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**ECOLOGY OF WHITE AND RED PINE  
in the  
Great Lakes—St. Lawrence Forest Region**

by  
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### **ABSTRACT**

This report presents observations on the specific site preferences and broad ecological relationships of white and red pine, particularly in the Great Lakes—St. Lawrence Forest Region of Canada. The pines are shown to be trees of relatively dry climatic and soil conditions. Their resulting distribution in different sections of the region is described. Occurrence of pine on a local physiographic site level is also considered, involving natural succession, fire and cutting effects, productivity, and regeneration capacity.

# Ecology of White and Red Pine in the Great Lakes — St. Lawrence Forest Region

by

K. W. Horton<sup>1</sup> and W. G. E. Brown<sup>2</sup>

## INTRODUCTION

White and red pine are trees of major importance in the Great Lakes—St. Lawrence Forest Region of Canada. They are found on a wide variety of conditions, yet there is little co-ordinated knowledge of their ecology, information which is basic to comprehensive silviculture. This note is an attempt at such co-ordination. It stems from an empirical survey of pine habits and developments over the range of site and stand history conditions existing in the region, together with an examination of pertinent literature.

## COMPARATIVE SITE RELATIONSHIPS

### Geography and Climate

The botanical range limits of white and red pine are shown in Figure 1. The northern commercial range of each corresponds reasonably well with the boundary of the Great Lakes—St. Lawrence (L) Region, also included in the figure. It is apparent from their wide geographic coverage that both pines have a broad environmental tolerance. However, there are certain specific differences; red pine extends somewhat farther westward and farther northward in the west than white pine, whereas the reverse applies in the east. Considering that the climate becomes generally colder and drier from east to west, it appears that red pine is somewhat better suited to the rigorous continental conditions.

There is plenty of evidence from distant plantations that both species will grow well outside their present ranges on a variety of sites. Within the natural ranges it is probably the cold climate which restricts their development to the north; however, both pines intrude well into the boreal region on favourable sites—the warmer, drier sites on coarse soils where competition from northern species is weak.

On similar sites at the prairie border in the west, pine outliers occur, surrounded by vegetation types better adapted to the cold, droughty climate and finer textured soils.

### Local Climate

Both pines will tolerate a variety of local climates, and a comparison of specific preferences is difficult because in most conditions local climatic effects are obscured by other site and stand factors.

Red pine appears to be more capable of withstanding extremes in local climate than white pine, as suggested by its predominance on the driest sand plains which are exceptionally hot in the daytime and cold at night. It is well recognized that white pine reproduction depends on some degree of protection for germination and survival (Smith 1951), more so than red pine. At the same time there can be too much protection; observations in mixed pine stands of eastern Ontario suggest that natural white pine reproduction is most abundant where, through exposure to wind and sun, evaporation is high.

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A major local climatic effect is frost damage, to which both pines are susceptible on low-lying sites where cold air collects, or on dry sand flats where night radiation promotes rapid cooling. Frost damage is greatest when the foliage first flushes in the spring, but cotyledonous seedlings may be affected throughout the growing season or in the autumn. Its symptoms are death of the tips, resulting in deformity or, in extreme cases, death of seedlings. In red pine plantations these effects of frost frequently appear in patches with scattered resistant specimens remaining unharmed. The fail spots in these cases are usually characterized by a "frost pocket" vegetation type composed of *Comptonia*, stunted *Vaccinium* spp., sedges and grasses.

Other weather effects of local silvicultural significance are windfall, sunscald and winter injury. As pointed out by Brown and Lacate (1959), both pines are relatively windfirm species on most soils but there are locations which are particularly susceptible, mainly sites where rooting is restricted. Sunscald and winter injury may be related. They both cause death of tree tissues on the southwest side of the trunks of trees facing openings. In one case of its occurrence in white pine, the trees most subject to damage were in the intermediate crown class (Huberman 1943). The cause was attributed to the trunks warming up in the afternoon sun in winter, then rapidly freezing at night.

### Light

White pine is definitely more tolerant than red pine, although both are classed as intermediate species in various relative shade-tolerance scales which have been devised, (Kramer and Decker 1944, Baker 1949, Graham 1954). On average upland sites in Ontario the pines and more commonly associated tree species might be arranged in decreasing order of tolerance as follows: balsam fir, sugar maple, beech, hemlock, white spruce, yellow birch, white pine, black spruce, white birch, red oak, red maple, red pine, jack pine, trembling aspen, largetooth aspen, and pin cherry. On the same basis the major competing shrubs decrease in tolerance as follows: *Acer spicatum*, *Viburnum alnifolium*, *Corylus*, *Rubus*, *Vaccinium* spp. and *Comptonia*.

Under a dense canopy of mixed pines, white pine reproduction may on some sites develop and persist, but red pine rarely becomes established and even more seldom persists. The hardier white pine seedlings can survive in a stunted form for up to 40 years under moderate to heavy shade, retaining a fair supply of needles. Upon release they require two or three years to develop the normal unrestricted growth rate. Red pine seedlings which have germinated under dense shade usually die the first or second year, rarely persisting to ten years. The persistent specimens have sparse foliage and, if released, take a few years longer than white pine to recover.

Red pine requires a minimum of about 35 per cent of full sunlight for satisfactory seedling establishment (Grasovsky 1929, Shirley 1932), whereas white pine requires only 20 or 25 per cent (Smith 1940, Atkins 1957). As to height growth in seedlings, that of red pine increases with light up to 63 per cent of full sunlight (Shirley 1932, Mitchell and Rosendahl 1939) while in white pine it increases only up to 55 per cent of sunlight (Logan 1959).

White pine remains more tolerant at later ages. In fact, Rudolf (1957) suggests that red pine loses some measure of tolerance after the seedling stage. In mixed pine stands the red pine grows faster for at least the first 40 years and often beyond 100 years (Smithers 1954, McCormack 1956), after which the white pine gradually achieves dominance, finally outliving the red.

### Soil Moisture

White pine is capable of growing on a wider range of soil moisture conditions than red pine. It is found from wet swamps to arid sand plains and rocky ridge

tops. Red pine is generally more restricted at the moist end of the scale but is well adapted to extremely dry sites. In some areas it is confined to coarse sandy outwash plains.

Superior growth rate in both species ordinarily occurs on fresh to moist, well-drained sites, although exceptionally favourable nutrient supply and soil structure can maintain excellent growth on somewhat dry sites, especially those suited to deep and extensive rooting. On the driest and wettest conditions growth of both species is, quite naturally, retarded. Excepting these extremes, and other variables being equal, there is a general direct relationship between soil moisture and pine height and diameter growth—the greater the available moisture, the better the growth (Husch and Lyford 1956, McCormack 1956).

On the wet sites white pine is often confined to raised humps, but it can grow on peaty soil with a high water table, probably depending on periodic lowering of the water level. Red pine, when it occurs at all on the moister conditions, is usually inferior to white pine in growth, but it can develop moderately well when the ground water is aerated.

On the driest sites red pine is often superior to white. This may be because red pine roots tend to penetrate deeper into very coarse sands or utilize the crevasses in rock more readily than those of white pine (Brown and Lacate 1959), thus taking advantage of deep moisture.

Soil Texture and Structure

If other factors, particularly soil structure and species competition, are constant, there is a correlation between occurrence of the pines and soil texture. Generally red pine is more abundant on the coarser sandy soils, and white pine on the finer sands or loams. Wilde (1946) considers 5 to 10 per cent of silt and clay as suitable for red pine, and 15 to 25 per cent for white pine, but he cautions against the use of this relationship in soils having strata of various textures. The following composite field samples illustrate typical differences in specific textural "preference" found in Ontario conditions:

		Sand (%)	Silt (%)	Clay (%)
Soils on which red pine is abundant	B <sub>2</sub> horizon.....	68	28	4
	B <sub>3</sub> horizon.....	80	18	2
	B <sub>c</sub> horizon.....	95+	3	0
Soils on which white pine is abundant	B <sub>2</sub> horizon.....	55	40	5
	B <sub>3</sub> horizon.....	63	34	3
	C horizon.....	72	25	3

A relatively high proportion of sand is characteristic of the soils most inhabited by both species. Thus they are more likely to be found on glacio-fluvial or aeolian materials than on tills or lacustrine soils.

Variations in reproduction capacity and growth rates of both pines have frequently been attributed to textural differences. Lutz and Cline (1946) and others have reported poorer white pine reproduction on heavier as compared with light sandy soils. Growth, on the other hand, can be greater on finer textured sandy soils with a higher silt and clay content, as Scott and Duncan (1958) have shown with height growth in red pine plantations. It is apparent that such relationships may not be directly attributable to soil texture. The finer materials are generally superior in water-holding capacity and nutrients, which could account for the superior growth; they also promote the development of competing vegetation which discourages pine reproduction.

The effects of soil structure are usually masked by those of other factors but do become evident under some circumstances. On compacted soils, root penetration is difficult for both species. White pine is generally more abundant than red pine on such conditions but there is little difference in respective growth rates. On soils with "hardpans", and on heavy lacustrine soils, red pine is somewhat more stunted, a situation that may be caused directly by the adverse structure, or indirectly through its effect in deteriorating vertical drainage.

The best conditions of texture and structure for outstanding pine growth are generally those that balance available moisture with good aeration. These may be found in interbanded soils of medium sand and finer materials where moderately shallow rooting occurs, or in loose, medium and fine sand mixtures of aeolian origin which permit exceptionally deep and extensive rooting.

### Soil Nutrients

Both pines ordinarily occur and grow satisfactorily on soils of moderate to low fertility. A sample analysis of a typical waterlaid sand or sandy till of granite origin, in the Central Ontario portion of the Great Lakes—St. Lawrence Region, is as follows:

Soil Horizons	pH	Chemical Composition, parts per million			
		P	K	Ca	Mg
A <sub>0</sub>	4.4	10	90	100	7
B <sub>2</sub>	5.1	—	60	145	4
B <sub>3</sub>	5.5	—	50	115	—
C	5.5	—	40	175	2

As emphasized elsewhere, the more tolerant species, particularly hardwoods, generally crowd out the pines on richer soils.

In the matter of soil pH, Wilde (1946) suggests that white pine has a wider tolerance in both directions, recommending a pH range of 4.7 to 7.0 for it as compared with 5.0 to 6.5 for red pine. Observations in natural Canadian stands indicate that both species are capable of performing well on soils tending to acidity but white pine is more tolerant of basic conditions. Satisfactory growth in either species may be found in moderately acid soils with a surface pH as low as 4.0, whereas on somewhat basic soils with a surface pH of 7.0 to 7.5, white pine can thrive but red pine may be inhibited.

White pine does not appear to be appreciably retarded in growth by lime concentrations near the soil surface; red pine does. However, a limy C horizon is not a serious drawback to red pine when overlaid by moderately acid A and B horizons.

A strong concentration of iron and humus in the upper B horizon appears to be adverse for both pines. Inferior white pines growing on such conditions are sometimes locally called "yellow pine". The characteristic chlorosis and poor vigour which results may be related to low nitrogen or potassium contents or to poor drainage which is often associated. Observations of plantations in Quebec indicate that such soil development may be more serious in restricting growth of red pine than of white pine; in certain of these cases a deficiency of magnesium and potassium was discovered (Lafond 1954).

In general, symptoms of nutrient deficiency are rare. They are more commonly seen in red pine plantations than in white, but this is probably because red pine has been planted much more extensively on a great range of sites, some of which are bound to be poor in nutrients. In the Ottawa valley, local patches

of poor-growth pine are associated with farmed-out, low-nutrient outwash sands, in which quartz is the principal mineral component. Obvious examples of site unsuitability are seen in the stunted, deformed and chlorotic red pine planted on old-field soils which are high in lime or low in magnesium and potassium. In severe cases, complete failure of single stems or patches can result. Artificial application of fertilizers is the quickest remedy in such cases (White 1956, etc.). Over a longer term the soil may be reconditioned by certain vegetation. As an example, it has been demonstrated that white birch helps restore potash-deficient forest soils, making the nutrients available to white pine and thus improving growth (Walker 1953).

Exceptional cases of nutrient surfeits and deficiencies may be found in some localities, usually associated with specific landtypes. An example of high nutrient supply occurs on the dune material of the Chalk River and Gatineau River areas in the Ottawa valley where dry sands with poor profile development give the highest site class for both species, and especially for red pine. Feldspars and micas are abundant in these soils, resulting in abnormally high fertility. Contrary to this situation is the very poor growth on dune material where quartz predominates—for example, the dunes of the Grand Lake Victoria area in Quebec, which have developed from washed beach sand. Outwash sands are generally poor, but in the Kipawa and Temagami areas an unusually rich outwash gives excellent growth in both species on dry sites. A similar richness in till materials in these areas produces exceptionally vigorous seedlings which can successfully compete with the prevalent shrubs.

### Soil Processes under Pine

The occurrence of both pines is closely associated with moderate podzolization. Pine litter, on decomposition, promotes an acid leaching process which usually produces minimal or normal (orderde) podzols on dry and fresh materials, and is associated with humic podzols, gleyed podzols and gleysols on moist to wet materials. The degree of podzolization is modified by the associated species, the nature of the parent soil material, the drainage, and the climate. Of the coniferous associates, hemlock, fir and the spruces, especially black spruce, encourage the process. The hardwoods, especially sugar maple and beech, and to a lesser extent the birches, tend to weaken it and encourage the formation of brown soils, such as the brown podzolic and the brown forest. Basic parent materials discourage podzolization, partly because they favour the hardwoods.

In Ontario, grey-wooded or calcareous podzols are found under pine in the Kenora area on limy materials. Brown podzolic soils occur in the central areas of the province with the hardwoods; brown forests or grey-brown podzolics occur in the southern sections, also with the hardwoods but on calcareous materials. Podzols are predominant in the north on all sites, whereas in the south they are more common on dry and wet sites. Profiles with strong iron and humus concentrations may be found in parts of Quebec, in conjunction with high-iron parent soil materials and heath vegetation.

A typical pine podzol condition such as may occur in a central section on moderately rich, granitic gneiss till, can be described as follows: the L, F, and H layers are clearly defined, the L and F being of similar depth. The L is composed of needle litter and the F of semi-decomposed needles. The H is thin, and usually shows a trace of charcoal mixed in with the humus from the lower F. Together, the three organic horizons may be  $1\frac{1}{2}$  to 2 inches thick. A trace to approximately one-half inch of  $A_1$  may be present, representing a mechanical mixing of charcoal and mineral particles from the  $A_2$  rather than a truly melanized layer. The A horizons are all acid and promote a fungus type of biotic development, forming a mor humus. Beneath the mor a grey, leached, siliceous  $A_2$  is always present, ranging from a trace to 3 inches in thickness. The upper portion of this horizon is mixed with the charcoal from the  $A_1$ , to give a salt and pepper appearance.

Next come the B sub-horizons, characterized by an accumulation of humic, iron and aluminium compounds. They are only moderately well developed and grade into one another, with a total thickness averaging about 12 inches. Texture usually varies from sandy loam to loamy sand, and the structure is poor, either single-grain or weakly granular. The B horizons vary from reddish brown to yellowish brown, darker when moist. The parent material, or C horizon, is commonly loamy sand or medium and fine sand, light yellowish brown in colour, and structureless or somewhat moulded in lenses. An ortstein or pan formation is uncommon in either the B or C horizons.

## DISTRIBUTION RELATIONSHIPS

### Geography and Climate

The individual physical site factors interrelate and combine with biological forces to control the establishment and development of the pines on a local level. But there are also broader effects involving the interplay of geography, physiography and climate which determine the distribution and relative abundance of pine subregionally. The general tendencies in the pine region of Ontario and western Quebec are summarized in Table 1 with reference to Halliday's revised forest sections (Rowe 1959) (Figure 1).

TABLE 1.—BROAD DISTRIBUTIONAL RELATIONSHIPS OF PINE

General Climate		Forest Section	Pine Distribution	Stable Species
*	**			
36	Cold-Moist	35 Northern L.4b	Scattered on dry sites	Spruces, fir, birches
36	Cool-Moist	34 Southern L.4b	Frequent on dry sites	Tolerant hardwoods
37	Cold-Dry	28 L.9, Western L.11	Abundant on dry-moist sites	Pine, spruce, fir
39	Cool-Dry	30 L.4c, Eastern L.10	Abundant on dry sites	Pine on dry, exposed sites. Tol. hwd. on fresh loams.
40	Warm-Dry	29 L.4c	Abundant on dry sites	Pine on dry, exposed sites. Tol. hwd. on fresh loams.
41	Warm-Moist	34 L.4d	Restricted to dry sites	Tolerant hardwoods

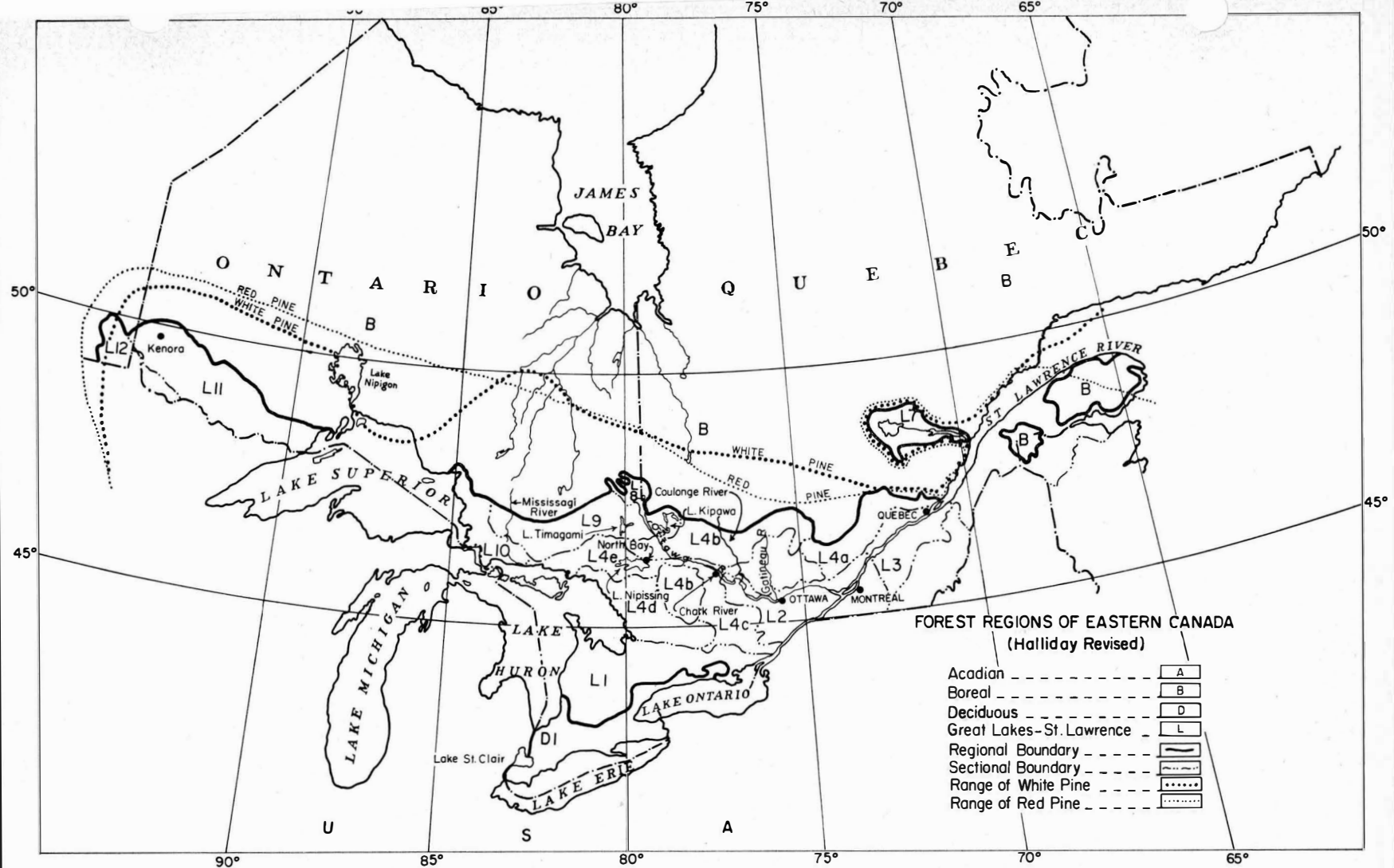
\*Annual Mean Temperature (°F.)

\*\*Annual Mean Total Precipitation (ins.)

Note that various sections and parts of sections considered representative of the sequential climate scale of the region are shown in Table 1, together with the relative distributions of pine and the characteristic stable tree associations. The basis for determining the sectional climates is partly local experience and partly the mean annual weather records (Anon. 1947). Though the differences in the weather data are not wide, they are consistent and indicate with some objectivity relative variations within the region.

Hills (1954) has classified climatic regions in Ontario on a different scale; in effect, three of his regions, numbers 4, 5 and 6 north to south, correspond with Halliday's Great Lakes—St. Lawrence Region, and Hills' regions 4 and 5, which largely cover the sections numbered in Figure 1, contain the greatest concentrations of white and red pine.

Generalizing, it is apparent that the pines prefer dry conditions. Stands are abundant and relatively stable only in the climatically drier sections, and in moister sections the pine species are largely restricted to dry sites by strong competition from tolerant hardwoods or, to the north, from boreal mixedwoods.



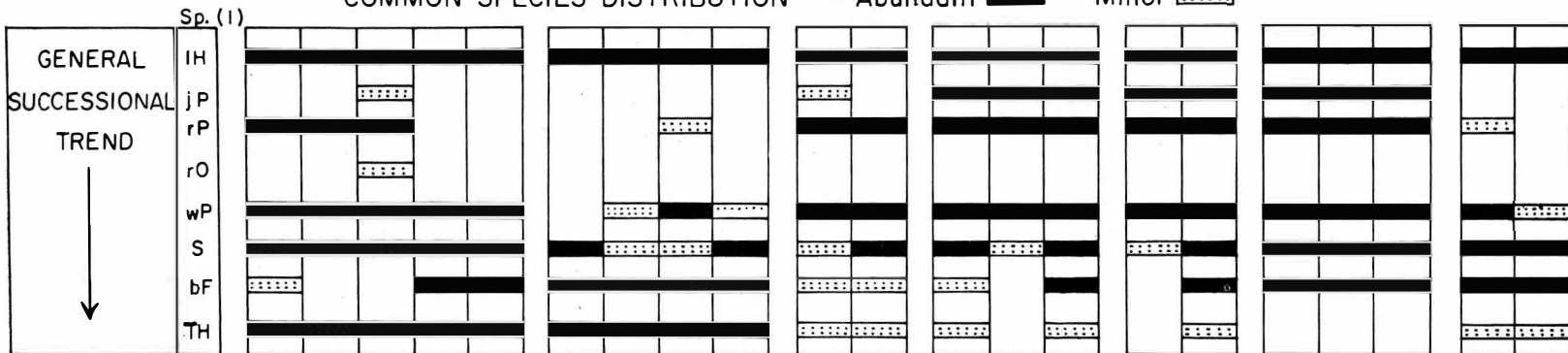
Prepared by Forestry Branch, Mapping Section.

FIGURE 1.

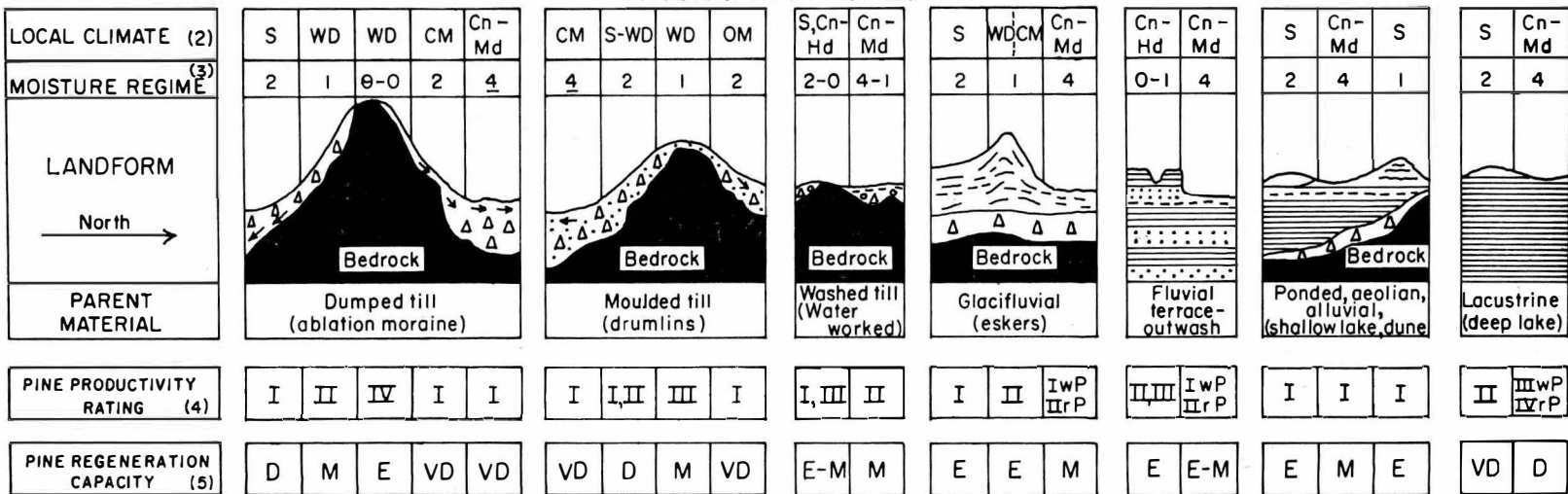
# FOREST ASSOCIATIONS IN RELATION TO PHYSIOGRAPHIC SITE

## IN THE MIDDLE OTTAWA SECTION

## SHOWING PINE PRODUCTIVITY AND REGENERATION CAPACITY

COMMON SPECIES DISTRIBUTION — Abundant  Minor 

## PHYSIOGRAPHIC SITES



(1) Species symbols- See appendix (2) S=Standard WD= Warm-dry CM = Cool-moist Cn-Md = Cool night, Mod. day Cn-Hd = Cool night, Hot day

(3)  $\theta$  = Very dry 0 = Dry 1 = Somewhat dry 2 = Fresh 4 = Moist (underlined - if seepage) (4) I = Good II = Mod. III = Poor IV = Very poor

(5) E = Easy M = Mod-easy D = Difficult VD = Very difficult

## Physiographic Site

The relationships of pine and associated species on a spectrum of physiographic sites in a particular section are shown in Figure 2. The site criteria stressed are soil moisture regime and local climate within distinct landforms, following Hills (1952, 1954, 1959). Landform is recognized by Hills, Logan and Brown (1956), Scott (1958) and others as a primary site variable indicative of soil texture, structure and nutrient characteristics combined. Moisture regime and local climate are rated in arbitrary scales as shown below the figure; both depend largely on topographic position; moisture regime also reflects soil porosity.

Again a tendency on the part of the pines to prevail on the drier conditions is evident, this time on a local site level. The dryness may be due to exposure, excessive topographic drainage, coarse soils or any combination of these. Thus pines predominate on the shallow upper slopes and ridges and on the water-worked and wind-blown materials, and as the physiographic site becomes more mesic, pine distribution generally wanes.

## Stand History

### *Fire Effects*

The pines are primarily fire species in that their silvical characteristics are adapted to conditions effected by forest fires. Climate and local site may not be directly responsible for natural pine distribution, but indirectly responsible through fire history. Fire will in the long run be more common in the drier conditions; so, therefore, will pine. Moreover, once established, the pine vegetation itself through its high combustibility will increase the probability of fire. Thus on dry areas a cycle develops and pine prevails, varying in local density according to seed availability. In contrast, the moister conditions tend to encourage fire-resistant vegetation—tolerant hardwood trees and dense deciduous shrubbery—which become stabilized, excluding pine.

Another factor in fire history is the existence of areas with an abnormally high frequency of dry electrical storms, which greatly increase fire frequency. Three such areas are around the Mississagi, Chalk and Coulonge Rivers, and each features extensive pineries today.

Fire is not necessarily beneficial in promoting the distribution of red and white pine. It may, if it is repeated at a short enough interval, or if it follows a clear cutting, destroy all advance growth and seed trees in a locality. In such cases the less desirable pioneer species, jack pine, aspen, or white birch, will replace red and white pine. This, unfortunately, has happened over a large proportion of the pine region, particularly in those sections less suited climatically and physiographically to the prevalence of pine. As Maissurow (1935) put it, the decline of white pine in Eastern Canada was not caused by either fire or logging directly, but by disturbance of the general balance between the seed-bearing capacity of the forest and the effectiveness of fires—namely, the elimination of seed sources, the overfrequency of fires in some areas and the lack of fire in others.

### *Cutting Effects*

Cutting, apart from fire, has influenced pine distribution in various ways. Obviously it has decimated the old-growth stands. Intensive operations have in some localities eliminated pine by destroying advance growth and seed source. Diameter-limit cutting, practised on pine for many years, ensured some seed supply and reproduction in most areas but it could seldom be called adequate either in quantity or quality. Competing trees and shrubs of both pioneer and tolerant classes, usually undesirable hardwoods, have been generally encouraged to the detriment of the pine. Satisfactory stands of white pine (rarely with red pine) have developed after cutting only when there was the coincidence of an

abundant, ripe seed crop and a receptive seedbed, or when a crop of suppressed seedlings was released. These circumstances probably occurred infrequently in former years but are becoming more common as pine management is intensified.

#### *Other Effects*

There are other natural processes which can bring about pine reproduction in quantity, but they too involve disturbance of the stand and site. Windthrow is one—periodic hurricanes are said to be responsible for extensive original white pine stands in parts of the northeastern States (Goodlett 1954). The pine became established on upturned mineral soil. Erosion or other soil disturbances may also create favourable regenerating conditions (Maissurow 1935).

Once pine reproduction has become established, there are a variety of external factors that can alter the normal course of stand history. White pine particularly is susceptible to damage—browsing and weevilling which reduce growth and ruin form, and blister rust which kills trees of all sizes. Red pine is relatively free of these drawbacks and thus, along with other competing species, gains an advantage over white pine in mixed stands.

## PINE ASSOCIATIONS

### Cover Type and Succession

Forest succession depends on all of the aforementioned conditioning effects plus species interactions and other biological forces. The result of all this is the mosaic of forest cover types. The pines will occur to some extent in practically every combination of common species but there are certain predominant associates on particular physiographic and historic conditions within a region or section, as is evident in Figure 2.

Broad cover types involving pine can be conveniently differentiated according to the main associate species, whether tolerant hardwoods, intolerant hardwoods or other softwoods. Successional tendencies of pine will differ radically in each of these cover types as the following details, gleaned from extended observation and from the literature (Logan and Brown 1956, Scott 1958) show:

#### **Pine—Tolerant Hardwood Cover Type**

The tolerant hardwoods prevail on the deeper, moulded or dumped tills. Red pine cannot compete under these conditions but white pine may be temporarily abundant on disturbed areas—severe burns or old fields. Once established, white pine may persist due to its longevity and superior height growth but reproduction has little chance except occasionally on rocky ridge tops or other dry locations. Elsewhere as a rule a dense understorey of hard maple and other tolerant hardwoods develops at an early stage and eventually dominates, precluding pine reproduction. Hard maple is the prevalent species; minor components, usually local, may be beech, yellow birch, red oak, basswood and hemlock.

#### **Pine—Intolerant Hardwood Cover Type**

This type is frequent over a wide range of sites. It originates after fire or cutting or both. The intolerant hardwoods, aspens and white birch, which dominate at first, become decadent early (50 to 70 years) on the drier sandy plains but continue to suppress the pines longer on till materials. Once they deteriorate, a rank shrub layer consisting mainly of *Corylus cornuta*, *Acer spicatum*, *Viburnum* and *Rubus* spp. develops. The previously suppressed pines will dominate the canopy for a time but their reproduction will be sparse. Balsam fir and spruce usually become established among the shrubs and may remain dormant for many years until the canopy thins. White birch may maintain a minor position by regenerating in temporary openings. On the till sites where a local seed source is available tolerant hardwoods may invade the type.

## **Pine—Softwood Cover Type**

This is relatively restricted in the south, becoming commoner to the north where it occurs on a broad range of sites. The softwoods other than pine are predominantly balsam fir and white and black spruce. Successional development is obviously toward the spruce-fir except on upper slopes and dry sand plains where white pine may reproduce and persist. On dry, limy sites in the south where white cedar and white spruce are significant associated species, the development is probably to cedar, with some white pine persisting in openings, especially on limestone plains.

## **Pine Cover Type**

Pine is relatively stable as a type only on drier conditions where pure stands have developed. On valley water-worked sites, stands of fire origin containing the three pines—white, red and jack—can be found. In the course of succession the jack pine will fall behind first, then the red pine, leaving the white dominant. Sporadic red and jack pine reproduction may occur in openings but white pine will generally reproduce in abundance, and fir and spruce usually intrude. Pine types on moister, richer sites are temporary and develop rapidly to spruce-fir-birch or to tolerant hardwoods, depending on which is locally prevalent.

## **CLASSIFICATION OF PINE SITE TYPES**

The co-ordination of pine distribution in relation to the spectrum of physiographic sites and associated species is illustrated in Figure 2. A fairly large number of sites and species are involved, presenting a complex picture. For most applications in forest management a broader grouping of conditions is required.

If the broad physiographic site or landtype is integrated with forest cover type the resulting unit, which may be termed a forest-site type, provides a convenient basis for local management. Logan and Brown (1956) have described several such site types involving pine with emphasis on their regeneration capacity for pine. With this as a background, four general pine site types have been developed and named according to their characteristic topographic occurrence. Three of them are further divided according to particular differences in site and species composition. They are shown in Table 2 along with their normal physiographic ranges, important associate tree species and characteristic lesser vegetation type (of Heimburger 1936<sup>3</sup>).

It must be stressed that the forest-site types classified are generalized representatives of a particular forest section where pine prevails. In the same section it is possible to recognize other, less common, site types, and every degree of transition between types. Also there will be unusual combinations of site and type resulting from unusual stand histories.

The site ratings shown in Table 2 and Figure 2 are considered next.

## **Productivity Rating**

An evaluation of relative productivity is the commonest aim of site classification. Productivity can be thought of in two senses, that of the existing stand and that of the site potential. Both involve physical site quality; the former also reflects the haphazards of stand history. Hills and Pierpoint (1959) outline a method for taking both into account using "ecological units" (comparable to forest-site types), each of which is assessed for pine productivity on the bases of present stocking, yield quality (from local measurements), degree of hardwood competition, and cost required to maintain pine through silviculture.

In relating existing pine stands to site, it has been noticed that productivity, or growth of individual trees within the stand, appears to be influenced directly by soil moisture regime. Husch and Lyford (1956) also found this in white pine

<sup>3</sup>Published in Sisam (1938).

TABLE 2.—BROAD SITE TYPES OF PINE IN THE MIDDLE OTTAWA AND SIMILAR SECTIONS

Pine Site Type	Type Division	Major Pine Species	Important Associates	Vegetation <sup>(2)</sup> Type	Topography	Parent Soil <sup>(3)</sup> Material	General Ratings <sup>(4)</sup>	
							Regeneration	Productivity
Pine Ridge.....	Southern <sup>(1)</sup> Northern	wP,rP jP,wP	rO,tA,etc. bS	Aster-Gaultheria Vaccinium	Dry granite ridge Dry granite ridge	d/b or w/b d/b or w/b	E	IV-III
Pine Plain.....	Xerophytic Mesophytic	rP wP,rP	jP jP,A,wP	Vaccinium-Comptonia Maianthemum-Corylus	Dry terrace or plain Somewhat dry plain	u,a+d/b,w/b u,a,p+d or w	M-E	III-II
Pine Upland.....	Mixedwood	wP,rP	A,wB,bF,wS	Aster-Corylus	Somewhat dry to moist slope	d,m+w,r		
	Softwood	wP	bF,S,wB	Cornus-Maianthemum	Moist lower slope, pocket or bench	u,w+a,p	D	II-I
Hardwood Pine Upland.	Mesophytic	wP	hM,Be,yB eH	Trillium	Somewhat dry to moist drumlin slopes, etc.	Rich d,m	V D	II-I

<sup>(1)</sup>Geographic Division—even within a forest section there is a general trend from deciduous to coniferous species progressing north.

<sup>(2)</sup>Heinburger's Petawawa types which most closely correspond with the chosen site types.

<sup>(3)</sup>Landform classes (minor representatives follow the + sign).

b = bedrock, d = dumped till, w = washed till, m = moulded till, u = uniformly stratified outwash and terrace.

r = roughly stratified eskers and kames, a = aeolian, p = ponded materials.

<sup>(4)</sup>Ratings are listed in Figure 2, and described in text.

stands in New England. The relationship in Ontario is shown in Table 3, using as a measure of productivity McCormack's (1956) figures of average site index, or relative dominant height at 50 years, grouped in four arbitrarily defined classes.

TABLE 3.

Productivity Rating	Average Site Index		General Moisture Conditions
	wP	rP	
I	61	61	fresh and moist
II	50	51	somewhat dry
III	43	44	dry
IV	34	36	1. very dry 2. wet

Other site factors may be indicative of quality—for instance Young (1954) found in Maine that the site index of white pine decreases as the depth of the A horizon and the percentage of stones in the B horizon increases. However, moisture regime is perhaps the most workable criterion.

This general relationship between pine productivity and soil moisture can be altered by special conditions. Exceptionally high productivity may result in some localities from unusually rich parent material originating from feldspars, micas, basic volcanic and sedimentary materials; and from particularly favourable rooting conditions. Subnormal productivity may occur where the soil nutrient balance is amiss, where rooting is restricted by bedrock, compacted soil or stagnant ground water, and where exposure is excessive.

### Regeneration Capacity Rating

Pine regeneration depends first on the abundance and vigour of the competing lesser vegetation and tree species. This in turn is controlled chiefly by the physiographic site and the stand history. Chance seeding and vegetative regeneration play some part, but in most cases this too is partially affected by the main factors through their control over species distribution in the preceding stand and in adjacent stands. Though the abundance of the competing species is readily discernible, the vigour may be temporarily suppressed by a dense main overstorey; it is the potential vigour that is important.

Four ratings of regeneration capacity recognized are listed below with characteristic features. They have been presented previously in a paper by Logan and Brown (1956). Their respective positions on the spectrum of physiographic sites are shown in Figure 2.

*Group E*—Sites where regeneration is easy, in sparse heath, heath-grass, and heath-herb types of lesser vegetation. The sites supporting these types usually have (a) very dry and poor soil, and (b) severe local climate (either warm-dry with desiccating winds, or cold-by-night, hot-by-day).

*Group M*—Sites where regeneration is moderately easy, in dense heath or weak shrub-herb and herb types. The sites included here are usually characterized by (a) somewhat dry and poor soil, and (b) moderately severe local climate (warm-dry southerly slopes with weakly desiccating winds).

*Group D*—Sites where regeneration is difficult, in moderate shrub-herb and herb types. The sites in this group usually have (a) fresh, rich soil, and (b) standard local climate.

*Group VD*—Sites where regeneration is very difficult, in shrub-herb, shrub, and herb types with a strong development toward dense shrubs or hardwoods. The sites in this group are usually characterized by (a) moist, rich soils, and (b) cool-moist local climates.



FIGURE 3. White pine on a fresh moulded till site; productivity = I; reproduction prevented by vigorous shrubs and maple advance growth.



FIGURE 4. A mixed pine-aspen type on somewhat dry dumped till; productivity = II; pine reproduction discouraged by dense shrub-herb vegetation.



FIGURE 5. A red and white pine type on a dry, sandy outwash plain; productivity = III; white pine seedlings frequent, amid the heath vegetation.



FIGURE 6. A poor stand of red pine, white pine, red oak, and aspen on a rocky ridge of dumped till; productivity = IV, scattered pine reproduction.

Exceptions to these general trends are not infrequent. Conditions which especially favour pine regeneration are the coincidence of a good seed supply with a fire which reduces competition and prepares a receptive seedbed, or with cutting in a well-stocked stand where ground competition is undeveloped. Subnormal reproduction levels may result from a continued seed crop failure or from an exceptionally dense overstorey of trees, shrubs, or advance growth fir or hardwoods. Summarizing, all features which discourage competition encourage pine reproduction and vice versa.

## General

Both productivity and generation ratings have been assigned to each of the physiographic sites of Figure 2, so that detailed correlations are possible.

They have also been generalized and applied to the four broad site types of Table 3. Here an interesting reversed relationship becomes evident—productivity of the pines increases to a degree with soil moisture whereas regeneration capacity decreases. This classification might be considered oversimplified but if its generalization is accepted it may prove useful, and it does serve to summarize the more marked ecological relationships of the pines. The approach is flexible and can be readily adapted in other pine areas.

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## APPENDIX I

### Nomenclature of Tree Species Mentioned

Symbol	Common Name	Botanical Name
bF	Balsam fir	<i>Abies balsamea</i> (L.) Mill.
S	Spruce species	<i>Picea</i>
wS	White spruce	<i>Picea glauca</i> (Moench) Voss
bS	Black spruce	<i>Picea mariana</i> (Mill.) BSP.
wP	White pine	<i>Pinus strobus</i> L.
rP	Red pine	<i>Pinus resinosa</i> Ait.
jP	Jack pine	<i>Pinus banksiana</i> Lamb.
wC	White cedar	<i>Thuja occidentalis</i> L.
eH	Eastern hemlock	<i>Tsuga canadensis</i> (L.) Carr.
hM	Hard maple	<i>Acer saccharum</i> Marsh.
rM	Red maple	<i>Acer rubrum</i> L.
wB	White birch	<i>Betula papyrifera</i> Marsh.
yB	Yellow birch	<i>Betula lutea</i> Michx. f.
A	Aspen	<i>Populus tremuloides</i> Michx. and <i>P. grandidentata</i> Michx.
Be	Beech	<i>Fagus grandifolia</i> Ehrh.
r●	Red oak	<i>Quercus rubra</i> L.
Bd	Basswood	<i>Tilia americana</i> L.
IH	Intolerant hardwoods	Aspens, white birch, etc.
TH	Tolerant hardwoods	Maples, beech, yellow birch, etc.