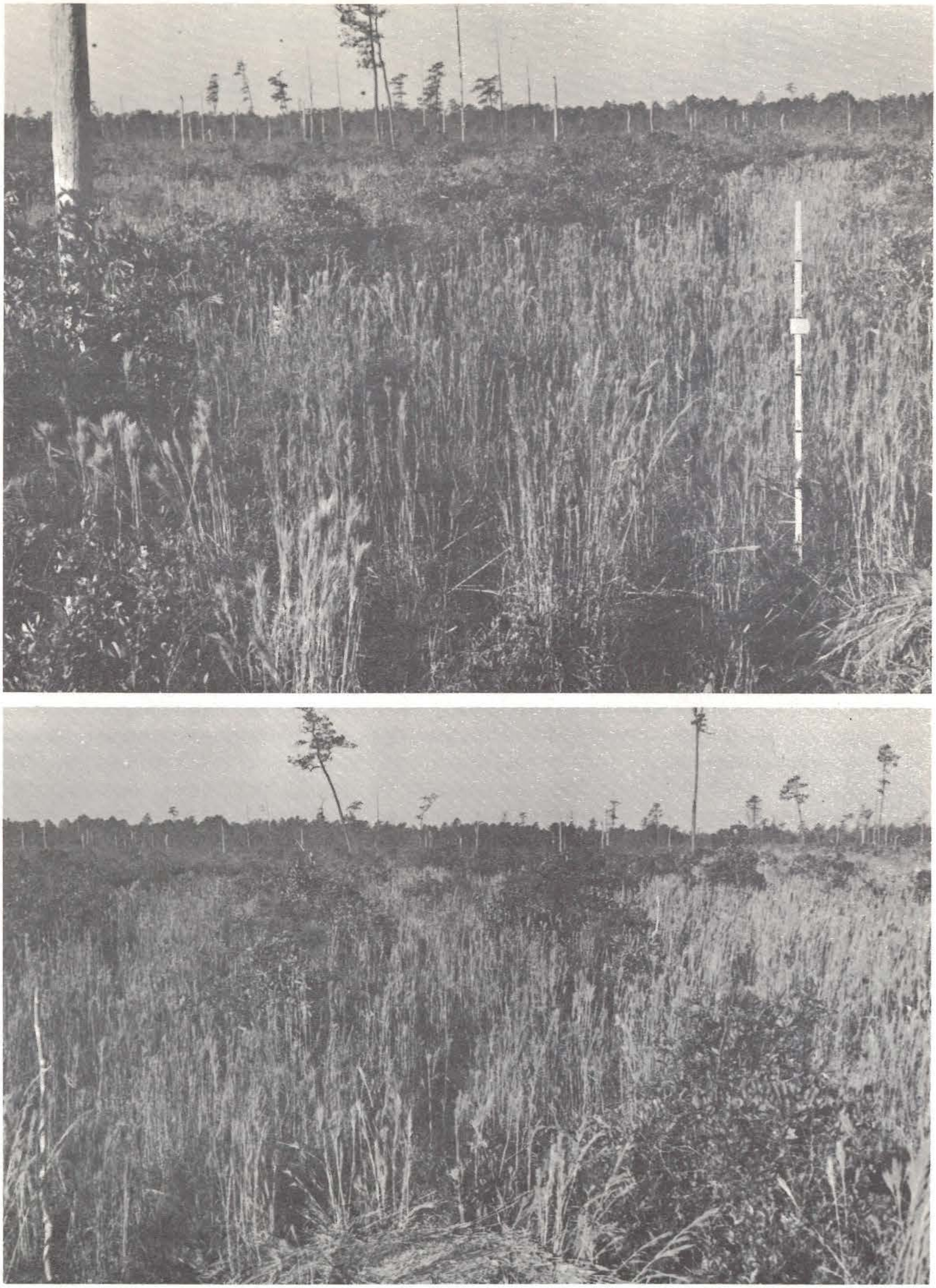


Figure 4.--Fuel type GB-7 (grass - low brush). Medium low blowup fire potential.

TYPE GB-7 (GRASS - LOW BRUSH)

Ovendry weight	Tons per acre
Vegetation	2.89
Litter	3.55
Total	6.44

Fuel type GB-7 is a low brush type in which the individual species usually do not exceed a height of 3 or 4 feet. Generally, this type is found on the shallower organic soils (6- to 8-inch-deep organic layer). Type GB-7 is generally the result of a recent disturbance by fire or logging and is characterized by a composition of approximately 60 percent grasses and herbaceous species, 10 percent common gallberry, and 10 percent redbay. Numerous other species, including greenbrier, honeycup, blackgum, dangleberry, bracken fern, sweet pepperbush, chokeberry, myrtle, and swamp cyrilla, are associated in varying amounts. Thirty-seven percent of the vegetation ovendry weight is in grasses and herbaceous species, 35 percent in common gallberry and redbay, and 28 percent in the remaining species. Generally, if the areas have been logged, the grasses and herbs are most common in old skid trails, whereas the woody shrubs are found in clumps throughout the type.

Litter depth varies from ½ inch in old skid trails to about 1 inch beneath the brush clumps.

No difficulty is experienced in traveling through the type on foot. Equipment trafficability is also good.

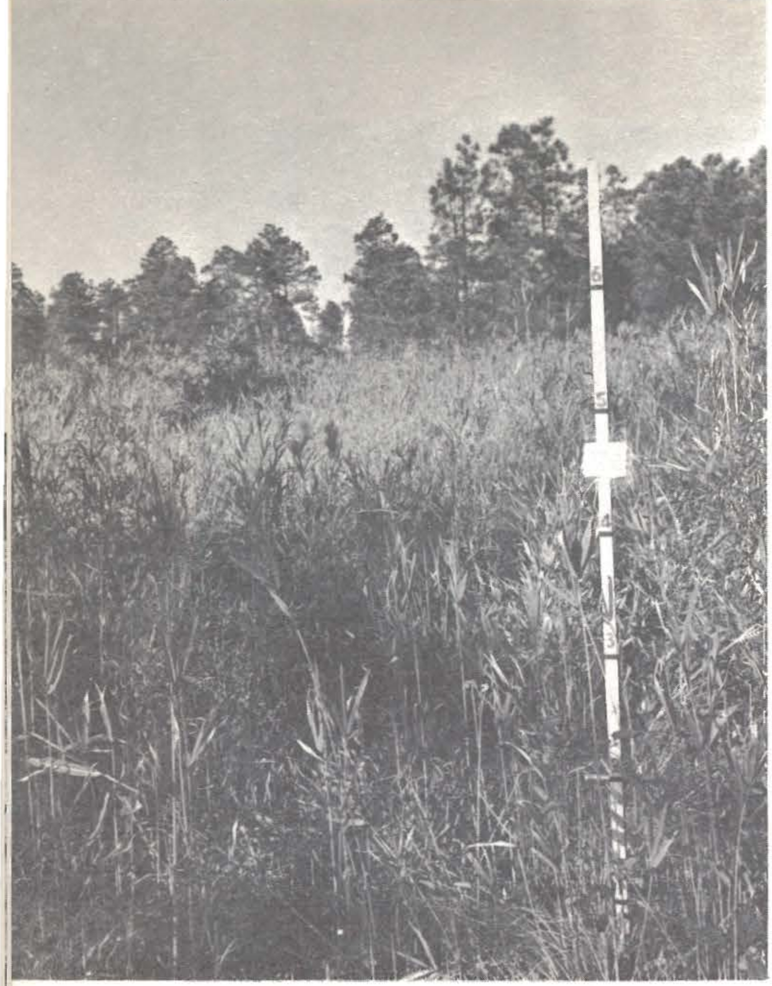


Figure 5.--Fuel type RG-7 (low reeds - grass). Medium low blowup fire potential.

TYPE RG-7 (LOW REEDS - GRASS)

Ovendry weight	Tons per acre
Vegetation	3.91
Litter	2.57
Total	6.48

Type RG-7 consists mainly of low reeds that average 4 feet in height. Reeds and grasses account for roughly 70 percent of the cover and about 77 percent of the total vegetation ovendry weight. Associated species include common gallberry, fetterbush, white bay, redbay, myrtle, blackgum, and chokeberry in roughly equal amounts.

The type generally occurs on fairly well-drained, shallow organic soils having an organic matter content of 40 to 50 percent.

As a rule these areas are the result of recent disturbances by either fire or logging and represent an understory growth of 2 to 3 years. Many of the logging trails contain dense stands of grass and low herbaceous species with reeds and brush species encroaching.

Current litter, mainly reed foliage, remains fluffy until compacted by winter rains and is generally 1 to 2 inches deep.

Access to the type is relatively easy, particularly along the old logging trails. Very little difficulty is encountered in operating equipment in this type, even when the water table is high, because of the excellent support of the reed rhizomes.

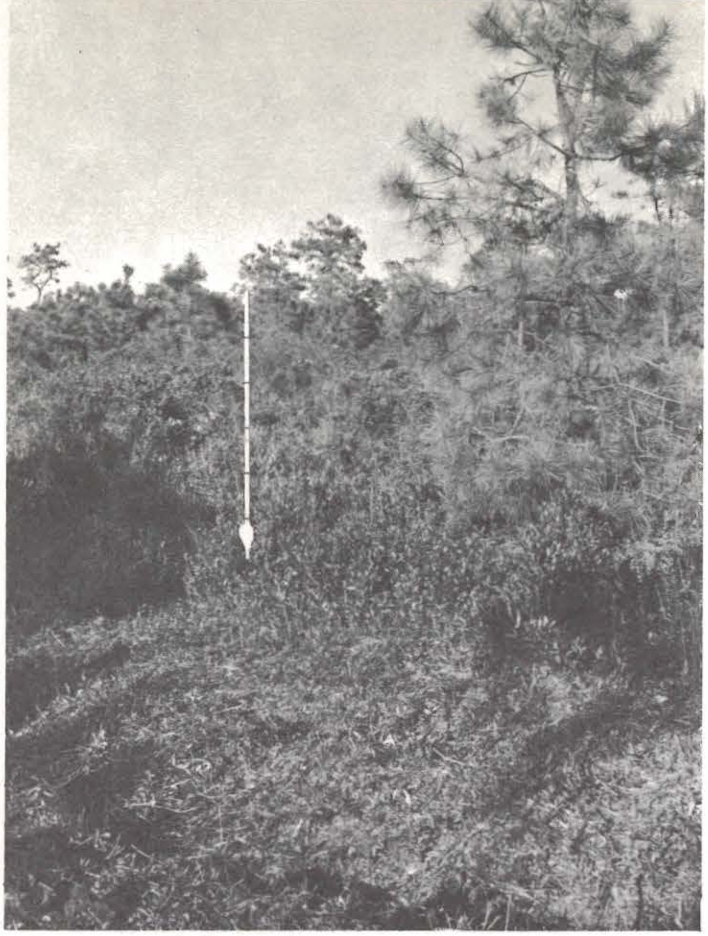
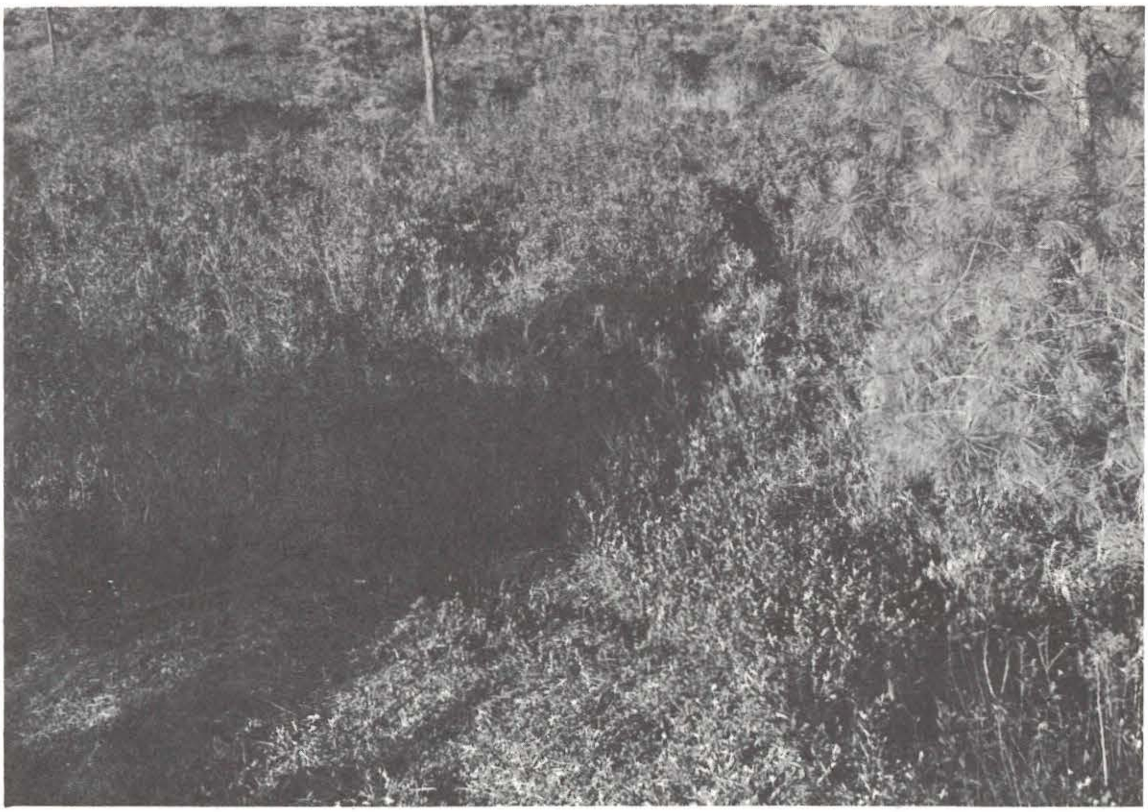


Figure 6.--Fuel type P-10 (low pocosin - dense). Medium blowup fire potential.



TYPE P-10 (LOW POCOSIN - DENSE)

Ovendry weight	Tons per acre
Vegetation	4.00
Litter	4.45
Total	8.45

Type P-10 is very similar to P-5 in species composition and height, but markedly different in density. Brush clumps are close together and at the base average 8 to 10 inches in diameter. Shrub heights range from 1 to 4 feet and average about 4 feet.

The principal species in the composition are swamp cyrilla, 35 percent; honeycup, 35 percent; fetterbush, 15 percent; and common gallberry, 10 percent. The remaining cover consists of chokeberry, redbay, white bay, bracken fern, and sheep laurel, with considerable amounts of greenbrier intertwining among all species. Roughly 82 percent of the total ovendry weight is contributed by swamp cyrilla, honeycup, and fetterbush. In addition, widely scattered clumps of loblolly-bay are present.

The overstory is widely scattered pond pine similar to that described under type P-5.

Average litter depth is 1 inch, for the most part is evenly distributed, although it may be somewhat deeper in the shallow depressions between brush clumps. Total fuel weight represents a brush growth and litter accumulation of 8 years.

The type is moderately easy to walk in and trafficability for foot travel and equipment is aided by the close spacing of the brush clumps.

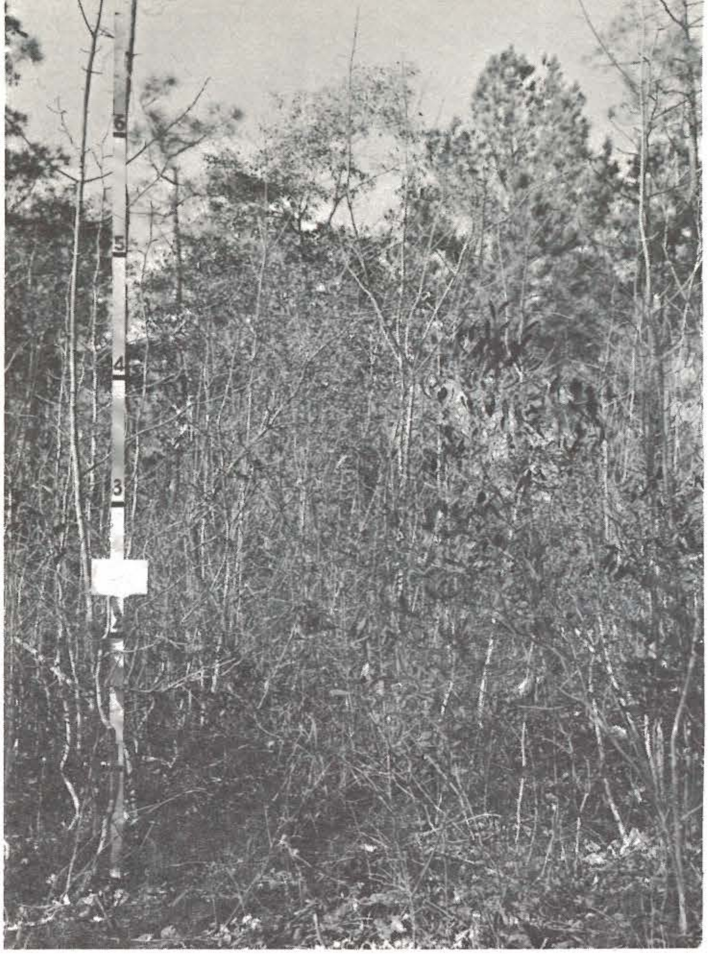


Figure 7.--Fuel type B(SR)-10 (brush - sand ridge). Medium blowup fire potential.

TYPE B(SR)-10 (BRUSH - SAND RIDGE)

Ovendry weight	Tons per acre
Vegetation	4.14
Litter	4.41
Total	8.55

Type B(SR)-10 is a sand ridge type found along the fringes of the pocosins. Although it does not occur on organic soils, it is important because many fires start in these areas and run into the pocosins.

Principal species include swamp maple, blackgum, sweetgum, myrtle, dangleberry, common gallberry, sweet pepperbush, and smooth sumac. Although B(SR)-10 and BG(SR)-10 appear to be distinctly different, they contain approximately the same total ovendry weight and the same species. B(SR)-10 has a smaller percentage of grasses and herbaceous species in the composition. B(SR)-10 appears less clumpy since it usually occurs on older logged areas and a smaller proportion of its weight is found in the litter which is well decayed logging slash. BG(SR)-10, on the other hand, is less compact and more clumpy. Also, B(SR)-10 has a height range from 1 to 7 feet as compared to 2 to 6 feet in BG(SR)-10.

The major distinction between the types is the number of undisturbed years. B(SR)-10 is an older logged type which has had about 6 years of healing over, whereas BG(SR)-10 is the condition about 2 years after logging.

Both types are easily accessible by foot or equipment and good trafficability is afforded heavy equipment.

Figure 8. - Fuel type RB-10 (medium reeds - brush). Medium blowup fire potential.

TYPE RB-10 (MEDIUM REEDS - BRUSH)

Ovendry weight	Tons per acre
Vegetation	4.70
Litter	4.05
Total	8.75

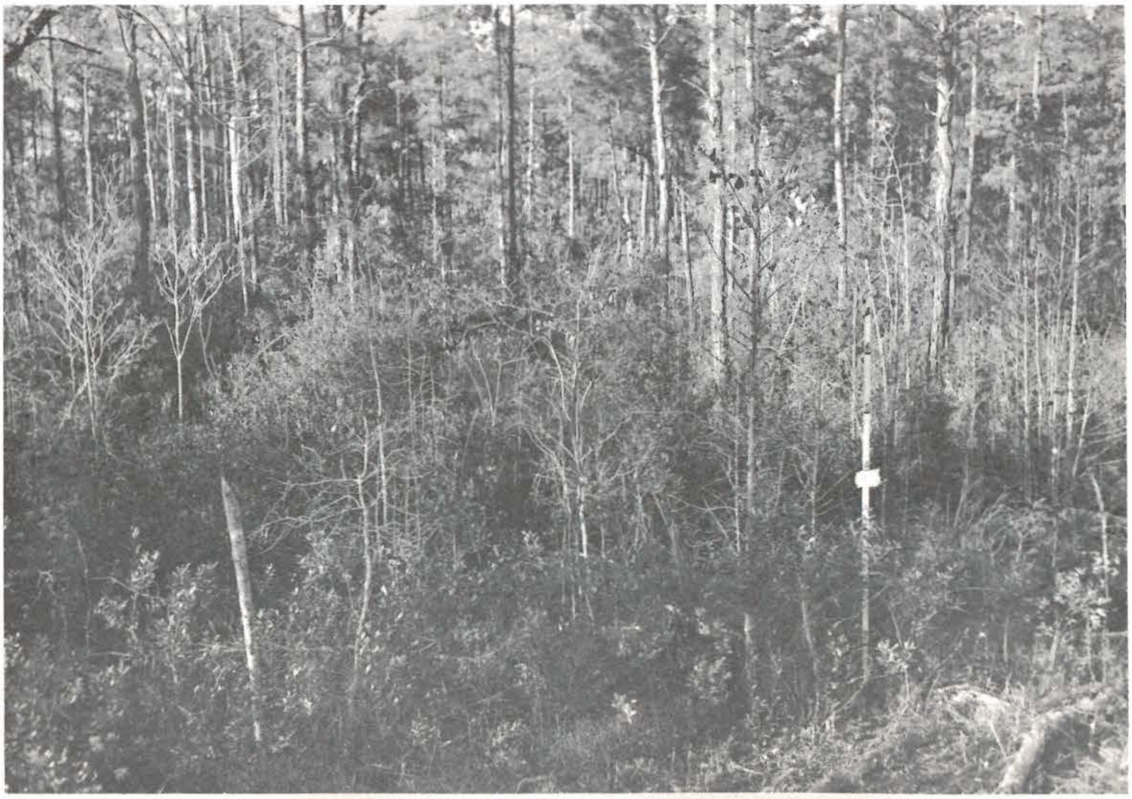
Fuel type RB-10 is a medium dense reed type averaging 5 feet tall, usually found on shallow, fairly well-drained organic soils. A few individual reed stalks may reach 6 feet in height.

The type is composed of reed, 80 percent; common gallberry, 10 percent; and associated species, such as swamp cyrilla, fetterbush, bracken fern, chokeberry, redbay, and grasses making up the remaining 10 percent. Reed and grasses compose 84 percent of the total ovendry vegetation weight. Greenbrier is intertwined with the reed and brush, slowing down foot travel through this type.

The litter is composed principally of the current year's reed foliage and may form a layer 3 to 4 inches deep before it is compacted by rainfall.

The type appears to be almost pure reed, but closer observation reveals that common gallberry, fetterbush, and other shrubs are abundant. During late fall and winter RB-10 appears as a light buff mass because of the persistent dead leaf sheaths on the reed stalks.

Figure 9.--Fuel type BG(SR)-10 (low brush - grass, sand ridge). Medium blowup fire potential.



TYPE BG(SR)-10 (LOW BRUSH-GRASS, SAND RIDGE)

Ovendry weight	Tons per acre
Vegetation	2.90
Litter	5.94
Total	8.84

Type BG(SR)-10 is a sand ridge type found along the fringes of the pocosins. Although it does not occur on organic soils it is important because many fires start in these areas and run into the pocosins.

Principal species include swamp maple, blackgum, sweetgum, myrtle, dangleberry, common gallberry, sweet pepperbush, and smooth sumac. Although BG(SR)-10 and B(SR)-10 appear to be distinctly different, they contain approximately the same total ovendry weight and the same species. BG(SR)-10 has a greater percentage of grasses and herbaceous species in the composition. BG(SR)-10 appears more clumpy since it usually occurs on recently logged areas and a larger proportion of its weight is found in the litter which is partially decayed logging slash. B(SR)-10, on the other hand, is more compact and not so clumpy. Also, BG(SR)-10 has a height range from 2 to 6 feet as compared to 1 to 7 feet in B(SR)-10.

The major distinction between the types is the number of years left undisturbed. BG(SR)-10 is a recently logged type which has had about 2 years of healing over, whereas B(SR)-10 is the condition about 6 years after logging.

Both types are easily accessible by foot or equipment and good trafficability is afforded heavy equipment.

Figure 10.--Fuel type BG-10 (medium brush - grass). Medium blowup fire potential.

TYPE BG-10 (MEDIUM BRUSH - GRASS)

Ovendry weight	Tons per acre
Vegetation	4.78
Litter	4.59
Total	9.37

Type BG-10 is a medium height fuel type (2 to 6 feet, average 5 feet), generally found on logged over, shallow organic soils. It differs from GB-7 in that the percent of grasses and herbaceous vegetation is reduced to about 15 percent. The most abundant shrubs in the composition are redbay, 20 percent; swamp cyrilla, 20 percent; greenbrier, 15 percent; sweet pepperbush, 10 percent; common gallberry, 10 percent; and blackgum, 10 percent. Swamp cyrilla and redbay contribute 47 percent of the vegetation ovendry weight; blackgum, 14 percent; common gallberry, 13 percent; and sweet pepperbush, greenbrier, and grasses, 21 percent.

The type appears clumpy but much less so than GB-7 since BG-10 is the result of earlier logging or fire. Old skid roads are generally grassed, with scattered shrubby species encroaching.

Litter depth varies from 3/4 to 1 inch and consists of grass and herbaceous material in the old skid roads and shrub foliage in the less disturbed areas.

Foot travel through the type is moderately easy.

Figure 11.--Fuel type R-10 (high reeds). Medium blowup fire potential.

TYPE R-10 (HIGH REEDS)

Ovendry weight	Tons per acre
Vegetation	6.06
Litter	4.01
Total	10.07

Fuel type R-10 is very similar to RG-7 and RB-10 in composition but reeds average about 7 feet in height and individuals up to 9 feet have been measured. Reed composes about 80 percent of the cover, with associated species of greenbrier, white bay, common gallberry, dangleberry, and loblolly-bay. Seventy-two percent of the vegetation ovendry weight is reed, with the remainder evenly divided among the associated species. The type is very difficult to walk in because of a heavy growth of greenbrier. In places this species forms an almost complete canopy across the tops of the reed. This canopy is usually characterized by abundant pine needle drape since type R-10 is generally found under medium-dense, mature or over-mature pond pine stands. The organic soil layer is usually between 2 and 3 inches in depth.

This type appears very homogeneous with only an occasional loblolly-bay or white bay overtopping the reed.

The litter is composed chiefly of reed foliage and pine foliage that may form a loose open layer 3 to 6 inches deep when newly fallen.

Trafficability for equipment is generally good because of the excellent support given by the dense mat of reed rhizomes and stalks.

Figure 12.--Fuel type R-14 (very high reeds). Medium high blowup fire potential.

TYPE R-14 (VERY HIGH REEDS)

Ovendry weight	Tons per acre
Vegetation	8.48
Litter	4.70
Total	13.18

Type R-14 is an almost pure reed type. The reed stratum averages 10 feet high but individual reeds may grow to a height of 12 feet. Openings throughout the type are usually vegetated with grass and low herbaceous species.

This type, like R-10, generally occurs under well-stocked mature and over-mature pond pine stands.

The litter is composed principally of pine needles and reed foliage in a layer 3 to 4 inches deep.

Travel through R-14 is rather difficult on foot because of the density of the reed stand, although equipment trafficability is aided by the stems and dense root mass.

Figure 13.--Fuel type P-14 (high pocosin). Medium high blowup fire potential.

TYPE P-14 (HIGH POCOSIN)

Ovendry weight	Tons per acre
Vegetation	5.95
Litter	9.05
Total	15.00

Type P-14 is a high brush type. Plants range in height from 2 to 16 feet with the average near 14 feet. The type generally occurs on soils having an organic layer 18 to 24 inches deep. P-14 is composed of 50 percent swamp cyrilla, 25 percent loblolly-bay, 15 percent common gallberry, 10 percent greenbrier and miscellaneous shrubs. Of the total vegetation ovendry weight, swamp cyrilla contributes 37 percent, common gallberry 15 percent, and redbay 15 percent. The remaining weight is composed of dangleberry, loblolly-bay, greenbrier, and fetterbush.

Type P-14 represents an undisturbed brush growth and litter accumulation for a 9-year period. The litter ranges from 4 to 6 inches deep. Generally the overstory is a medium density pond pine stand and as a result the understory is characterized by a moderately heavy pine needle drape. Movement through the type is very difficult because of the large amount of greenbrier present and the large number of closely packed stems.

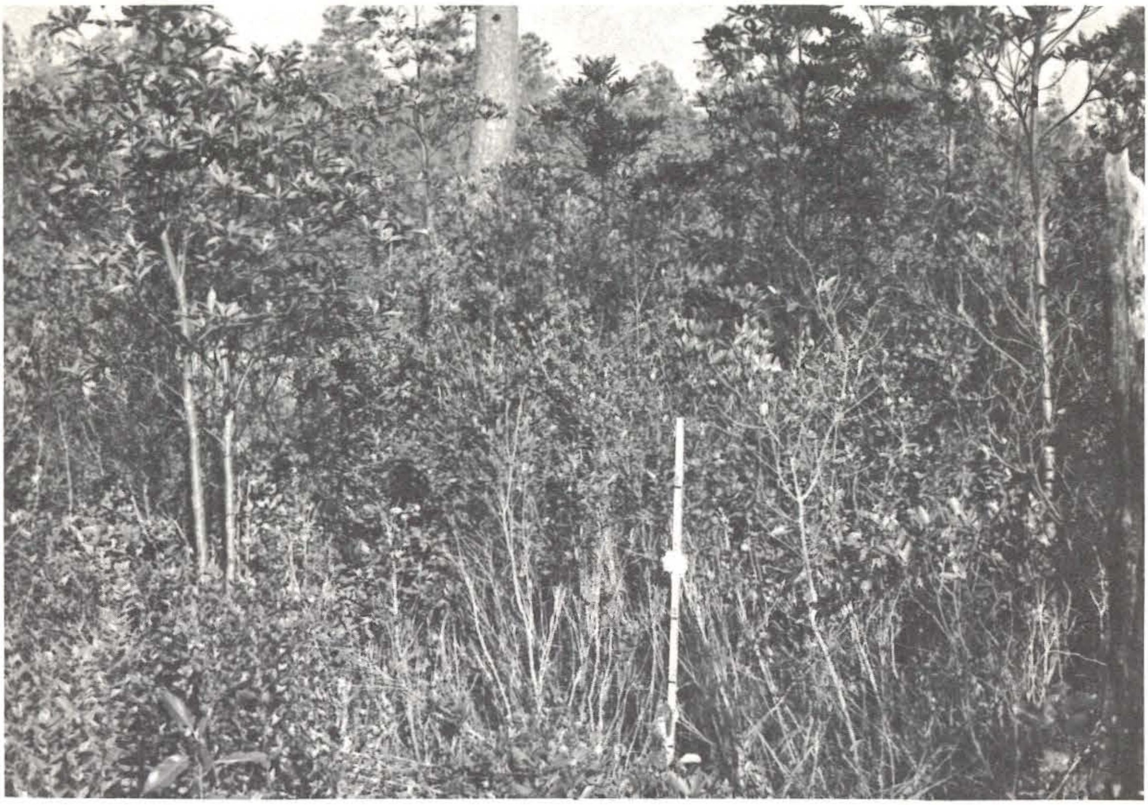


Figure 14.--Fuel type B-20 (high brush). High blowup fire potential.

TYPE B-20 (HIGH BRUSH)

Ovendry weight	Tons per acre
Vegetation	11.98
Litter	5.36
Total	17.34

Type B-20 is a high brush type composed principally of 50 percent fetterbush, 10 percent tall gallberry, 10 percent loblolly-bay, 10 percent dangleberry, and minor amounts of white bay, honeysuckle, greenbrier, swamp cyrilla, honeycup, and sheep laurel. Height ranges from 4 to 12 feet with an average of 8 feet. Three species, fetterbush, tall gallberry, and loblolly-bay, account for 82 percent of the vegetation ovendry weight, with fetterbush comprising 44 percent of this figure.

The type generally occurs on the outermost fringes of natural drainages, on soils having an organic layer 10 to 12 inches deep.

Litter averages 2 inches in depth and is concentrated in depressions between the brush hummocks.

Like P-14, type B-20 is very difficult to travel through because of an abundance of greenbrier. When the water table is high equipment trafficability may be poor.

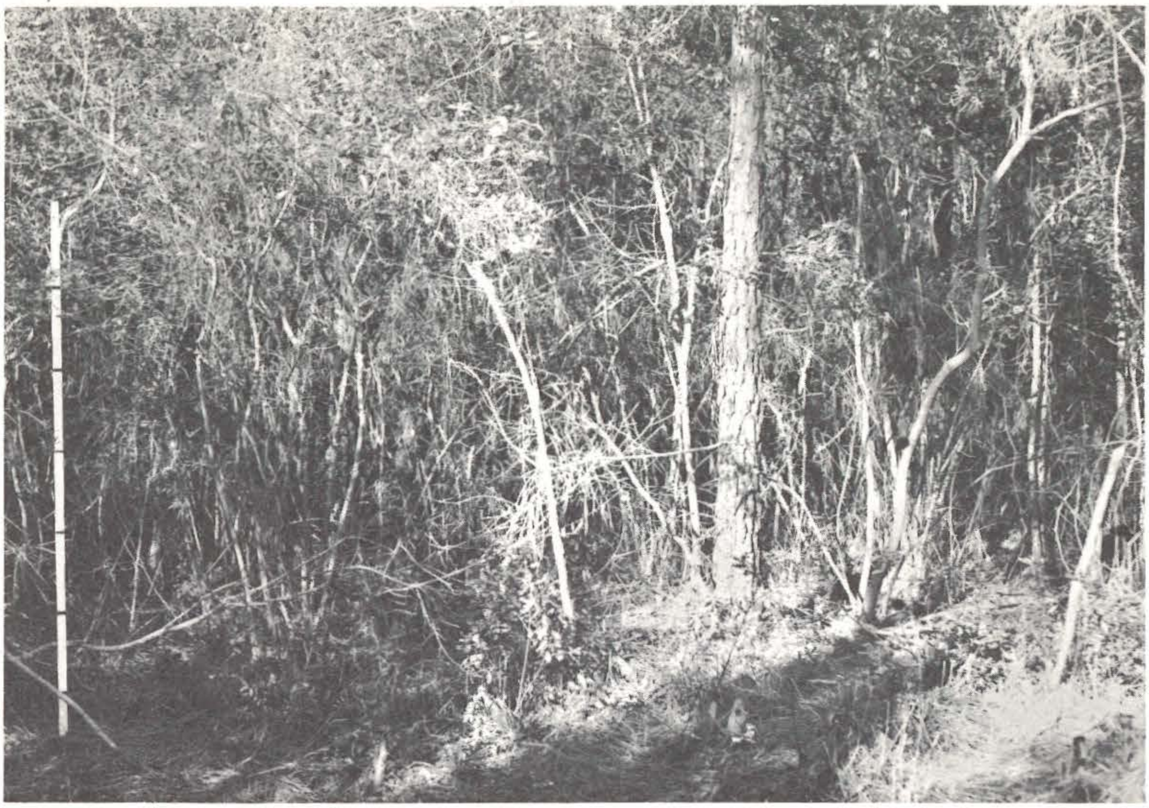


Figure 15.--Fuel type B(S)-20 (high brush - swamp). High blowup fire potential.

B(S)-20 (HIGH BRUSH - SWAMP)

Ovendry weight	Tons per acre
Vegetation	15.64
Litter	5.36
Total	21.00

Fuel type B(S)-20 is a high brush type generally found at the head of a natural drainage. It is composed principally of 85 percent swamp cyrilla and 10 percent blackgum; together they constitute 93 percent of the vegetation ovendry weight. Swamp cyrilla averages about 14 feet high and blackgum 12 feet. A large proportion of the stems at ground line are between $1\frac{1}{2}$ and 2 inches in diameter. Where a pine overstory exists, the type is characterized by a heavy needle drape.

From the roadside B(S)-20 appears massive and impenetrable but once inside the type foot travel is not too difficult because there are fewer but larger stems contributing to the total weight.

The soils here have an organic layer 15 to 18 inches in depth and are fairly well drained because they are close to natural waterways.

AN ENERGY BASIS FOR CLASSIFYING FUELS

Probably the most significant aspect of the behavior of a fire is its intensity or rate of energy output. Because of the chain reaction nature of fire propagation, and because of interactions between a fire and the environmental atmosphere, the relationships between fire intensity, rate of spread, the fuel factors, and the atmospheric factors are very complex. These relationships appear to be greatly simplified, however, by the recent development of energy concepts (2, 3, 4, 12, 13, 14) that may also have an important application in the measurement, rating, and classification of fuels.

The Energy Rate Number

The rate of a fire's energy output is closely related to the convective activity of a fire. The structure and nature of the convection is determined both by the rate of energy output of the fire and by the rate of flow of kinetic energy in the wind field above the fire. Especially important is the ratio of the two energy rates which may be defined as the energy rate number (13). The magnitude of this dimensionless number, both at the earth's surface and in the atmosphere aloft, appears to determine not only whether a convection column can or cannot exist but certain characteristics of the convection as well. Although precise values will have to be determined experimentally both in the laboratory and in the field, it is likely that a convection column can exist if the energy rate number is equal to or greater than 1.00 (energy output of the fire dominating). On the other hand, if the energy rate number is small, say, in the neighborhood of 0.05 or 0.10 (energy of the wind field dominating), the convection pattern would be a weak plume drifting downwind and maintaining contact with the ground. This plume would have but little organized upward flow of hot gases such as exists in the center of a well-formed convection column.

Basic Fuel Factors

An energy description of a complex heterogeneous fuel in terms of expected fire behavior requires several basic fuel factors. These are:

1. Total fuel energy: the amount of energy released if all of the fuel is consumed; it is the upper limit of both the available fuel energy and the fuel energy available for convection.

2. Available fuel energy: defined as the amount of energy released by the fuel which actually burns.

3. Fuel energy available for convection: that portion of the available fuel energy which is fed into the base of the convection column.

4. The combustion period: the time required for a given fuel component to burn up completely.

5. Critical burnout time: the maximum length of time that a fuel can burn and still be able to feed its energy into the base of the forward-traveling convection column.

6. Quantity and quality of firebrand material available for spotting.

An energy description of fuels in terms of fire behavior is considerably simpler when burning conditions are severe than when they are not. This is also true for some fuel types such as those in the pocosin areas which have no large fuel components that burn for long periods.[7] It thus appears that one of the simplest descriptions of a fuel on an energy basis would be for a pocosin type under the worst burning conditions. In this case available fuel energy, fuel energy available for convection, and total fuel energy are essentially the same because for high-intensity fires the combustion periods for the various fuel components would be less than the critical burnout time. Hence, under these conditions, the basic fuel factors reduce to (1) total fuel energy, (2) combustion period, and (3) quantity and quality of firebrand material. Total fuel energy is thus a major factor in blowup fires and for this reason its study was started first.

Ember Lifting Power and Blowup Potential

There are several possible ways of comparing the effect of quantity of fuel on fire behavior. One of the best ways is by means of an index directly proportional to a fire's ember lifting power because spotting is a dominating behavior characteristic of large fires (13). This is given by the scaling equation

$$W/W_o = (I/I_o)^2 \, (D/D_o)^{-2} \qquad (1)$$

in which W_o is the weight and D_o the density of an ember which can just be supported by the updrafts in the convection column over a fire with a reference intensity I_o. The weight W and density D apply to an ember which can just be supported by the updrafts over a fire of any given intensity I. The fire intensity I is equal to the product of three quantities: the heat yield H, the fuel weight w, and the rate of spread r. Equation (1) can thus be written as

$$W/W_o = (H/H_o)^2 \, (w/w_o)^2 \, (r/r_o)^2 \, (D/D_o)^{-2} \qquad (2)$$

For a given kind of ember material, the ratio D/D_o can be taken as unity. If the heat yield is approximately the same for the fuels of two different fires then H/H_o is also unity. If the rate of spread is the same for the two fires the ratio r/r_o is unity and the relative ember lifting power of two different fires is equal to $(w/w_o)^2$ which is the desired index. This quantity is designated as the blowup potential and is plotted in figure 16 as a function of w.

7/ A possible exception is the organic soil itself when it is dry enough to burn but this causes no great difficulty. One of the most significant of the fuel factors is the fuel energy available for convection and a thin layer of the organic soil contributes to this energy. The burning of the deeper layers would be too slow to appreciably influence fire behavior.

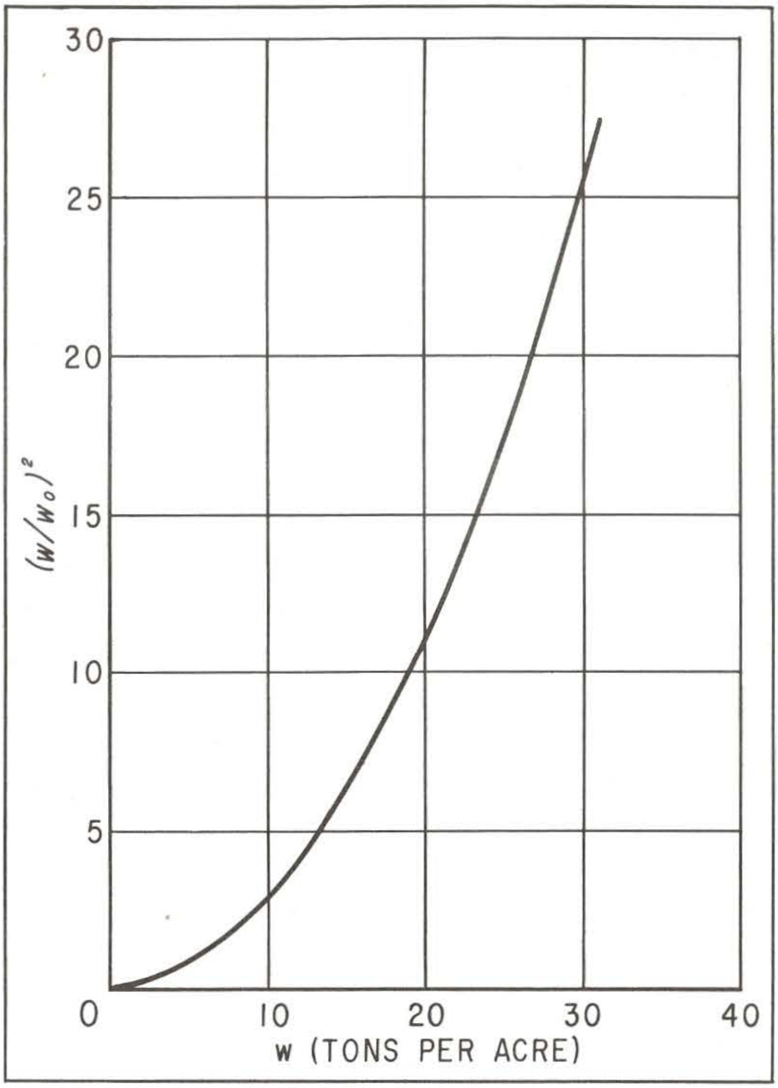


Figure 16.--Blowup potential, $(w/w_o)^2$, plotted as a function of fuel weight, w, for a reference fuel weight, w_o, of 6.0 tons per acre.

The blowup potential is only one of a number of basic quantities which determine the ultimate behavior of a given fire. However, in combination with the combustion rate [8] it promises to give an effective quantitative energy description of fuels that is needed before the probability of major fires can be established. In turn, an estimate of this probability will require that additional factors be brought in such as wind speed, and the vertical wind speed profile which determines how the energy rate number varies with height above the earth's surface.

8/ The combustion rate is defined as the rate of energy release per unit of burning area.

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