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Compiled and Edited by
R.L. Trowbridge and A. Macadam

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IMPACT OF PRESCRIBED FIRE ON THE PRODUCTIVITY OF INTERIOR FORESTS

R.G. McMinn[1]

INTRODUCTION

The impact of prescribed fire on forest productivity depends on the characteristics of the fire and on the type and condition of the ecosystem affected (Feller 1982, Kozlowski and Ahlgren 1974). Effects may be long term as well as short term. This discussion reviews factors considered to be relevant to interior forests, especially those of the Sub-Boreal Spruce Zone.

FIRE SEVERITY AND PERIODICITY

Severity

For a site to be severely affected by prescribed fire, the fire must have sufficient intensity and duration. Intensity may be defined as the rate of heat release per unit of ground surface area. Dry, fine fuels (dry twigs and branches) ignited during a period of low humidity release heat rapidly. Impact may, however, not be great in terms of surface organic matter reduction if duration is short, which occurs when a fire quickly moves on in the absence of larger fuels. Surface organic matter may be singed, with little else affected. If larger fuels ignite and sustain the fire in place, much of the surface organic matter may be burned. Amount of reduction is also dependent on other conditions such as moisture content of the surface organic matter. Severity of burning can be defined in terms of amount of surface organic matter consumed, degree of reddening and change in structure of mineral soil, and in the proportion of the site severely affected.

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[1]Forest Ecologist, Canadian Forestry Service, Pacific Forest Research Centre, 506 West Burnside Road, Victoria, B.C. V8Z 1M5

Periodicity

Even if a site is severly burned, that is most of the surface organic matter is consumed, there will be less impact on site productivity if such a fire occurs once in a thousand years rather than every fifty years on a dry site in a dry climate. Severe fires (consumption of all surface organic matter) at relatively short intervals could well be a factor limiting productivity of lodgepole pine stands in the Chilcotin. Even more frequent burning to keep fuel loading down can be useful in preventing less frequent but more damaging fire occuring at longer intervals when fuel loadings have built up. Preemptive fires are reported to be an option used in some Australian equcalyptus forests (Gill *et al*. 1981). Periodic burning is also reported to be an effective disease control during the grass stage of longleaf pine (Boyce 1961).

ENVIRONMENTAL FACTORS

Soil

How did the clay, silt, sand, gravel and boulder left by the glaciers of the last ice age and more recently river deposited alluvial silt, sand and gravel differ from the soils on which the productivity of our forests depends? An essential difference is the biological activity, the effects of plant roots and soil structure (Armson 1977). Water and nutrient holding capacity were increased and fine textured materials made permeable and penetrable. Fire impact on soil varies with differences in physical and chemical properties, some intrinsic to soil parent materials but many the product of biological activity since parent materials were laid down.

Soil Organic Matter

Soil organic matter affects the productivity of forest soils in several ways. Organic matter is the chief source of nitrogen and may be an important source of other macro-nutrients (P, K, Ca) and of micro-nutrients depending on the mineralogy of the mineral material. Organic acids formed during decomposition of organic matter are important in weathering and release of nutrients from the mineral consituents of the soil. The colloidal nature of organic matter makes it a significant component of the exchange complex. The exhange complex retains nutrient ions, keeping them in the soil profile ready for uptake by roots rather then allowing them to be leached through the profile and "wasted" in runoff. This characteristic of soil organic matter is particularly important in coarse-textured soils (sands and gravels) which, unlike fine-textured soils, have low exchange capacity in the mineral soil and therefore low capacity to retain nutrients. The presence of soil organic matter is a major factor in the development of soil structure in fine-textured soils. Without structure, such soils would be impermeable to water and impenetrable by roots. Organic matter increases the water holding capacity of soils; in fine-textured soils by improving soil structure; in coarse-textured soils organic matter provides the main water holding mechanism. A layer of organic matter on the soil surface facilitates infiltration of rain so that soils may be readily rewetted after dry periods and runoff and erosion reduced. Removal of organic matter from the surface of fine-textured soils may result in fine pores becoming clogged, reducing infiltration rates.

Fire impact on soil organic matter differs according to its location in the soil profile and the amount accumulated. Grassland soils in adequately warm and moist climates accumulate and incorporate organic matter to considerable depths, as much as 50 cm below the soil surface. Such soils are relatively impervious to deleterious impact by fire because there is little surface organic matter to burn off and not enough fuel for severe burning. Incorporated organic matter below the soil surface is essentially unaffected by fire.

In forest soils the proportion of organic matter which remains above the mineral soil, and is therefore vulnerable to fire, varies with ecosystem association. In xeric, oligotrophic ecosystem associations (eg. SBS d/.02, Pine-Lichen ecosystem association), production of organic matter is low and most remains on the soil surface as L and F layers. Fire can readily consume this surface organic matter, perpetuating unproductiveness. Organic matter in the Bm (mineral soil horizon) would be unaffected, but there is little to start with in xeric, oligotrophic soils.

Toward the upper end of the moisture and fertility scale in the Subalpine Fir Subzone of the SBS Zone, the Ah of soils in the fine textured phase of the Oakfern ecosystem association (SBSe/.07(b)) constitutes a considerable proportion of the organic matter present. Such incorporated organic matter is not readily destroyed by fire. Therefore, fire can be used for silvicultural objectives such as planter access or competing vegetation control with little probability of long term negative impact on productivity. Deleterious reduction of organic matter is unlikely to occur in wetter ecosystems such as SBSd or e/09 (Horsetail ecosystem associations) although burning opportunities may be limited by wetness.

Soil Texture

Interactions between fire and soil texture are often indirect through impact on soil organic matter. In fine-textured soils in dry climates (eg. Vanderhoof clay: SBSd/07 Bunchberry-Moss ecosystem association) rooting is confined to uppermost horizons because only surface organic matter and uppermost mineral soil horizons modified by incorporation of organic matter have sufficiently penetrable structure for extensive rooting. Organic matter production is limited by lack of moisture (dry climate, shallow rooting depth). Since severe burning may occur in dry climates because surface organic matter can become quite dry, reduction of organic matter can be considerable. Reduction of organic matter can have a long term deleterious effect on forest productivity because production of new organic matter is slow in dry sites made even drier by reduction in effective moisture storage capacity and rooting depth. Short term beneficial effect, through release of nutrients from burnt surface organic matter would probably be more than counterbalanced by reduced moisture availability. Soil temperature increases might be greater than optimal, or, if potentially beneficial, negated by lack of moisture.

Short term impact of fire on moister fine-textured soils, (eg. SBSe/08(b) Devil's club ecosystem association, fine textured phase) on the other hand, is likely to be favourable. Nutrients released by burning slash and surface organic matter (except for those volatilized) will be retained for recycling by plants by the exchange complex of unburned incorporated organic matter and clay minerals. Since moisture is not limiting, rooting depth has not been reduced and soil temperatures are likely to have been beneficially increased, short term effect is likely to be accelerated growth. As short term benefits diminish, the productivity of the ecosystem is likely to return to its previous level. Nutrients lost by volatilization during burning will probably not impose significant limitations on the productivity of fertile sites, or they can be replaced by weathering of mineral soil particles and recycling from the organic matter remaining, following the fire.

Burning on coarse-textured soils (eg. SBSd/03 Pine-Lichen-Moss ecosystem association) as noted previously is likely to have deleterious effects because reduction in organic matter reduces moisture storage capacity and nutrient capital.

Impact of organic matter reduction would be less severe on moister, coarse-texured soils, such as deep gravels (SBSe/04 Submesic Bunchberry-Moss ecosystem association) because greater availability of moisture would allow quicker recovery of organic matter accumulations. Short term effects are still likely to be negative because destruction of surface organic matter would reduce nutrients and moisture storage capacity. Seasonal moisture shortages can occur in coarse textured soils not continuously supplied with moisture. When coarse-textured soils are supplied with seepage moisture, a more productive ecosystem association would be present (eg. SBSe/08(a) Devil's club ecosystem association, coarse textured phase) and fire impact would be positive or marginally negative at worst.

Soil Temperature

Experimental results suggest that soil temperatures as high as 25° C may be optimum for growth of spruce seedlings (Dobbs and McMinn 1977). Field measurements east of Prince George in the Sub-Boreal Spruce Zone indicate that maximum temperatures at 5 cm below the soil surface in untreated clearcuts rarely exceed 15° C. Reduction of insulating surface organic matter by fire should therefore beneficially affect growth of planted seedlings in ecosystem associations where reduction of surface organic matter does not otherwise have deleterious effects (eg. SBSd/08, /09; SBSe/07, /08, /09).

Whether planting should be delayed on burned sites until lesser vegetation has reestablished some shade seems doubtful. Shading vegetation on dry sites uses soil moisture needed for seedling growth. The benefits of shade may consequently be outweighed by the disbenefits of moisture depletion. In moister ecosystems, vegetation encroachment may smother seedlings if planting is delayed. A critical appraisal of relative benefits and disbenefits of immediate or delayed planting for each ecosystem association for which fire is appropriate seems called for.

Soil Nutrients

Organic matter (surface and incorporated) and residues (cull logs and logging slash) represent a major proportion of the nutrient capital of many sites. When these materials are burned, the total quantity of some elements (N, P, S) is redcuced by volatilization. The availability of some of these elements (N and P) and exchangeable cations (K, Ca, Mg) is increased because they are changed into more soluble forms in the ash. Increased availability may result in an immediate flush of growth. Increased availability may also result in nutrient depletion because in their more available form these elements may be leached from the profile. Leaching losses will be greatest in coarse-textured soils and where growth of vegetation is sparse following fire. With sufficient vegetation regrowth on fine textured soils having adequate incorporated organic matter, leaching losses may be slight even where much of the L, F, H layer has been reduced. Serious long term nutrient losses following burning are unlikely in ecosystem associations such as SBSd/09 (Spruce-horsetail ecosystem association) and SBSe/07, /08 (Oakfern and Devil's club ecosystem associations) both because sufficient vegetation is present soon after the fire to take up mobile elements, and incorporated organic matter in the soil profile provides sufficient exchange capacity to trap released nutrients. Prescribed fire which does much more than singe the litter layer should be avoided on mesic or drier sites. Even on moister sites with very coarse textured parent materials fire should be of low severity to minimize long term nutrient losses despite the attractiveness of short term increases in availability.

Moisture Holding Capacity, Infiltration and Water Repellency

The moisture holding capacity of coarse textured soils is largely dependent on surface organic matter. Therefore reduction in surface organic matter by fire would reduce the productivity of coarse textured soils not well supplied by seepage water. Burning, unless light, should therefore be avoided in xeric to submesic soils with coarse textures or with very fine texture (eg. Vanderhoof clay) as noted previously. Also as noted previously, infiltration rates may be reduced when all organic matter has been burned off because pores in mineral soil can become clogged by displaced mineral particles. Water repellency caused by condensation of volatilized organic substances has been noted in some coarse textured soils when burning has been moderate to severe.

pH

The presence of ash following burning raises the pH of soils. This could have adverse effects in soils developed on Limestone because forest productivity may in part be dependent on effects of organic matter reducing pH to favourable levels for conifers and associated micro-organisms. pH levels could become excessive on burned, dry Ponderosa pine sites, although the amount of material available for burning is probably insufficient to produce long term adverse effects even though the ph is raised. Beneficial or adverse effects of lasting significance caused by increased pH following burning do not seem to have been demonstrated.

Soil Microorganisms

Activity of soil microorganisms such as bacteria will be increased because burning increases temperature and pH of soils that were previously cool and acid. When soils are moist and adequately supplied with nutrients, increased microorganism activity may result in increased fertility and seedling growth. Exposed surface horizons may however become drier than they would have been with less insolation and exposure to wind. Microorganism activity may consequently be reduced in dry, shallow surface organic matter exposed by fire. Mycorrhizal organisms may also be reduced by extremely severe burning and reduction of organic matter. Effects on microorganisms are probably contributary causes, accentuating the undesirability of severe burning and organic matter reduction, rather than the main cause of reduced productivity.

Climate

The full range of choice in obtaining prescribed fires of different severities can be limited by climate. In wet climates, dry periods may not be long or frequent enough for fuels to dry sufficiently to produce severe burning even where desirable. Conversely, in dry climates a greater degree of choice is possible. Even then, severe burning on wet sites, sites where severe burning could be potentially advantageous, may only be possible in drier parts of climatic cycles.

VEGETATION

Prescribed fire can affect both the tree component of forests and the lesser, perhaps competing, vegetation. These effects can have an impact on forest productivity.

Trees

When prescribed fire destroys the seed source available in lodgepole pine cones on slash or on the ground, fire will have affected the productivity of the site. This effect can be remedied by planting. But when budgetary constraints limit the planting option, ill advised fire destroying cones can be considered to have reduced forest productivity. Likewise, if advance regeneration of subalpine fir would have produced an acceptable new tree crop, prescribed fire to achieve some other objective would affect productivity unless the dollars are available for planting. Admittedly these are institutional rather than biological constraints on productivity, but they may be real nevertheless.

Lesser Vegetation

Lesser vegetation can have an important direct negative effect on forest productivity by smothering seedlings. Sites then may become unproductive by lack of regeneration. Fire of sufficient severity can control the competitive effects of lesser vegetation without accompanying adverse effects when sites have sufficient incorporated organic matter and are sufficiently well supplied with moisture (eg. SBSe/08 Devil's club ecosystem association). Removal of the shading effect of dense lesser vegetation can increase productivity through enhanced soil temperature promoting faster decomposition of surface organic matter and release of nutrients. Striking increases in productivity have been found with vegetation removal without direct modification of surface organic matter (McMinn 1982). These effects will be greatest where vegetation is dense (eg. SBSe/06 Moist thimble-berry - forb ecosystem association). Whether fire should be used for vegetation control depends on whether other parts of the ecosystem would be adversely affected - as they could be in moist thimble-berry - forb ecosystem associations on colluvial sites with limited organic matter accumulations.

Lesser vegetation can be extremely important after fire because uptake and cycling by plants retains nutrients made mobile by burning organic matter within the ecosystem. Such nutrients might otherwise be leached out and "wasted". The role of lesser vegetation in nutrient trapping is most important on sites with coarse-textured soils where nutrient retention by the exchange complex in the absence of organic matter is least effective. Fortunately light burning on such sites (eg. SBSe/01 Mesic Bunchberry-moss ecosystem associations), if burning is needed at all, would have low impact on vegetation regrowth. Vegetation regrowth therefore would have a role in nutrient retention. Fortunately in most ecosystems where severe burning is needed to control vegetation, adverse impacts would be least and conversely where vegetation has an important role in nutrient retention, the need for severe burning is likely to be low.

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