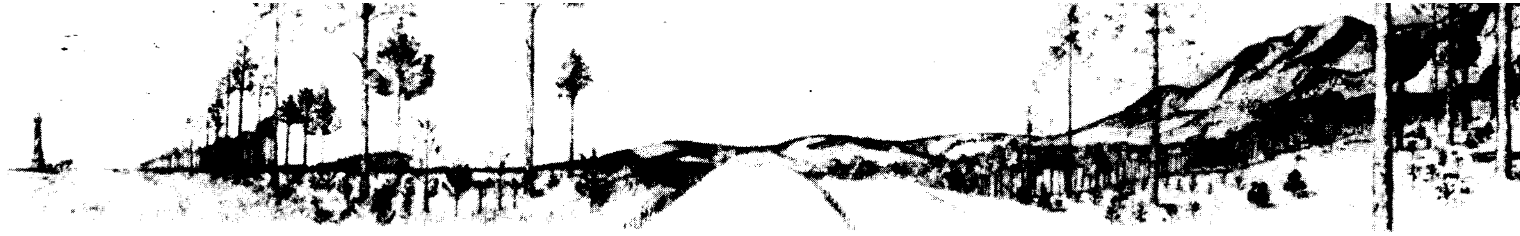

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IMPACT OF PRESCRIBED FIRE ON UNDERSTORY AND FOREST FLOOR NUTRIENTS

by Walter A. Hough[1]

ABSTRACT.-The impact of low-intensity prescribed fires on slash pine/saw-palmetto/gallberry understory and forest floor nutrients was estimated from measurements before and after burning. Highly significant correlations existed between weight loss of these fuel components and the weight loss of several elements. Energy loss was also highly correlated with forest floor and understory weight loss. The data also indicate that annual or biennial burns do not reduce the macronutrients in the soil surface layer. but, in fact, increase them; and that even though a significant amount of N (1 10 kg/ ha) may be lost by burning a 5-year fuel accumulation there still is 160 kg/ ha of N in the ash and residue following the fire. as well as about 700 kg/ ha in the upper 10 cm of the soil profile.

Keywords: ***Serenoa repens*, *Ilex glabra*, *Pinus elliottii*, *Pinus palustris*,** pine/ saw-palmetto/gallberry. macronutrients, micronutrients.

Nutrients are constantly being added to and released from undisturbed forest stands. When trees are harvested and removed or when fire is used to reduce hazardous fuel buildups, the nutrient status of the stand is changed.

The data reported here are taken from a comprehensive investigation of the use of prescribed fire in the South and the effects of such fires on air quality (Southern Forest Fire Laboratory 1976). The information presented is for the aboveground plant parts of the saw-palmetto (*Serenoa repens* (Bartr.) Small)/gallberry (*Ilex glabra* (L.) Gray) understory vegetative complex and the associated forest floor material found under natural slash (*Pinus elliottii* Engelm.)/ longleaf pine (P. *palustris* Mill.) stands. These components of the forest stand are drastically altered by the low-intensity fires used in prescribed burning operations. Dry-weight measurements and element analysis were made before and after burning to determine the quantity of nutrients in the various understory and forest floor components.

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METHODS

Vegetative materials used in this study were plants and forest floor layers collected from eight forest stands in Georgia and Florida, with understories dominated by the saw-palmetto/ gallberry plant association. Prior to the burns applied in these tests, the time since last disturbance of the understory and forest floor varied from 1 to 8 years. Past disturbance in all stands was from prescribed fire.

Prescribed backfires were applied to the forest stands, and fuels were sampled before each burn and immediately after the fire was out. Vegetative samples were collected by species and size class (foliage; stems < 0.64 cm, 0.64 to 2.5 cm, 2.5 to 7.6 cm, and > 7.6 cm) from 1-m^2 plots. Forest floor materials were separated by size class only on these plots. Samples were ovendried at 85°C and weighed, and all samples of the same type material from a single stand were combined and run through a hammer mill with 2-cm screen to obtain a coarsely ground, well-mixed composite sample. After milling, the material was stored in paper bags until analyzed.

Subsamples of this material were analyzed for element composition at a cooperating laboratory.[2] The coarsely ground material was ovendried at 80°C, ground to pass a 20-mesh screen, and a portion was ashed at 500°C for4 h. Ash digestion in a standard 5-percent Li-HCl solution preceded analysis with a Spark-Emission direct-reading spectrograph of the following: P, K, Ca, Mg, Mn, Fe, B, Cu, Zn, Al, Mo, Sr, Ba, and Na. Total S in another portion was measured following dry ashing of plant tissue with MgO, using a Leco Automatic Sulfur Analyzer.[3] Total N in another portion of the dried and ground material was measured by a semi-micro Kjeldahl method with an Autoanalyzer.

Analysis of C-H-O, total ash, Si, and energy content was carried out on separate subsamples of the coarsely ground material.[4] Following ovendrying at 85°C, the sample was ground to pass a 100-mesh screen. C-H-O measurements were made with a Perkin-Eimer Elemental Analyzer. Heat values of, the ground materials were determined in a Parr Bomb Calorimeter. Si content was measured by acid digestion of ashed material.

Estimates were made of the weight per unit area of fuel components before and after the burns. Chemical analysis of understory and forest floor material was used to estimate the total weight per unit area of each element in the stand prior to and following the burn.

The data presented are represenative of "total" amounts of elements found in both organic and inorganic forms in plant material. 'The values reported give no indication of how much material is "available" for plant growth.

RESULTS

The reduction of hazardous fuel buildup was the principal reason for the type of prescribed burning used in this study. In the stands burned, total understory and forest floor fuel reduction ranged from 40 to 74 percent. Consumption of the understory varied from 55 to 88 percent, while forest floor reduction ranged from 25 to 75 percent. The actual fuel reduction on a dry-weight basis depends on the weather-fuel moisture conditions and is also highly dependent on the amount of fuel that has accumulated on the site. For example, a prescribed burn in a stand where fuel has accumulated for only 1 or 2 years could result in a high percentage of fuel reduction (75 percent) but may actually consume only 6,900 kg/ ha. However, a burn in a stand where fuel has accumulated for 5 years could give a lower percentage reduction (53 percent) but actually consume more fuel--17,300 kg/ ha. A procedure for estimating fuel consumption on prescribed burns in the South has been proposed by Hough (1978).

Measurements made during application of prescribed backfires showed that all burns were of low intensity for all fire behavior factors. Flame length varied from 0.15 to 1.2 m, forward rate of spread ranged from 0.15 to 0.8 m per minute, and Byram's (1959) fireline intensity varied from about 50 to 275 kW/m. Only the understory and forest floor were directly involved in the fire; overstory foliage was not scorched and on most sample points the H layer was not burned.

Results of nutrient-loss calculations based on chemical and biomass data derived from samples collected before and after each prescribed burn were variable, but do indicate some general trends. The data also show that many more samples must be collected ii' information about micronutrients is to be meaningful. Understory and forest floor fuels show high variability, thus requiring intensive sampling to estimate weight of material before and after fire. Inaccuracies in the chemical analysis of elements occurring in very low concentrations in unburned samples may have also introduced errors.

Another source of error was the failure to collect all of the ash left on the surface after the fire. Because of the relatively large-size sample plots (1 m^2), the ash, char, and unburned material were collected by hand. A small fraction of this material was observed to drift off the plot and escape collection. Because there was no way to estimate how much ash was lost on each plot, no attempt was made to adjust the field data.

There appeared to be a high degree of correlation between weight loss of the forest floor (FF) plus understory (US) and weight loss of several elements (table 1). Energy loss was also highly correlated with FF + US weight loss. Regression analysis was used to provide the following equations:

$$\begin{aligned} C &= 136.49 + 0.4730\,(X), & r^2 &= 0.99 \\ N &= -10.55 + 0.0071\,(X), & r^2 &= 0.96 \\ P &= -0.44 + 0.00031\,(X), & r^2 &= 0.86 \\ Mg &= -0.36 + 0.00045\,(X), & r^2 &= 0.89 \\ S &= -1.19 + 0.00067\,(X), & r^2 &= 0.98 \end{aligned}$$

where element weight loss (kg/ ha) is a function of US & FF weight loss, X (kg/ ha).

Trendlines for these equations are shown in figure 1 for comparison. The energy loss equation was:

Energy loss (kJ/ ha) = 7217.6 + 19.41 (X), $r^2 =$ 0.99. There was a weak but significant correlation

[2]Soil Testing and Plant Analysis Laboratory, University of Georgia, Athens, Georgia.

[3]Use of trade names does not constitute an endorsement by the U.S. Department of Agriculture or the Forest Service to the exclusion of other products that may be suitable.

[4]Engineering Experiment Station. Georgia Institute of Technology, Atlanta, Georgia.

between FF + US weight loss and weight loss of K, Ca, and Mn. The following equations resulted from regression analysis:

$$K = 4.25 + 0.00054\ (X), \quad r^2 = 0.45$$
$$Ca = 8.70 + 0.00107\ (X), \quad r^2 = 0.51$$
$$Mn = 0.277 + 0.000028\ (X), \quad r^2 = 0.47$$

Although only limited data are presented on the effects of prescribed burning on nutrient content, results are within the variation that can be found in the literature. For example, N loss has been reported to vary from 20 to 900 kg/ ha for various fuel and fire situations (Allen 1964; Christensen 1977; Grier 1975; Harwood and Jackson 1975; Wells and others 1979). Loss of P ranged from 0.1 to 10 kg/ ha, Ca losses ranged from 4 to 100 kg/ ha, and K loss from 4 to 282 kg/ ha.

Allen (1964) and Allen and others (1969) investigated heather burning in northern England and its effect on the distribution of mineral nutrients. They found over half the C, N, and S in the heather was driven off with the smoke. They found that any loss from burning the plant complex can be restored by minerals contained in precipitation.

Most citations give data from one burn or perhaps different intensities of burn but in the same fuel conditions (Kodama and VanLear 1980). None present data over a range of fuel weights and, therefore. there are not enough data in the literature to test the regression equations presented in this paper. For low-intensity prescribed burns used in slash pine/ saw-palmetto/ gallberry stands, these regression equations can be used to estimate the loss of N. P, Mg, S, C, and energy if the amount of fuel consumed is measured or estimated (Hough 1978). Also, for the low-intensity fires studied here, the equations developed for Ca, K, and Mn are probably representative of similar-type burns.

Fire releases nutrients to the atmosphere, the remaining forest floor material, and the mineral soil. The litter and vegetative components of a slash pine stand constitute a large nutrient sink if undisturbed. It appears, therefore, that prescribed burning at 4- to 5-year intervals not only reduces the fire hazard caused by fuel buildup but also rapidly releases a portion of the nutrient capital that has been made temporarily unavailable because of the slow decomposition rate of biomass and litter. Even though 100 kg/ha of N in the understory and litter materials might be lost in a prescribed burn of a pine stand with a 5-year fuel accumulation, there still remains about 160 kg/ ha in the residue and ash, 116 kg/ ha in the slash pine overstory, as well as about 700 kg/ha in the upper 10 cm of the soil profile. If the contributions from precipitation and dry fallout are added, plus new growth of vegetative material that may fix N on the site (Wells and others 1979), it is not surprising that N does not decrease following one burn or even repeated burning (Wells 1971). In fact, a more detailed analysis of the soil chemical properties on the Baker County, Florida, plots shows that prescribed burning does not deplete nutrient levels but is beneficial to nutrient cycling.[5]

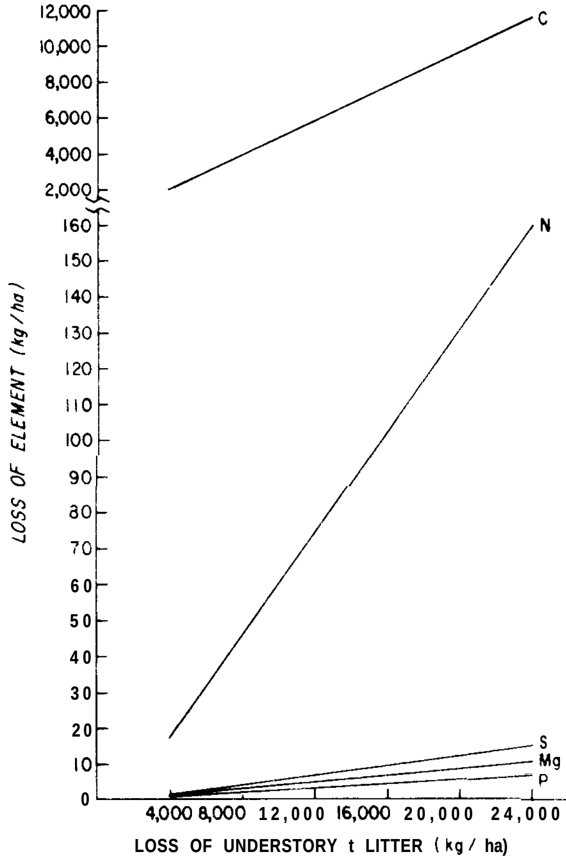

Figure 1 .-Relationship between understory plus litter dry-weight loss and loss of various elements following a prescribed fire.

CONCLUSIONS

Although these data are from a limited number (n = 10) of prescribed burns, there are several relevant features that should be noted. The C fraction is highly volatile and weight loss is positively and significantly correlated with fuel weight loss. Energy loss is also directly correlated with loss of understory and forest floor weight. Loss of N, P, Mg, and S shows a highly significant correlation with fuel weight loss. K, Ca, and Mn weight loss is not as strongly correlated. Several of the micronutrients showed increases following these fires (Cu, Al, and Mo), while others showed medium to large losses (Fe, Sr, B, Ba, and Zn). This indicates that sampling procedures must be intensified and improved if reliable results are expected for micronutrients.

[5]William H. McKee, Jr., Soil Scientist, Southeastern Forest Experiment Station, Charleston, South Carolina, personal communication.

Table I.-Average fuel weight and nutrient loss, nutrient remaining in the ash and unburned residue following low-intensity prescribed fires, and nutrient in the 0- to IO-cm soil layer

Item	Prescribed burn location (county)			
	Baker, Florida[a]	Clinch, Georgia[b]	Pierce, Georgia[c]	Ware. Georgia[d]
	kg/ha			
Understory and litter loss	6,510	7,397	18,691	25.380
N loss	39	43	112	194
N in residue	28	22	161	109
N in soil (O-10 cm)	1,099	746	732	--
P loss	1.5	2.5	4.6	8.4
P in residue	4.2	2.8	15.7	10.6
P in soil (O-10 cm)	76.5	51.4	41.0	--
K loss	9.0	9.0	10.6	24.5
K in residue	5.7	5.2	34.9	23.9
K in soil (O-10 cm)	53.4	38.2	33.1	--
Ca loss	12.9	25.3	23.0	49.5
Ca in residue	21.7	15.1	70.0	57.7
Ca in soil (O-10 cm)	289.5	140.5	85.0	--
Mg loss	1.8	4.6	7.7	12.4
Mg in residue	6.5	3.4	16.5	14.2
Mg in soil (O-10 cm)	70.3	41.2	32.8	--
S loss	3.4	3.8	10.8	17.4
S in residue	3.3	2.2	15.0	10.8
S in soil (O-10 cm)	30.1	15.3	20.5	--
Mn loss	0.4	0.7	0.6	1.3
Mn in residue	0.7	0.5	2.1	1.8
Mn in soil (O-10 cm)	7.2	6.8	6.8	

[a]Plots unburned for 1 or 2 years but stands had been burned repeatedly on an annual (n =1) and biennial (n = 2) basis over the last 14 years.

[b]Plots (n = 2) unburned for 1 year with possibly two burns applied during life of stand.

[c]Plots (n = 4) unburned for 5 years with possibly three burns applied during life of stand.

[d]Plot (n = 1) unburned for 8 years with possibly three burns applied during life of stand.

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