Surface Fires in Northern Ontario

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THE CREATION of conditions favorable to the initiation of surface and crown fires in northern Ontario are largely the result of the variable continental climate. Variability in seasonal temperatures and precipitation are most important but other factors, including wind and humidity, which affect evapotranspiration play a role as well. Disturbance of the natural vegetation by man's activities such as settlement, lumbering and farming have increased the frequency of fire. However, in more recent times the extent of individual fires has been restricted, also because of the activities of man. Restriction in extent has come about by effective forest fire control and the subdivision of large areas into smaller units by road construction and other means.

Fire severity is also related to the variable climate and to some extent to the activities of man. Warm, dry conditions that occur at any time from April to October result in conditions conducive to severe fire. Lumbering operations often involve clear cutting which leave large surface areas exposed to drying. The slash and debris deposited from such activities plus the rapid drying add to the severity of surface fires.

While much of the forested regions of northern Ontario have been or will be subjected to fire there are certain landform types which have increased propensity to fire. One example is the sandy out-wash plain, many of which were formed during the retreat of the Wisconsin ice sheet (Baldwin 1958). These areas, often referred to as "sand plains", overlie mainly non-calcareous precambrian bed-rock. The acid sandy soils belong to the Podzol Great Soil Group.

The vegetation community occupying the sandplains is composed predominantly of *Pinus banksiana* and *Vaccinium* spp. Consequently they are sometimes referred to as jack pine barrens. Other trees and tall shrubs present include *Populus tremuloides*, *Prunus pennsylvanica*, *Alnus crispa*, *amelanchier* spp. and *Salix* spp. The wild blueberries, *Vaccinium angustifolium* and *V. myrtilloides* are replaced locally by *Comptonia peregrina*, *Kalmia angustifolia* and *Pteridium aquilinum*. Broad-leafed herbaceous plants are usually few in number but in some situations *Carex* spp. and various grasses are the most abundant surface flora.

The ecologist is interested in the jack pine barren from the standpoint of gaining an improved knowledge of the ecological effects of fire and of the boreal forest ecosystem. The forester is concerned with their low productivity of lumber products and pulpwood. An alternative use for the barrens is to develop the natural stands of blueberries for fruit production. Development procedures with wild blueberries almost invariably involve repetitive burning. Whatever the objective, either from that of intrinsic interest or for economic advantage, everyone can benefit from an improved knowledge of the complex effects of fire and their interrelationship with soil and vegetational changes after fire. This paper deals with investigations which concentrated on certain aspects of the direct and indirect effects of surface fire on the soil in the jack pine barren community in northern Ontario.

AREA AND PROCEDURE

The research site, located in German Township, Cochrane District, Ontario (Fig. 1) was topographically level or slightly sloping (Fig. 2). Fire records obtained from the Ontario Department of Lands and Forests indicate that the area had been burned by a severe crown fire in 1916. No fires have been recorded since that year.

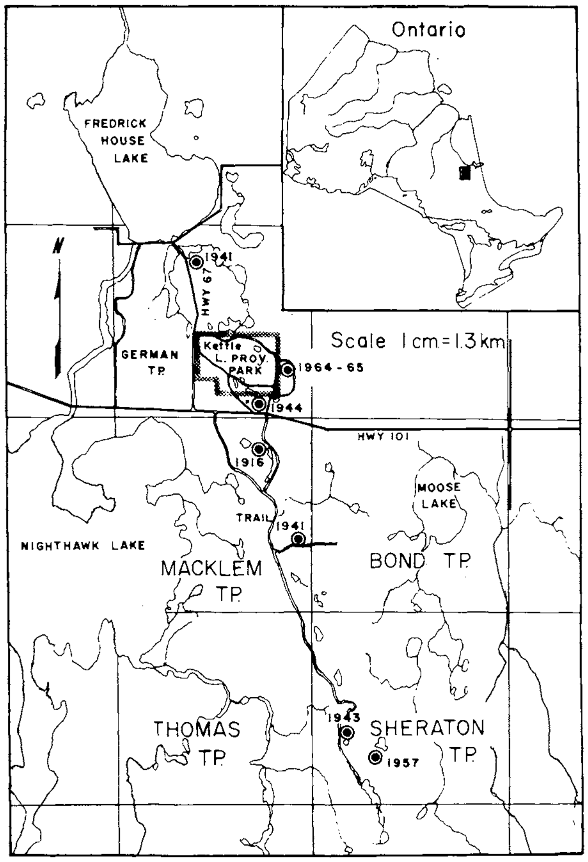

FIG. 1. Map showing the location of this study (point labelled 1964–65).

The experiment, started in 1964 and terminated in 1966, involved burning at controlled intensities and durations on three dates, early spring, summer and late fall. The experimental design, with replicated date blocks and intensity-duration plots randomized permitted statistical analyses of subsequent records. The burning treatments were completed with a "Solo" gasoline powered kerosene flame-thrower mounted on a 3-wheeled carrier (Fig. 3). The carrier was constructed to provide for maneuverability and to maintain a

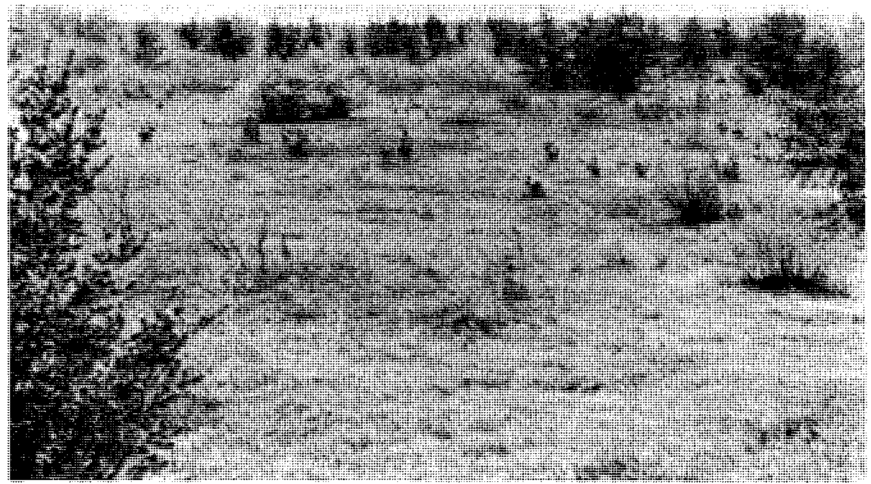

FIG. 2. View of the experimental area taken in May 1964.

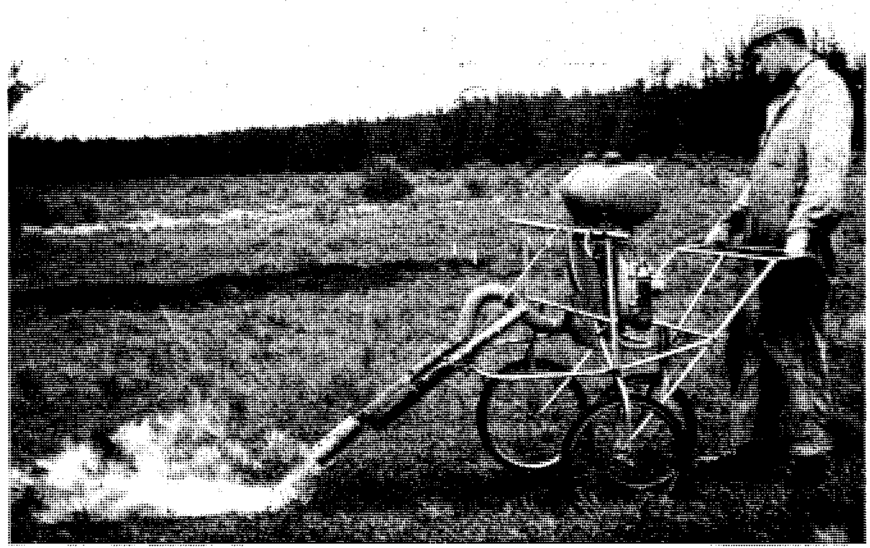

FIG. 3. The kerosene flamethrower and carrier during the application of burning treatments in the spring of 1964.

relatively constant distance between the nozzle and the soil surface. Set at a 45° angle the nozzle had adjustable settings for 10 and 30 cm above the surface thereby regulating intensity (maximum surface temperature). The burning duration treatments were achieved by regulating the rate at which the carrier was drawn lengthwise across the plots. The durations were 20, 40 and 80 sec/m^2. Control plots not burned, were included in each date block.

Maximum temperatures of the burning treatments were determined using 5 x 12 cm mica and aluminum plates with stripes of a selected series of "Thermocolor" crayons applied on one side (Canadian Distributor: Carson Instruments Ltd., 162 — Bentworth Ave., Toronto 19, Ontario.). A higher temperature series was used for the surface temperature determinations and a lower series for the below the surface measurements. A "Thermolyne" pyrometer with thermocouples was used also.

Burning was completed in periods of low wildfire hazard and the plot areas were provided with mineral soil firebreaks.

Soil sampling and sampling of the vegetation and surface litter were completed immediately before and after the application of the burning treatments. The soil was sampled to a 30 cm depth at intervals until the termination of the experiment in the fall of 1965. Soil moisture levels were determined during the experiment with gypsum resistance blocks.

RESULTS

The mean maximum surface temperatures were 302 and 327°C at the 20 sec/m^2 duration, 362 and 417°C at the 40 sec/m^2 and 702 and 823°C at the 80 sec/m^2 duration. Considerable overlap in range of temperatures occurred between the intensities of each duration during the burning. Two factors were mainly responsible: a) the burning surface vegetation almost eliminated the intensity difference of the flamethrower at the two settings and b) horizontal and vertical fluctuation in the flamethrower nozzle increased the temperature range at each intensity. It was therefore not always possible to distinguish between the effects of the two intensities of each duration treatment. For brevity in further discussion the mean maximum temperatures in °C are followed with their respective durations in sec/m^2 as i.e. 302/20 or 823/80.

Maximum temperatures in the soil during the burning were comparable for all 3 dates of burning. No increases were recorded at 1 cm with the 20 sec/m^2 duration. Maximum temperatures ranging from 65–100° C were recorded at 1 cm but no increase at 2 cm occurred with the 40 sec/m^2 duration. The 80 sec/m^2 treatments reached temperatures as high as 175° C at 1 cm and 100° C at 2 cm. No temperature increases were recorded below a 2 cm depth of mineral soil.

The immediate effects of the burning treatments on the soil were restricted to the top 2 cm. These effects included the burning of the surface litter to a maximum of 72 percent and a moisture loss from the surface of 75 percent. An increase in pH from between 4.06–4.22 to 5.10–5.63 was accompanied by an increase of 324 percent in the level of total soluble salts at the surface.

All nutrients for which analyses were completed showed immediate increase in concentration. This increase was mainly in the water soluble fraction. For example, increases in the surface varied with intensity and duration of burning to maximums of; 398 of potassium, 351 of calcium and 525 percent of phosphorus. These changes in chemistry resulted mainly from the combustion of the vegetation and surface litter and the deposition of their ash on the surface. The magnitude of the changes were related mainly to burning duration.

The edaphic changes which occurred within a short period after burning also varied with burning severity. For example, wind erosion removed as much as 35 percent of the surface ash during the first month after burning at 702/80 and 823/80 (Fig. 4). Erosion of ash resulted in a proportionate loss of the nutrients contained in them. In fact, the loss of nutrients probably exceeded the quantitative loss of the ash and unburnt organic matter. Wind action was selective in removing the lighter and more completely burned materials which contained a higher concentration of the nutrients.

Factors which affected the amount of ash removed included; the occurrence of precipitation soon after burning, variation in windspeed and variability in the seasonal distribution of precipitation. Date of burning was important, winter snow cover reduced the loss

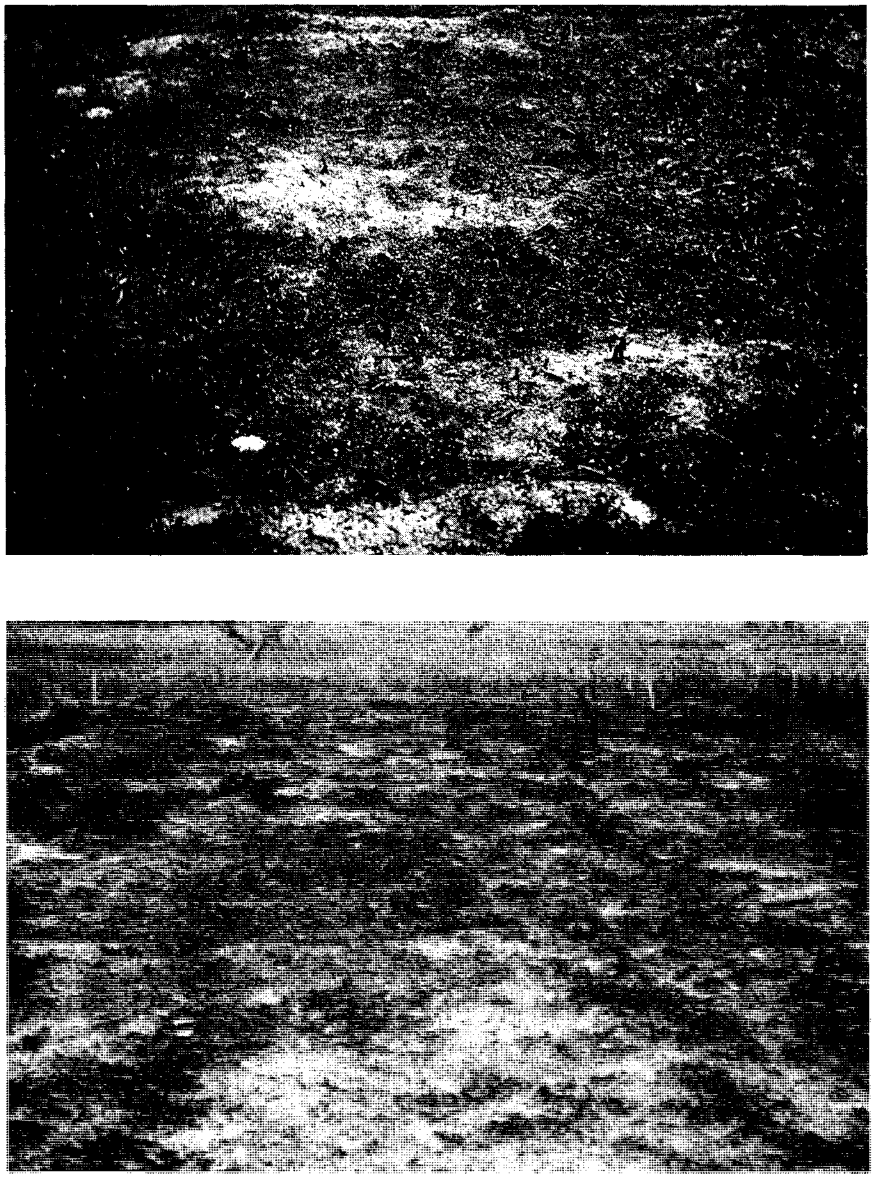

FIG. 4. Close-up views of the severe burning treatment (823/80) soon after burning in May, 1965 (top) and three weeks later (bottom).

of ash by erosion. The loss of surface litter by burning and the subsequent loss of ash by erosion are important because the bulk of the available nutrients in the sand plain soil is contained in this organic matter.

Moisture content of the soil immediately after burning varied with burning severity (Fig. 5). Decreases in moisture content, in comparison to the unburnt control, were small at the 20 and 40 sec/m^2 durations except at the surface. With the 80 sec/m^2 duration soil moisture was decreased to a 10 cm depth in periods of dry weather during the first 3 months after burning (Fig. 6). However, precipitation was well distributed during the course of the experiment and moisture availability was not an important factor affecting the re-establishment of vegetation.

Leaching of nutrients was coincident with the loss of nutrients in ash by wind erosion. Rapid decrease in levels of pH, total soluble salts and individual nutrients in the surface soil during the first 4 months after burning were accompanied by increases at mineral soil depths. Leaching was most evident after the severe burning at 80 sec/m^2. The most important factors affecting the leaching of individual cations included; the amount of precipitation, the ionic content of the rainwater and cation uptake by vegetation. But their individual chemical properties appeared to play a role as well. For example, monovalent potassium showed increases in the water soluble form but no increase in the acid extractable fraction in the mineral soil. Divalent calcium, on the other hand, showed increases in both the water soluble and the acid extractable fractions. Presumably calcium was retained by the surface soil in greater concentration, in comparison to potassium, because of its increased adsorptive properties.

The concentration of acid extractable phosphorus in the surface decreased after burning to as low as 19 percent of the initial preburn content with the severest burning treatment. Evidence suggests that a major portion of this loss was the result of fixation in unavailable form with iron and aluminum. A small portion was leached to mineral soil depths. The loss of phosphorus after burning at the 20 and 40 sec/m^2 durations was small and often no loss was evident.

The combined losses of nutrients from the surface by all factors

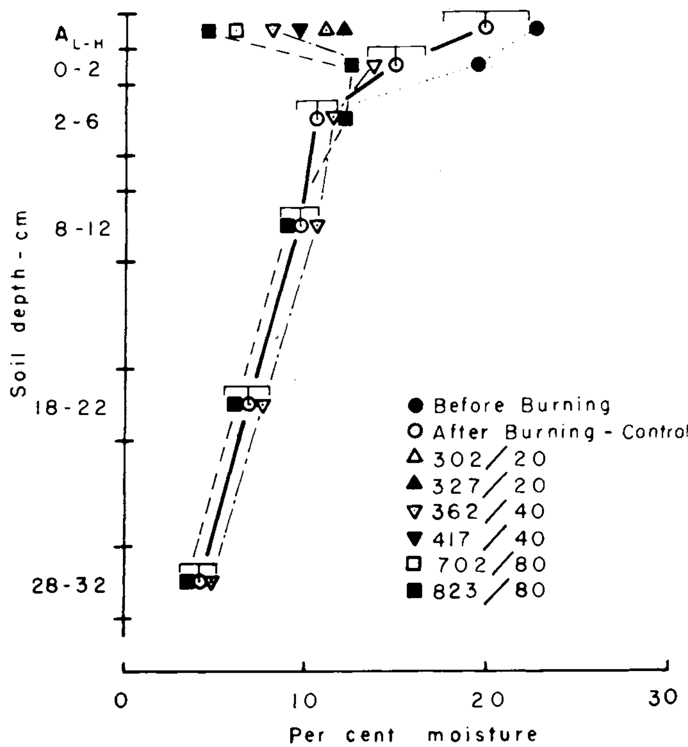

FIG. 5. Soil moisture levels before and after burning in May 1965. Brackets indicate the $P_{.05}$ limits of the control.

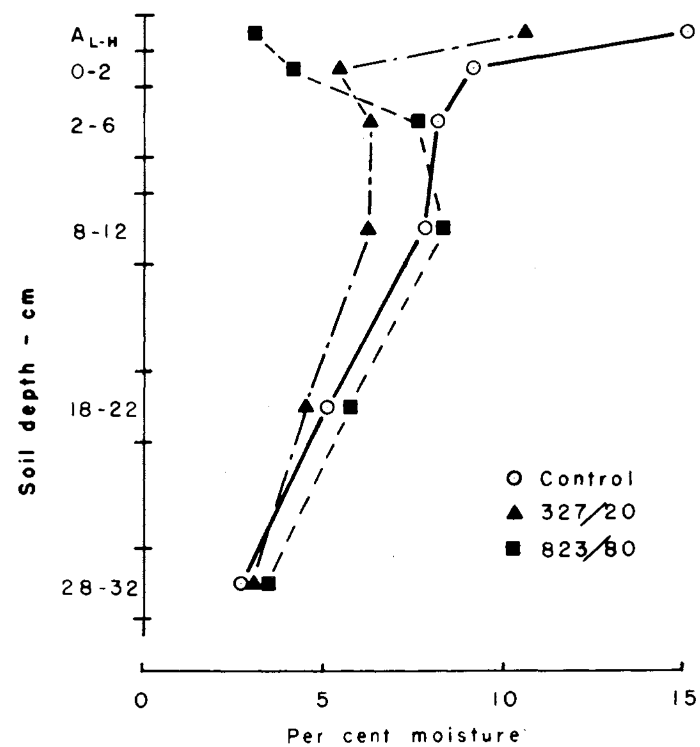

FIG. 6. Soil moisture levels for two burning treatments six weeks after burning.

was considerable during the first year after severe burning. The total loss, on a weight/area basis reached 93 percent of potassium. This loss was partly offset by additions from rainwater and leaf litter. Estimates suggest that it would take approximately 8 years for a return to pre-burn concentration of potassium in the surface and much longer to regain the total amount lost on a weight/area basis.

Loss of calcium reached 80 percent on a weight/area basis after severe burning. Replenishment of calcium occurred mainly from leaf litter. The larger amount of calcium contained in leaf litter and its improved adsorption properties were probably the chief reasons for the smaller loss of calcium from the surface soil in comparison to potassium. It is estimated that a return to pre-burn levels after severe burning would take 3 years.

The loss of extractable phosphorus, 91 percent on a weight/area basis after severe burning was possibly the most important from the standpoint of vegetation productivity. Replenishment would accompany litter accumulation and would probably require 25 years or longer.

The loss of nutrients, by leaching and wind erosion varied with the amount of surface litter burned. When only a small portion of the litter was burned, i.e. at and below an intensity of 362°C and the 40 sec/m^2 duration, the loss of nutrients was small and often not evident. Amounts deposited in ash were retained in the unburnt surface litter.

The effects of severe burning were evident from a decrease in density and productivity of the wild bluberries which formed the most abundant pre-burn surface flora. The blueberry rhizomes at or near the surface were often either burned or subjected to lethal high temperature (Fig. 7). Probably the reduced productivity of the species was partly because of the low levels of nutrients in the surface soil also. Several species, more tolerant to severe burning, replaced the blueberries. These included, *Comptonia peregrina*, *Carex aenea*, *Danthonia spicata* and other grasses.

Moderate burning at an intensity of 362°C and 40 sec/m^2 duration increased the density and the productivity of the blueberries (Fig. 8). Presumably the increase was mainly the result of the increase in available nutrients in the surface soil. The burning also had a stimula-

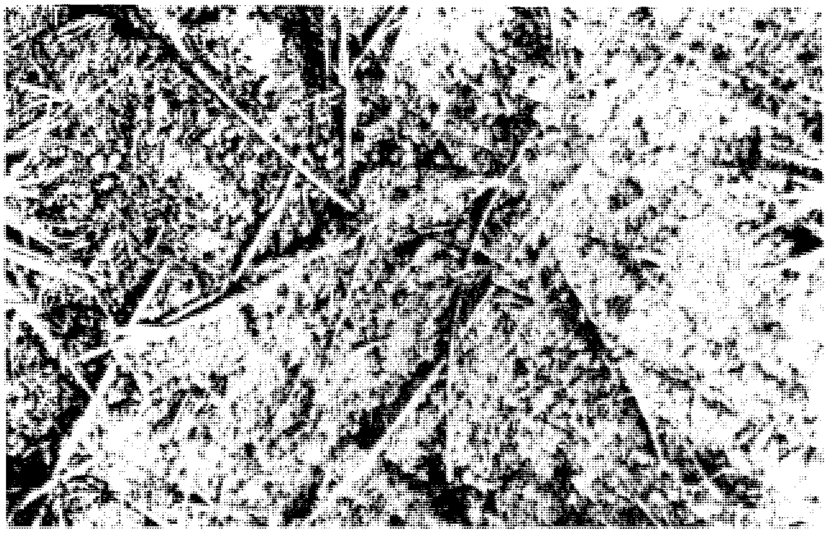

FIG. 7. Close-up view of the surface after severe burning showing the exposed rhizomes of wild blueberries.

FIG. 8. Stand of wild blueberries after late fall burning.

tory effect by removing the old senescent aerial portions of the plants. Date of burning was important. No increase in density or productivity occurred when burning was completed during the period of active growth in the summer.

SUMMARY AND CONCLUSIONS

1. The direct effects of burning at two levels of intensity of each of each of three durations were restricted to the surface 2 cm of soil. These effects included the loss of organic litter to a maximum of 72 percent after the severest burning treatments.
2. The chemical changes in the surface associated with the direct effects of burning resulted mainly from the combustion of the vegetation and surface litter. Increase in concentration of basic nutrients was mainly in the water soluble fraction. The increase of phosphorus was of the acid extractable fraction.
3. Large losses of basic nutrients from the surface during the first first 4 months after severe burning occurred by leaching and wind erosion as well. Depletion of phosphorus appeared to be mainly the result of its fixation in unavailable form.
4. Although the concentration of available nutrients was increased at the surface after burning at and below intensities of 362° C and 40 sec/m^2 duration only small losses were evident. Presumably these losses were small because the unburnt surface litter retained most of the nutrients preventing their loss by erosion and leaching. Appreciable reduction in soil fertility probably would only occur with repetitive burning at short intervals.
5. The density and productivity of the blueberry species which formed the most abundant components of the pre-burn surface flora was reduced by severe surface burning. This appeared to be the result of the destruction of their rhizomes near the surface, and the low soil fertility.
6. Increase in density and productivity of the blueberry species was evident following burning at durations of 40 sec/m^2. This was related to the increase in available nutrients in the surface soil plus the stimulatory effects of removing the older and senescent aerial shoots.

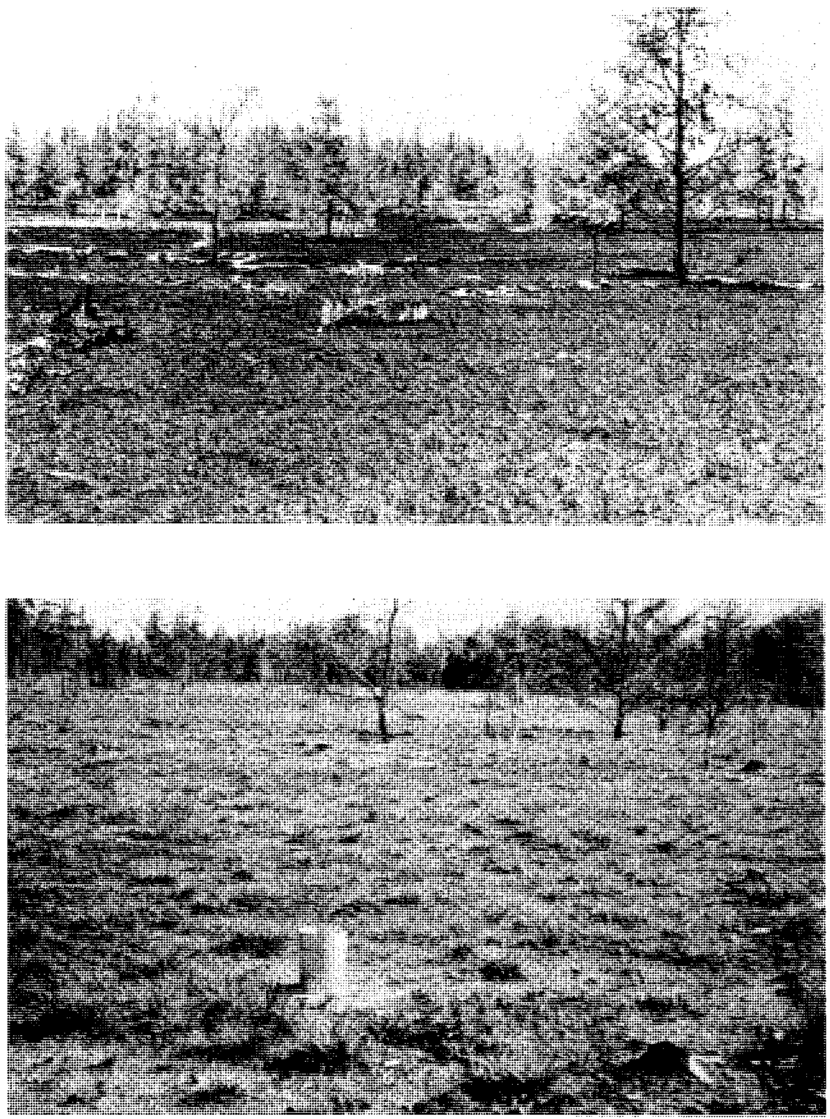

FIG. 9. Views of area subjected to severe surface fire, top–immediately after burning in July 1964, bottom–one year after burning.

Severity is one of the important factors determining the effects of surface burning on the soil of the sandplains areas in northern Ontario. Loss of nutrients from the surface was proportional to burning severity. Presumably a portion of the loss is attributable to volatilization during burning (Allen, 1964). However, a large loss occurred by wind erosion and leaching during the first 4 months after burning. Other reports of wind erosion are few but lent support to the results of this study (Beaton, 1959). Leaching has been shown to be important in single grain textured soils in other regions also (Uggla, 1957).

Undoubtedly the effects of severe fire on the soil and vegetation composition and productivity are important to the maintenance of the jack pine barren community. This community is recognized as a relatively stable seral stage in the succession to a mature boreal forest (Fig. 9).

Change in the vegetation community type and the depletion of surface soil fertility was slight when moderate burning was completed in early spring or late fall. In fact, the productivity of the wild blueberries, the most abundant component in the surface flora, was increased. When it is desirable either to retain the wild blueberry community for fruit production or to improve the seedbed for tree species "prescribed burning" in northern Ontario should involve only the removal of the aerial portions of the vegetation. The surface litter should remain intact to retain released nutrients and reduce erosion. Because of the variable climate this prescribed burning can best be accomplished using a fiamethrower in periods of cool damp weather in either spring or fall. Under these conditions fire severity can be controlled and burning will not be dependent on the surface litter for fuel.

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