Some Basic Ecological Factors in Prescribed Burning in Northeastern Minnesota

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THE SUBJECT OF FIRE is nothing new to anyone here. A great deal of work has been done in studying various aspects of the effect of fire on forest lands all over the world. In this country, studies have been carried on in widely different forest regions. In most cases, we cannot generalize from the ecological changes wrought by fire in one region and expect the same results in another region. Therefore it is important that the effect of fire be studied thoroughly in each forest region, and that the basic, underlying factors involved in ecological changes be understood.

We began studying ecological effects of wildfires in northern Minnesota with the hope of gaining some insight into the principles involved. The first studies, begun in 1952, were more or less of an inventory nature—following plant succession and soil changes after wildfires. These studies now cover 1,300 acres. It became apparent that more information should be obtained, not only to understand the basic factors involved in the post-wildfire ecology, but also to help understand the principles which would be involved if prescribed burning were to become a general practice in the northern coniferous forests. In the northern Lake States region, prescribed burning has had very limited use because of limited knowledge about it.

Our Center began a prescribed burning study in 1959, with the support of the National Science Foundation and the Iron Range Resources and Rehabilitation Commission of Minnesota, and in cooperation with the U.S. Forest Service, and with the assistance during the burning procedure by the U.S. Steel Company, Oliver Mining Division, Research Branch and the U.S. Marines.

The study areas are located in a stand of mature Jack Pine. The stand was divided into three 10-acre tracts, each as similar to the others as possible in vegetation, soil, and topography. One of these tracts was reserved as a control and left untouched. The other two tracts were logged in the fall of 1960, and slash was evenly distributed. One of the cut-over tracts was burned in the spring, 1961. The other was left cut and unburned. Thus, three tracts were available for study: one cut-over and burned, one cut-over and unburned, and one uncut and unburned. The areas were separated by uncut buffer zones approximately 150 feet wide. These areas had been studied ecologically for two years prior to cutting and burning. Within each area, thirty 10-square meter plots placed 30 meters apart were established for detailed study.

Just prior to beginning this study, I spent three months in Finland studying burn research there. In discussing the factors involved in ecological change, I will draw on all three of these studies: our wildfire study, observations in Finland, and our prescribed burning study.

During the growth of any plant community, there is continuous interaction of at least six factors. These are:

1. The surrounding biotic community
2. Source of reproduction—vegetative or seed
3. Nutrients
4. Moisture
5. Temperature
6. Light

Changes in the biotic community and the subsequent effects on tree reproduction were among the first things which became apparent in the wildfire studies. There was usually a striking, lush growth of herbs following fire. Tree reproduction was often good among this growth—the herbs providing the moist, cool microenvironment necessary for early stages of Jack Pine seedling growth. Soil chemical analyses and growth of sunflower and oats on soil from burned areas

Fig. 3. Experimental area prepared for prescribed burning, leaving nine seed trees per acre. Note uniform distribution of slash, an important aspect of prescribed burning preparation. Photo courtesy J. H. Dieterich, U. S. Forest Service.

and comparable unburned areas showed that the ash resulting from burning stimulated plant growth.

On the prescribed burning study other biotic factors are being investigated. Changes in the microbial population are followed by quantitative plating on selective media. Composite samples from each of the three areas were taken immediately before burning, one day after burning, and at weekly intervals for one month and two week intervals thereafter. Samples from the top layer and from the transition between humus and mineral soil were obtained. Composites were plated on three selective media: Soil Extract Agar for bacteria, Martin's Medium for fungi, and Jensen's Medium for streptomycetes.

Bacterial and streptomycete populations increased greatly in the top level 37 days after fire. This increase occurred 48 hours after the first heavy rain of the summer and undoubtedly would have been evident earlier under conditions of normal moisture. No significant changes in these populations were noted on the unburned areas. Fungal populations increased in all three areas after the rain, but the increase was significantly greater on the burn. Normal, pre-fire level populations were obtained the second year on all areas, both levels.

The rate of carbon dioxide evolved by soil samples from the three areas was determined both years. The results confirmed the platings.

Using the North American Census Method for small mammals, it was found that the population of seed-eating small mammals (largely *Peromyscus maniculatus gracilis*) increased markedly the first growing season after fire, but declined to near normal levels the second year. Laboratory studies of a *Peromyscus* litter revealed that 1 mouse consumed an average of 185 Jack Pine seeds daily, and in 7 days each mouse consumed 1,293 seeds. Observations of bird life on the burns showed an increase in seed-eating species such as Pine Siskin immediately after fire. The second season, however, the increase was not evident.

A second factor to be considered is the source of reproduction. In general, the distribution of plants on burned land is dependent on the type of reproduction, whether vegetative or seed, and the extent to which the species is able to compete in the opening created by the fire. We found that the species occurring only on unburned land were minor associates in the vegetation—perennial, vegetatively reproduced shade plants. The species found only on the burned area were largely annuals, reproduced by seed, with a few vegetatively sprouting species.

The source of seed for tree reproduction on burned areas is being investigated. Frequently, seed is introduced into forest stands from unknown sources, and the end results can often be discouraging. Experience in Europe showed that best results were obtained when seed was obtained from the area to be seeded. To accomplish this in our prescribed burn area, seed tree burning was done. From a sample of felled trees, the number of seeds per tree size was obtained and germination tests run. On this basis, seed trees were selected for the area to be burned and left standing after cutting. They were left with the intent of having heat from the burning open the serotinous cones and disperse seed. Seed traps placed in the area immediately after burning indicated that the area should be adequately stocked. Reproduction the first year was very sparse, possibly because of the extremely dry conditions. The second year, however, reproduction corresponded very closely to that predicted.

Brush is a competitive factor in relation to tree and herb growth.

On the wildfire areas examined, fire often retarded the growth of brush species for at least two years following burning. This allowed other plants, including trees, to become established. The same pattern is evident on the prescribed burning area.

As indicated by the quick recovery of herbs, burning did increase soil fertility, at least temporarily. Soil nutrients were studied on both wildfires and prescribed burns. On each of the prescribed burn study areas, composite samples consisting of ten 100 cc. cores from ten different plots were obtained from three different soil layers: the top inch depth of soil, the second inch depth of soil, and the 8 inch depth of soil. These were collected immediately before burning, 1 week after burning, 2 months after burning, 4½ months after burning, and 14 months after burning.

In the top level, there were increases in nitrogen, phosphates, magnesium, potash, and calcium immediately after fire. Increases in phosphates, potash, magnesium and nitrogen occurred in level 2 late the first summer. Nitrogen, potash, and calcium returned to pre-burn levels the second growing season. The increase in phosphate continued the second growing season in the first and second layers. Organic matter was not significantly affected. pH was higher immediately after the fire, returning to normal the second year.

Because of the contradictory evidence in the literature, and because few of the reported studies followed changes for more than 1 year, we propose to continue the soil tests yearly for 5 years. Tests will be made of the new area to be burned in 1963 at monthly intervals.

Soil moisture on the burned area was less than on the unburned areas for two growing seasons after fire. This reduction was less than 10%, however, and the extent to which this is biologically significant has not been determined. Of more significance in tree seedling growth was the compaction of the organic mantle. The burning reduced the mantle from a three inch to a one inch average depth as a result of compaction. The remaining one inch mantle is now ideal for seed germination.

Recording hygrothermographs measure humidity in each of the areas at surface level and three meters in the air. Analysis of data for three meter heights was not completed for inclusion here. However, humidity on the ground was lower on the burned area than on the unburned areas the first growing season. The second year, with the appearance of herbaceous vegetation, the humidity on the three areas was very similar.

Rainfall was recorded with Hellman type rainfall recorders, from May to early September. Daily precipitation was important for correlation with and interpretation of the microbial activity. The data show that the forest canopy on the uncut area reduced rainfall reaching the ground from 5 to 20%.

A fifth factor of importance in plant succession is temperature. In our investigation, we have followed temperature during the burning process and after the fire. During the burning, temperature was recorded at the ground line, between the organic mantle and the mineral soil, one meter above ground, and 13 meters above ground in seed trees with a thermocouple attached to a 12-point recorder. Additional measurements on the ground surface were made with Tempil tablets.

In general, the temperature between humus and mineral soil reached a little over 400 degrees Fahrenheit. On the soil surface, 1,400 degrees was attained, and at one meter, temperatures went above 1,500 degrees. Tempil tablets showed surface temperatures ranging from 300 to 900 degrees. These temperatures are high enough to kill seeds of many species in the humus.

Following fire, 3-point recorders were set up to record temperatures at the ground surface, between the organic mantle and mineral soil, and one inch in the mineral soil. These records are run from May to September and will be continued for a 5 year period. Results can best be summarized by comparing temperatures in July 1961 with those of July 1962. The first year, the maximum and minimum temperatures were lower on the burned area during the night and were higher on the burned area during the day. In 1962, however, both maximum and minimum temperatures were not significantly different on the two areas. The differences found the first year were apparently the result of the lack of insulating vegetation.

Light is recorded with a Norwood Director Meter at ground line, one meter and two meter heights. Nine readings are taken at each study plot. Of course, changes in light intensity are caused by the lack of vegetation and its subsequent recovery. This recovery is slow, and we have no conclusions yet. From this, however, we hope to obtain a fairly accurate picture of the extent to which various fire following plants affect light conditions and to correlate this with the vegetation which develops below them.

In summary, then, we feel that alteration of the six factors mentioned: biotic community, source of reproduction, nutrients, moisture, temperature, and light, must be studied separately and in synthesis before the effects of fire can be fully understood and used to greatest advantage. In different areas, the interplay of these factors will be different, and different results expected. Only by studying these factors, will we understand these different results.

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