Recognition of Tree Species on Aerial Photographs

L. Sayn - Wittgenstein

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RECOGNITION OF TREE SPECIES ON AERIAL PHOTOGRAPHS

by

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Forest Management Institute
Ottawa, Ontario
Information Report FMR-X-118

Canadian Forestry Service
Department of the Environment
November 1978

ABSTRACT

A manual for the identification of the most important Canadian tree species on aerial photographs has been completed. The choice of scale of photography, focal length, flying height, films and filters as well as ecological species characteristics and the pattern of species association are discussed in general terms. Considerable emphasis is placed on the characteristic crown shapes and branching habits of individual trees and on the role of seasonal variations as an aid to photo interpretation. The identifying characteristics of approximately forty tree species are described in detail and guidelines and keys for their identification are presented. Many illustrations, in particular stereograms at large and medium scales, are included.

RÉSUMÉ

Un manuel devant servir dans l'identification sur des photographies aériennes des essences d'arbres les plus importantes au Canada a été complété. On y discute de façon générale du choix de l'échelle des photographies, de la distance focale, de la hauteur de vol, des films et des filtres ainsi que des caractéristiques écologiques des essences et du modèle de l'association des essences. On met une emphase considérable sur les formes caractéristiques des cimes et les habitudes d'embranchement d'arbres individuels et sur le rôle des variations saisonnières en tant qu'aide en photo-interprétation. Les caractéristiques d'identification d'environ quarante essences sont décrites en détail et on offre des lignes directrices pour leur identification. Plusieurs illustrations sont incluses, particulièrement des stéréogrammes aux échelles grande et moyenne.

CONTENTS

Contents (cont'd)

RECOGNITION OF TREE SPECIES ON AERIAL PHOTOGRAPHS

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INTRODUCTION

In the process of identifying tree species on aerial photographs, an interpreter usually begins by eliminating those species whose presence is impossible or highly improbable because of location, physiography or climate. Next, he will use his knowledge of species associations and of the ecological and site requirements of trees, to establish which groups of species occur in the area examined. The identification of individual tree species in these groups, using crown characteristics and other indicators is the final stage. Throughout this process the interpreter requires a thorough background knowledge of the forest, and he must rely on many weak clues, none of which would be sufficient if used alone.

However, the desirable experience and knowledge of forest conditions are often lacking and the indirect indicators of species, such as topography, drainage, aspect and association may be unreliable. These problems would become insignificant if one could use inherent species characteristics such as crown shape, type of trunk, branching habit, and the characteristics of the foliage as key features. It is not possible to identify trees solely by such morphological characteristics, at least not at small and medium scales, but the further one can advance the knowledge of how to identify species by the appearance of the trees themselves, the closer one will be to an objective method of species identification on aerial photographs.

It is therefore the purpose of this publication to concentrate on the relevant morphological characteristics, such as crown shape, branching habit and foliage characteristics. The complex but important subject of seasonal changes in the appearance of trees is also treated in some detail, because it is of vital importance in interpretation. Following this, tree species are discussed individually and for some species the more important distinguishing characteristics are combined to produce elimination keys. However, it is rarely possible to identify a species using only a key: reference to the individual tree descriptions is usually necessary.

The present publication combines previously published material (Sayn-Wittgenstein 1960, 1961 and 1967) with extensive revisions. No attempt has been made to cover the identification of forest types by analysis of Landsat data, for that is a book in itself. Brief references are made to space and aircraft projects involving aerial photography at very small scales, but emphasis remains on conventional scales of photography (e.g. 1:15,000, 1:25,000) and on large scales (e.g. 1:1000, 1:3000) which today play an increasing role in forest inventories (Aldred 1978).

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Most photographs in this publication are examples encountered during forest inventory projects of the Forest Management Institute (FMI). The details given with each illustration include location, data, scale and photo numbers. Photographs with the prefix "A–" can normally be purchased from the National Air Photo Library, Department of Energy, Mines and Resources, Ottawa. Photographs with the prefix "X–" and with a single photo number per stereogram are 1951 Sonne camera photographs; they are still among the sharpest prints held at FMI.

The author would like to acknowledge the valuable contribution of Mr. D.A. Wilson, Forestry Research Technician, FMI, who selected and prepared many of the stereograms, and provided technical comments for their discussion.

Other Publications

Some of the most important references on species identification are not concerned with aerial photography. Two books which are almost indispensible for Canadian photo interpreters are "The Native Trees of Canada" (Hosie 1972) and "Forest Regions of Canada" (Rowe 1969). The former includes botanical descriptions and information on the range of species while the latter describes common species associations and forest types, as well as the relationship between vegetation and topography in the different regions of Canada.

An excellent guide to the interpretation of all important Ontario tree species is Zsilinszky's (1966); it contains in-depth descriptions of each species together with excellent illustrations. The descriptions emphasize appearance on 1:15,840 photographs and the key characteristics include crown shape, tone, texture, site requirements and association. A very useful feature is the systematic treatment of the difference between easily confused species: Zsilinszky presents tables summarizing distinguishing features. The following is an example of this approach which often is more useful than a dichotomous key:

Features	Sugar Maple	Red Maple
Crown shape	flatly rounded, usually regular	upright growing branches, irregular
Crown size	wide	moderately wide
Crown texture	billowy	tufted
Crown density	compact	open rather than compact
Crown outline in vertical view	definite	indefinite
Canopy	closed	fairly open

Another valuable guide to the interpretation of forest types is available for Quebec (Ladouceur 1969). It summarizes general approaches to interpretation and then presents a series of high quality stereograms. All photographs are in black and white and at a scale of 1:15,840; photographic specifications and details on the stands involved are given for each stereogram.

The advantages of colour aerial photography for species identification are treated by Heller, Doverspike and Aldrich (1964) in a publication, which deals with most conifers and some hardwoods of the northeastern United States. It contains excellent colour illustrations at scales ranging from approximately 1:1200 to 1:4000 as well as descriptions of crown shapes, profiles, and the appearance of crown tops and margins; botanical terms are used. Another systematic description of shape and colour of eastern conifers is by Parry, Cowan and Heginbottom (1969). As in Heller *et al.* (1964) this publication uses Munsell colour values and proves the superiority of colour photography over panchromatic for species identification. Strong arguments are presented for combining colour data with morphological descriptions.

Western conifers are described in an undergraduate thesis by Aldred (1959) which includes detailed comments on morphology, tone and shadow patterns. An article by Lyons (1967) on fixed air base photography in British Columbia contains excellent stereograms at very large scales. The western species are also covered in the British Columbia Forest Service "Classification and Sampling Manual" (Anon. 1972).

A few western trees are described by Miller, Heller, Ulliman and Johnson (1976) in a pamphlet which discusses the interpretation of riparian vegetation and gives guidelines and keys to the interpretation of several shrubs and hardwoods.

Hegg (1966) has written a guide to the identification of land and forest types of interior Alaska. This well-illustrated publication, which contains several elimination keys, emphasizes medium scale photography and the description of forest types and their relation to site. It is an excellent reference for those involved in interpretation in Alaska, or in the Yukon and the Mackenzie River Basin.

Lauer (1967, 1968) deals with the identification of trees and lower vegetation of California on aerial photography. He concentrates on small scale photography, including Gemini VII photographs, but he also provides species descriptions at medium and large scales. Excellent photos illustrate the complex influences of scale, film, season and time of day.

European literature includes the work of Bos (1974) which is a systematic discussion of the appearance of several conifers and hardwood species. This work includes general discussions of crown shapes, texture and shadow patterns as well as information on individual species. Rabenau and Blasbichler (1969) have prepared a short key and description of the appearance of the most common native trees of Austria.

The interpretation of plantations and natural forests in India is covered by Tiwari (1975). The interpretation key developed relies on tone, texture and general crown shape; the study compares two scales of photography, 1:5000 and 1:20,000.

There have been several attemps to identify tropical tree species. An up-to-date review of literature on this topic is given by Sayn-Wittgenstein, de Milde and Inglis (1978) along with the results of experiments to evaluate the possibilities of identifying some Surinam trees on large scale photographs.

Photo interpreters should also be aware of the existence of two guides to the identification of forest damage. One of these, by Wear, Pope and Orr (1966), deals with western species; its emphasis is on the approach to sampling and analysis. Murtha (1972) has completed a richly illustrated manual on the interpretation of forest damage through insects, diseases and other causes, and he provides keys for the classification of damage.

GENERAL CONSIDERATIONS IN THE RECOGNITION OF TREE SPECIES

Scale of Photography

The extent to which species can be recognized on aerial photographs is to a high degree determined by the scale of photography.

The value of the characteristics of tree form, such as crown shape and branching habit, which are used for identification on large scale photographs, becomes progressively less as the scale is decreased, until eventually these features become so indistinct that they are replaced as key characteristics by photographic tone, texture and shadow pattern. These in turn depend upon too many variables to make specific rules of interpretation possible. Some of these variables are altitude of the sun, length of exposure, method of printing and developing, atmospheric haze, and characteristics of camera and lens construction.

As scale decreases, tone or colour becomes more important for identification; they are, however, strongly influenced by photo specifications and phenological changes, which will be discussed in a subsequent section. Species identification on small-scale aerial photographs is more of an art than a science if it is pursued by conventional interpretation methods. Its success will, to a high degree, depend upon the interpreter's skill and background knowledge of the area photographed.

Interpretation is always a subjective procedure, even if one has the facilities and experience to rely on computer-assisted pattern recognition and other methods for the classification of digital data, multidate overlays and enhancement. None of these methods is so mechanical and objective that it can be successfully applied without the background knowledge and intuition of the interpreter. The ability to observe details of crown shape, branching habit or foliage directly is lost at smaller scales, but the basic tree characteristics will still express themselves indirectly as changes in spatial patterns or as different spectral signatures.

The detail which can be seen at different scales varies with the quality and method of photography and the nature of the forest photographed, but the following may serve as a rough guide. On photographs at very large scales, such as 1:500, most species can be recognized almost entirely by their morphological characteristics because twig structure and leaf arrangement can be observed. For example, the individual leaves of ash and butternut become visible. At such scales one can usually draw up objective descriptions of the distinguishing characteristics of each tree species.

At scales of 1:2500 or 1:3000, small and medium branches are still visible, and individual crowns can be clearly distinguished. At 1:8000 individual trees can still be separated, except when growing in dense stands, but it is not always possible to describe crown shape. On the familiar 1:15,840 ("four inches to the mile") photographs, crown shape can still be determined from tree shadows, for trees growing in the open, or for large trees. At smaller scales individual trees generally cannot be recognized when growing in stands, and photographic tone and texture become the important means of identifying forest types, while crown shape is of little value. There are, however, exceptions: on particularly sharp photographs at a scale of 1:38,000 (Figure 29), the narrow pointed crowns of big white spruce trees could be seen clearly.

Photographs at much smaller scales (1:80,000, 1:100,000, 1:135,000) have been successfully used for mapping forest types and other vegetation types in boreal conditions where species composition is simple. Good examples of such applications can be found in the surveys of the Mackenzie River Corridor (Anon. 1974, 1975). Nielsen and Wightman (1971), using high quality colour infrared photographs at 1:160,000, have recognized major physiographic units, which combine vegetation characteristics and topographic features. Hardwoods and conifers could also be identified: upland hardwoods (mostly maple) were identified as a group; black spruce was recognized through a combination of tone and site and the poplars (mostly aspen) appeared consistently in a distinctive brick-red colour. The amount of information which could be extracted was surprisingly high if one considers the large jump involved in moving to this very small scale from the traditional scales near 1:10,000 or 1:20,000.

The term "scale of photography" is inappropriate when discussing images produced by Landsat scanners. However, Skylab photography shows the possibilities with very small scales. The U.S. Forest Service has carried out a series of Skylab experiments (Aldrich, 1976). The results are complex because independent experiments are involved. In general on Skylab photography from the S 190 B terrain mapping camera (enlargements from original scale of 1:900,000), forest land could be distinguished from nonforest land with acceptable accuracy and sometimes groups of cover types such as pine and pine-hardwood mixtures could be mapped.

Focal Length and Flying Height

Changes in scale of photography involve changes in focal length and flying height. Photo interpreters should be aware of the influence of focal length on the appearance of trees on aerial photographs.

With a long focal length trees are essentially viewed from above. There is little apparent difference due to changes in perspective within one photograph. However, in photographs taken with a short focal length, trees near the centre are viewed from above, but trees closer to the edge are seen at an oblique angle which approaches side view. The profile of trees can be observed. For example, Figure 1, which is a portion of a vertical photograph taken with a 150 mm lens appears to be an oblique. This oblique view is sometimes an advantage because many trees present a more characteristic appearance in profile. On the other hand, photo interpreters will have to realize that similar trees may appear quite differently in various portions of a single photograph (Figure 2). Allowances for differences in perspective and for the related changes in shadow patterns have to be made.

The large parallax differences, which result from the increases in air photo base often associated with the use of a short focal length lens, lead to very strong stereoscopic impressions. Tree crowns may appear of exaggerated height (cf. Figures 30 and 31).

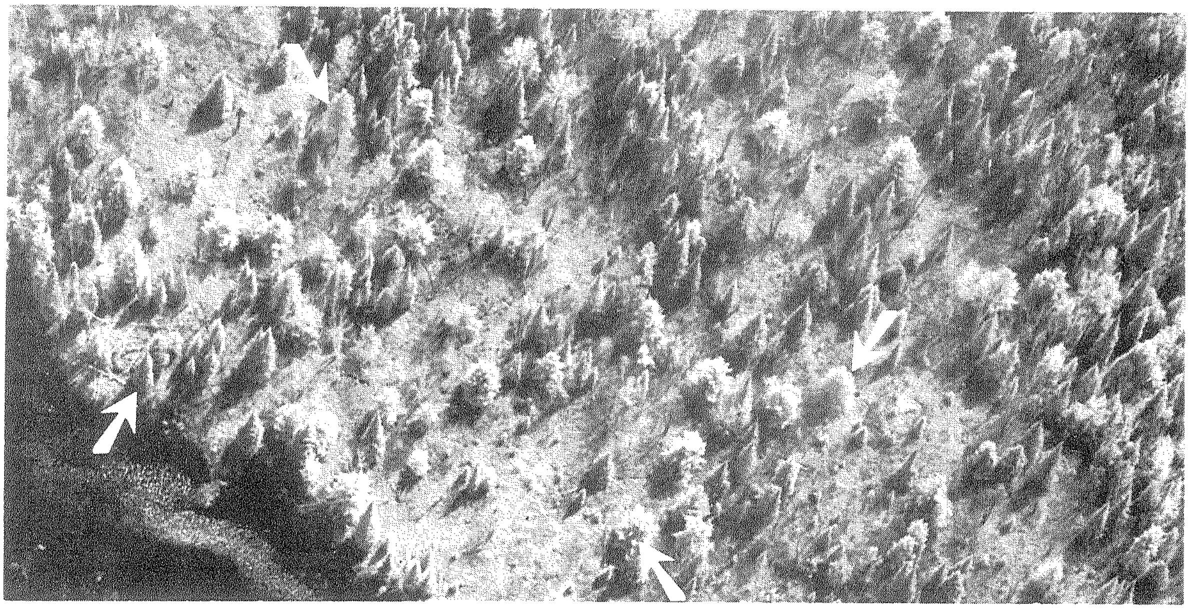


Figure 1. General crown shapes are easily observed on this infrared photograph which is a 4X enlargement from a contact scale of 1:7920. This is a vertical photograph, but trees are seen at an oblique angle because the position reproduced is near the edge of the photograph. Tree species indicated are, clockwise from lower left: balsam fir, red pine, red pine, white pine. (Petawawa, Ontario; May 6, 1959; scale enlarged to 1:1980 from 1:7920; photograph A-16387, 103).

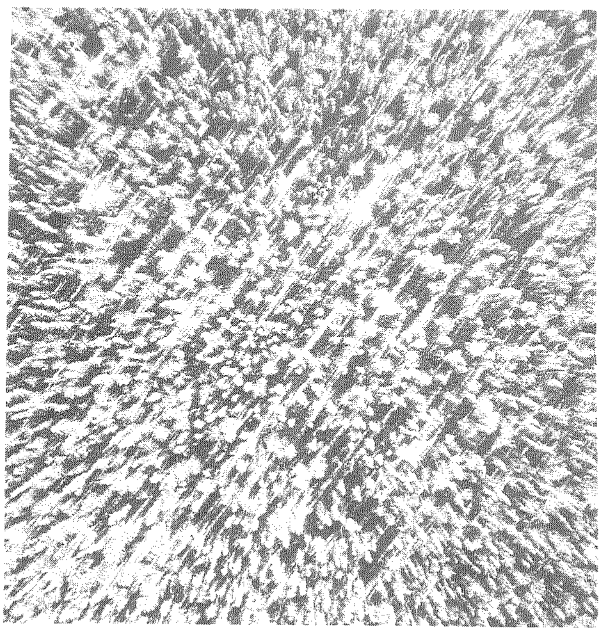


Figure 2. An area largely covered by white spruce, black spruce, aspen and lodgepole pine. The photograph is taken with a short focal length lens (76 mm). Trees near the edge of the image are therefore seen obliquely, while those near the centre are in overhead view. Illumination patterns vary greatly. Trees at upper right are backlighted, whereas the illuminated images and fewer shadows are seen at lower left. The appearance of similar trees therefore can vary greatly on this photograph.

Films and Filters

There is an abundance of literature on the importance of films and filters in forestry photo interpretation and no attempt will be made here to give a comprehensive review. However, the main points concerning the choice of films are as follows:

Panchromatic Photography

This is the type of photography which interpreters will most commonly encounter, and it therefore receives much attention in this publication. There are, of course, exceptions, but generally panchromatic photography at scales larger than 1:20,000 is satisfactory for interpretation in forests where species composition is simple, such as in the boreal forests. Its advantages include the fact that copies can be readily produced with simple darkroom facilities; also the wide exposure latitude of panchromatic film may offer an opportunity to correct mistakes in exposure and it permits darkroom procedures to reveal detail in the shadows or to enhance or reduce contrast. Costs are lower than for colour photography. Since there is a considerable record of experience in interpretation, using panchromatic photography, one can usually find old interpretated photographs for comparisons.

Black and White Infrared

This photography has declined in popularity. Its main advantage is that it produces a definite distinction between conifers and hardwoods; the latter appear in very light tones while the former are dark. The larches are the only exception: they appear in very light tones on infrared photographs. This separation of hardwoods and conifers, however, is achieved at the expense of a reduction in species difference among hardwoods; they all tend to appear in more or less the same light tones and differences are far fewer than on panchromatic photography (Figure 3). Also, on several sets of photographs examined, image details were not as clearly defined as on panchromatic photographs of similar scales. However, for high altitude photography, including most summer photography taken from above 10 000 m, infrared may have more significant advantages because of its ability to penetrate some haze, although not heavy haze and smoke.

Normal Colour Photography

For many years there has been much evidence that colour photography is superior to panchromatic photography for species identification. Two relevant references already cited are Heller *et al.* (1964) and Parry *et al.* (1969). Not only is species identification more accurate on colour film, but results are achieved more quickly. Other results suggest that even tree measurements, for which panchromatic photography was traditionally preferred, may be more accurately completed on colour (Aldred 1976). Little doubt remains that reliable interpretation of hardwood species will have to rely on either normal colour or colour infrared photography.

The disadvantages of colour photography include higher cost and the requirement for more complex film-processing facilities. Colour film also has narrower exposure requirements; it is not unusual to see, within one role of film, frames that have been significantly overexposed and others that are too dark due to underexposure. Such problems can be overcome by more experience, attention to quality control and proper equipment.

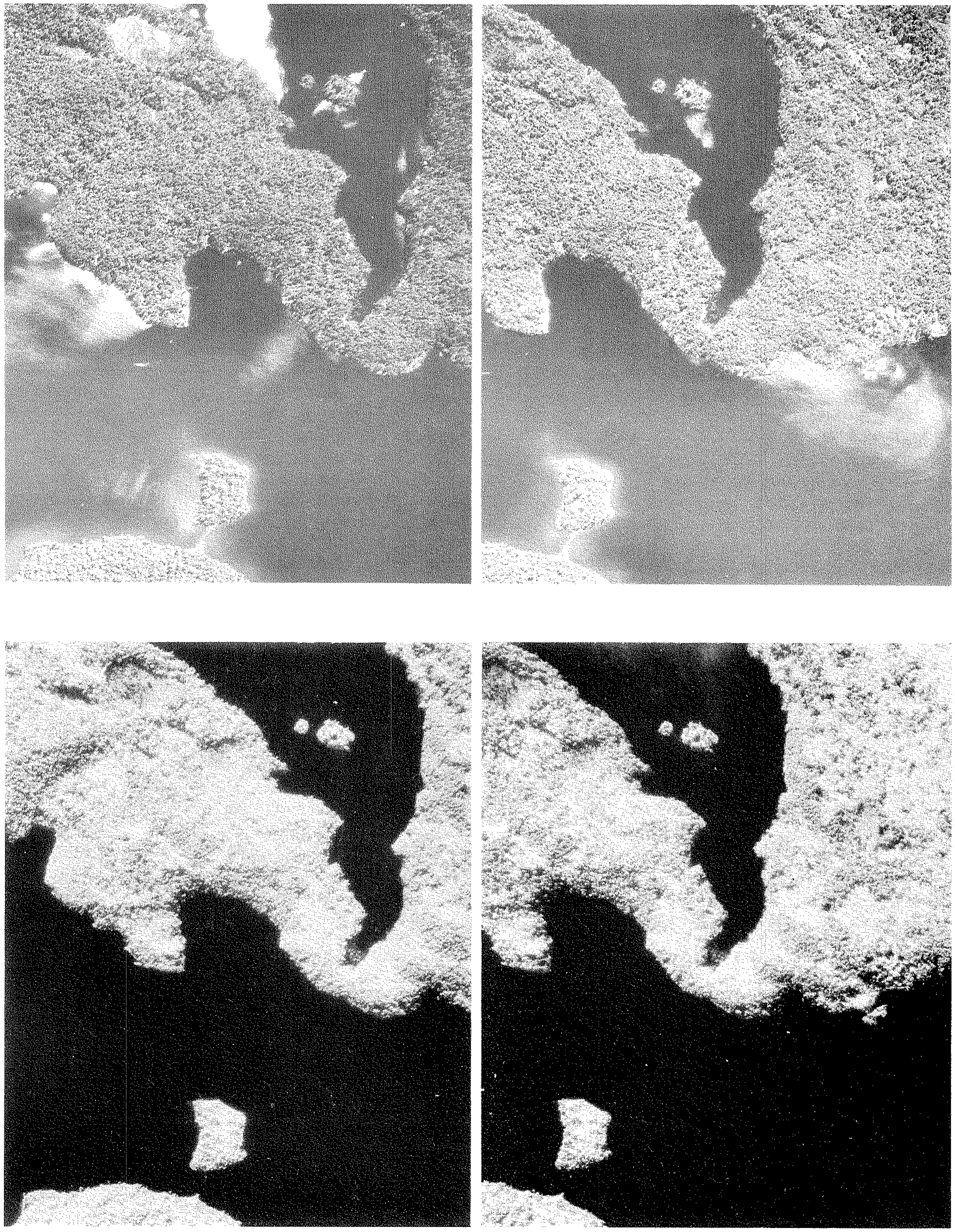


Figure 3. This comparison of panchromatic (top) and infrared (bottom) prints indicates the advantage of infrared in the basic separation of deciduous (light tones) species from the evergreens (dark tones). On closer examination one will see that the infrared emulsion limits the identification of broadleaved species. This example also illustrates that panchromatic photographs are superior to infrared for the interpretation of aquatic vegetation, shoals, shallows and wave and current patterns. (Whitefish Indian Reserve, Ontario; for panchromatic photograph: August 18, 1968; scale 1:12,000; photographs A-20708, 53, 54; for infrared photograph: July 16, 1965; scale enlarged to 1:12,000 from contact scale of 1:16,000; photographs A-18908, 50, 51).

There are significant differences between colour negative film (negative leading to paper print) and reversal film (which yields a positive transparency). In FMI experience, reversal film has been the most unforgiving where errors in exposure are concerned. Colour negative film allows more latitude and also provides opportunities for modifications in the printing process. The amount of image detail, however, is much greater on diapositive material than on paper prints.

Colour Infrared Photography

This film undoubtedly has potential for species identification, but its disadvantages must also be considered. The film has traditionally found most use in vegetation damage surveys, but most recently, particularly for small scale photography, it has been applied in other vegetation surveys. For high altitude photography, for example in FMI experiments at flying heights near 13 000 m, it proved far superior to panchromatic and normal colour film. This superiority, largely due to a haze penetration capability, is confirmed on theoretical grounds.

The disadvantages include a considerably higher cost for materials and stringent requirements for film handling before and after exposure. Quality control is critical and differences in the quality of results from one mission to the next are common. Also, because the yellow filter prescribed for colour infrared films blocks out the blue portion of the spectrum, which is the main constituent of light in the shadows, shadows on photographs are very dark and little detail appears in the shaded portions of crowns and on the forest floor.

Colour infrared photography will reveal an abundance of hues and colours, but photo interpreters will have difficulty in relating these artificial colours to ground observations. For many interpreters the problem is thus one of too much information being offered. The necessary training and experience with this film is often not available and allowances for time spent in learning its characteristics must be made.

Silvics, Ecology and Species Identification

A knowledge of the ecological and silvical characteristics of tree species is of great value in the interpretation of aerial photographs. Identification of a species on this basis alone is not positive, for no species has such rigid site requirements that exceptions do not occur and some, as for example white pine, will grow on a great variety of sites. Yet most species have well-known site preferences and in practice the consideration of soil, site and climate offer important keys to species recognition. For instance, if hardwoods are observed on a swampy location, they are more likely to be elm or black ash than beech or oak, and similarly black spruce can often be recognized because of its tendency to grow in bogs, while white spruce is more often found on better drained soils. A shallow layer of soil, which may be indicated by frequent outcrops of bedrock, would exclude trees which have a deep root system. Familiarity with the common species associations found in the forest will also be most useful, for example where a species which is difficult to identify is commonly associated with one which is easily recognized. If one of the two is recognized in a stand, then the presence of the other can be expected. Conversely the presence of one species may make the presence of another most unlikely, for some species rarely occur together.

The interpretation of Figures 29 and 47 is a good example of the value of background knowledge. An experienced photo interpreter would immediately recognize this area as alluvial flat land. With this observation and with an understanding of species association and ecological succession in northern Canada, he would proceed without difficulty to identify white spruce, balsam poplar, and the shrubs of this area. In this process he would be assisted by descriptions from past vegetation surveys or forest inventories of the area. Such reports are a valuable aid to photo interpretation even if they make no reference to aerial photography.

The type of stand, pure or mixed, which species tend to form, can be a guide to identification. Some species, for example, aspen, jack pine and black spruce, often form pure stands, (*see*, e.g., Figures 19, 33 and 50), others such as basswood and ash usually grow in mixtures. Figure 72 shows one of the rare examples of an extensive pure stand of black ash; had it not been for the wet site involved, identification would have been extremely difficult. If trees that are intolerant to shade, such as larch and aspen, grow in mixtures with other species, they tend to be dominants. Tolerant northern hardwoods, often develop all-aged stands and may therefore be recognized by the presence of many different crown sizes.

The property of aspen to reproduce root suckers and to form clones may identify this species. Clones are sometimes well differentiated from each other during periods of rapid phenological change (leafing out and leaf fall) because there may be differences between clones in the rate of phenological development. Other species such as white birch and basswood tend to coppice and to develop several stems in a cluster (Figures 54, 70, 71).

The knowledge of ecological succession and typical stand histories is a valuable asset. For example, it is known that eastern white cedar and eastern red cedar are pioneer species which invade abandoned fields and pastures; this knowledge is applied in identifying the trees in Figure 43. Jack pine, lodgepole pine, Douglas fir, aspen and white birch frequently come in after forest fires or windthrow; old fire boundaries and evenaged stands are therefore good indications of the presence of such species. Another interesting example is the identification of alder in Figure 57.

Evidence of damage and disease is an indirect aid in identification. For example, the fact that the trees in Figure 48 have been felled by beaver adds to the strength of their identification as aspen. The presence of dead trees in a suspected elm stand is valuable supporting evidence because of the prevalence of Dutch elm disease. The widespread attacks of spruce budworm have made it easier to identify balsam fir and white spruce in eastern Canada (Figure 41).

Identification by Crown Characteristics

On vertical aerial photographs trees are often seen in an unusual perspective and, therefore, many key characteristics by which trees are ordinarily identified are no longer visible, while new ones appear. For instance, the trunk may be hidden by the crown, but the branching habit in the upper parts of the crown will show itself distinctly. Sometimes these new features are surprisingly prominent; *see*, for example, the tufted branching of red maple (Figure 69). In general it is easier to identify trees seen in side view, such as on oblique photographs or near the edge of photographs taken with a wide angle lens.

To use aerial photographs to best advantage it is essential that trees be viewed stereoscopically. This is particularly so with vertical photographs, for it is most difficult to recognize even general crown shape without stereoscopic examination. This publication contains stereograms which should be viewed through a stereoscope.

Although there is one, or in some cases several, typical crown shapes for each species, there will be many deviations, for crown shape varies greatly due to the influences of environment and genetics. In this publication emphasis is placed on the description of typical crown forms. Some species are less variable than others, but exceptions exist for all.

A few species have typical crowns which can be easily described, but often, especially for hardwoods, a description of typical crown shape is difficult. Common crown types are shown in Figure 4.

Satisfactory definitions for the terms used in describing crown shape, texture and branching habits have yet to be developed. Some definitions have recently been assembled for a project dealing with the identification of tropical trees on large scale photographs (Sayn-Wittgenstein 1978).

With the increasing use of large scale photography, branching habit deserves more attention. Branching characteristics which ought to be recognized are listed below; examples are given in Figure 5.

- length and thickness of branches,
- variation in branch size (e.g. "a few prominent large branches, regular, uniform branching"),
- branch direction: ascending, horizontal, drooping,
- branch form: straight, crooked, twisted,
- arrangement of branches and twigs; e.g. two-ranked, dichotomous,
- density and coarseness of twigs,
- colour of bark.

The characteristics of foliage also influence the appearance of tree crowns. Tone and colour of trees in leaf are, of course, largely determined by the foliage. Trees with large and glossy leaves tend to appear in lighter tones and may sometimes produce highlights due to specular reflection. For some species wind can introduce deceptive variations in tone and colour, because leaves are turned, exposing the lower surface which may differ from the upper surface. For this reason a silver maple in a breeze will appear whitish green, while balsam poplar may show a brownish tinge. Dense foliage often gives the impression of a "solid" crown and if accompanied by a regular crown shape it can leave a strong impression of a crown as a regular geometric solid (e.g., balsam fir, basswood).

Shadows visible inside the crown, (Figure 23), as well as the shadows cast on the ground, indicate crown features. It is occasionally possible to see the entire shadow of a tree in an opening in the forest, and in such cases the shadow may reveal more than the tree image. Hardwoods photographed on sunny winter days offer good examples.

At larger scales the density of the shadow cast is a useful identifying characteristic. A dark shadow will indicate a compact crown and dense foliage, while a light shadow is the result of an open crown and thin foliage. For instance, against a background of snow, both the crown and the shadow of spruce will be darker than for jack pine. Similarly for trees with dense foliage, there will be a greater tone contrast between the shaded and the sunny side than for trees with little foliage. If no large shadows are visible inside a crown this may mean that the individual branches are not prominent or that the crown is closed. This feature is much less apparent at small scales than at large ones.

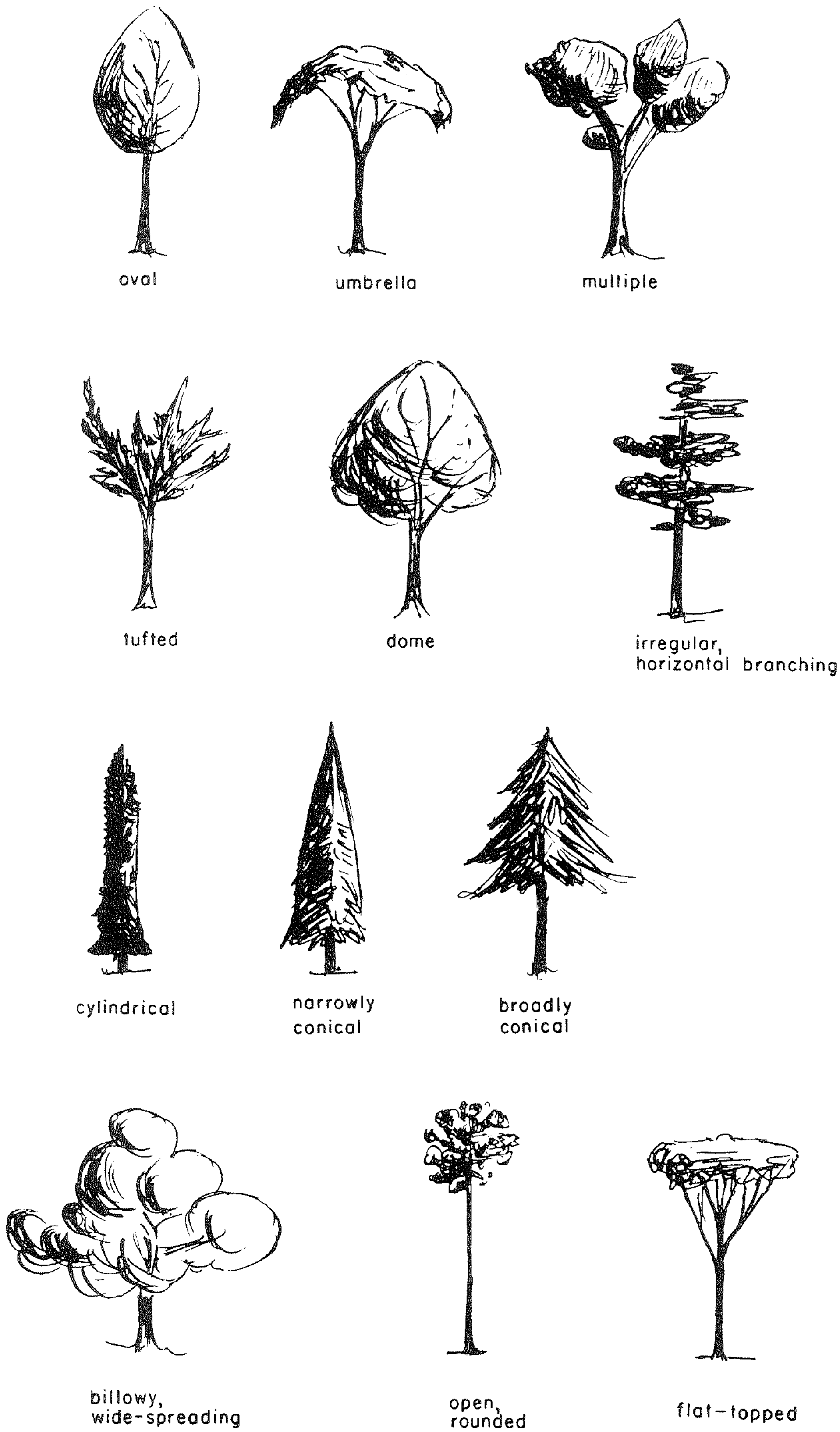


Figure 4. Some common crown types.

Figure 5. Typical branching habits. Clockwise, from upper left: The somewhat irregular branching of aspen. Note that small twigs are relatively coarse and that the central bole is clearly defined; the fine ascending branches of red maple; the coarse, relatively short and rapidly tapering branches of basswood. The arrangement of smaller branches and twigs explains why the crown perimeter is usually smooth and well defined on aerial photography; the dichotomous or staghorn branching of sumac; the long, relatively straight and slender branches of elm; the coarse and twisted branches of bur oak.

Conifers are more easily recognized than hadwoods, because most have a definite and characteristic shape, while hardwoods tend to be irregular. It is difficult to identify young trees of any species because they often have not developed typical shapes.

The northern tolerant hardwoods, the maples, beech, elm, and yellow birch are the most difficult species to identify, although as a group they can be recognized by their large, dense and rounded or irregular crowns. With the exception of sugar maple, they seldom form pure stands, but usually grow in complex mixtures, frequently with white pine, hemlock, white spruce or red pine. Such stands are characteristically all-aged and many different crown sizes can be observed. The identification of individual hardwoods in this group is often impossible at medium and small scales because the various species either do not possess a sufficiently distinct crown form, or they cannot develop it in a closed stand where they tend to develop tall trunks and small crowns. In the open they would be more branchy, with a deeper and more symmetrical crown. Overmature trees, whether growing in a forest or in the open, develop wide-spreading open crowns.

Often the only difference which can be detected between species will be a slight difference in tone. The interpreter may therefore be able to establish that several species are present, but to identify them he will be forced to rely on his familiarity with species associations, phenology, or on his knowledge of the relationship of species distribution and physiography. He may have to develop a local tone-key.

Before proceeding to describe the species composition in a given area using aerial photographs it is normal to begin by examining the photographs to determine which characteristics appear to be the most useful for identification: it may be tonal differences, or crown form, or some regular patterns of species association. These observations should be considered in conjunction with existing ground information and doubtful conditions should be noted. Then, if at all possible, the interpreter would go into the area with the photographs to spot check and to develop a local interpretation key which would then be used for detailed mapping of timber types.

The Season of Photography

Seasonal variations are among the most important influences on the appearance of trees on aerial photographs. Phenology should therefore be studied to make recommendations concerning the best season for aerial photography. However, the problem is much broader: photo interpreters often do not have control over the date of photography, and if they did they would find that what is the best season for one purpose is only second best for another. The choice of season of photography involves many compromises and anyone attempting to identify tree species will have to understand the patterns of phenological change in a forest. The following pages will, therefore, discuss the more important phenological developments in the forest and the properties of aerial photographs taken in different seasons.

Spring Photography

(1) Before the leaves appear. Photographs taken in the early spring, before the first trees leaf out have much in common with late fall and winter photographs. In both cases deciduous trees are bare and easily distinguished from evergreen (e.g., Figure 34). Individual evergreens can often be successfully identified because the view of their crowns is not obstructed by deciduous foliage. Small and suppressed conifers, which would remain hidden on summer photographs, can be detected. However, this prominent appearance of evergreens leads to a tendency to overestimate their proportion in mixed stands. A special advantage of early spring photography is that there are no leaves on shrubs, and tall herbs, such as ferns, have been matted down by the snow during the winter. The ground surface is therefore more clearly defined than at any other time of the year.

If sharp photographs at relatively large scales are used, then the characteristics of the trunk, the branching habit, and the twig structure are guides to the recognition of hardwood species. For example the chalk-white trunks of white birch show up clearly and this species can be distinguished from the tolerant hardwoods, which have darker bark, and from aspen with its greyish bark (Figures 54 and 34).

Should colour photographs be available, some trees can be identified by the colour of their bark. For example, the bark of trembling aspen is greenish-grey or whitish, that of largetooth aspen similar, but with an orange touch, while the bark of balsam poplar is dark. The twigs and the immature catkins of white birch are reddish-brown; the crowns therefore have a distinctive colour before the leaves emerge.

Since the ground surface can be seen in hardwood forests, small drainage channels and rock outcrops are revealed. This helps in site evaluation and provides indirect evidence of the occurrence of species.

(2) During the period of leaf development. As the foliage appears on trees, it obscures the trunk and branches and dominates the appearance of crowns on aerial photographs. It is easy to distinguish a tree that has leafed out from a bare one, and it is therefore important to understand to what extent one can rely upon the order of leafing out for identification. Foliage changes in colour, size and density as it matures: the rate of leaf development must, therefore, be considered. In a few cases the flowers of trees result in a characteristic appearance during the spring.

(a) The order of leafing. Even a casual observer of trees in the spring will notice that there are large differences between the dates when different trees leaf out. Some trees will be in full leaf, while the buds on others appear dormant. If spring is long and cold then these differences are particularly great. This order of leafing out is illustrated by a summary of phenological records from several parts of Canada (Appendix, Tables 1 to 3).

Before drawing conclusions from such data, one should consider a limitation. Phenological events are part of a continuous process (as is illustrated by Figures 6 and 7) and it is difficult to describe their start or end by an exact date. One must therefore be cautious in ascribing significance to differences of only a few days.

The data in Table 1 (Appendix), confirm that there is a degree of regularity in the sequence in which different species leaf out. Some are consistently among the first to leaf, while others are always among the last. In the first group we find, for example, tamarack, trembling aspen, and white birch, while beech, oak, and hickory are among the later species. Figure 7, which describes the time of leaf development and leaf fall for trembling aspen in different locations, could therefore be used as a rough guide to the dates of leafing and leaf fall of other species. Figure 56 shows a good example of how knowledge of the order of leafing out can help in identification.

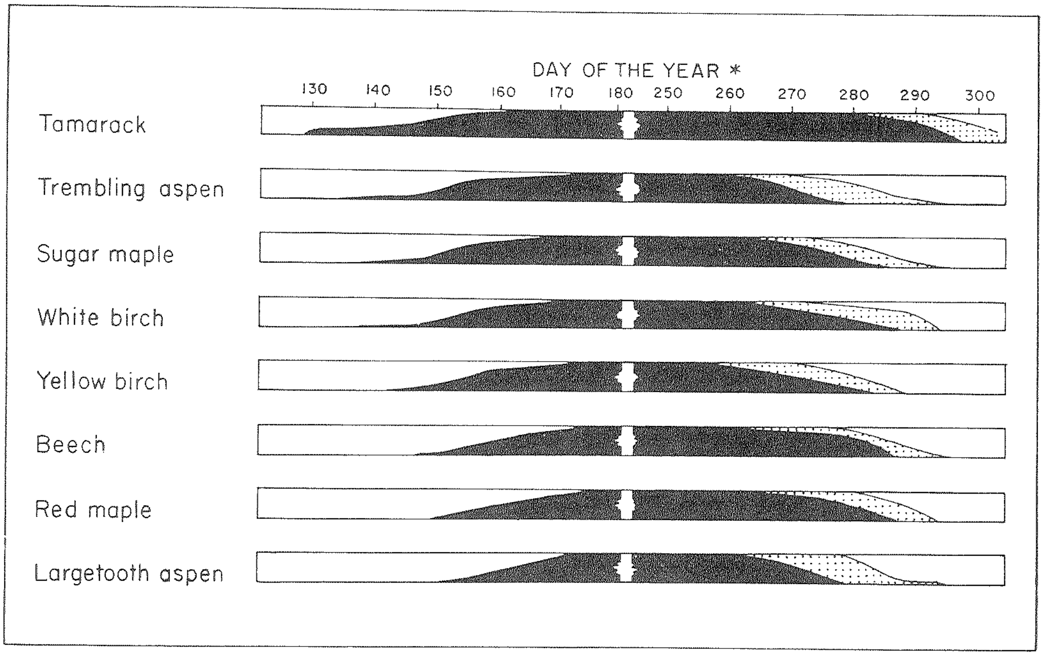


Figure 6. Illustration of the gradual nature of the development and fall of foliage. The portion of foliage developed in the spring and of green foliage remaining in the fall is indicated by the dark areas, while the light, dotted areas show the part of the foliage in fall colours. The figure is based on one year's observations on a small area and is not intended to show the typical sequence for the various species. (Drawn from data collected in 1948 near Petawawa Forest Experiment Station by C.J. Lowe and D.G. Fraser, Canadian Forestry Service).

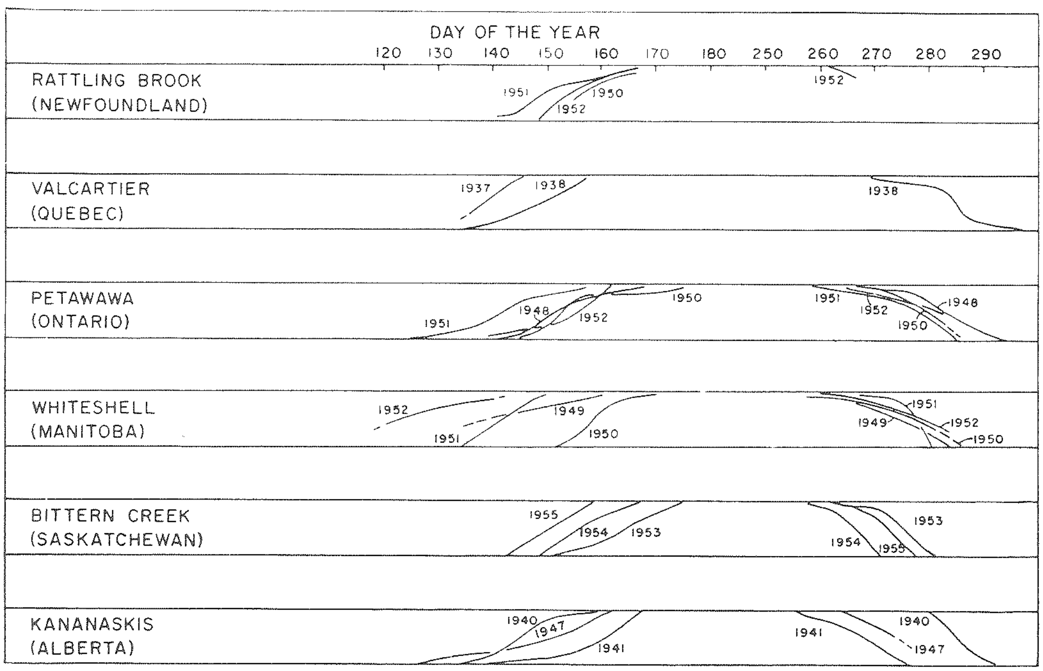


Figure 7. The portion of the foliage of trembling aspen developed or fallen on a given date is shown for various locations. The curves were drawn from data of the Forest Fire Research Institute, Canadian Forestry Service.

There is a relationship between the limits of the latitude of the natural range of a species and the time of leaf-flushing. Trees with a natural range extending to the far north (e.g., willow, tamarack, white birch) are among the first to leaf out, while the more southern species (e.g., beech, hickory, yellow birch) come later. In Ottawa, the last to flush are southern species such as catalpa, Kentucky coffee-tree and sycamore.

The order of leafing often varies from year to year for a number of reasons including the following:

(1) differences in site,
(2) variations in temperature in the period between dormancy and the flushing of the leaves,
(3) genetic differences within one species,
(4) age and vigour of trees, incidence of disease.

Differences in site, that is, mainly in local climate and soil, are obvious reasons for variations in the date of leafing. On swampy locations and cool, north-facing slopes leafing will occur later than on warm and sunny sites. For example, on the same location sugar maple will leaf out earlier than red maple, but sugar maple growing on a cold and wet site, will leaf out later than red maple on a dry and sunny site. Differences of up to two weeks between the dates of leafing on different sites have been observed. MacHattie and McCormack (1960) have observed that, although numerous exceptions exist, the trend is for vernal phenological events to occur first on the ridge top, then on the south slope, and last on the north slope. The change to fall colours tends to occur in reverse order.

A change in the sequence of leafing of different species is best explained by variations in the early spring temperatures. There is a theory that for each species a certain summation of temperature (time X temperature above a minimum) is necessary to produce a given phenological event. This theory, which implies a fixed order of leafing out, has been criticized in detail by Tamas (1959). The main criticisms are:

(1) The rate of growth activity does not vary directly with temperature, but for each species there is an optimum temperature at which activity will be faster than at any higher or lower temperature. Should the air temperature remain near the optimum temperature for any one species for a significant time, then that species will leaf out relatively earlier.

(2) The minimum temperature at which growth activity begins varies for different species. If this minimum temperature is -5°C for species A and -7°C for species B, then only A will advance during those periods when the temperature fluctuates between -5°C and -7°C.

Often one can observe differences between individuals of one species growing on the same site that appear to be due to genetic variations. Leopold and Jones (1947) report differences in the time of blooming and leafing of trembling aspen clones, which were not related to site. In another instance (Anon. 1958) two adjacent clones of trembling aspen, in both cases males of similar ages, differed by about two weeks in time of leafing. After an intensive study of phenological variations in sugar maple, Kriebel (1957) came to the conclusion that the time of flushing is under rigid genetic control.

Age and vigour seem to influence phenology. Seedlings and sprouts leaf out earlier than mature trees. In a few cases diseased trees leafed out much later than healthy ones; on the other hand it is reported that certain virus infections stimulate early leafing.

Some statistics on the flushing of leaves are given in the Appendix, Tables 1, 2 and 3 and in Figures 6 and 7.

(b) Characteristics of spring foliage. Young leaves are lighter than mature ones and often have a fresh green or yellowish colour. According to measurements by Shull (1929), young basswood leaves reflect up to three times as much light as mature ones. Differences of this kind were less in cottonwood, another native species investigated. The tone contrast between hardwoods and evergreens in the spring is so pronounced that panchromatic photographs taken in that season resemble infrared photographs, with many hardwoods, particularly the sugar maples, appearing very light, the conifers dark. However, not all hardwoods appear light: white birch and balsam poplar are almost as dark as the conifers (Figure 8).

The contrast between the light hardwoods and the conifers is further accentuated in early spring because dark green, sometimes even brownish winter colours still characterize the foliage of conifers.

About three weeks after the leafing of hardwoods has begun the difference in tone between hardwoods and conifers is much smaller because the hardwood leaves have darkened and the growth of fresh, light green coniferous foliage has begun (Figure 9). Slight differences in colour and rate of development of young foliage of balsam fir

Figure 8. In late spring and early summer many hardwoods have light colours, while the conifers, with the exception of tamarack, are darker. The resulting tonal differences are almost as distinct as the difference between hardwoods and conifers on summer infrared photography. (Petawawa, Ontario; June 2, 1965; average scale 1:700; oblique photograph F-45, 111).

Figure 9. Black spruce branches showing the tone contrast between young and old needles (Petawawa, Ontario; July 18, 1960).

and white spruce may help to distinguish these species. Another possibly significant observation is that in southeastern New Brunswick new foliage appeared on red spruce approximately two weeks later than that of balsam fir.

The rate of growth of leaves varies between species, although these differences may be diminished by the sudden onset of warm weather, which will cause rapid growth on all trees. The leaves of basswood and sugar maple appear to reach full size rapidly, while those of the oaks, white birch and elm grow slowly.

Spring and early summer photography are the best for distinguishing sugar maple and yellow birch. In one instance yellow birch appeared sufficiently darker than maple to make it possible to identify individual trees at a scale of 1:12,000 (Figure 53). This tone contrast, greatest on photographs taken in the spring has also been observed on late summer photography. It is caused by both phenological and other characteristics of the two species. Yellow birch has a more open crown and smaller leaves than sugar maple, with the result that it reflects less light and shows more of the shadows contained in the crown. In addition the leaves of sugar maple are lighter than those of yellow birch, particularly during the late spring when they have a definite yellowish hue.

Largetooth aspen is easily distinguished from trembling aspen and from other hardwoods on late spring photographs. First, it leafs out much later than trembling aspen, and secondly, its leaves are covered with a fine, white down that gives the crown an almost white appearance (Figure 10). This lightness is in part also due to the conspicuous catkins which appear before the leaves. The foliage loses its light colour about two weeks after leafing. Separation of the two aspen may seem inconsequential, yet by positively identifying largetooth aspen the photo interpreter may, through his knowledge of the forest, obtain evidence of the occurrence of other species. Another useful difference between young leaves involves red oak and sugar maple, as illustrated in Figure 11.

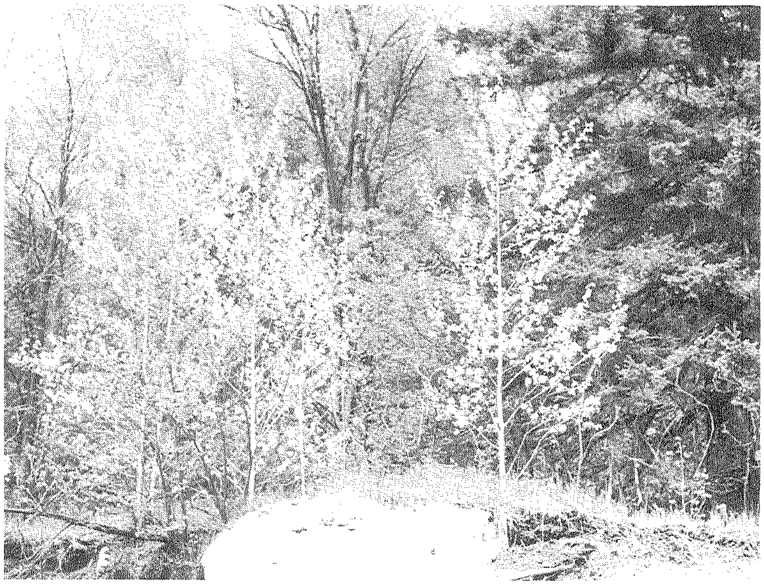


Figure 10. The almost white, young foliage of largetooth aspen contrasts sharply against a background of other trees (aspen, white elm, sugar maple and white pine). (Ottawa, May 15, 1960).

Figure 11. Comparison of the tone of young foliage of red oak (right) and sugar maple (left). The oak leaves are significantly darker, because they have a purplish tinge. When mature they are large and glossy and give the crown a light appearance on aerial photographs (Ottawa, May 15, 1960).

(c) The flowering of trees. Because most Canadian trees have small and inconspicuous flowers, their appearance on aerial photographs is affected only if the flowers are relatively large and abundant (basswood), or appear before the leaves. The date when flowering begins varies for reasons corresponding to those which affect the time of leafing. In addition there is the difficulty that the end of flowering is subject to great irregularities. For example, a strong wind can blow the flowers off soon after they are formed.

The white catkins of the poplars and willows and the red flowers of the red and silver maple are distinct and could be useful identifying features on colour photographs. Poplars and willows, however, are notorious for genetic differences within species; these differences probably include the time of flowering.

Summer Photography

Summer is a widely used season for photography because the weather is usually good for aerial photography and also because the appearance of a single species will not vary within a large area, as it often does in spring and fall. For these reasons several large forest inventories in Canada have relied on summer photography.

However, the many colour differences between the immature foliage of hardwood species disappear during the summer; young foliage darkens as it matures and the difference in tone between hardwoods and conifers becomes so insignificant that it may be necessary to resort to infrared photography to distinguish these groups.

The tone contrast on infrared photographs is the result of less infrared radiation being reflected from conifers than from broadleaved trees. Consequently one of these groups may be either over or underexposed, which has a detrimental effect on the quality of photography. The tone difference between conifers and hardwoods on infrared photographs appears to decrease gradually as the summer advances. One would therefore expect that infrared photography taken in the late summer is superior to that taken in the early summer, because over or underexposure of hardwoods and conifers is avoided.

Phenological changes of trees during the summer are usually inconspicuous or very gradual and are unimportant in the identification of species on aerial photographs. Two minor phenomena are the flowering of the basswoods and the fruiting of hop-hornbeam. In both cases the brightness of the crowns involved increases. The cones of conifers, such as white spruce, black spruce and balsam fir are often clearly visible on large-scale colour photographs. Differences in the colour and arrangement of cones may help in identification.

Fall Photography

The change to fall colours is a gradual process, which partly overlaps with the loss of foliage (*see* Figure 6). Among the first to turn colour are some, although by no means all, red maple and white elm. The other species then follow without reliable order. Cottonwood, the oaks, silver maple and hawthorn remain green after most other trees have turned. Drought tends to hasten the change of colour, and for this reason trees on rocky and dry sites assume their fall colours earlier. This, however, needs to be qualified. For example, red maple in swamps or depressions usually changes colour first, because of local forests. Also, a high water table or flooding may cause early colouration. The work of Kriebel (1957) suggests that the time of colouring is under strong genetic influences. It follows from all this that there is a substantial risk of errors if one relies on fall colours for identification. Differences between individuals of one species in the time of colour change usually are too great to make this phenomenon of practical usefulness in species identification. Exceptions however do occur, especially if few species are involved (Figure 51).

(a) The fall colours. As has been just stated, the order in which trees change to their fall colours is erratic. In addition the colours of any one species vary due to genetic differences, soil characteristics, the weather and other factors. For example, sugar maple foliage ranges from the usual yellow or orange to red. One tree may also pass through several distinctly different phases of colouring, as for example beech, which first turns yellowish brown before reaching a more russet colour.

However, if that heavy leaf-fall does not occur too soon, there will be several days during which most deciduous species will be in their fall colours and will exhibit characteristic differences in colour or corresponding tones on panchromatic photos. At that time the distinction of deciduous trees and evergreens is easy because, as on early spring panchromatic or summer infrared photos, the evergreens are relatively dark.

The majority of the deciduous species turn yellow or light brown in the fall. In this group are the elms, poplars, birches, hop-hornbeam, silver maple and tamarack. Sugar maple sometimes turns orange-yellow or red; the leaves of red maple turn a brilliant red. The contrast between yellow and red trees can be increased on panchromatic photographs by the use of filters. Beech and oak have their own characteristic russet or reddish brown colours, and therefore appear darker than other hardwoods on panchromatic photographs. With colour photography they are easily distinguished from the maples (Figure 12). Basswood and willow lose many of their leaves while they are still partly green.

While many different species distinctions can be seen on fall photographs, the appearance of the foliage varies too much to make hard and fast rules for identification possible. In practice it is usually necessary to make field checks and to draw up a local key. An example of such a key is that by Chase and Korotev (1947). The successful identification of several species and species groups on fall photographs of the Petawawa (Ontario) area has been described by Losee (1942).

(b) The falling of the leaves. The order in which trees lose their leaves is an unreliable guide to their identification, for although it follows some rules, there are too many exceptions. Variations are often due to site, vigour of the tree, and exposure to the elements. Alternating freezing and thawing accelerates leaf-fall (Büsgen and Münch, 1929). The extent to which trees are exposed to wind is one of the major factors affecting leaf-fall. However, frequently, and for no apparent reason, some trees are only beginning to lose their leaves, while others of the same species and growing nearby, are almost completely defoliated. The crowns of partly defoliated trees appear hazy and indistinct on air photos.

One of the general observations about leaf-fall is that the large and compound leaves are the first to fall. Thus black ash and butternut are the first trees in the Ottawa area to lose their leaves. Then follows the majority of species with no clear differences between them. The leaves of the elm and basswood are falling when cottonwood and some oaks are still green. The oaks, beech, and the poplars are among the last to be defoliated. (Figure 7 shows the time of leaf-fall for trembling aspen in different locations). Red oak keeps its leaves longer than bur oak. In most cases white

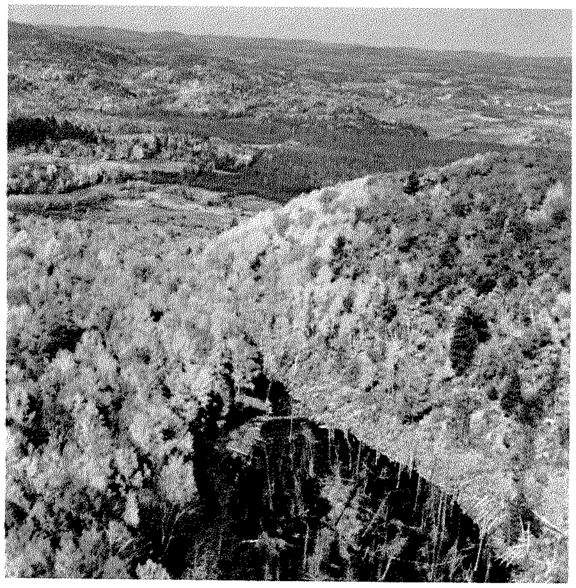


Figure 12. Several hardwood species can be recognized by their fall colours. The orange and dark yellow colours of the stand at the left are largely due to sugar maple. The light yellow trees near the centre of the photograph are aspen, while the dark brown and russet crowns near the top of the hill on the right are red oak. (Gatineau Park, Quebec; October 13, 1972).

birch loses its leaves before both species of aspen. Some exotics, such as Norway maple, are peculiarly late in dropping their foliage. Tamarack is the last species to lose foliage and its crowns retain a distinctive yellow colour well into November. A few oak and beech trees, usually young ones, keep some of their foliage throughout the winter.

Statistics on leaf-fall and colouration are given in the Appendix, Table 4.

Winter Photography

Winter photographs are characterized by sharp contrasts: fields, swamps, lakes and rivers are covered with ice and snow and appear in brilliant white, while coniferous forests are very dark. It is perfectly obvious that coniferous forests can be quickly recognized when the landscape is snow-covered. But, this advantage is achieved at considerable cost: snow obscures most details of the ground surface, and those interested in the study of soils, geology and agriculture, will be severely hampered. Even bodies of water are often improperly identified. Snow on evergreen crowns will interfere with identification and photogrammetric measurements. It is, however, also true that, as Seely (1949) has observed, trees and their shadows will often appear very clearly against a bright background of snow. Losee (1952) recommends photography taken after the first snowfall as excellent for surveys of evergreen regeneration. These advantages are offset by the fact that much photographic detail may be lost due to irradiation and halation. Light from bright objects tends to spread in the photographic emulsion and thereby to obliterate the images of darker objects. This is most noticeable when the branches of deciduous trees are photographed against a bright background of snow; they appear thinner than they actually are, or they may be completely washed out. These are severe limitations, which become less important if photography is taken on cloudy days. There is also evidence that conifers which have been partially defoliated by insects can be best recognized in the winter.

DESCRIPTION OF INDIVIDUAL SPECIES

1. THE CONIFERS

Key to Eastern Conifers

1. Crowns small, or if large then definitely cone-shaped.

   2. Crowns broadly conical, usually rounded tip, branches not prominent . . . . cedar.

   2. Crowns have a pointed top, or coarse branching, or both.

      - crowns narrow, often cylindrical, trees frequently grow in swamps, foliage and cones may form dense clump at top, ... swamp-type black spruce.

      - crowns conical, deciduous, light-toned (very light-toned in fall) . . . . tamarack.

      - crowns narrowly conical, very symmetrical, top pointed, branches less prominent than in white spruce . . . . balsam fir.

      - crowns conical, top often appears obtuse on photograph (except northern white spruce), branches (especially of mature trees) more prominent than in balsam fir . . . . white spruce, black spruce (except swamp type).

      - crowns irregular, with pointed top, has thinner foliage and smoother texture than spruce and balsam fir . . . . jack pine.

1. Crowns large, spreading or rounded not narrowly conical, top often not well defined.

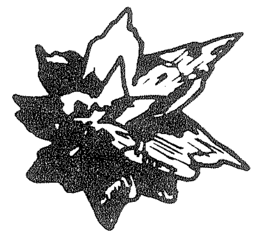
   3. Crowns very dense, irregular or broadly conical.

      4. Individual branches very prominent, crown usually irregular . . . . white pine.

      4. Individual branches rarely very prominent, crown usually conical, becoming irregular with age . . . . eastern hemlock.

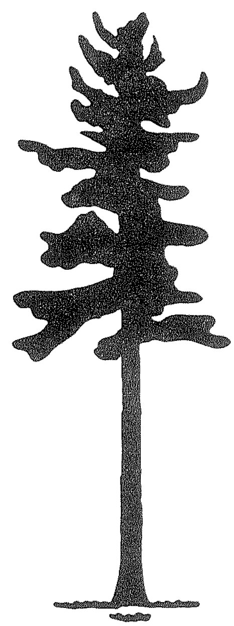
   3. Crowns open, oval (circular in plan view) . . . . red pine.

Eastern white pine *(Pinus Strobus* L.*)*



This species usually has a straight and undivided trunk and a large crown of horizontal or ascending branches. The higher branches sometimes sweep upwards in a pronounced curve resulting in a bowl-shaped structure. The larger branches are very prominent, giving the crown an irregular, star-shaped outline when seen from above (Figures 13, 15, 16). This is the most useful distinguishing characteristic. Young trees often have a nearly conical crown, although less conical than that of most other conifers.

White pine is sometimes difficult to distinguish from over-mature eastern hemlock, which may develop a ragged and star-shaped crown, although hemlock is usually more conical. White pine tends to appear in lighter tones than white spruce, balsam fir or eastern hemlock. This is particularly noticeable on black and white infrared photographs (Figure 1). White pines frequently tower above the other trees in the forest with the result that they will be more fully illuminated and therefore brighter than crowns at lower levels. Internal shadows contained in the crown are very dark. The colour of white pine differs from red and jack pine; it often resembles the colour of hardwoods (Figure 14).



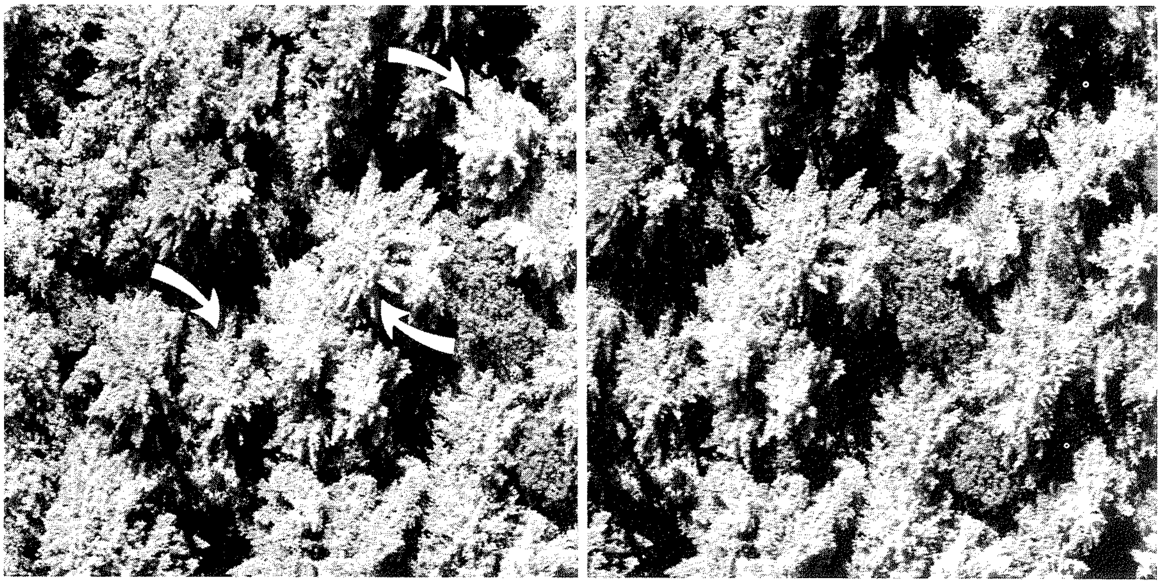


Figure 13. The typical star-shaped crowns of white pine. (Petawawa, Ontario; August 20, 1951; scale enlarged to 1:400 from contact scale of 1:600; photograph X-225, 54).

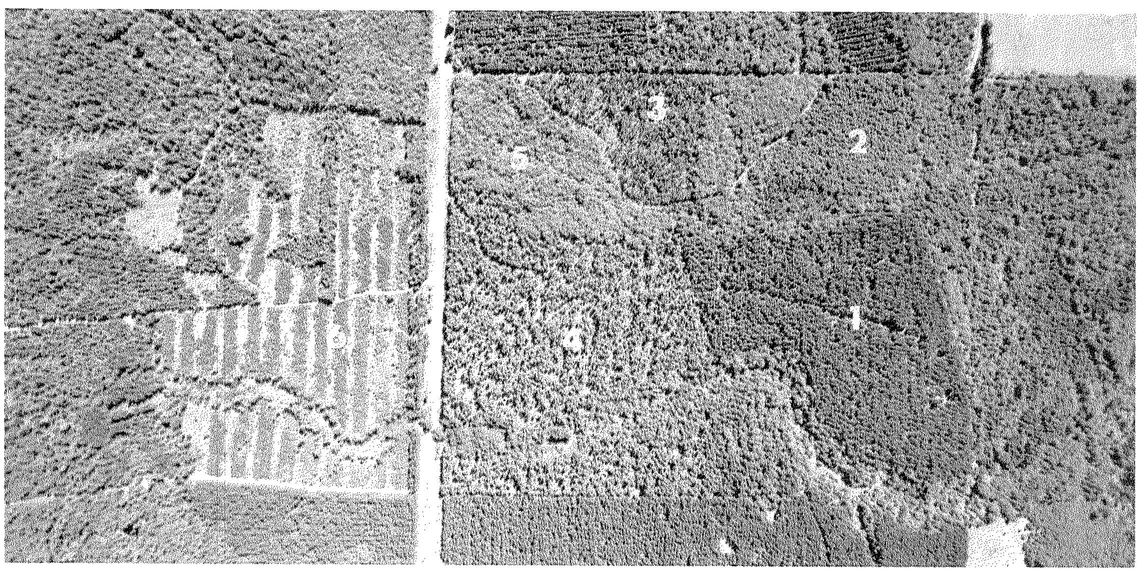
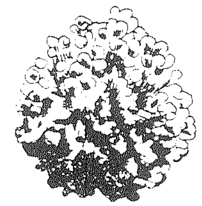


Figure 14. The potential of colour for separating red pine (1), white pine (2), jack pine (3) and scots pine (4) is illustrated. Area 5 is a deciduous mixture. In Area 6, cut strips alternate with 3 m high pine and spruce. The photograph is taken with an 88 mm lens, and parallax is therefore high. (Bourget, Ontario; September 1, 1972; scale 1:10,000; photograph A-30362, 138).

Red pine *(Pinus resinosa* Ait.*)*



Red pine has a straight and undivided trunk which is usually clear of branches for at least one half its height. Its crown is oval, not very dense and consists of stout, whorled, spreading branches. The tufts of foliage at the ends of the upturned branchlets give the tree a distinctive appearance (Figures 15, 16). In overhead view it is characterized by the rounded outline of its crown (Figure 16), beyond which individual branches rarely protrude, as they usually do in white pine. Because the foliage is not as dense as that of white pine, the contrast between the illuminated and the shaded parts of the crown is less pronounced and the trunk may show through the crown. This feature, as well as the characteristic round or oval crown is sometimes very pronounced at large and medium scales (Figure 1). Crown colour is shown in Figure 14.

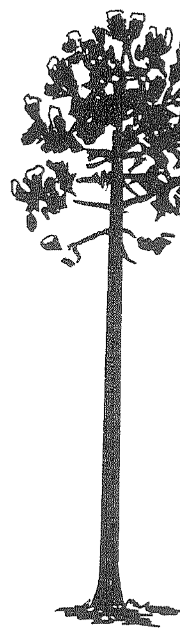


Figure 15. Several red pines are indicated. The crowns are open and rounded. Clumps of foliage at branch ends are characteristic. Other softwoods include a white pine (top centre of left photo) and balsam fir at upper right and lower right. (Petawawa, Ontario; August 20, 1951; scale enlarged to 1:350 from contact scale of 1:600; photograph X-225, 30).

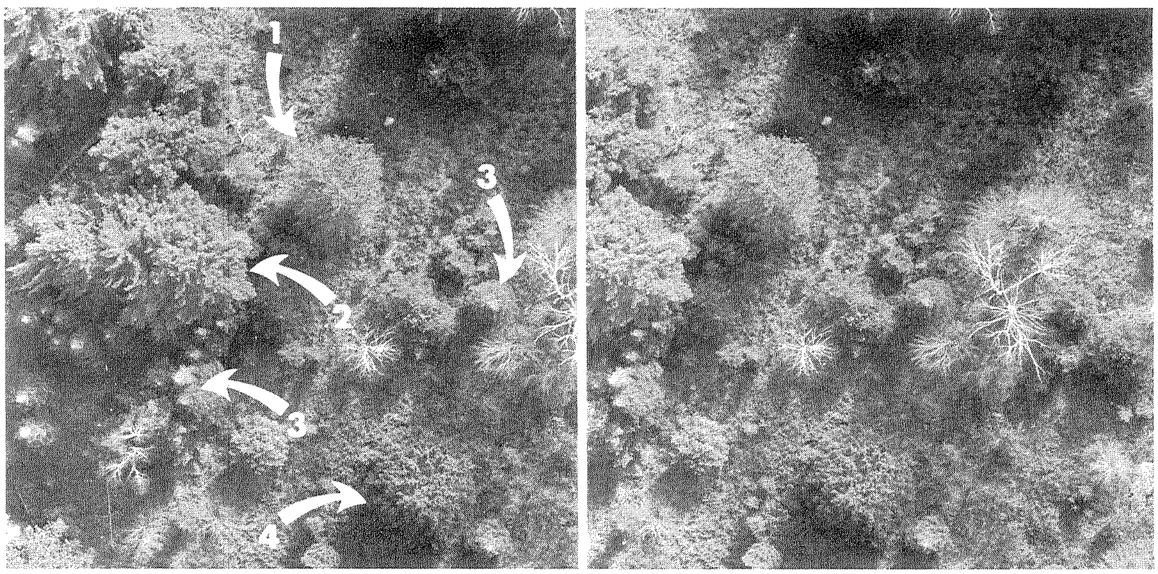


Figure 16. This red pine (1) shows the typical symmetrical and nearly spherical crown and the characteristic foliage clumps. It is easily distinguished from the white pine (2). Several balsam fir (3) show dense tops and characteristic highlights near the top. A large white spruce (4) has a more pointed crown than the pines; its upper branches are ascending, and are coarser than in balsam fir; the top is more open and its tone is darker than that of white pine. (Petawawa, Ontario; October 25, 1964; scale enlarged to 1:750 from contact scale of 1:1200; photographs F-42, 132, 133).

Jack pine (*Pinus banksiana* Lamb.)

In closed stands jack pine forms a small, narrow, open crown of many short and twisted branches, which are restricted to the upper portion of the tree. The top is usually pointed. In the open, the crown shape is very variable, with a general tendency toward a more rounded, but irregular form.

Jack pine is not difficult to distinguish from red pine with its almost spherical, regular crown, or white pine with its wide and star-shaped crown, but it is sometimes difficult to separate from spruce. At large scales the characteristic hazy texture of jack pine foliage is an effective identifying feature (Figure 17). For pure stands this separation is also not difficult, because jack pine stands appear hazy and show a very smooth and even texture, which contrasts with the more ragged appearance of spruce (Figure 18). When growing in mixture with spruce the smooth appearance of individual jack pine crowns sometimes makes identification possible. In some cases the two can be distinguished because spruce casts a denser shadow than jack pine. Jack pine appears in relatively light tones on winter photographs, because its foliage is thin. On panchromatic photographs, pure jack pine stands usually have a characteristic dark tone. Nevertheless it is sometimes confused with aspen, for both species grow in pure and evenaged stands.

Jack pine stands are often of fire origin (e.g., Figure 19); pure stands are common. Comments on the relationship to lodgepole pine are given in the subsequent description of that species.

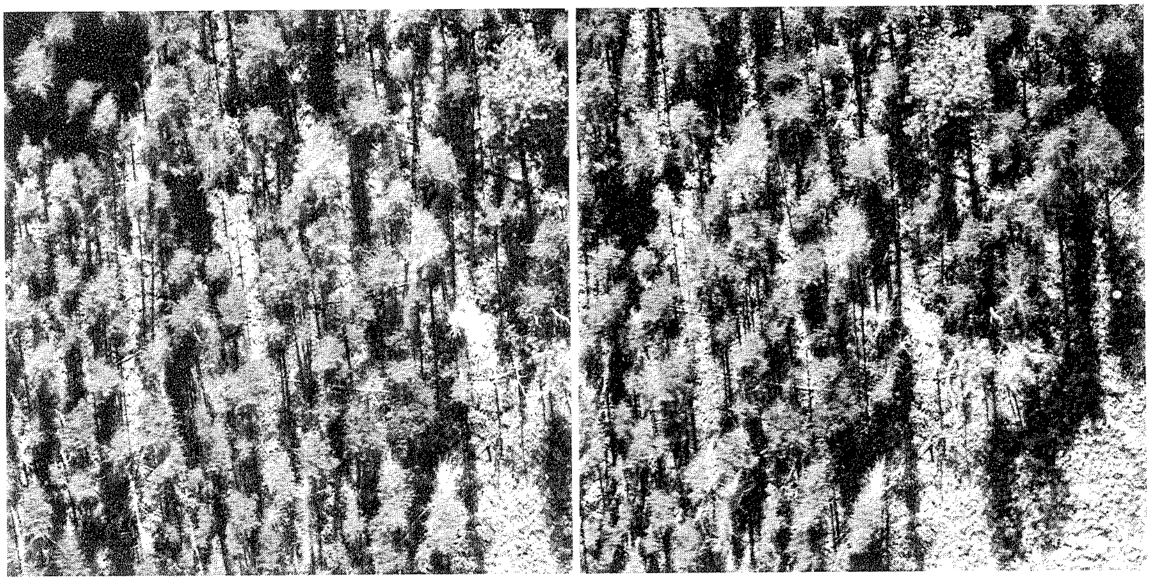


Figure 17. Jack pine. This stereogram shows the irregularly rounded, relatively small, fuzzy crowns of jack pine; the crowns are confined to the upper portions of the trunk. Note the typical red pine crown at the upper right of the left photograph. The few hardwoods on the photograph are probably aspen and there appear to be some partly defoliated spruce trees near the bottom of the photograph. (Petawawa, Ontario; August 20, 1951; scale enlarged to 1:400 from contact scale of 1:600; photograph X-225, 85).

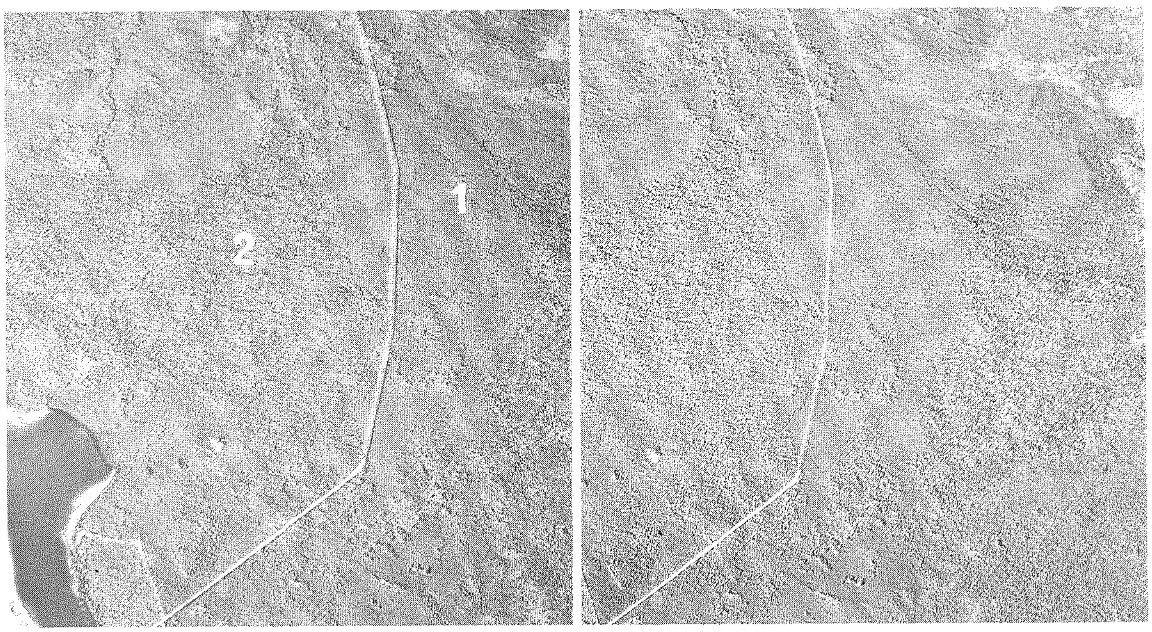


Figure 18. A jack pine stand (1) and a white spruce stand (2). Note the smooth appearance of the jack pine stand and the more ragged appearance and lower crown density of the spruce stand. (Wood Buffalo Park, NWT; September 6, 1955; scale 1:38,400; photographs A-15160, 136, 137).

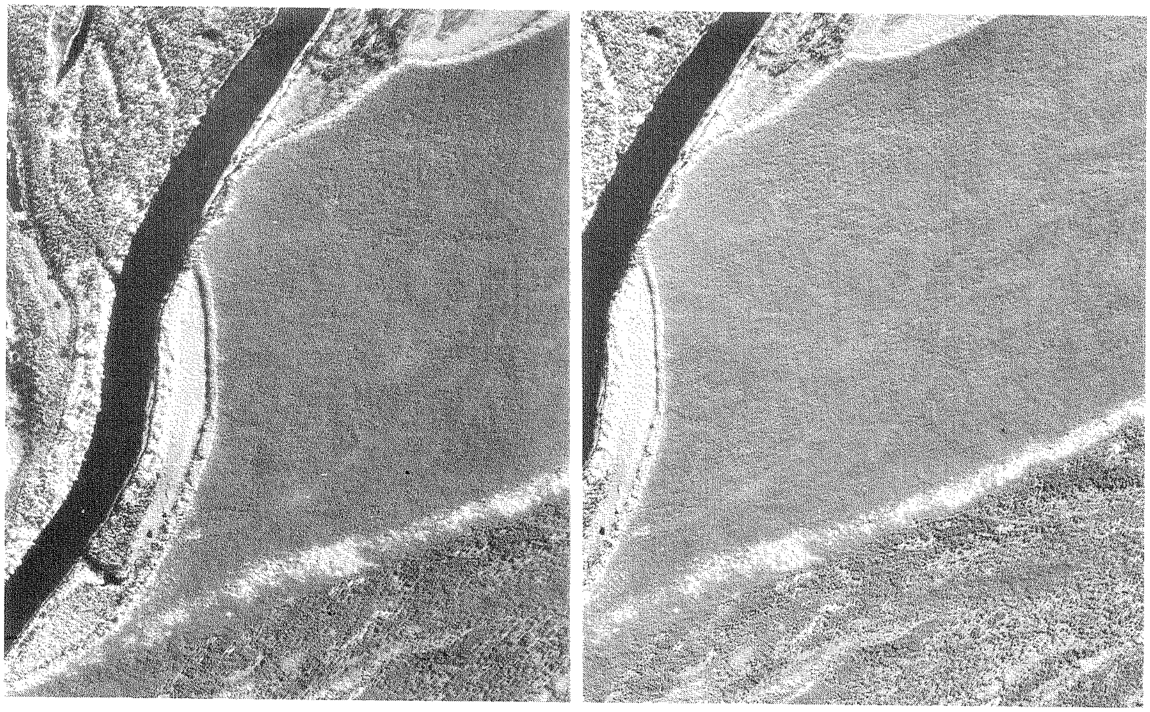


Figure 19. The homogeneity of this 7 m high jack pine stand indicates its fire origin. This fact helps to distinguish it from young black spruce which could have a similar texture. Fire boundaries can be a major aid in photo interpretation. In this case, however, river terraces (top and side) and sand dunes (bottom) have limited the stand. These limits are well within the fire boundaries. (North of Embarras, Athabasca River, Alberta; July 24, 1965; scale 1:15,840; photographs A-18952, 111, 112).

Lodgepole pine *(Pinus contorta* Dougl.*)*

Lodgepole pine is a western species which is very similar to jack pine, both in form, and in its site preference. It, too, tends to form pure stands, but also often grows in association with the spruces and aspen. There are two distinct forms of lodgepole pine, a short scrubby strain growing along a narrow range of the British Columbia coast, and the inland form which is tall, slender and straight. The range of lodgepole pine slightly overlaps that of jack pine, mainly in Alberta. There are hybrids between the two species which cannot be distinguished by branching habit and crown shape (recognition must rely upon examination of the cones).

Like jack pine, the inland lodgepole pine has a short and narrow crown; foliage texture and colour and the general shape resemble jack pine, except that the inland lodgepole pine tends to be straighter. Branching is regular and foliage is largely at the branch ends. Illustrations are given in Figures 20 and 21.

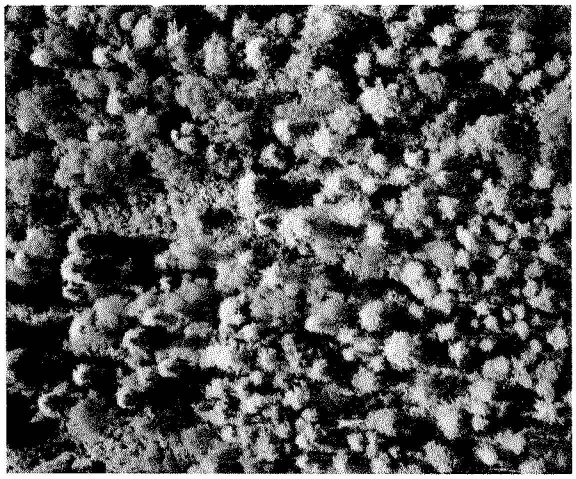


Figure 20. The irregularly rounded crowns with short vertical dimensions are lodgepole pine. Characteristically, individual branches are prominent. Foliage is in tufts. White spruce scattered throughout the area is recognized by its conical, symmetrical crown and its more even-textured crown surface. A few alpine fir can be seen; the hardwoods are aspen. The yellowish cast in these photographs is unusually strong. (Nisutlin River, Yukon Territory; June 24, 1977; scale enlarged to 1:1115 from contact scale of 1:800; photographs FMI 77-17, 290, 291).

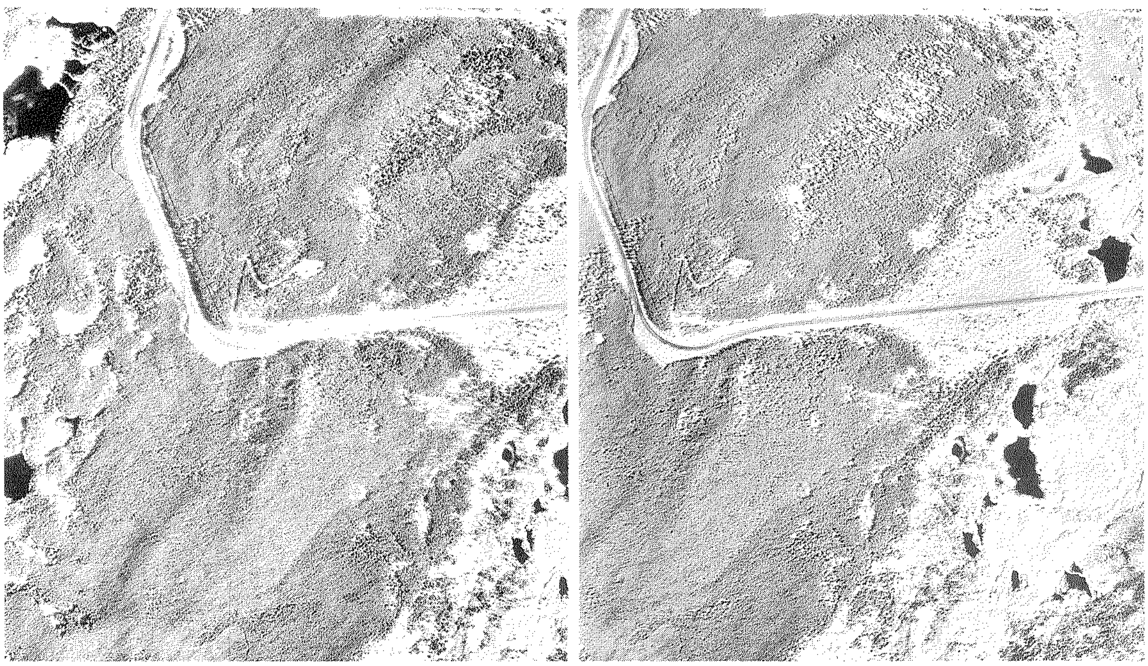


Figure 21. Most of the area shown on this stereogram is occupied by a 12 to 15 m high stand of inland lodgepole pine, which shows the characteristic even texture. Within this stand there are areas of much lower crown density; they are mixtures of alpine fir, spruce, Douglas fir and lodgepole pine. (Waterton Lakes National Park, Alberta; July 12, 1967; scale 1:20,000; photographs A-19979, 92, 93).

Tamarack *(Larix laricina* (Du Roi) K. Koch*)*

Tamarack has a narrow, open, symmetrical, conical crown (Figure 22), which in old trees may become broad and irregular. Twigs are slender and the surface texture of foliage appears very fine on large scale photographs (Figure 23). On panchromatic fall photographs it is easily distinguished from other conifers by its light, almost white tone, which is due to the yellow colour of its foliage. In the summer it can usually be distinguished from black spruce, its common associate, by a somewhat broader crown and very light tone. In the winter it can be separated from the hardwoods by its slender, straight, and undivided central stem and its conical crown.

Tamarack is commonly found in swamps, and because it is intolerant to shade, it tends to grow in the open or, if found under forest conditions, it is a dominant with its crown above the general canopy level. Tamarack is often found in small groups or in mixed stands in which it constitutes a small portion of the total volume.

Figure 22. Tamarack.

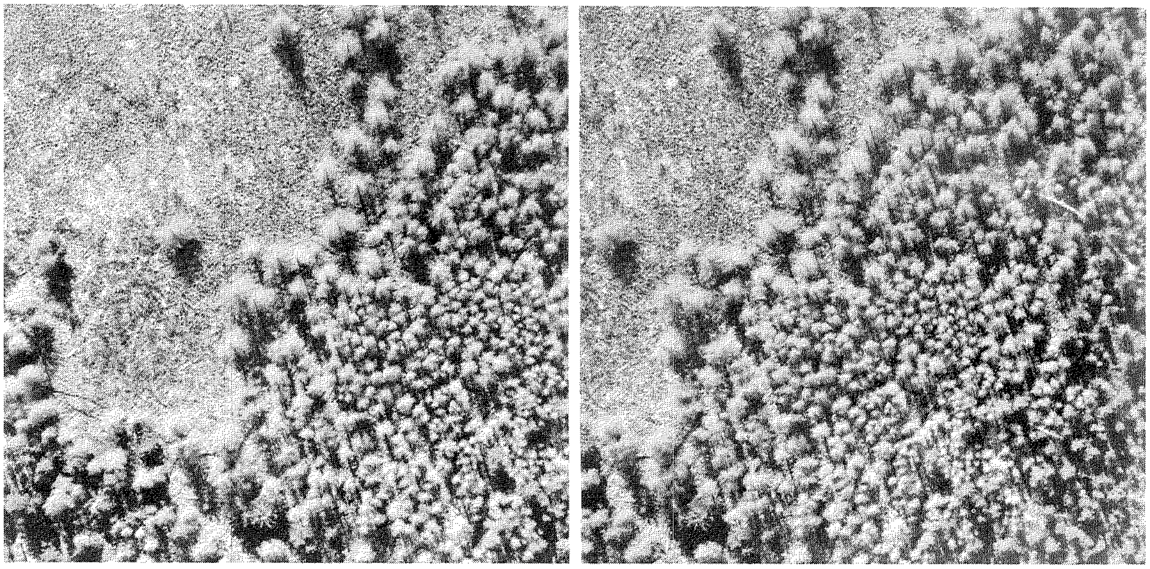


Figure 23. These tamarack show the characteristic light tone. For the large trees bordering the open area, the trunks and their shadows are clearly visible through the crown; evidently foliage is not yet fully developed. (Hants County, Nova Scotia; June 3, 1974; scale enlarged to 1:1130 from contact scale 1:2260; photographs FMI 74-8, 227, 228).

Western larch *(Larix occidentalis* Nutt.*)*
Alpine larch *(Larix lyallii* Parl.*)*

The main characteristics of crown shape and foliage of these two species are similar to tamarack. Western larch is a large tree of southern British Columbia. It is very intolerant to shade, grows on deep soils, commonly in association with Douglas fir, Engelmann spruce, alpine fir and other conifers.

Alpine larch (Figure 24) is a small tree which grows on high slopes, at and near the timber line in the Rocky Mountains of southern British Columbia and Alberta.

Figure 24. Alpine larch.

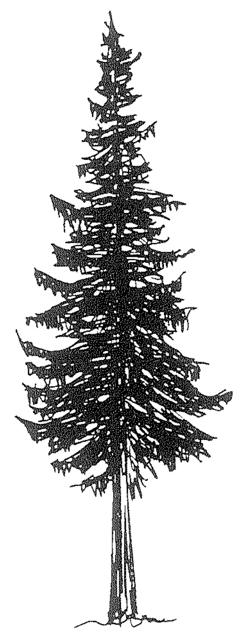
White spruce (*Picea glauca* (Moench) Voss)

White spruce has a single, straight, central trunk. Branching is dense and branches are long. Its crown is dense and symmetrical and for open-grown trees may extend to the ground (Figures 25, 26, 27). The apex of the crown usually appears obtuse on photographs, because the slender tip is not resolved (Figures 30, 40). Northern white spruce is different: its particularly narrow crown and short branches give it a needle-like appearance (Figure 28).

Because of coarser branching, the crown of white spruce is more irregular than that of balsam fir. Crown shape and branching habit may also be used to distinguish it from black spruce. This distinction, however, can sometimes be made by size. Mature white spruce often reaches or exceeds a height of 20 m, but black spruce rarely does. White spruce prefers moist but well-drained soils and is common along streams, rivers or lakes. It is also a characteristic species of alluvial sites along northern rivers (Figures 29, 47).

As with all conifers, the colour of spruce foliage changes with the season. The darker greens of late summer, fall and winter are replaced by fresh, light greens in late spring. In the Ottawa area the colour of white spruce is completely dominated by this young foliage in late May and June.

Other illustrations of white spruce are Figures 30 and 31.



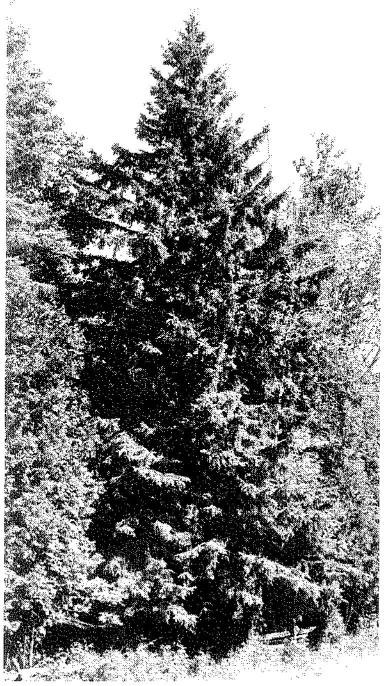


Figure 25. White spruce.

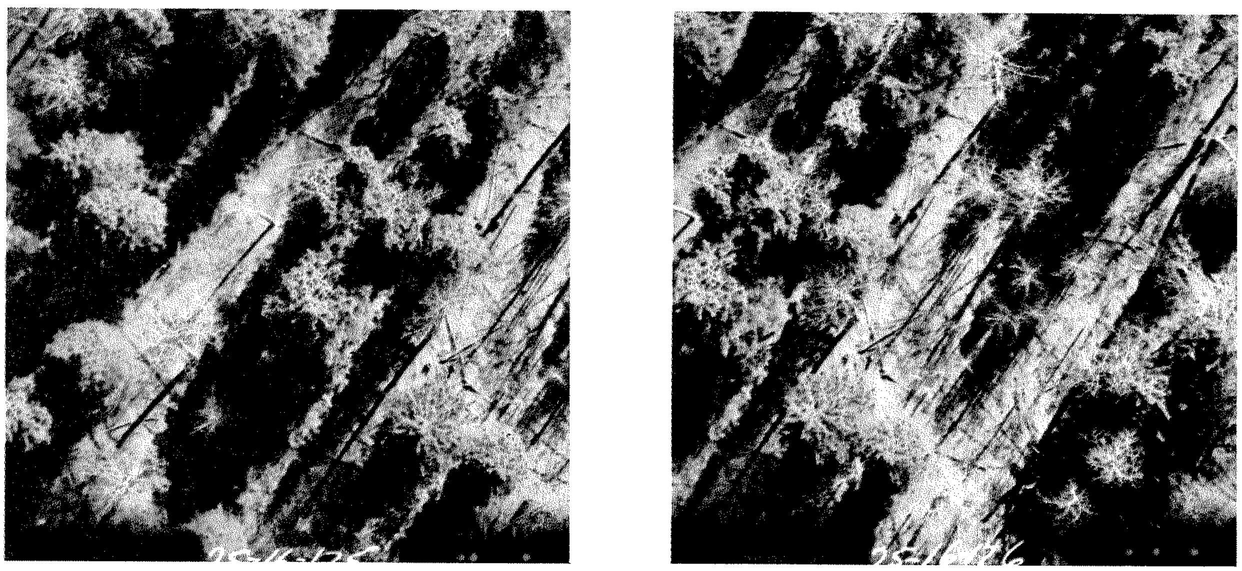


Figure 26. Several white spruce are readily discernible on this stereogram. Note branching habit and obtuse appearance of crown top. The upswept branches are characteristic of large trees. The leafless hardwoods are aspen. These photographs were obtained with the FMI large scale photography system. The first six digits at lower left indicate time. The next three digits are flying height above ground, in meters. The white numbers show year flown, roll and print number. The binary code gives measurements of camera attitude at the instant of exposure. (Peace River, Alberta; May 6, 1975; scale enlarged to 1:600 from contact scale of 1:840; photographs FMI 75-16, 175, 176).

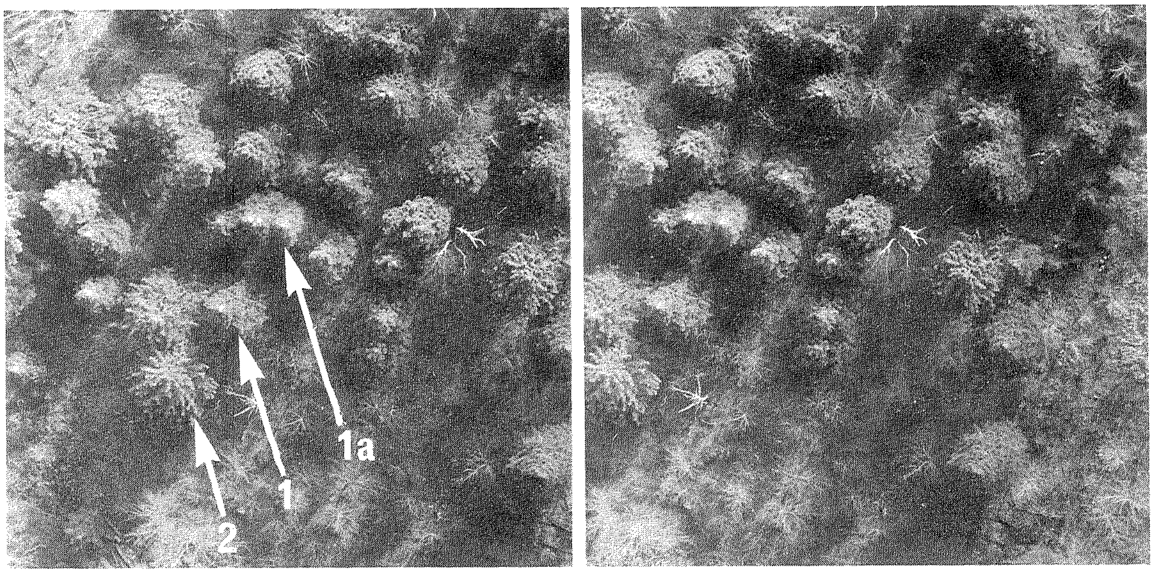


Figure 27. This stereogram illustrates the difference between balsam fir (1) and white spruce (2). Note the pointed top and more symmetrical shape of balsam and the more open tops and coarser branching of spruce. Three types of branching are evident in the softwoods. These range from the poorly defined, "soft" branches of small, densely-crowned balsam fir (1a) to the coarse heavier boughs of white spruce. (Petawawa, Ontario; October 25, 1964; scale enlarged to 1:600 from contact scale 1:1200; photographs F-42, 117, 118).

Figure 28. The very narrow, candle-shaped crowns of northern white spruce. (Hunter Bay, NWT; August 13, 1931; photograph A-4116, 83).

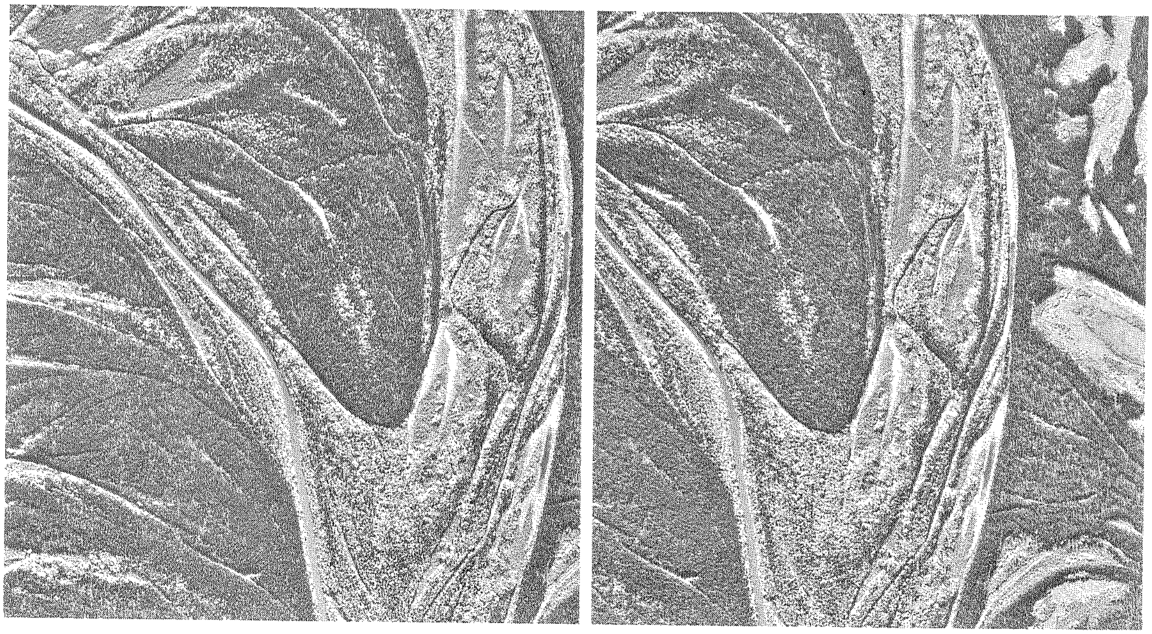


Figure 29. Mature northern white spruce (dark tones stands), and balsam poplar (light-toned stands), in alluvial lowlands. (Wood Buffalo National Park, NWT; September 23, 1955; scale 1:38,000; photographs A-15204, 38, 39).

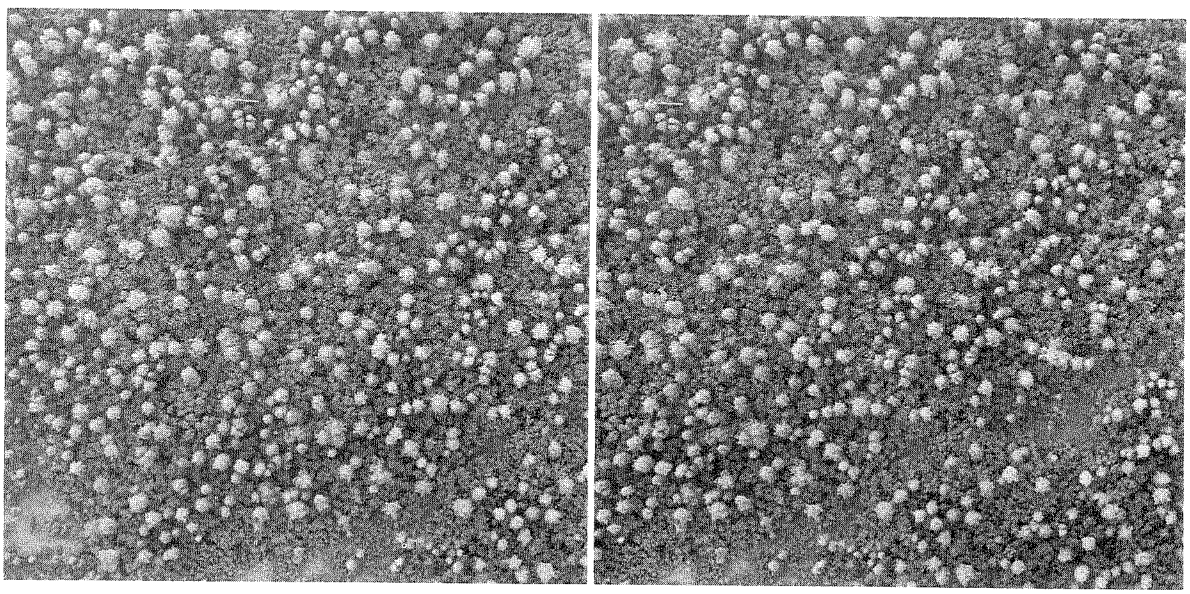


Figure 30. White spruce in the Mackenzie River Delta. This stand is characterized by low stand density. Trees have narrower crowns characteristic of northern white spruce. Tops are often blunted, perhaps due to slow growth rates or as a result of breakage through ice storms and snow. There is a dense ground cover of alder and willow. (Mackenzie Delta, north of Fort McPherson, NWT; August 8, 1965; scale enlarged to 1:1250 from contact scale of 1:2000; photographs F-62, 57, 58).

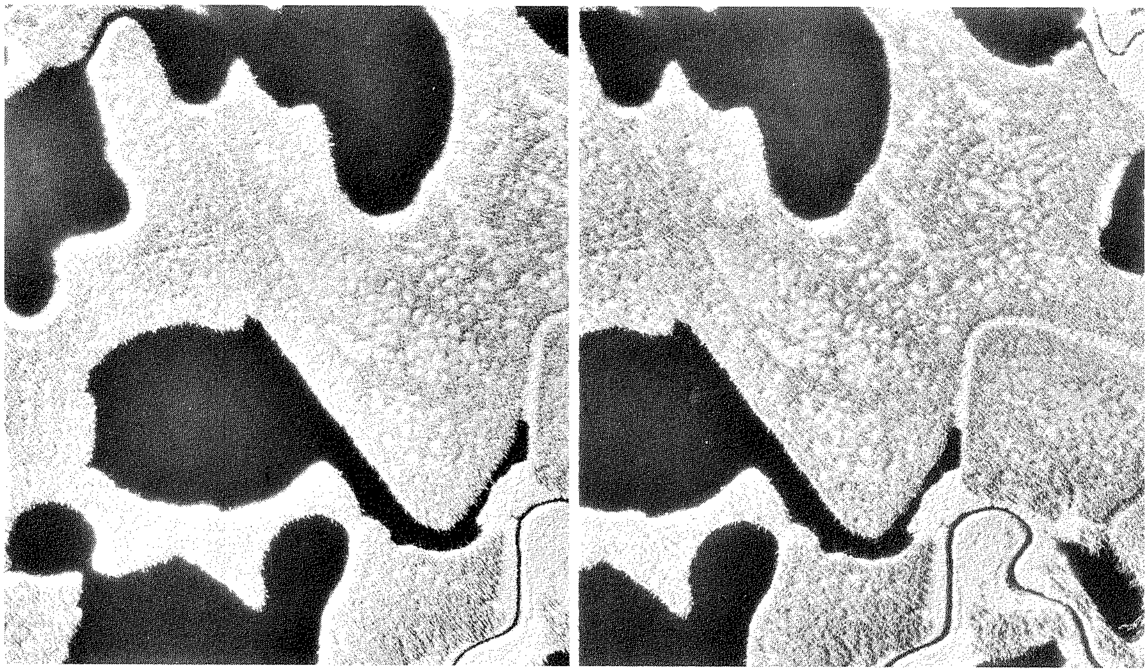


Figure 31. Infrared photograph of white spruce in the same general area as Figure 30. Crowns appear narrower and more pointed than in Figure 30, largely as a result of increased vertical exaggeration produced by the wide-angle 152 mm lens. Figure 30 was taken with a 305 mm lens. These figures illustrate the need to consider photogrammetric characteristics in interpretation. (Mackenzie Delta, north of Fort McPherson, NWT; August 20, 1965; scale 1:16,000; photographs A-18992, 111, 112).

Engelmann spruce (*Picea engelmannii* Parry)

Engelmann spruce is a species of the southern subalpine forest of British Columbia and Alberta. It hybridizes with white spruce, from which it is often difficult to distinguish on the ground. Its main morphological characteristic is a very symmetric and narrow crown (Figure 32).

Figure 32. Engelmann spruce.

Sitka spruce *(Picea sitchensis* (Bong.) Carr.*)*

Sitka spruce is a western species which grows in a narrow strip along the Pacific coast. It attains heights of 40 and 60 m. Sitka spruce grows in pure stands and in association with other species, such as western hemlock, western red cedar and occasionally Douglas fir.

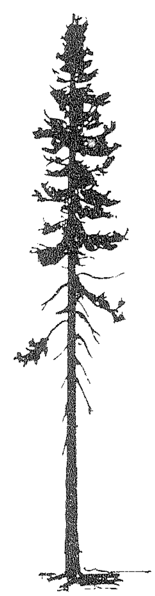
Aids in identification are its narrow range and the fact that it rarely grows at elevations above 300 m but does occur up to 700 m. Its crown is somewhat more open than that of white spruce, and individual branches are therefore more prominent, radiating out from the central hole. Branchlets are pendant and dense and distributed along the entire branch; this further increases the prominence of individual branches. Branch ends are rounded as in white spruce. Foliage colour has a bluish cast.

Red spruce *(Picea rubens* Sarg.*)*

Red spruce is an important species in Nova Scotia, New Brunswick and southern Quebec. Its range reaches into eastern Ontario. It can be difficult to distinguish from both white spruce and black spruce; intermediate forms exist. Its distinguishing features are more open branching and a crown that is broader than that of the other two species. Branches turn upward near the tips. Foliage is more yellowish than in white and black spruce.

Black spruce *(Picea mariana* (Mill.) B.S.P.*)*

Black spruce is usually a small tree, which seldom attains a height of more than 15 m, although on very good sites it may exceed 30 m. It grows on a great variety of sites, but is characteristic of swamps and muskeg where it grows in almost pure stands (Figure 33). Usually it develops a slender, straight trunk and a very narrow, almost cylindrical crown. A dense clump or ball of twigs frequently forms at the top and it can sometimes be seen on photogrpahs at larger scales (Figure 33). These features are useful in distinguishing it from white spruce and balsam fir. The stems of black spruce growing in the open are often covered with branches for their entire length. Large trees develop a wider, more irregular and open crown, and sometimes cannot be distinguished from white spruce.



Dense black spruce stands appear dark and carpet-like. When cedar is mixed with black spruce the stand appears mottled, due to the lighter tone of cedar. On drier sites black spruce may grow in mixture with jack pine and the percentage species composition of such stands is difficult to estimate at medium and small scales. The use of colour photography, or photography timed to coincide with phenological changes that accentutate differences, might help to overcome this problem. *See also* Figure 19 for comments on the differences from jack pine and Figure 9 for an illustration of young black spruce foliage.

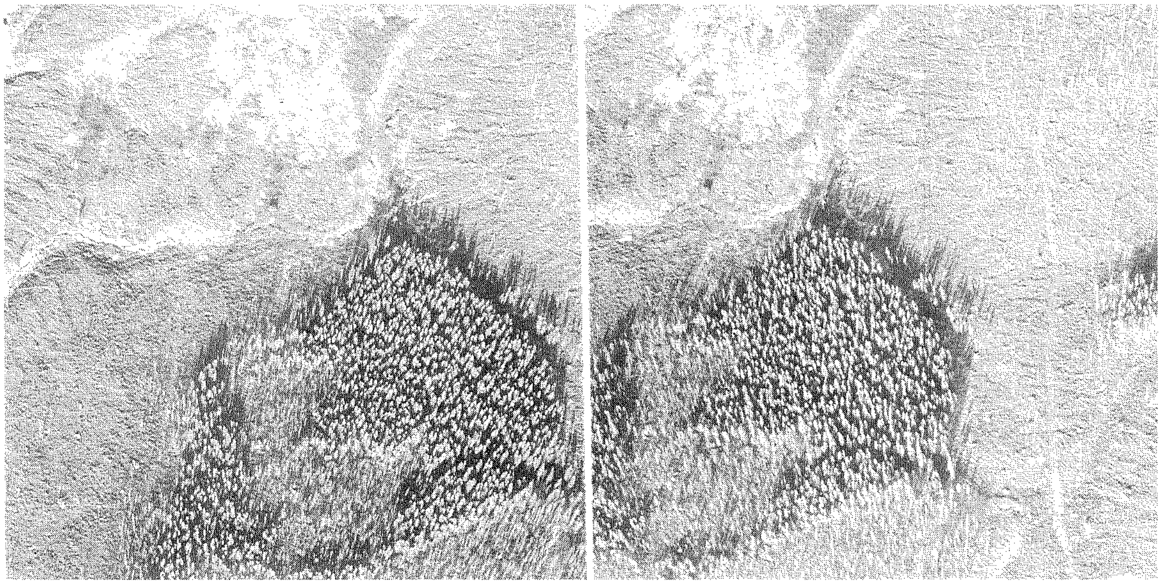
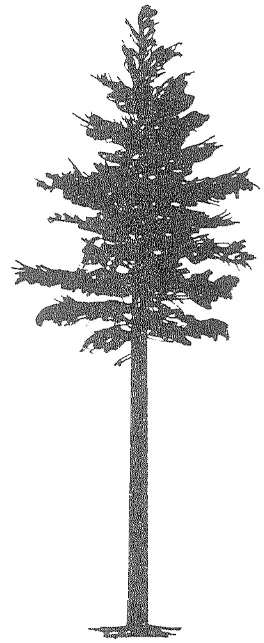


Figure 33. A black spruce stand, a remnant, after the surrounding area has been cut and partly burned. Note the characteristic narrow crowns. Evidence of the typical dense clumps of foliage at the tree top is provided by the lighter tone near the crown top. This stereogram is prepared from obliques obtained in tri-camera photography. The terrain is relatively flat, but under stereoscopic examination it appears to be falling away in the direction of the shadows. This effect is even stronger if the stereogram is viewed upside down. (Clova, Quebec; November 1, 1948; scale 1:2400; photographs 160L, 36, 37).

Eastern hemlock *(Tsuga canadensis* (L.) Carr.)

Eastern hemlock may grow in pure stands, but is more characteristic of mixtures with northern hardwoods, white spruce, red spruce and northern tolerant hardwoods. It is characteristic of fresh sites, with a tendency to grow on north-facing slopes.

Eastern hemlock develops a broad conical crown which is more obtuse than the crowns of the spruces and of balsam, but more pointed than white pine (Figure 34). Otherwise it may resemble white pine, except for its usually more regular outline. Eastern hemlock has dark foliage and is tolerant of shade. Its dense foliage results in a strong contrast between highlights and shadows in the crown.



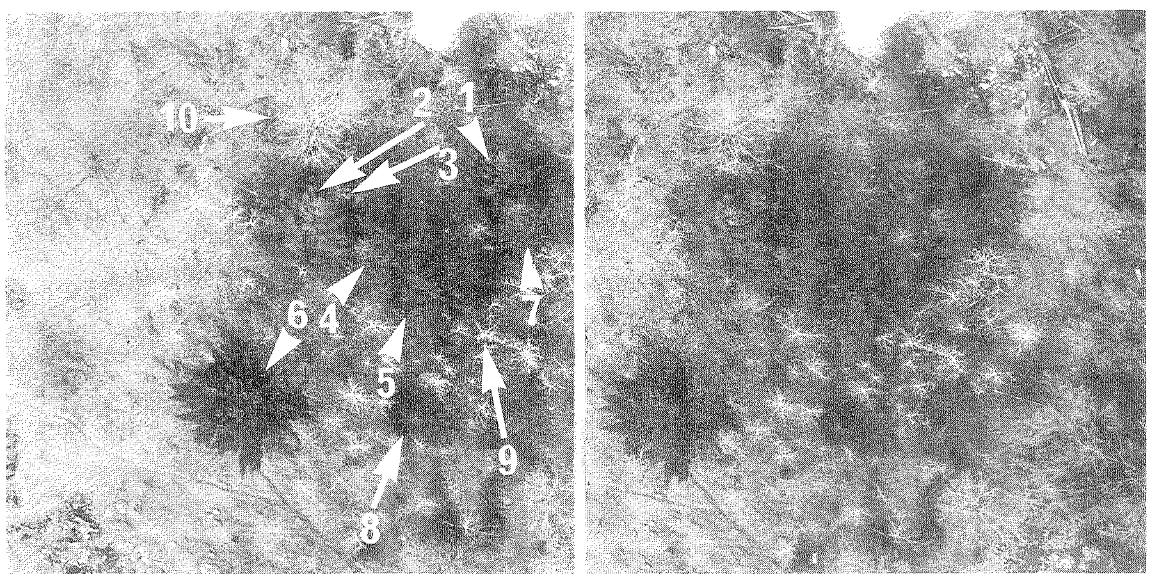
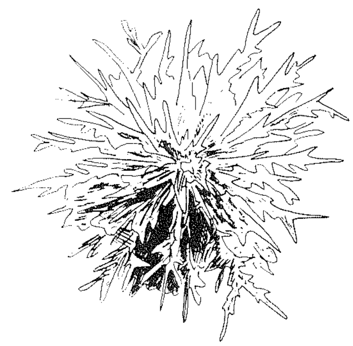


Figure 34. Comparison of several conifers. The broad conical crowns of the eastern hemlock (1, 2, 3), are readily distinguished from the rosette-shaped crowns of the white pines (4, 5, 6), with their more prominent branches. The tops of the hemlock trees are well defined, in contrast to the flatter white pines. Elsewhere (7) one recognizes the fine branching of eastern white cedar and the pointed crown of balsam fir, with the typical highlight at the top (8). The hardwoods (9, 10) with coarse, light-toned branches and twigs are largetooth aspen. (Marmora, Ontario; May 5, 1950; scale 1:600, photograph X-185, 26).

Western hemlock (*Tsuga heterophylla* (Raf.) Sarg.)

Western hemlock is a large tree (45-60 m) which is often a dominant, but seldom grows in pure stands. It favours mixtures of western red cedar, Douglas fir, grand fir, black cottonwood or red alder.



It is not an easy species to identify and is particularly difficult to separate from Douglas fir. The tone of the two species is similar: at large and medium scales generally darker than western red cedar and lighter than amabilis fir. Its crown is conical, but becomes very broad with age. The foliage of older trees is denser than in Douglas fir; and branching extends closer to the ground; crown surface texture is fine and feathery. Branch ends tend to be forked. In very large scale aerial photographs (e.g., 1:600), the characteristically drooping top may be seen. Illustrations are given in Figures 35, 36 and 45).

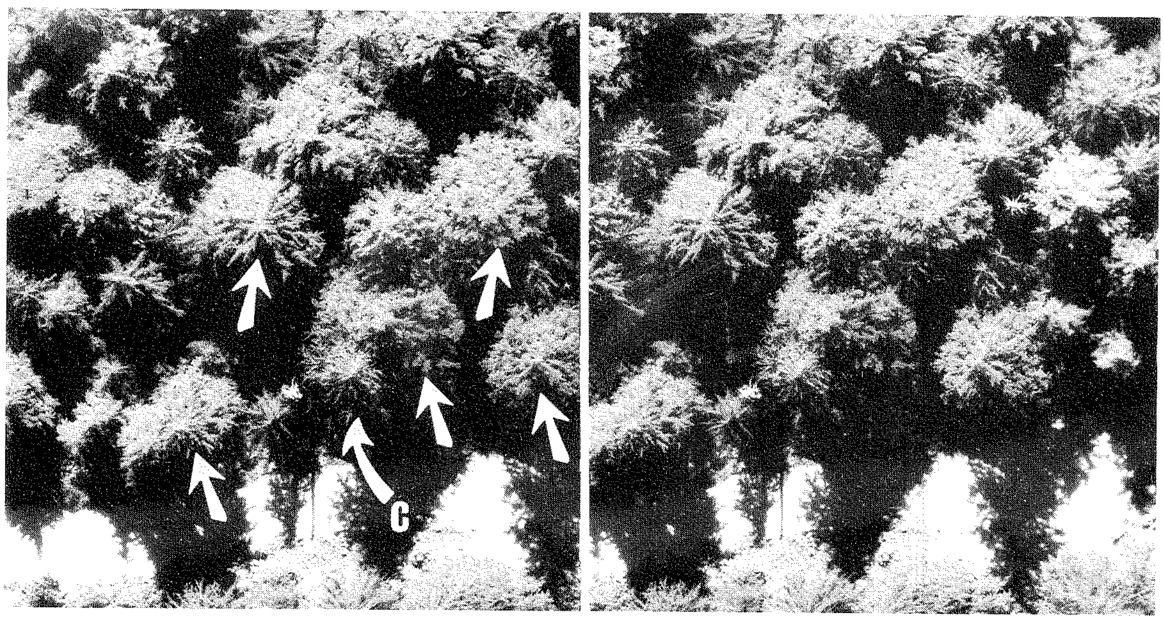


Figure 35. The many forked branch tips help to identify western hemlock. Branches are much wider than those of yellow cypress (C). (Placid Lake, B.C.; July 21, 1971; scale enlarged to approximately 1:800 from contact scale of approximately 1:1500; photographs FMI 71-14, 343, 344).

Mountain hemlock *(Tsuga mertensiana* (Bong.) Carr.*)*

Mountain hemlock has a range which overlaps that of western hemlock. It is a small tree or a shrub. Its foliage is denser and its branching heavier than that of western hemlock.

Douglas fir *(Pseudotsuga menziesii* (Mirb.) Franco*)*

Douglas fir is characteristically a very tall tree with a relatively short crown which is initially conical, but becomes increasingly flat-topped as the tree matures. It is a fast-growing species and intolerant of shade; therefore it tends to be a dominant when growing in mixtures. Its most common associates are western hemlock, amabilis fir and western red cedar. Douglas fir will often have the largest and broadest crowns in these mixtures.

Douglas fir crowns tend to have irregular shapes; the fact that the largest branches are prominent and few in number contributes to this. Photographic tone is variable, but it is usually darker than red cedar and always lighter than amabilis fir. Douglas fir occurs in two forms: the larger coastal, and the smaller interior varieties; the latter is also characterized by broader and more irregular crowns. For illustrations *see* Figures 36, 37 and 38.

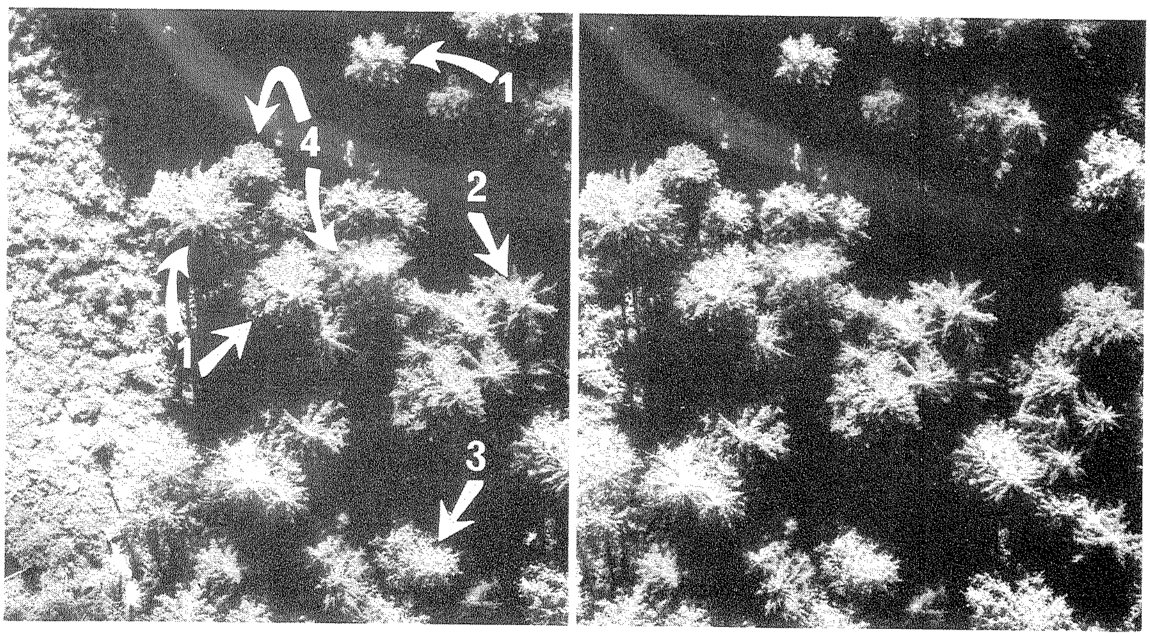


Figure 36. Douglas fir, western hemlock, western red cedar and amabilis fir. The blunt top and dense crown of Douglas fir (1) contrasts with western hemlock (2) which shows more slender branch tips and a more open crown. Western red cedar (3) displays the characteristically very fine branching; most specimens show exposed limbs and several have the characteristic tufted arrangement of foliage. Two amabilis fir are identified (4). Note the lighter tone of the older tree on the right. (Loon Lake, B.C.; July 21, 1971; scale enlarged to approximately 1:800 from contact scale of approximately 1:1400; photographs FMI 71-21, 160, 161).

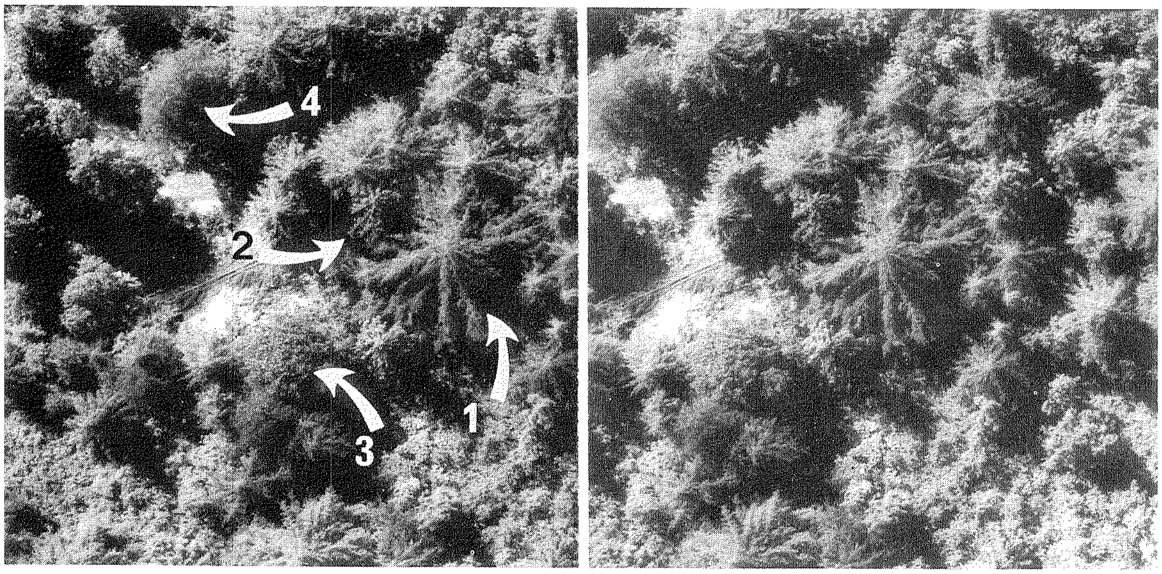


Figure 37. Douglas fir (1), western red cedar (2), red alder (3) and white birch (4). As is often the case, Douglas fir is the tallest tree and has the widest crown; the top is flat because an old tree is involved. Main branches are very large, but few in number. (Jocobs Lake, B.C.; July 21, 1971; scale enlarged to approximately 1:750 from contact scale of approximately 1:1500; photographs FMI 71-14, 431, 432).

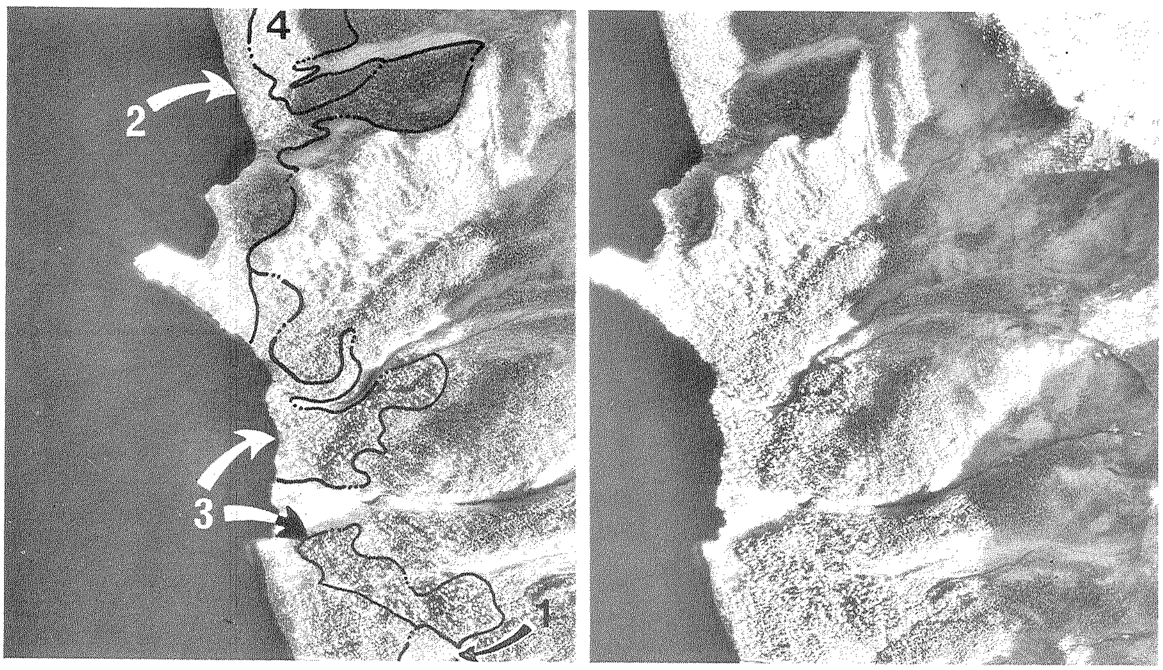
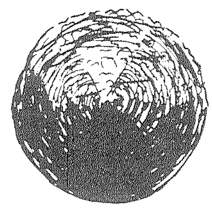


Figure 38. The Douglas fir stands on this infrared photograph all appear in light tones. The stand at (1) is dense with trees under 6 m high. Trees at (2) reach heights up to 24 m; the stand at (3) is taller, more open and crowns are larger, irregular and somewhat rounded. Note the different tone of the lodgepole pine stand at (4). (Waterton Lakes National Park, Alberta; July 12, 1967; scale 1:20,000; photographs A-19979, 12, 13).

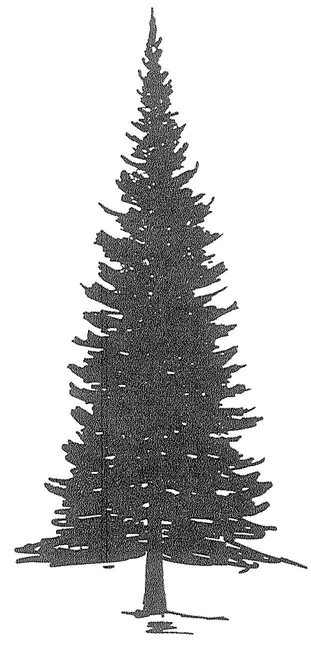
Balsam fir *(Abies balsamea* (L.) Mill.*)*

Balsam fir has dark foliage and a very dense, narrow, cone-shaped crown of slender branches, which on open-grown trees extends nearly to the ground. It is distinguished by its very symmetrical form and by its characteristically dense, rigid and spire-shaped tip (Figures 39, 40). The individual branches of balsam fir are less prominent than those of white spruce and its crown usually appears in a darker tone. A highlight, caused by reflections from the dense foliage near the top is common (Figures 39, 34).



Balsam fir frequently grows in association with white spruce; if white spruce is identified in a mixture with hardwoods, this is an almost certain indication that balsam fir is present, provided the location lies within the natural range of balsam fir. Observations on the difference between balsam fir and white spruce are given in the description of the latter. Figure 34 gives a comparison with eastern hemlock.

In late spring the colour of balsam fir crowns undergoes a major change as the much lighter young foliage develops. Anyone interpreting balsam fir should also be aware of the extensive spruce budworm attacks in eastern Canada (Figure 41). Two relevant references on interpretation of this damage are Murtha 1972 and Ashley, Rea and Wright (1976).



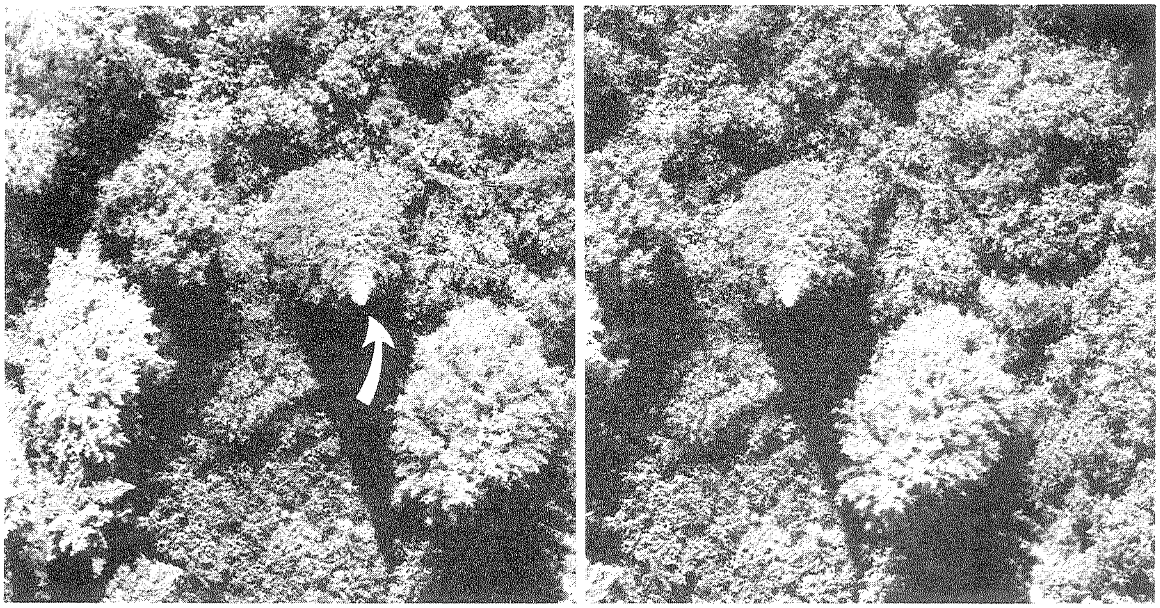


Figure 39. This balsam fir shows the characteristic cone-shaped crown and the sharp spire-shaped top. The highlight, which is the result of reflection from the dense foliage and cones, is typical. (Petawawa, Ontario; August 20, 1951; scale enlarged to 1:300 from contact scale of 1:600; photograph X-225, 94).

Figure 40. The top of a typical crown of balsam fir (left) and white spruce (right). The individual branches of the more open top of the spruce will often not be resolved on aerial photographs, thus leaving the impression of a blunt tip. The dense, closed branching of the balsam will result in an image showing a sharply pointed cone.

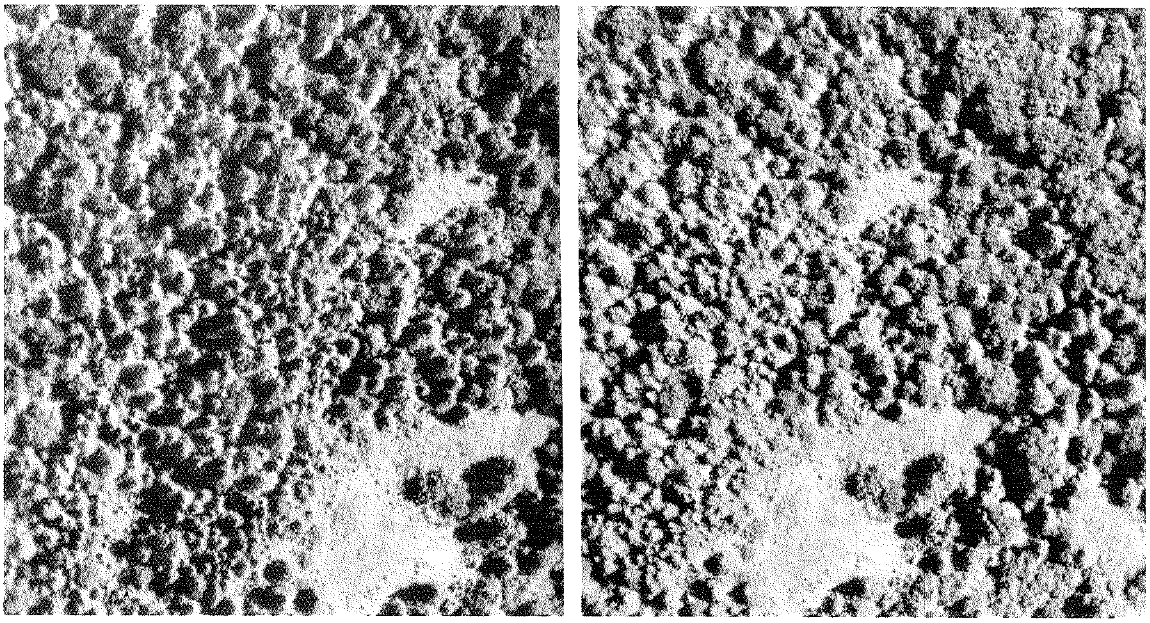


Figure 41. The crowns of balsam fir (and a few white spruce) recently attacked by spruce budworm appear in various brownish and orangy hues. Completely defoliated, dead and dying trees are grey. White pine and unaffected hardwood are easily distinguished. (Petawawa, Ontario; July 12, 1974; scale 1:2000; photographs FMR 74-10, 165, 166).

Alpine fir *(Abies lasiocarpa* (Hook.) Nutt.*)*

Alpine fir is a western species which is very similar to balsam fir. One difference from balsam fir is that branches tend to be shorter and crowns narrower and more pointed than in balsam fir (Figure 42). The geographic range of alpine fir overlaps that of balsam fir in some parts of Alberta. Its range in elevation, from approximatley 600 m to 2300 m is a useful identifying characteristic.

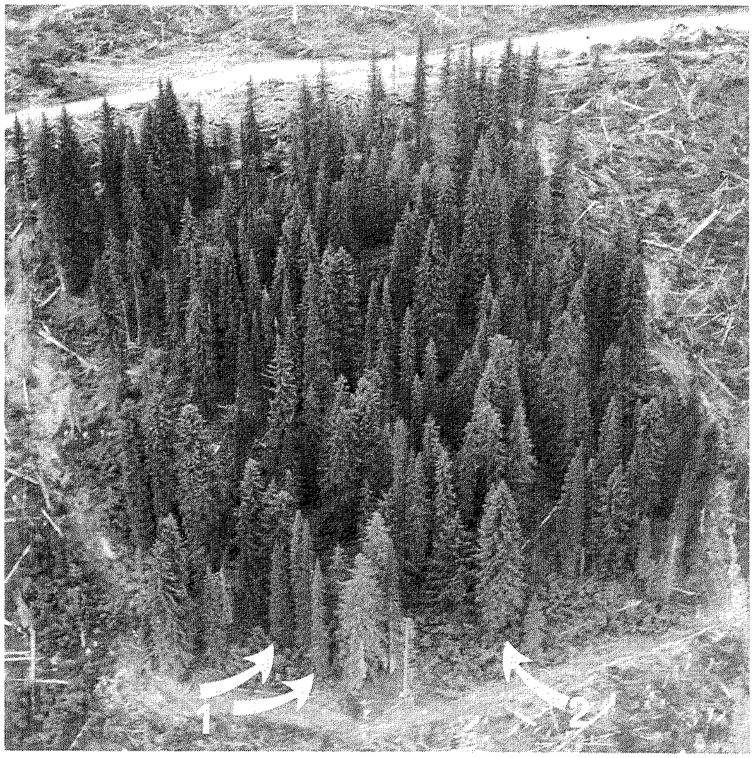


Figure 42. Oblique photograph showing the characteristic narrow crowns of alpine fir (1) and the wider "cigar-shaped" crowns of Englemann spruce (2). (Lardeau River, B.C.; photograph Pacific Forest Research Centre 71432-12).

Amabilis fir *(Abies amabilis* (Dougl.) Forbes*)*

Amabilis fir is confined to the coastal and subalpine forests of British Columbia. It can reach heights of 40 m, tends to grow in association with other western conifers, is tolerant of shade and favours the wetter sites.

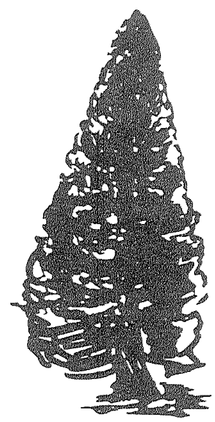
Amabilis fir has a compact very dense, and spire-like crown (Figure 46). The top of old trees may be flattened. Its photographic tone is very dark; this is an important identifying characteristic. The tone of older trees is lighter, probably because their crowns are more open; *see*, for example, Figure 36. Individual branches follow a characteristic scale-like arrangement; each has a rounded branch apex (Lyon 1967, Figure 46). These features are readily observed at scales larger than 1:1000; foliage is dense and crown shape fairly symmetrical so that, except for the rounded branch ends, it is difficult to distinguish individual branches.

Eastern white cedar *(Thuja occidentalis* L.)

Eastern white cedar is usually a small tree which is found in swampy areas. However, as a pioneer species, it also grows in abandoned fields and pastures where it forms clumps or pure stands, often on dry, shallow soils with underlying limestone bedrock (Figure 43).

Eastern white cedar is sometimes difficult to distinguish from small, open-grown spruce or balsam fir, although it can ususally be identified by its lighter tone and more rounded top (Figure 44). In stands black spruce has a tone similar to cedar. On dry sites the top tends to be blunt (for a conifer) and the conical crown shape persists to the ground. On wet sites, crowns tend to be narrower and more pointed, which may lead to confusion with the spruces and balsam fir. The conical crown is very smooth and, because it is dense, no large shadows are visible inside the crown, as is the case for trees with coarser branching (Figure 13). Large trees, which may be up to 1 m in diameter and 25 m in height, are rare. The common height is about 13 m. The upper part of the crown of such trees is frequently dead and the trunk may appear as a spike above the living crown.

In years when cone production is abundant the upper portions of the crowns of cedar assume a distinct yellowish colour in late summer; this colour becomes brownish as the cones mature.



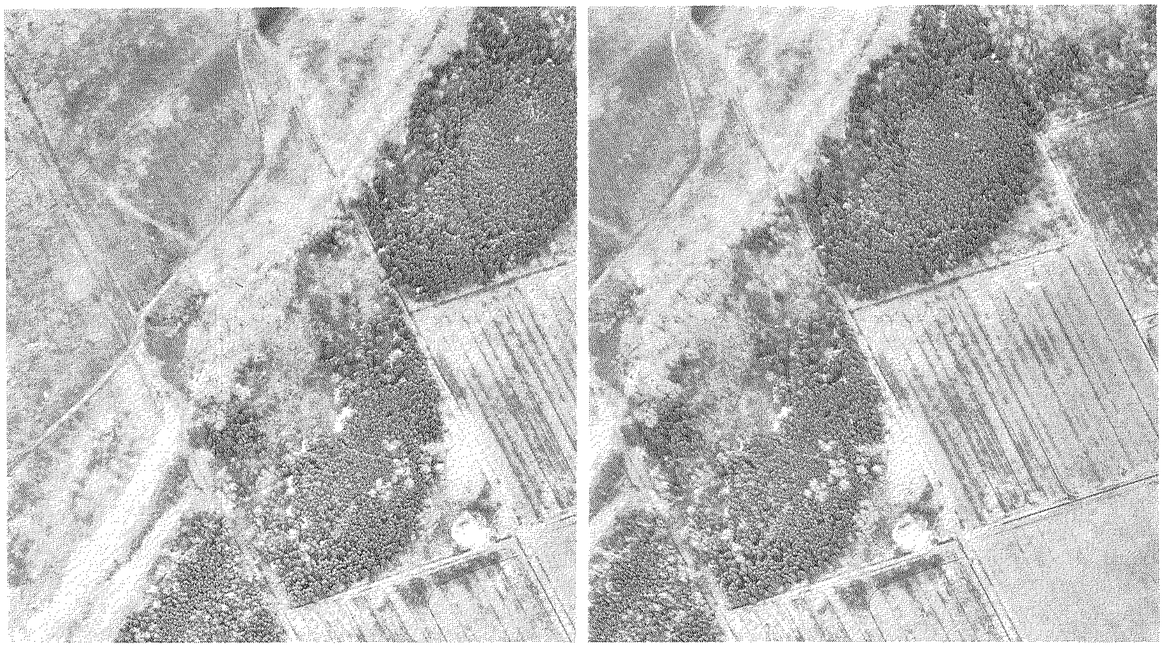


Figure 43. Stands of eastern white cedar. (Ottawa, Ontario; May 8, 1971; scale 1:6000; photographs A-22226, 18, 19).

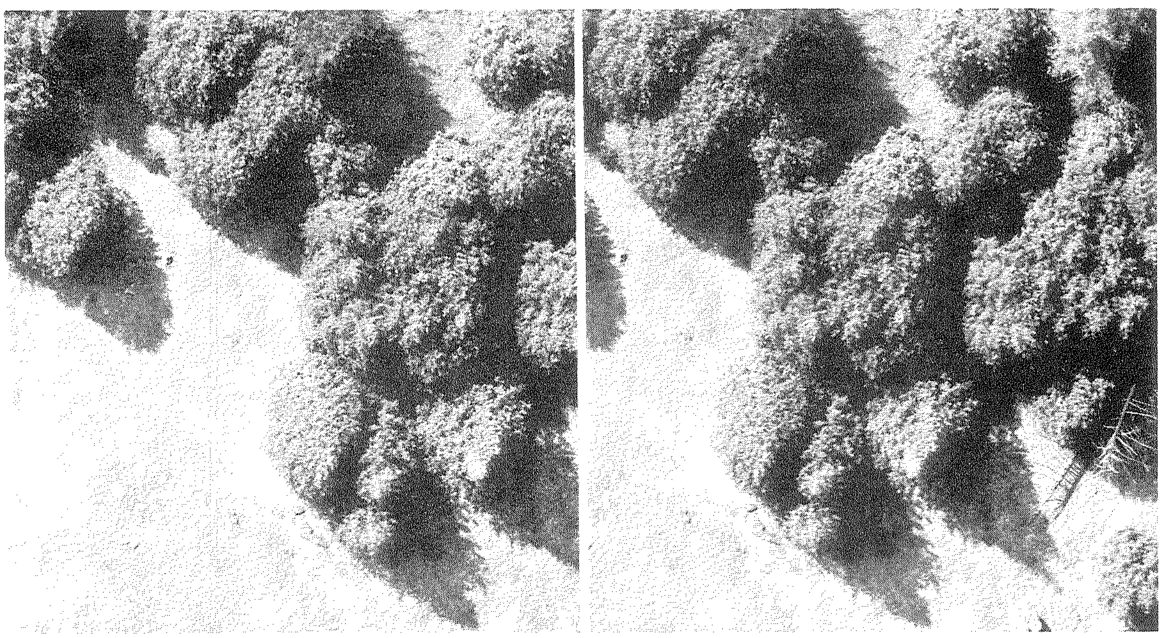
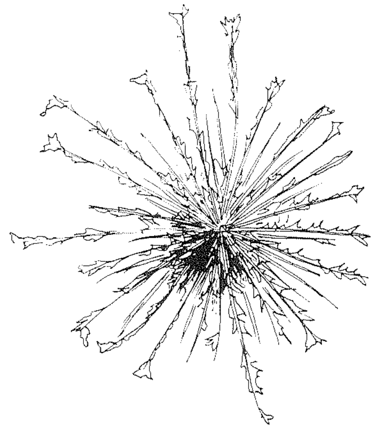


Figure 44. Eastern white cedar is recognized by its regular, symmetrical crown and its rounded top. (Between Madoc and Marmora, Ontarip; May 5, 1950; scale enlarged to 1:350 from contact scale of 1:600; photograph X-185, 111).

Western red cedar *(Thuja plicata* Donn*)*

Western red cedar is a large tree of British Columbia; it can reach heights of 60 m, but can also be stunted and scrubby on poor sites. It seldom grows in pure stands and is often associated with Douglas fir, sitka spruce and western hemlock.



Its crown is narrowly conical. On large scale aerial photographs its relatively fine and long branches and their long, regular sweep are characteristic. Branches are spreading and on vertical photographs appear to radiate like spokes; they have a tendency to turn up at the ends. Branches sometimes appear bare when seen from above and limbs are more visible than in yellow cypress. Overmature trees develop a characteristically narrow top which may end in a dead spike (Figure 45).

Photographic tone is usually light but darkens somewhat with age, perhaps due to the more drooping branches of older trees. The crown is open and gives the impression of being partly defoliated, with remaining foliage in tufts and patches, especially on older trees.

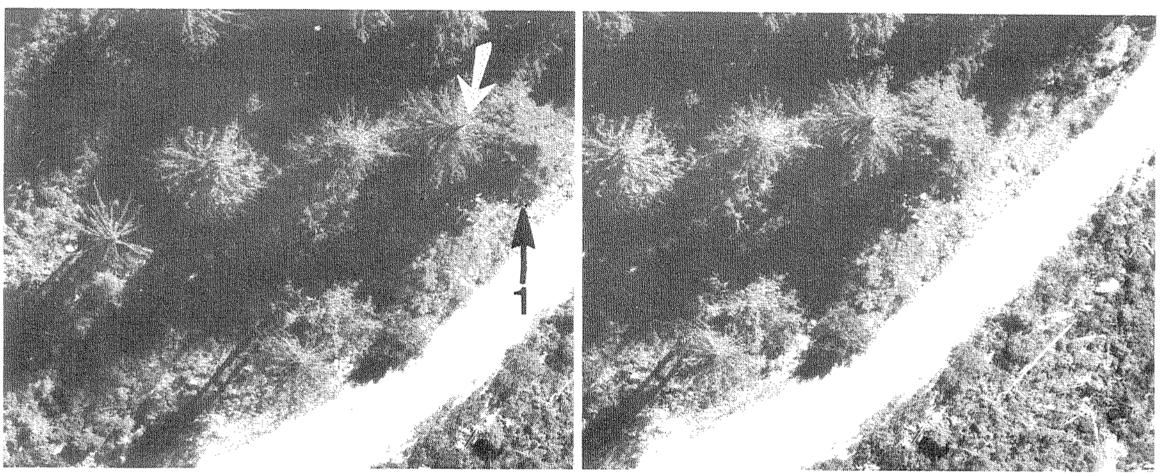
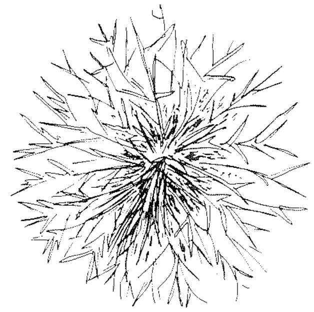


Figure 45. Western red cedar. These trees show the characteristics of mature western red cedar: narrow branches radiating like spokes, dead branches and in one case a dead top (white arrow). The tree at the right (1) is a western hemlock. (Gwendoline Lake, B.C.; July 20, 1971; scale enlarged to approximately 1:900 from contact scale of approximately 1:1600; photographs FMI 71-14, 286, 287).

Yellow cypress *(Chamaecyparis nootkatensis* (D. Don) Spach*)*

Yellow cypress is largely confined to the coast of British Columbia. It is a tree of medium size, commonly in the 20-25 m range. Yellow cypress grows in clumps, or singly, in association with other conifers.



The crown is conical with a pointed tip (Figure 46). The branches tend to droop more than in western red cedar. The branchlets hang almost vertically and the branches therefore appear finer than those of western red cedar and have a lacy appearance which western red cedar does not have. The crown is moderately open and gives the impression of being evenly and partly defoliated. This differentiates it from western red cedar which appears "defoliated in patches". Foliage is dark green and appears in medium greys on panchromatic photographs (Figure 46). For further comparisons see the description of western red cedar and Figure 45.

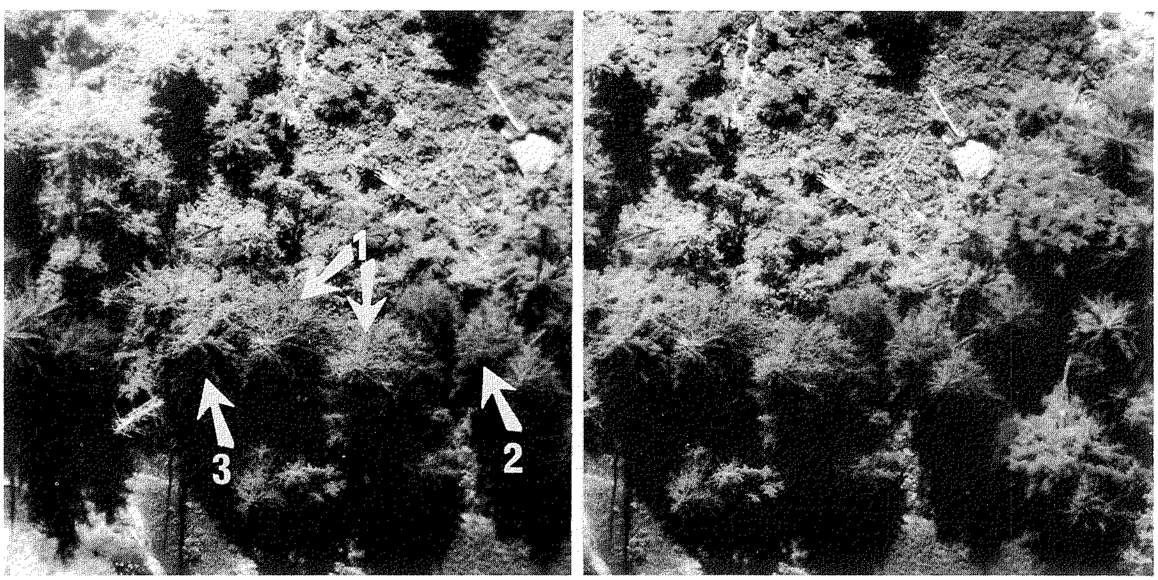


Figure 46. Yellow cypress (1), amabilis fir (2) and western hemlock (3). (Placid Lake, B.C.; July 21, 1971; scale enlarged to approximately 1:750 from contact scale of approximately 1:1500; photographs FMI 71-14, 334, 335).

2. THE BROAD-LEAVED TREES

Key to Hardwoods in Summer

1. Crowns closed, dense, large.

    2. Crowns very symmetrical and very smooth, oblong or oval, trees form small portion of stand . . . . basswood.

    2. Crowns irregularly rounded (sometimes symmetrical), or billowy, or tufted.

        3. Surface of crown not smooth, but billowy or rounded . . . . oak*, sugar maple*, beech*.

        3. Surface of crown not smooth, irregularly rounded or tufted . . . . yellow birch*.

        3. Crown texture smoky, indistinct, hazy . . . . beech, black cherry.

        (*A local tone-key and reference to detailed species descriptions are necessary to distinguish these species).

1. Crowns small, or if large, open or multiple.

    4. Crowns small, or if large, open and irregular, revealing light-coloured trunk.

        5. Trunk chalk-white, often forked, trees tend to grow in clumps . . . . white birch.

        5. Trunk light, but not white, undivided trunk reaching high into crown, generally not in clumps . . . . aspen**.

        (**Small balsam poplar may be included; refer to species descriptions).

    4. Crowns medium sized or large, trunk dark.

        6. Crown tufted, or narrow and pointed.

            7. Crown tufted, branches and twigs fine . . . . red maple.

            7. Crown pointed, branches and twigs coarse . . . . . . balsam poplar.

        6. Crowns flat-topped or rounded.

            8. Crowns medium-sized, rounded, undivided trunk, branches ascending . . . . ash.

            8. Crown large, wide, trunk divided into big spreading branches.

                9. Top of crown appears pitted . . . . elm.

                9. Top of crown closed . . . . silver maple.

Willow *(Salix* L.*)*

There are many species of willow in Canada. Most do not reach tree size. All tend to display a fine foliage texture and light-toned foliage. Photo interpreters will frequently encounter a uniform blanket of willow brush on moist sites, in particular along rivers or creeks. A knowledge of the role of willow in ecological succession, covered in Figure 47, is important.

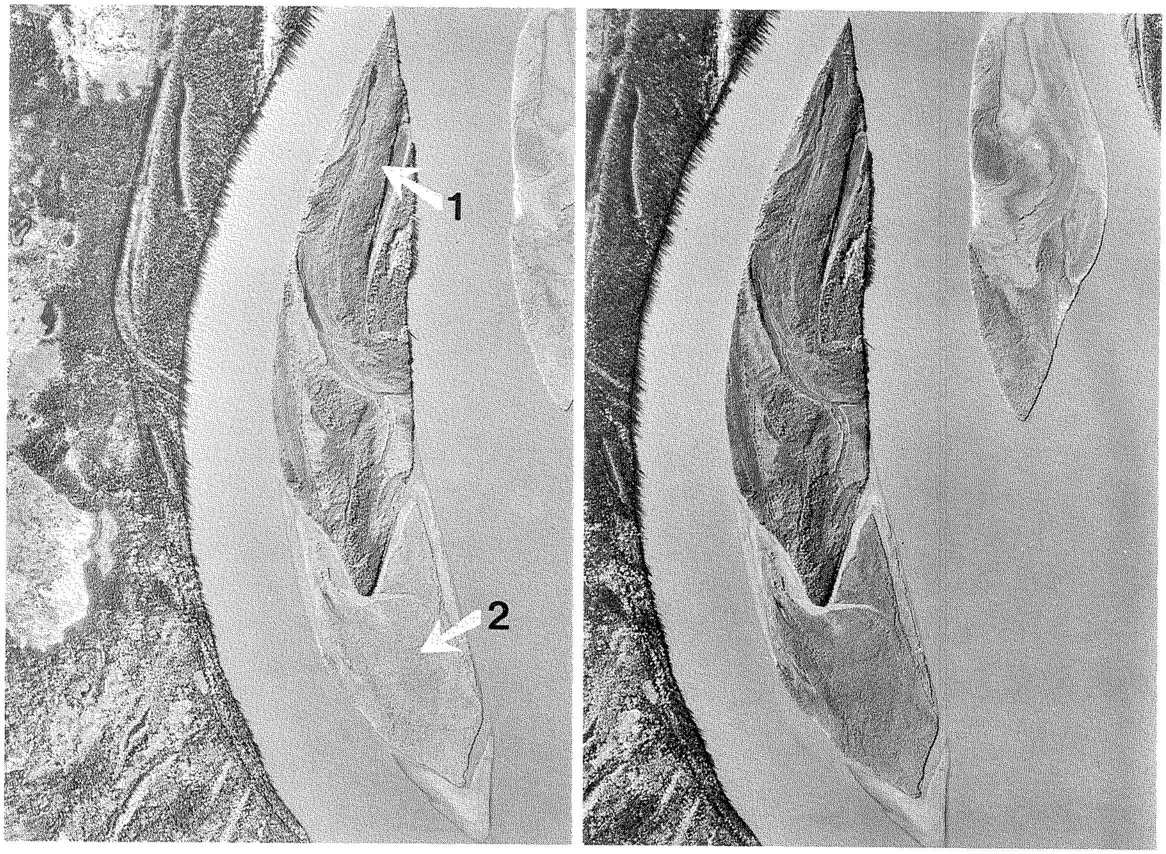


Figure 47. A characteristic sequence of vegetation on northern alluvial sites is: horsetails (*Equisetum* sp.) on the newest sites, followed by willow and then alder, balsam poplar or spruce. Knowledge of this order helps in the identification of alder (1) and willow (2) on the island shown above. Note that willow appears in lighter tones than alder. (Slave River, NWT; September 27, 1957; scale 1:23,000; photographs A-15874, 24, 25).

Trembling aspen *(Populus tremuloides* Michx.*)* and **Largetooth aspen** *(Populus grandidentata* Michx.*)*

Trembling aspen and largetooth aspen both have a single, gradually tapering trunk with reaches almost to the top of the crown. The crown which consists of relatively few branches is small, round-topped, and open. Aspen frequently grows in pure stands which are of fire origin. On aerial photographs such stands are medium or light tones and show an even, fine-grained texture. Aspen is very intolerant and, if it grows in mixture with tolerant species, it will be a dominant unless finally overtopped. The foliage of aspen is thin and as a result its shadow will usually not be as dark as that cast by hardwoods with dense crowns.

The two species of aspen are similar and to separate them on aerial photographs is of no practical importance. Yet this distinction can be made on photographs taken during the period of leafing, because largetooth aspen leafs out significantly later than trembling aspen. Largetooth aspen can also be identified by the young leaves which are covered with a white down and give the crown an almost white appearance on panchromatic aerial photographs taken a few days after leafing (Figure 10).

Aspen can be difficult to distinguish from white birch, a species with which it is frequently associated, but aspen has a more distinct crown perimeter (Figure 55). The two species are best separated on photographs taken when the leaves have fallen, because then the single trunk of aspen can be distinguished from the usually divided trunk of white birch which has a tendency to coppice. White birch stands are generally denser than aspen stands. Although both species have light-coloured bark when compared with other hardwoods, the stems of white birch will show up considerably brighter than those of aspen. At large scales and in leafless condition, the most reliable distinction is based on the fact that all twigs of aspen are light in colour. The smaller branches and twigs of white birch are reddish brown; on panchromatic photographs they are far less distinct than those of aspen.

Differences between aspen and balsam poplar are illustrated in Figure 52. Other illustrations at various scales are Figures 48, 49 and 50.

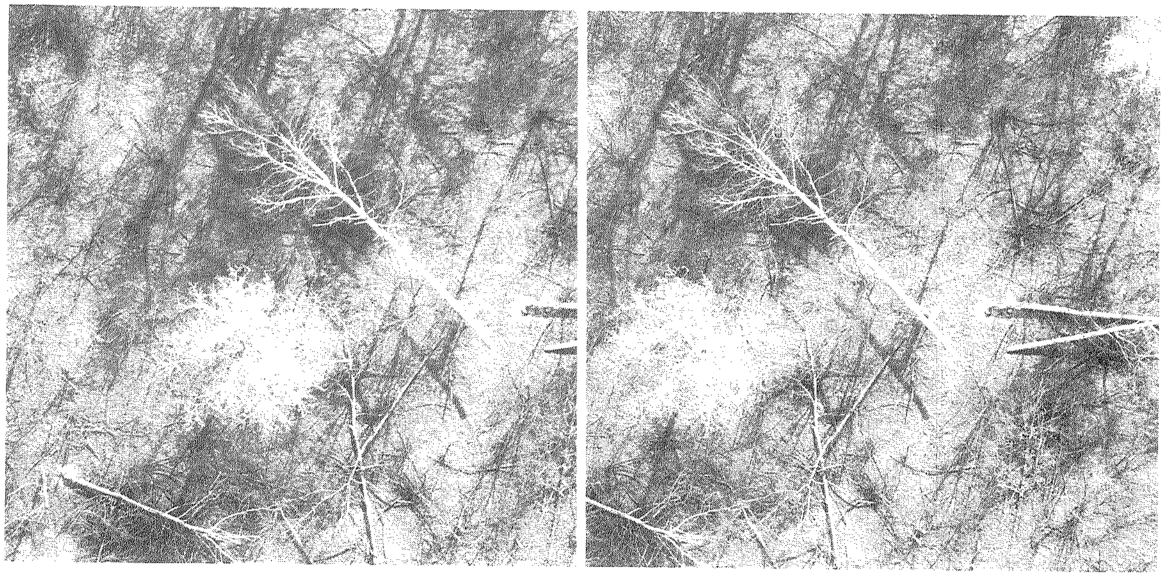


Figure 48. Standing and beaver-felled largetooth aspen. Note light colour, gradually tapering trunk, rounded crown and coarse light-coloured twigs. (Marmora, Ontario; May 5, 1950; scale enlarged to 1:350 from contact scale of 1:600; photograph X-185, 68).

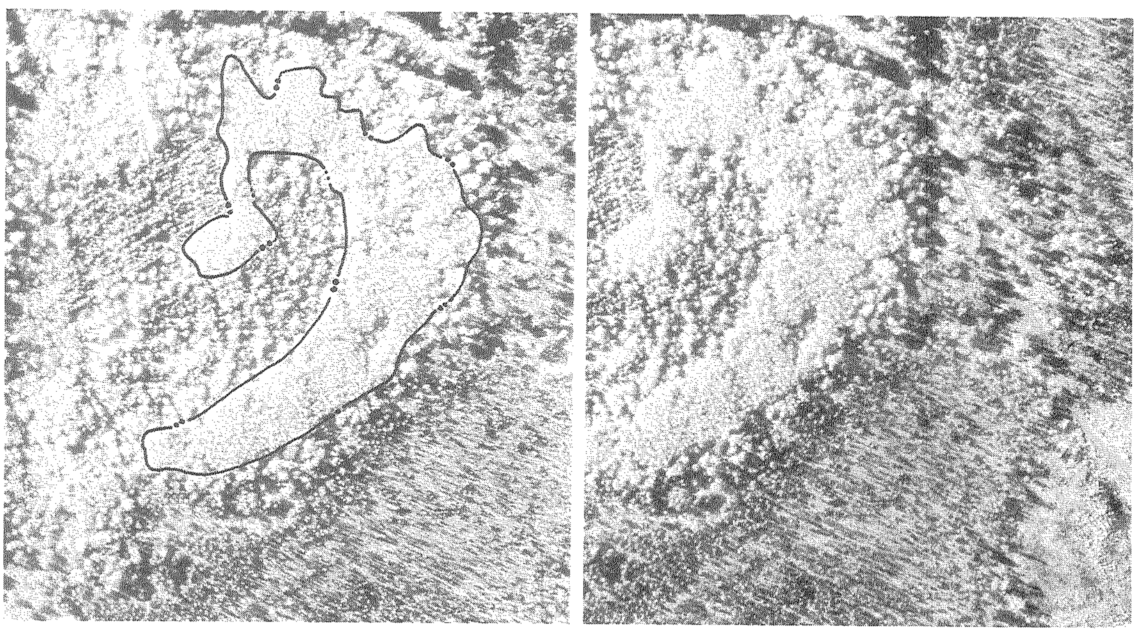


Figure 49. The type line surrounds a pure stand of young trembling aspen. The crowns are small, open and rounded. The very light tone is due to the use of infrared photography. (Petawawa, Ontario; July 17, 1958; scale 1:4000; infrared photographs A-16147, 42, 43).

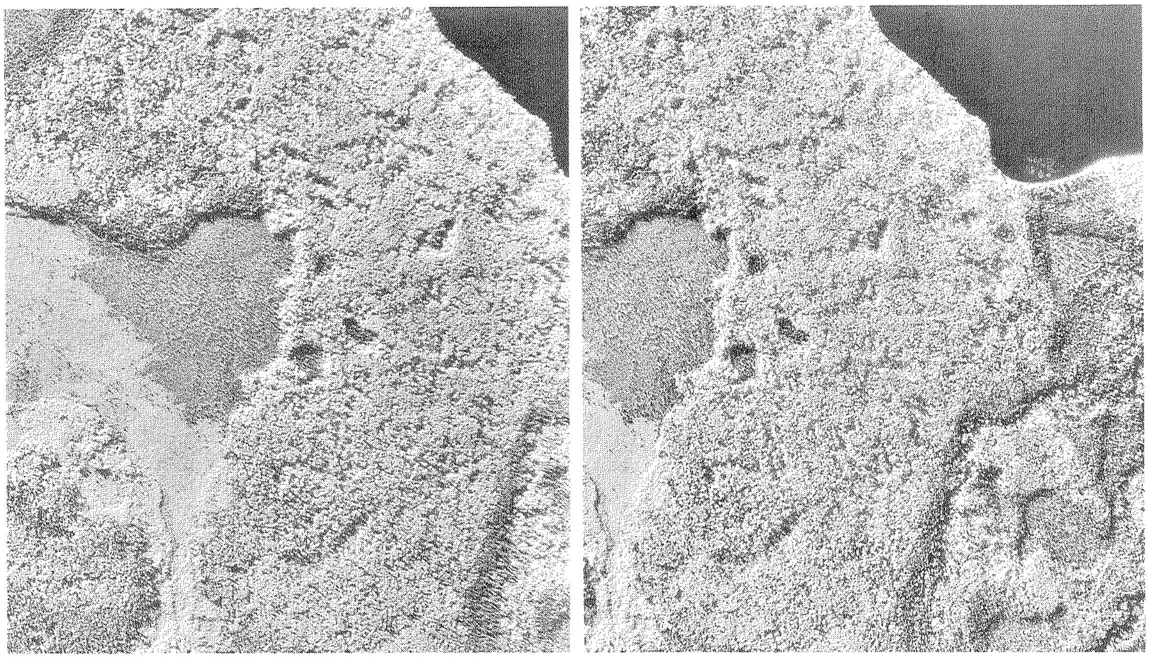


Figure 50. Trembling aspen on infrared photography. All crowns are of about the same size; they are irregularly rounded and small in relation to tree size. A tendency to form clones can be observed. Some white spruce occurs throughout the stand. A swamp with small conifers appears left of centre. (Wabasca, Alberta; September 13, 1962; scale 1:15,840; photographs A-17481, 39, 40).

Balsam poplar *(Populus balsamifera L.)*

Balsam poplar is characteristic of moist soils and therefore is commonly found along rivers and lakes or in rich bottom lands, where it grows in small pure patches or in association with willow, alder, white birch, spruce and balsam fir. In alluvial flatlands in the Northwest Territories it occurs in pure stands (Figures 29, 51).

Balsam poplar has a straight, usually undivided trunk and a narrow, open, conical crown which is formed by a few stout, ascending branches. These branches are relatively straight and longer than those of aspen of similar size (Figure 52). Except for very old trees the tops are usually pointed. Balsam poplar is very intolerant and will therefore be a dominant when growing in mixture with other species.

Figure 51. The yellow fall colours of balsam poplar readily distinguish it from the dark-coloured white spruce. Some of the willows and alders in the brush areas have also changed to fall colours. (Nagle Channel, Slave River Delta, NWT; September 16, 1966; scale 1:24,000, photographs A-30018, 78, 79).

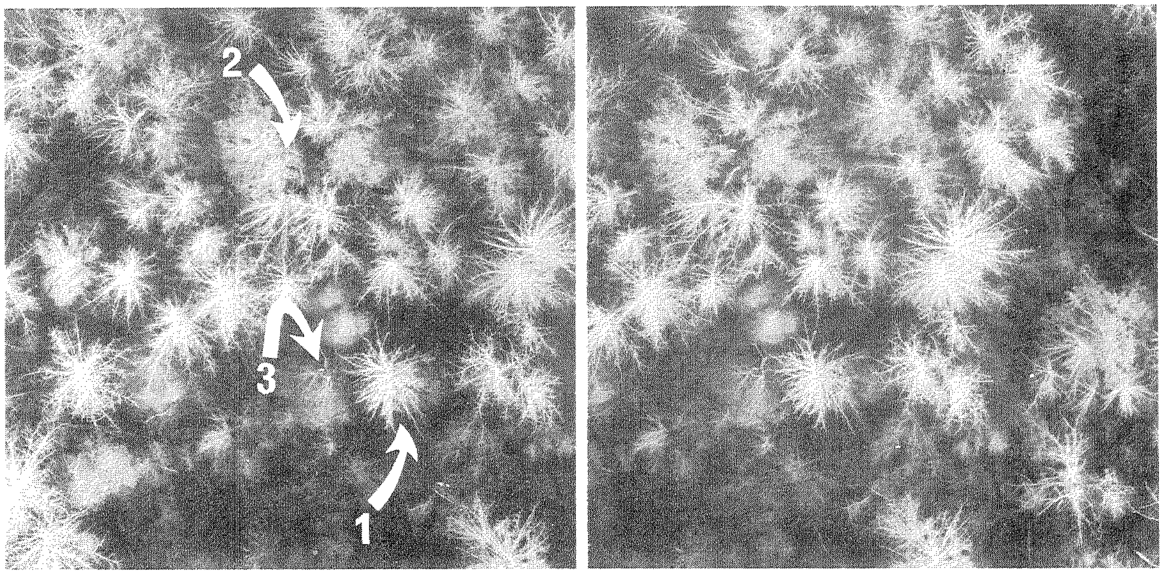


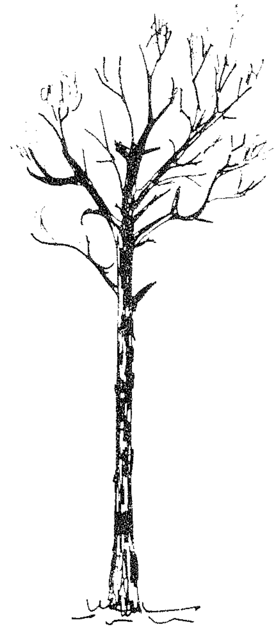
Figure 52. The long, relatively straight and ascending branches of balsam poplar (1) distinguish it from trembling aspen (2) which has shorter and more irregular branching. The smaller branches and twigs of both species are coarse, in contrast with white birch (3). (Near Whitecourt, Alberta; May 12, 1978; scale enlarged to 1:570 from contact scale of 1:1140; Alberta Forest Service photographs 21, 649, 650).

Black cottonwood *(Populus trichocarpa* Torr. & Gray*)*

This western species is similar to balsam poplar in both appearance and site requirements (Figure 65).

Yellow birch *(Betula alleghaniensis* Britton*)* *(Betula lutea* Michx. F.*)*

Except when growing in the open, yellow birch develops a long and massive, well-defined central trunk which supports an irregularly rounded or tufted crown which is widest near the top. The main branches which are coarse and few in number, rise at an acute angle to the trunk before dividing to form a hazy twig structure.



Yellow birch is often associated with sugar maple although it prefers moister and cooler locations. The result is that the two species can sometimes be separated by their site requirements: maple is more common on the higher hills, upper slopes and ridges, while yellow birch is more characteristic of lower slopes. The two species can also be separated by the darker tone of yellow birch (Figure 53); this difference is particularly strong in late spring and early summer.

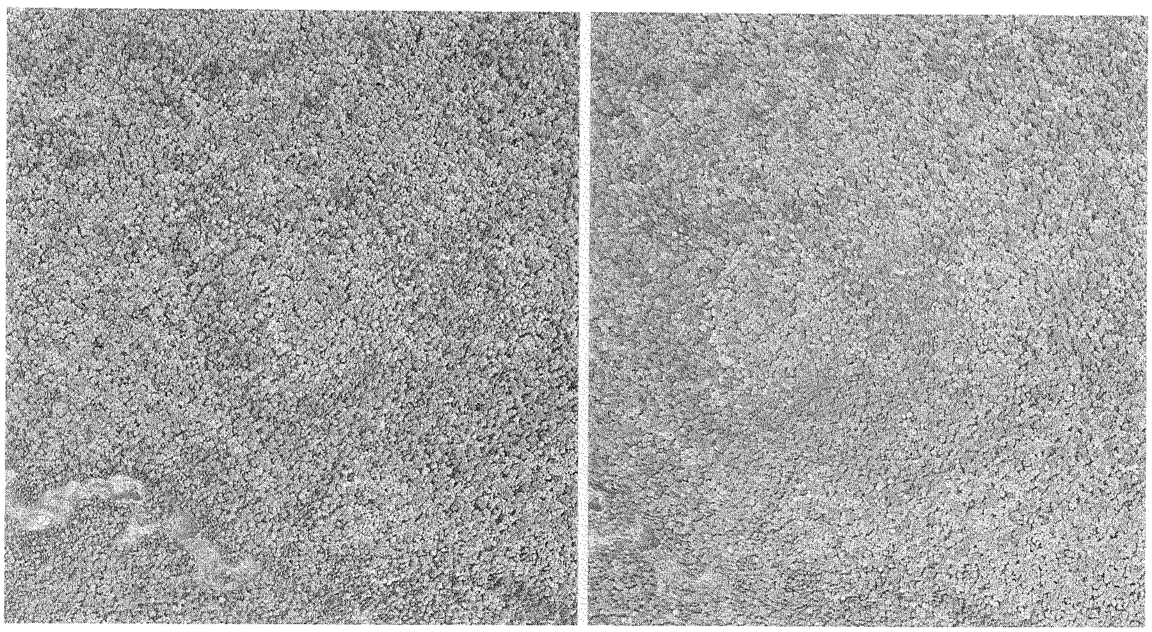
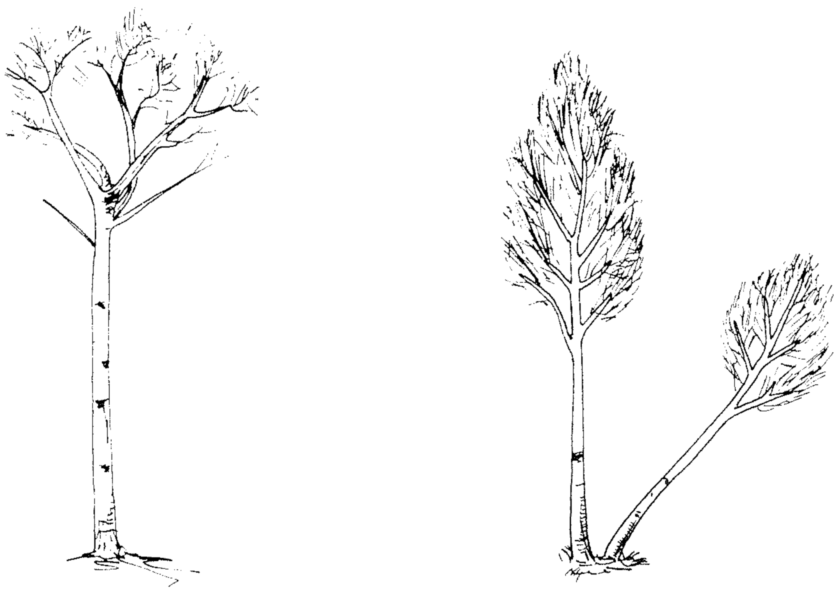


Figure 53. Yellow birch and sugar maple can often be distinguished in the late spring or early summer. The darker, large crowns are yellow birch, the lighter ones are sugar maple. (Goulais River, Ontario; June 4, 1959; scale 1:12,000; photographs A-16537, 13, 14).

White birch *(Betula papyrifera* Marsh.)

White birch is an intolerant tree which grows in pure or mixed stands. Young trees have small, conical crowns, while the crowns of old trees are more rounded and irregular. The trunk, which is characterized by its white colour, is commonly forked and divides into a number of large ascending branches. The white trunk identifies white birch on photographs taken when the leaves have fallen (Figure 54). On such photographs, even at scales as large as 1:600, only the trunk and a few main branches will show because the fine, reddish-brown branchlets and twigs are blurred. The result is that the main branches and the trunk appear to be surrounded by a haze. The same effect is not observed on aspen, because the small branches of these trees are coarser and lighter in colour.

White birch frequently grows in clusters of several stems, often leaning or crooked. On panchromatic summer photographs its foliage appears in darker tones than aspen. It is often difficult to distinguish from aspen and some of the characteristics used for this distinction have been given in the description of aspen and in Figure 55.



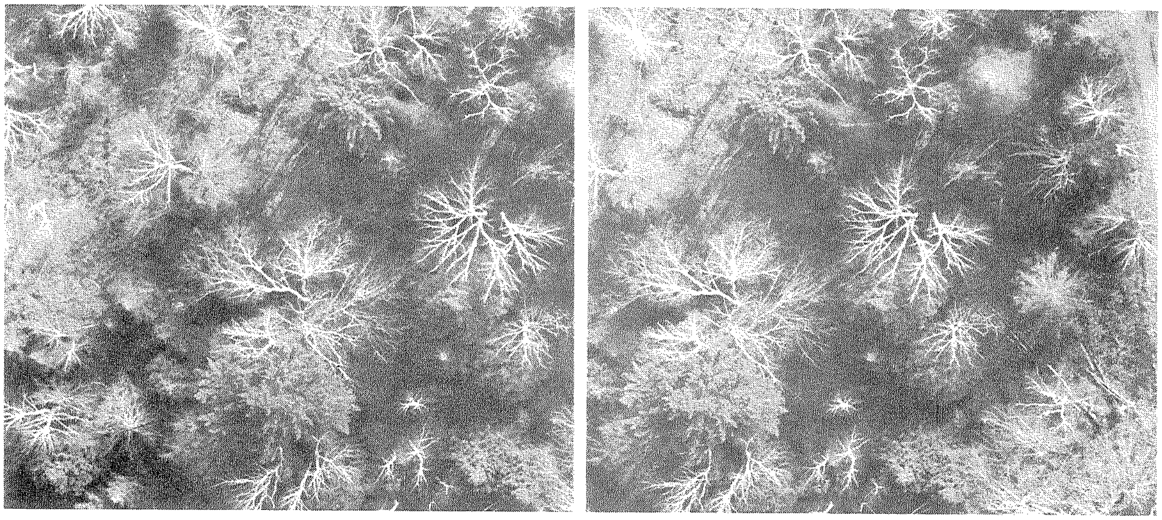


Figure 54. White birch in all but leafless condition. The wide main branches are clearly visible, but smaller branches which are russet in colour appear fuzzy and grey on this stereogram. A few remaining leaves give the only indication of the presence of the smallest twigs. The large conifer at lower left of the right image is a white pine. (Petawawa, Ontario; October 25, 1964; scale enlarged to 1:600 from contact scale of 1:1200; photographs F-42, 142, 143).

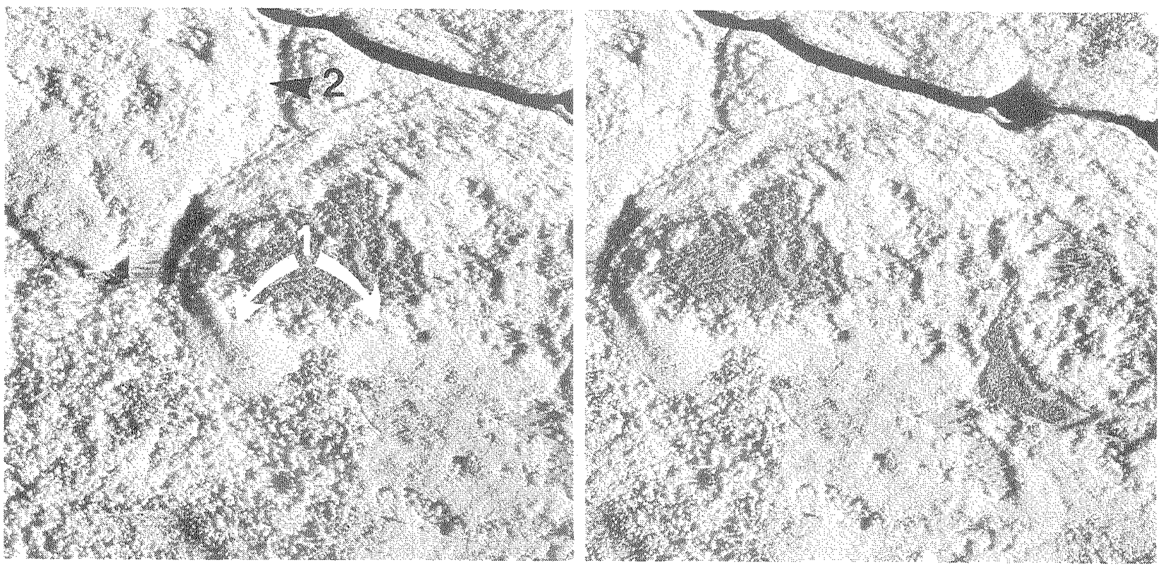


Figure 55. Infrared photograph showing that the crowns of white birch (1) are typically smaller than those of aspen. The stand at (2) consists largely of aspen. Its average height is 13 m, which is less than for the white birch stand. Nevertheless, the aspen crowns are wider. (Dokis Indian Reserve, Ontario; August 11, 1965; scale 1:15,840; photographs A-18917, 55, 56).

Grey birch *(Betula populifolia* Marsh.)

This is an eastern species, similar to white birch. It has a limited range and is a small tree with height usually below 12 m. Grey birch has a strong tendency to grow in pure stands (Figure 56), while white birch has a stronger tendency to grow in mixtures.

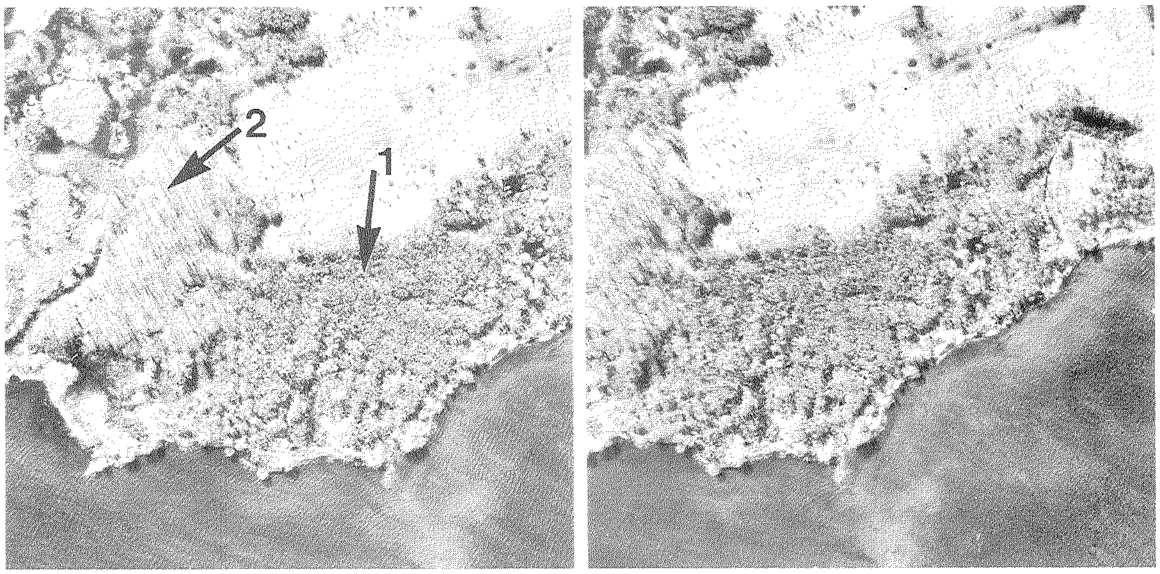


Figure 56. A stand of grey birch (1) and a stand of red and white oak (2). The grey birch stand shows the typical small crowns and a characteristic tendency to grow in clumps. The main difference between the stands is phenological: the birch stand is largely in leaf, while the oaks are bare. (Grenadier Island, St. Lawrence Islands National Park, Ontario; May 1, 1974; scale 1:8000; photographs A-23672, 155, 156).

Speckled alder *(Alnus rugosa* (Du Roi) Spreng.*)* *(Alnus incana* (L.) Moench*)*

Speckled alder is usually a high shrub which forms clumps of several crooked stems. The crowns are indistinct and merge to form what appears to be a uniform grey blanket on medium scale panchromatic photographs.

Site requirements are important in recognizing alder. Alder grows in swamps or on wet sites along lakes and rivers (Figure 57): some drainage is required, but this condition is less important than with willow. Alder is highly intolerant of shade and therefore grows in pure stands or in stands with only scattered individuals of other species. The important relationship of alder and willow is described with Figure 47.

The separation of alder and willow from young aspen or white birch may cause problems. A knowledge of site and stand history will be helpful: aspen and birch are to be suspected after fires or in cutovers. Also, as Zsilinszky (1966) illustrates by examples, birch and aspen do not form a uniform crown canopy; rather, individual trees are visible.

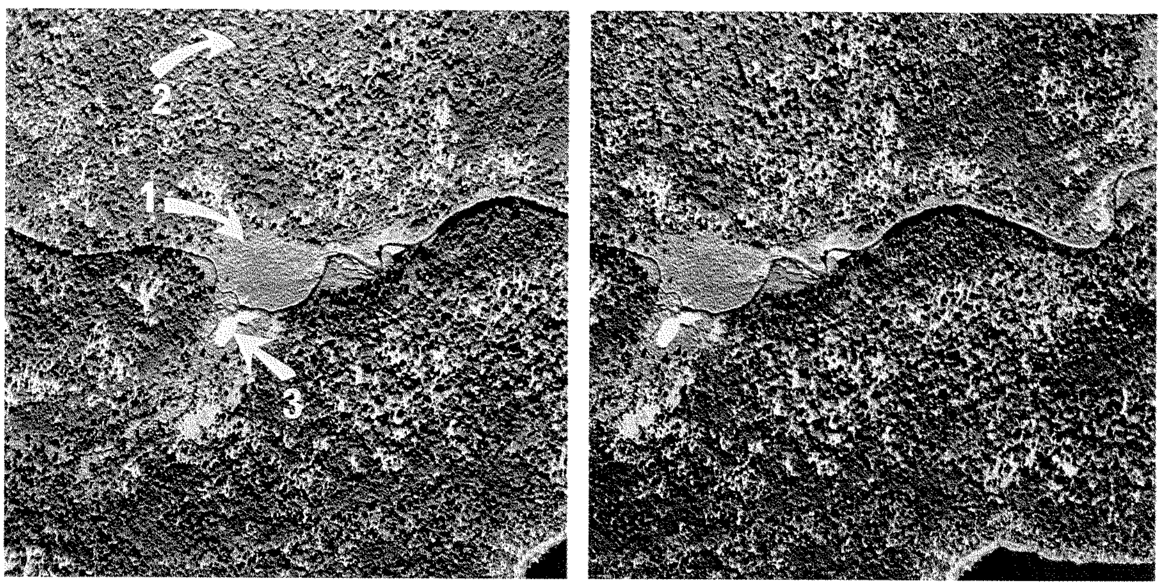
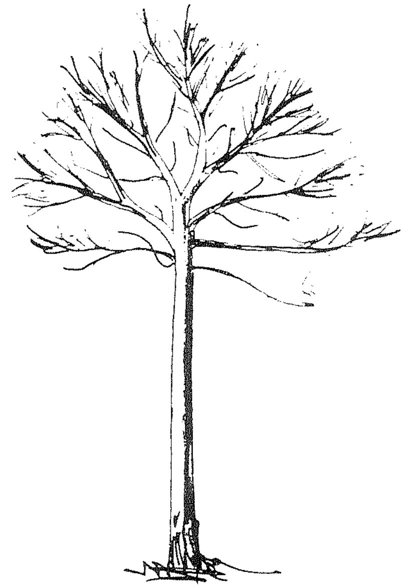


Figure 57. On this colour infrared photograph speckled lader (1) appears in magenta, similar to other hardwoods (2). The light area (3) is a sawdust deposit which indicates that the area now covered by alder was probably once the bottom of a mill pond. (Fundy National Park, New Brunswick; September 12, 1970; scale 1:10,000; photographs FMI 70-67, 54, 55).

American beech *(Fagus grandifolia* Ehrh.*)*



Beech is a very tolerant tree commonly associated with sugar maple and yellow birch, from which it is difficult to distinguish on summer photos. When growing in a stand it develops a massive, straight trunk, which has smooth grey bark. The lower branches are almost horizontal and form large, flat sprays with fine surface texture (Figure 58). On aerial photographs the crown has a fine and hazy texture. Zsilinszky (1966), with reference to 1:15,840 photographs, compares it to a "grey cloud of smoke". This feature can distinguish it from the solid, billowy crowns of sugar maple; the darker photographic tone of foliage is another distinguishing characteristic. The crown is wide-spreading and, because of its many fine branches it appears fuzzy and indistinct on winter photographs. The light-coloured trunk could also be an identifying feature.

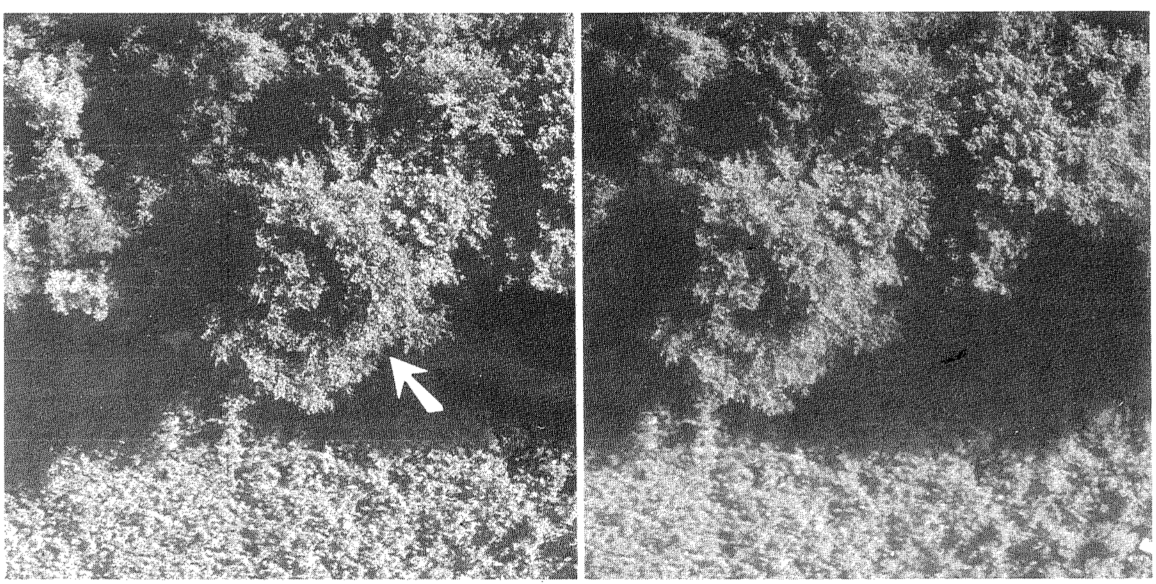


Figure 58. This American beech displays the characteristic horizontal branching habit. Individual branches are not prominent, texture is fine, and foliage forms dense layers. (Meach Lake, Quebec; August 20, 1951; scale enlarged to 1:270 from contact scale of 1:600; photograph X-226, 26).

White oak *(Quercus alba* L.)
Bur oak *(Quercus macrocarpa* Michx.)

These species develop massive, broad crowns when growing in the open, while in the forest they have a straight trunk and a smaller crown. The differences from red oak are slight. White oak tends to develop a somewhat smoother crown, while the branching of bur oak is more gnarled and twisted than that of red oak and white oak. There is also the difference in the colour of young foliage, mentioned in the description of red oak.

Figures 59 (bur oak) and 60 (white oak) illustrate the main branching characteristics of the three oak species described.

Red oak *(Quercus rubra* L.)

Under forest conditions red oak develops a tall and straight bole and stout branches which form a solid, round-topped crown. The larger branches are very prominent and tend to show up individually, which on summer photographs gives the crown a billowy appearance. Because of its lustrous, bright-green leaves and its compact crown, red oak reflects much light and appears light on photographs. However, any shadows seen in openings will be very dark.

Losee (1942) reports that on panchromatic fall photographs taken near Petawawa in Ontario, red oak appeared darker than any other broad-leaved species. The reason for this is that oak leaves in the fall turn reddish-brown, while other hardwoods in the area, such as birch, aspen, maple and elm, turn yellow or red (*see* Figure 12).

Young, emergent leaves of red oak have a reddish tinge which on panchromatic photographs results in a distinctly darker tone than sugar maple (Figure 11) or white and bur oak.

Figure 59. Bur oak – leafless and in leaf. The upper trunk divides into radiating, crooked branches.

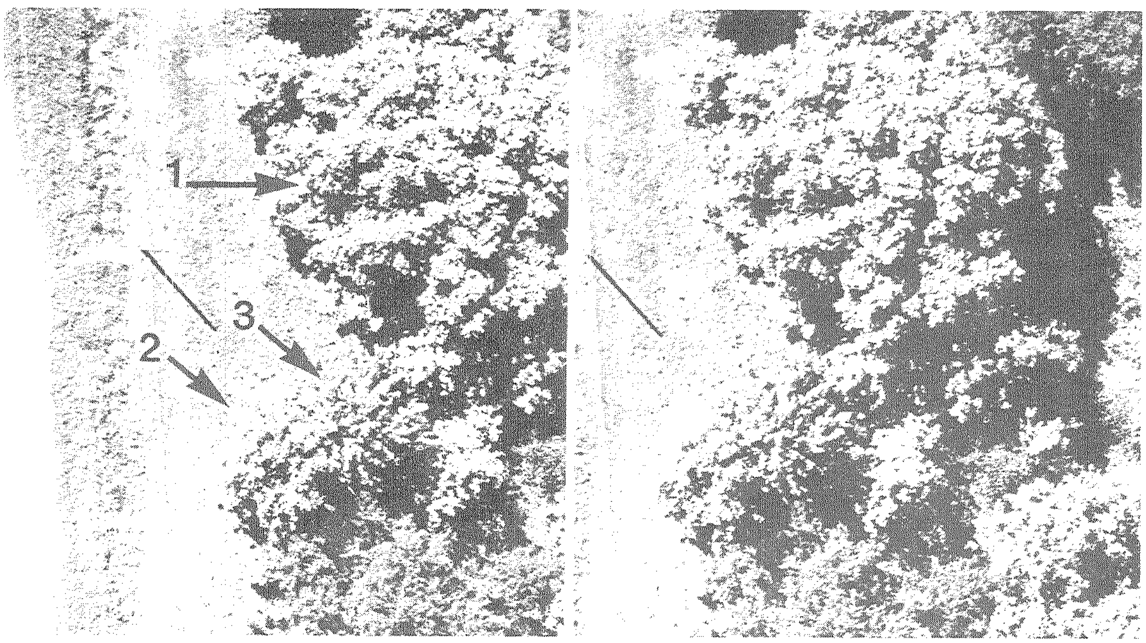


Figure 60. The irregularly rounded crown of a large white oak (1) has prominent individual branches and a coarse-textured crown surface. At this scale the similarities with sugar maple (*see* Figure 63) are great and tonal differences would have to be relied upon for identification. The distinction between a younger white oak (2) and a red maple (3) is not as difficult. (Bourget, Ontario; June 10, 1971; scale enlarged to approximately 1:400 from contact scale of approximately 1:1200; photographs FMI 71-11, 387, 388).

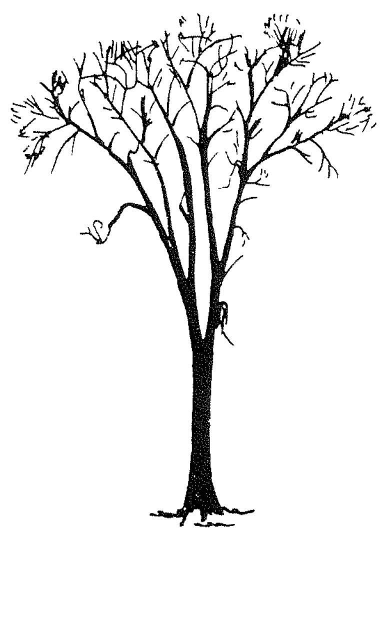
White elm *(Ulmus americana* L.)

When growing in the open, elm is easily recognized by its broad and umbrella-shaped crown, which is formed by the gradually spreading, large limbs into which the trunk divides, often close to the ground (Figure 61). Under forest conditions elm develops a straight trunk, which may be undivided for a considerable height.

Except on large scale photographs, where the characteristic branching habit can be seen, elm is most difficult to identify when growing in a forest. Its more open and often composite crown, which appears to be divided into segments (Figure 62), may be distinguished from the solid, rounded or billowy crowns of the oaks, sugar maple, basswood, and by its size it can be separated from aspen and white birch. On panchromatic photographs its tone is darker than that of sugar maple.

White elm is often associated with silver maple. A feature distinguishing these species is that silver maple has a dense top of fine branches while the main limbs of elm are spreading and leave openings in the crown surface. White elm seldom forms pure stands.

Dutch elm disease (*Ceratocystis ulmi*) has greatly reduced the elm population; in much of its natural range it is difficult to find groups of trees without seeing some dead elms or the symptoms of the disease: wilting foliage, partly defoliated crowns, or early change to fall colours.



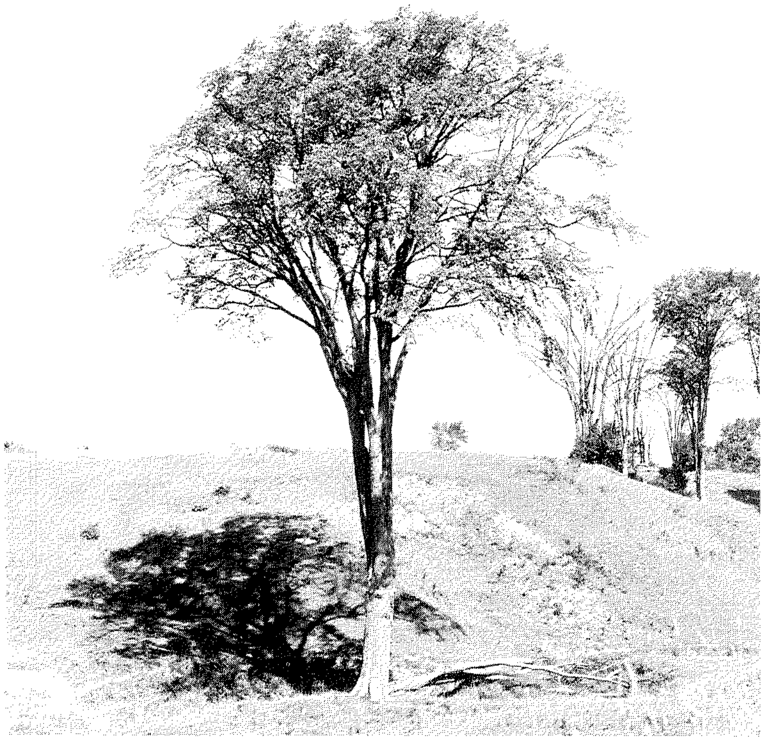


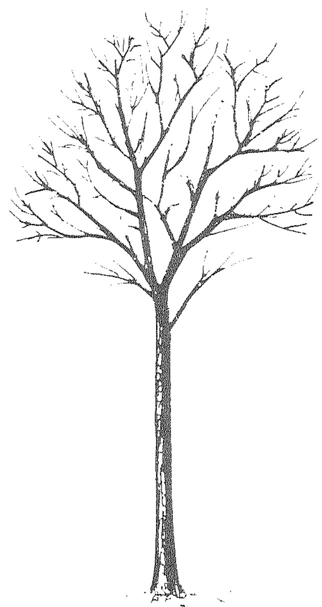
Figure 61. A typical white elm with its umbrella-shaped crown. Some of the trees in the background have died as a result of Dutch elm disease.

Figure 62. White elm on spring photography with foliage at an early stage of development. Note the characteristic lacey texture and the fact that crowns are divided into irregular segments. At smaller scales these crowns would appear in more regular shapes. (Ottawa, Ontario; May 8, 1971; scale 1:6000; photographs A-22226, 191, 192).

Sugar maple (*Acer saccharum* Marsh.)

Sugar maple is the most common of the northern tolerant hardwoods and it is the only one which commonly occurs in pure stands. On good sites and in closed stands sugar maple will have a straight trunk which rises to a considerable height before it divides into several big branches. In the open and on poor sites its trunk will be short and with many branches.

The branches of sugar maple, which are slender and ascending, form a rounded, sometimes symmetrical crown. The crown is dense and billowy (Figures 63, 64). Foliage is always lighter in tone than yellow birch or elm. This contrast is strongest in early summer (Figure 53). A number of references to sugar maple are in the preceding chapter on "The Season of Photography"; *see*, for example, Figures 11 and 12.



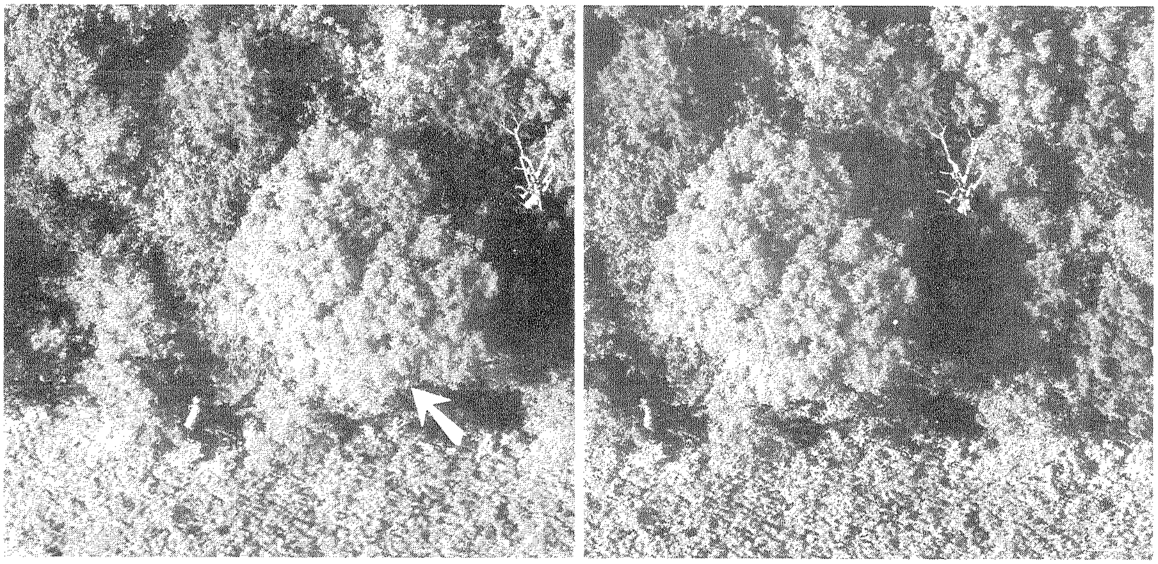


Figure 63. Sugar maple at large scale. The crown is large, solid, rounded, and has a fairly smooth surface. (Meach Lake, Quebec; August 20, 1951; scale enlarged to 1:300 from contact scale of 1:600; photograph X-226, 20).

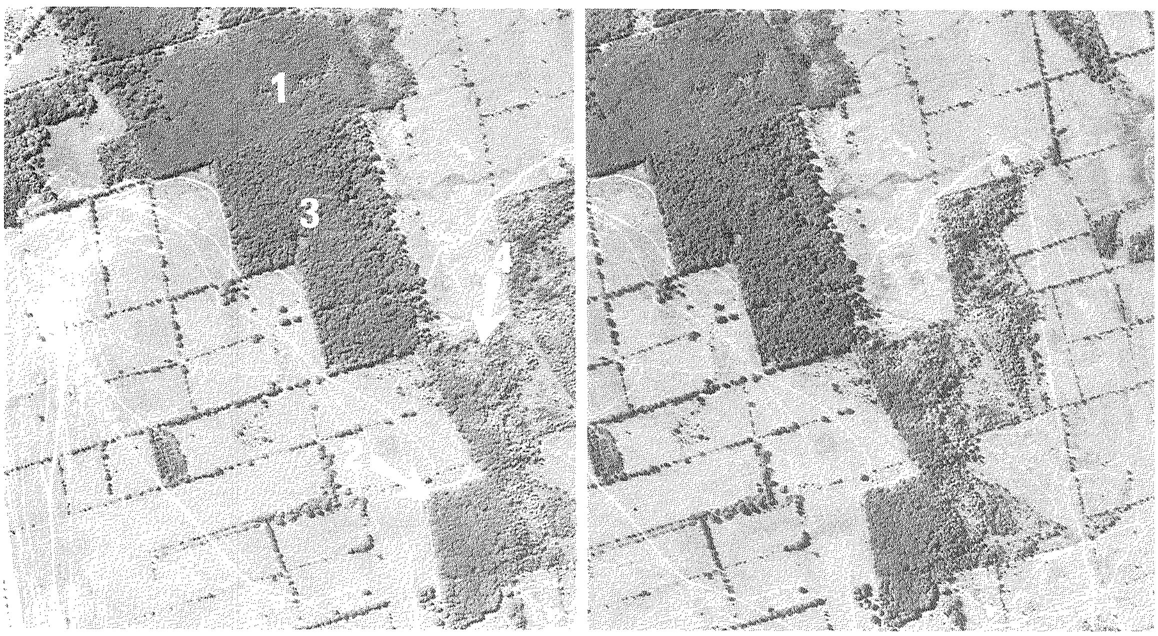


Figure 64. Several stands of sugar maple. The stand at (1) is very dense, 12-15 m high and has an even canopy. The stand at (2) (height 21-25 m) has well-defined, billowy crowns. The stand at (3) (average height 23 m) shows more variation in tree height and photographic tone. The marked tonal variations and generally lighter tones of the 15 m height stand at (4) are the result of lower vigour and poor crown development on this exposed slope. (Camp Meaford, Ontario; August 2, 1962; scale enlarged to 1:18,500 from 1:24,000; photographs A-17616, 79, 80).

Bigleaf maple *(Acer macrophyllum* Pursh*)*

This species is one of the few hardwoods of the coastal region of British Columbia. It has a deep, rounded crown which becomes broad when growing in the open (Figure 65). One of its distinguishing characteristics are very large leaves (up to 30 cm across) which may be individually visible at large scales.

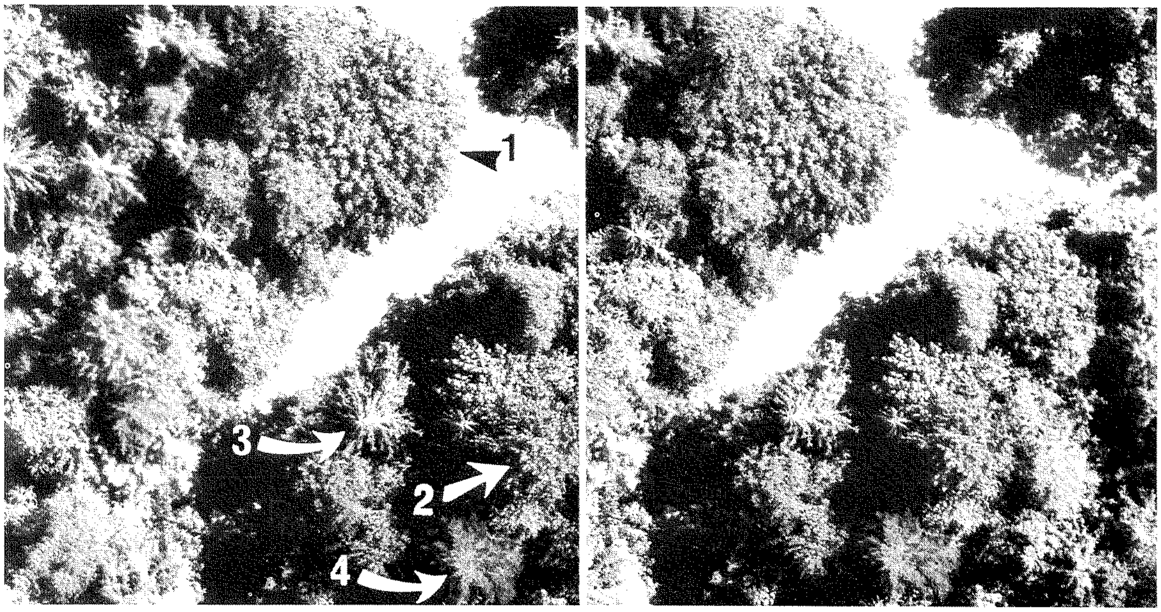


Figure 65. Bigleaf maple (1), black cottonwood (2), western red cedar (3) and Douglas fir (4). (Loon Lake, B.C.; July 21, 1971; scale enlarged to 1:850 from contact scale of 1:1700; photographs FMI 71-21, 377, 378).

Silver maple *(Acer saccharinum* L.*)*

Silver maple generally grows in moist and swampy locations. Its trunk divides near the ground into several ascending, big branches, which form a wide-spreading crown. The smaller branches are slender and the twig structure is dense. The bark of young trees and of the branches of old trees is silvery grey (Figures 66, 67).

On hot days and in a light breeze, the leaves have a tendency to turn to expose the whitish green undersides. The result is that crowns have a lighter tone and colour than under other conditions.

Figure 66. Silver maple. The trunk characteristically divides near the ground.

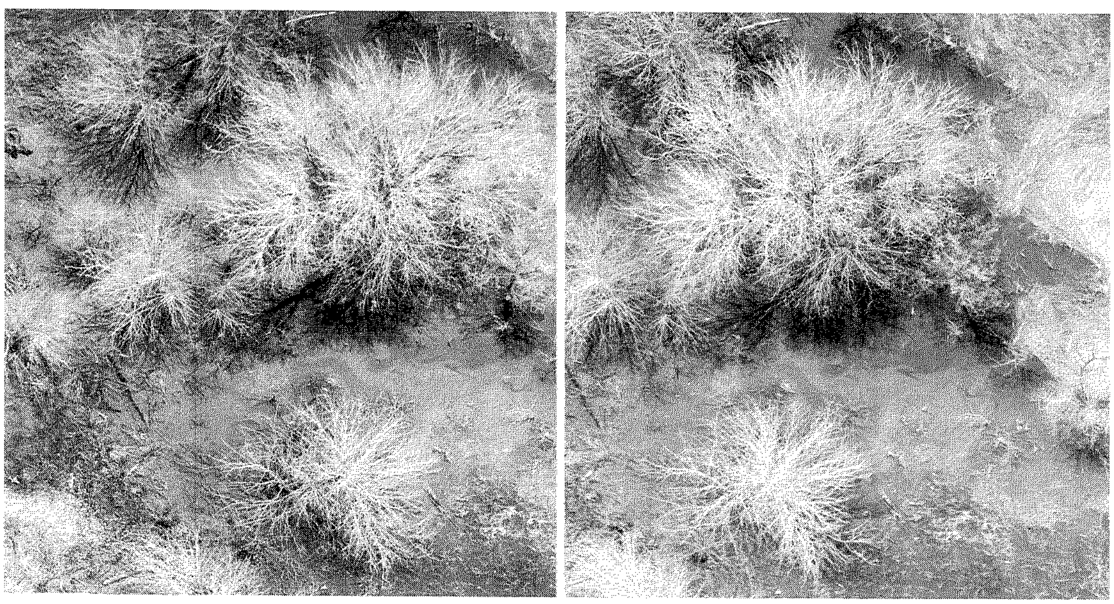


Figure 67. Silver maple in leafless condition. Note the divided trunk and slender branching. Opposite branching is characteristic of all maples and ashes and is visible on some twigs. (Marmora, Ontario; May 5, 1950; scale enlarged to 1:350 from contact scale of 1:600; photograph X-185, 25).

Red maple *(Acer rubrum* L.)

On poor and dry soils red maple is often a shrub, but on moist and swampy sites it attains tree size. In that case it may have a single straight trunk, but commonly its trunk will be divided, or it may grow in a cluster of several stems.

The bigger branches, which grow upward at a sharp angle to the trunk, divide into numerous spreading or ascending branchlets (Figure 68). In fast-growing trees individual branches protrude beyond the general outline of the crown and give the crown a tufted appearance which is very characteristic of this species and is a most valuable help in identification (Figure 69).

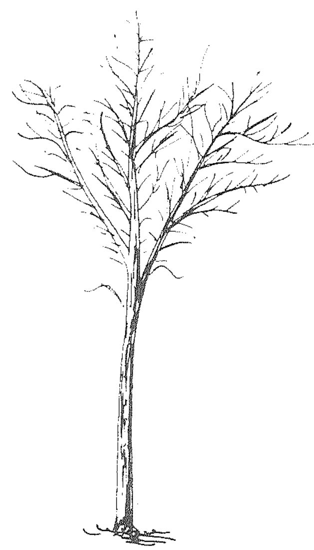


Figure 68. The distinctive, ascending branches of red maple.

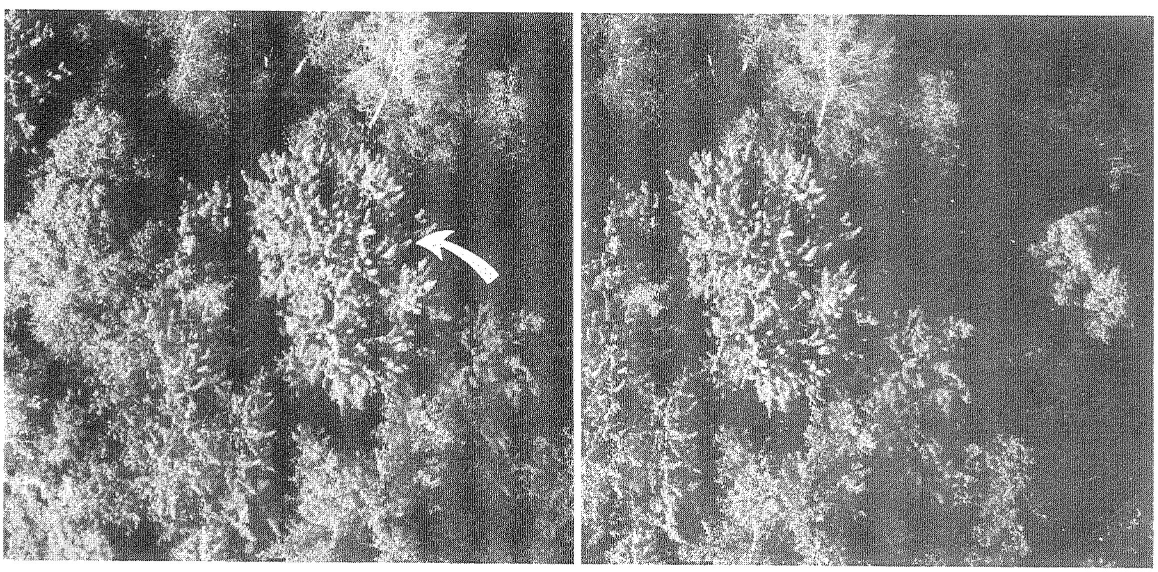


Figure 69. Red maple. The tufted appearance which is caused by ascending individual branches is characteristic of this species. (Meach Lake, Quebec; August 20, 1951; scale enlarged to 1:330 from contact scale of 1:600; photograph X-226, 14).

Basswood *(Tilia americana* L.*)*

Basswood, which never grows in pure stands, develops a tall, clear bole under forest conditions. This bole reaches high up into the crown before it divides into relatively short and rapidly tapering branches which often arch downward (Figure 70). The smaller branches and twigs are arranged to produce a well-defined crown perimeter.

At the larger scales basswood, when in leaf, can usually be distinguished from other hardwoods by its very symmetrical, closed, oblong or oval crown which shows a strikingly smooth surface. The crowns of overmature trees, however, are often open and irregular. Basswood has a tendency to grow from sprouts, which sometimes results in several trees growing in a clump (Figures 70, 71). The crowns of the trees in a clump often merge to produce the impression of a single, large tree.

Basswood flowers are numerous and large enough to affect the colour of the crown as seen from a distance. One can, therefore, expect basswood crowns to have a noticeable yellowish tinge in late June and throughout July. This probably also results in a lighter tone on panchromatic photographs.

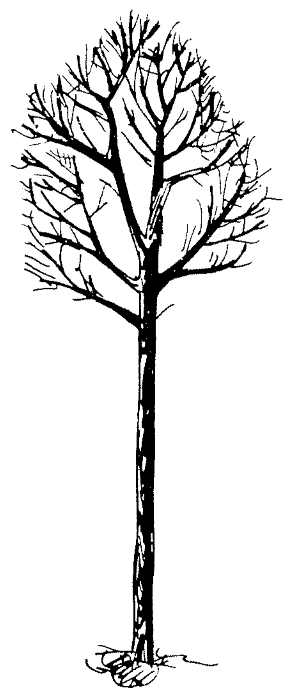


Figure 70. A clump of basswood trees.

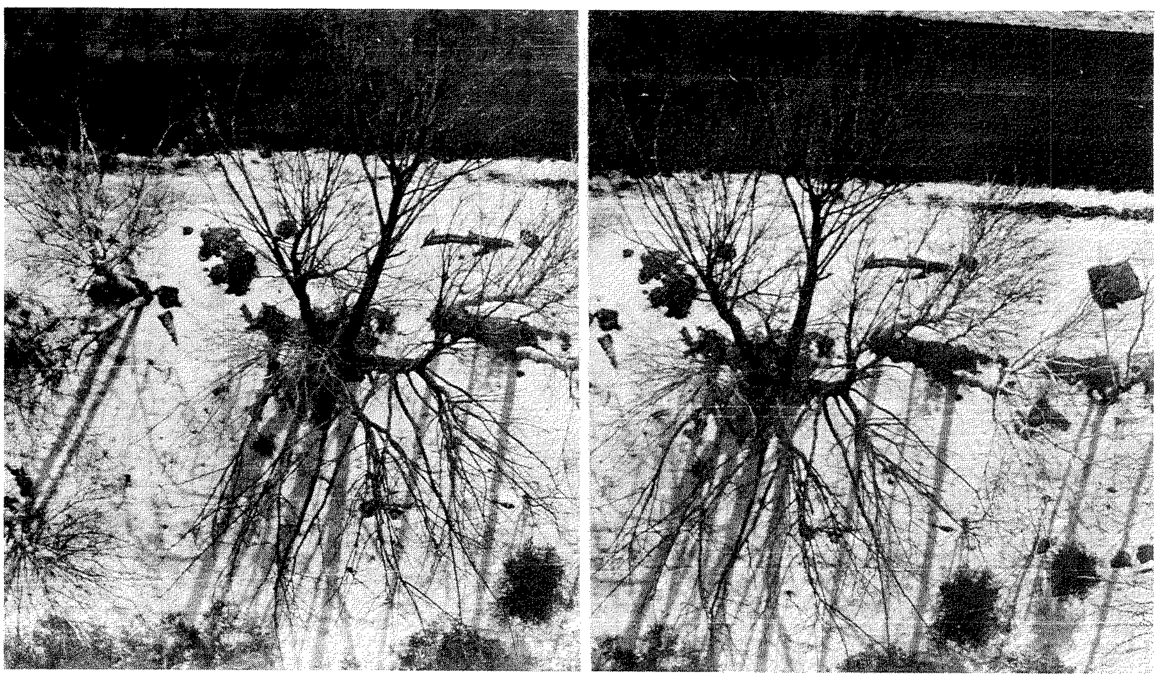
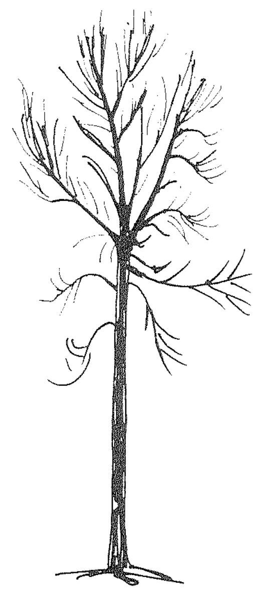


Figure 71. Stereogram of a clump of basswoods in leafless condition. (Petawawa, Ontario; March 29, 1963; scale enlarged to 1:200 from 1:600; photographs F-23, 143, 144).

The Ashes *(Fraxinus* L.)

Several species of ash occur in eastern Canada. They rarely form pure stands (Figure 72), but grow singly or in small groups; all prefer rich and moist soils.

All ashes, except when growing in the open, usually have straight trunks with little taper, and a medium-sized, shallow, rather open crown, formed by ascending branches. Altogether there is little very characteristic about the crown shape of ash and it remains a difficult species to identify on aerial photographs. Black ash (*Fraxinus nigra* Marsh.) can sometimes be identified by its characteristic site requirements, for it often grows in patches in swamps or other wet areas. Ash is sometimes found in the same locations as elm and silver maple, but it can be distinguished from these species by crown size or by the fact that it does not have any drooping branches. Also its crown diameter is less than the sizes attained by the larger elms or sugar maples. The photographic tone of the foliage of ash is lighter than that of elm.



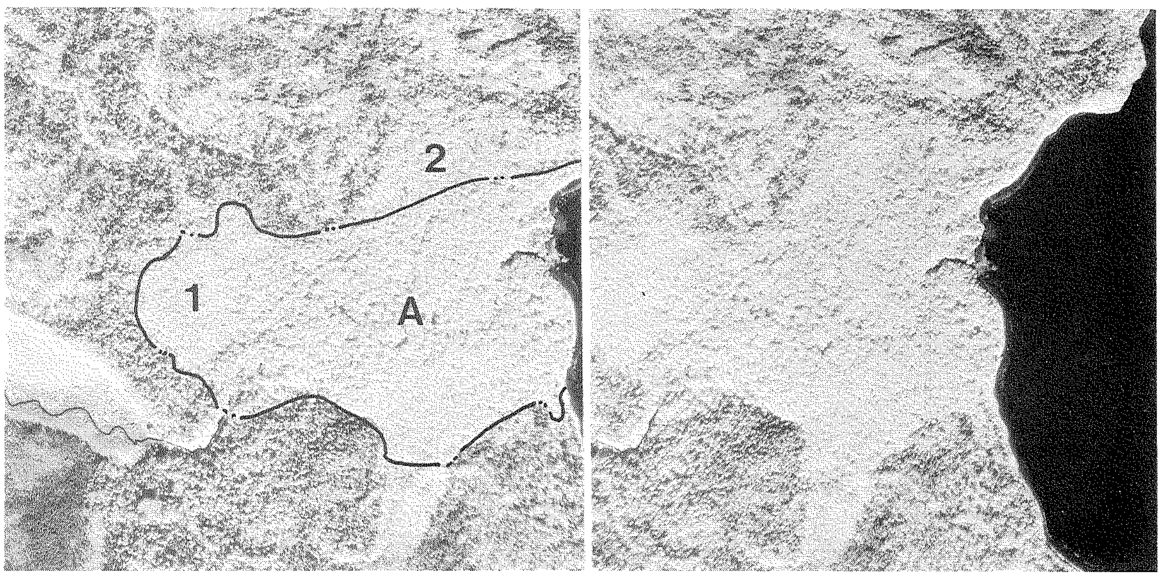


Figure 72. Infrared photograph showing a rare example of a pure stand of black ash (A). In this case the moist and wet site is a good interpretation clue. A comparison of the young, slightly fuzzy crowns around Point 1 with the poplar species and white birch at 2, illustrates the similarity of hardwoods on infrared photography. (Whitefish Indian Reserve, Ontario; July 26, 1965; scale 1:16,000; photographs A-18908, 107, 108).

REFERENCES

Aldred, A.H. 1959. Identification of tree species on aerial photographs. Undergraduate thesis. Dep. For., U.B.C. 76 p.

Aldred, A.H. and J.J. Lowe. 1978. Application of large-scale photos to a forest inventory in Alberta. For. Manage. Inst., Ottawa, Ont., Inf. Rep. FMR-X-107. 57 p.

Aldred, A.H. 1976. Measurement of tropical trees on large-scale aerial photographs. For. Manage. Inst., Ottawa, Ont., Inf. Rep. FMR-X-86. 38 p.

Aldrich, Robert C. 1976. Evaluation of Skylab (EREP) data for forest and rangeland surveys. USDA For. Serv. Res. Pap. PSW-113. 74 p.

Anon. 1958. Can. Dep. Agric., Sci. Serv. For. Biol. Div., Bi-mon. Progress Rep., Nov-Dec. 1958.

Anon. 1972. Classification and sampling manual. B.C. For. Serv., For. Invent. Div. 340 p.

Anon. 1974. Vegetation types of the Mackenzie Corridor. For. Manage. Inst., Infor. Can. Cat. No. R72-9073. 85 p.

Anon. 1975. Vegetation types lower Mackenzie and Yukon. For. Manage. Inst., Infor. Can. Cat. No. R57-43/1975. 73 p.

Ashley, Marshall D., James Rea and Linda Wright. 1976. Spruce budworm damage evaluations using aerial photography. Photogramm. Eng. Remote Sensing, 42(10):1265-1277.

Bos, N. 1974. Ovservatii privitoare la coroana arborilor si coronamentul arboretelor; rolul acestor elemente in fotointerpretarea speciilor forestiere (Observations on tree crowns and stand canopies: the role of these elements in the photo-interpretation of forest species), Revista Padurilor-Industria Lemnului, Silvicultura si Exploatarea Padurilor (1974) 89(5):224-228 + smries.

Chase, C.D. and J.R. Korotev. 1947. Key to forest types in Marinette County, Wisconsin on infrared with minus blue filter at 1:12,000. Autumn pictures. U.S. For. Serv., Lake States For. Exp. Stn. Mimeo.

Hegg, Karl M. 1967. A photo identification guide for the land and forest types of interior Alaska. U.S. For. Serv. Res. Pap. NOR-3 1967. 55 p.

Heller, R.C., G.E. Doverspike and R.C. Aldrich. 1964. Identification of tree species on large-scale panchromatic and color aerial photographs. U.S. Dep. Agric. For. Serv. Agric. Handbk. No. 261, July. 17 p.

Hosie, R.C. 1973. Native trees of Canada. Can. For. Serv., Dep. of the Environ. 380 p.

Kriebel, Howard B. 1957. Patterns of genetic variation in sugar maple. Ohio Agric. Exp. Stn. Res. Bull. 791.

Ladouceur, Gilles. 1969. Stéréogrammes des principaux peuplements du Québec. Service des Inventaires Forestiers. Ministère des Terres et Forêts. Québec. 37 p. + Appendices.

Lauer, Donald T. 1967. The feasibility of identifying major timber types by means of high altitude multispectral imagery. Sch. For., Remote Sensing Lab., Berkeley, Calif. Annu. Prog. Rep. NASA. 72 p. + Append.

Lauer, Donald T. 1968. Forest species identification and timber type delineation on multispectral photography. Sch. For. Conser., For. Remote Sensing Lab., Berkeley, Calif. Annu. Prog. Rep. NASA. 85 p.

Leopold, A. and S.E. Jones. 1947. A phenological record for Sauk and Dane Counties, Wisconsin. 1935-45. Ecol. Monogr. 17(1):81-122.

Losee, S.T.B. 1942. Air photographs and forest sites. For. Chron. 18(3):129-144 and 18(4):169-181.

Losee, S.T.B. 1952. The application of photogrammetry to forestry in Canada. Photogramm. Eng. 18(4):742-753.

Lyons, E.H. 1967. Forest sampling with 70 mm fixed air-base photography from helicopters. Photogrammetria 22:213-231.

MacHattie, L.B. and R.J. McCormack. 1961. Forest microclimate: a topographic study in Ontario. J. Ecol. 49(2):301-323.

Miller, Thomas B., Robert C. Heller, Joseph J. Ulliman and Frederic D. Johnson. 1976. Evaluating riparian habitats from aerial color photography. Coll. For., Wildl. and Range Sci., Univ. Idaho. Bull. No. 11. 12 p.

Murtha, P.A. 1972. A guide to air photo interpretation of forest damage in Canada. Can. For. Serv., Publ. No. 1292. Ottawa. 63 p.

Nielsen, U. and J.M. Wightman. 1971. A new approach to the description of the forest regions of Canada using 1:160,000 color infrared aerial photography. For. Manage. Inst., Ottawa, Ont. Inf. Rep. FMI-X35. 25 p.

Parry, J.T., W.R. Cowan and J.A. Heginbottom. 1969. Color for coniferous forest species. McGill Univ., Montreal, Canada. Photogramm. Eng. 35(7):669-678. July.

Rabenau, Gerhard and Dieter Blasbichler. 1969. Hilfsmittel zur Holzartenerkennung im Luftbild. Allgemeine Forstzeitung Nr. 6, Juni.

Rowe, J.S. 1959. Forest regions of Canada. Dep. North. Aff. and Nat. Resour., For. Branch Bull. 123. 172 p.

Sayn-Wittgenstein, L. 1960. Recognition of tree species on air photographs by crown characteristics. Can. Dep. For., For. Res. Div. Tech. Note No. 95. 56 p.

Sayn-Wittgenstein, L. 1961. Phenological aids to species identification on air photographs. Can. Dep. For., For. Res. Branch, Tech. Note 104. 26 p.

Sayn-Wittgenstein, L. 1967. The best season for aerial photography. Transl. of Int. Symp. on Photo Interpretation. Paris, 1966.

Sayn-Wittgenstein, L., R. de Milde and C.J. Inglis. 1978. Identification of tropical trees on aerial photographs. For. Manage. Inst. Inf. Rep. FMR-X-113.

Seely, H.E. 1949. Air photography and its application to forestry. Photogramm. Eng. 15(4):548-554.

Shull, C.A. 1929. A spectrophotometric study of reflection of light from leaf surfaces. Bot. Gazette. 87(5):583-607.

Tamas, P. 1959. Über die Ursachen der Zusammenhänge zwischen Temperaturgestaltung und Aufblühdaten von Obsthölzern sowie über die Temperaturempfindlichkeit der Pflanzen. Der Züchter, Vol. 29, No. 2.

Tiwari, K.P. 1975. Tree species identification on large scale aerial photographs at New Forest. The Indian Forester 101 (2):132-136 + 1 tab (En. 4 ref.).

Wear, J.F., R.B. Pope and P.W. Orr. 1966. Aerial photographic techniques for estimating damage by insects in western forests. Pac. Northwest For. and Range Exp. Stn., USDA For. Serv. 79 p.

Zsilinszky, V.G. 1966. Photographic interpretation of tree species in Ontario. Dep. Lands and For. 85 p.

APPENDIX

Phenological Data

Table 1. Date of leaf flushing (day of the year)

Species	1958	1959	1960
Willow	100	111	114
Tamarack	110	114	116
Manitoba maple	119	116	118
Trembling aspen	110	122	118
Balsam poplar	135	123	118
Ironwood	115	124	120
Choke cherry	119	114	121
Sugar maple	122	123	122
White birch	117	119	123
Black cherry	129	124	123
Silver maple	132	115	125
Pin cherry	–	123	127
Red maple	132	125	127
Basswood	131	126	127
Butternut	130	–	128
Largetooth aspen	143	127	129
Beech	128	128	129
White elm	120	125	130
Yellow birch	128	130	130
Carolina poplar	142	130	130
Eastern cottonwood	133	124	131
Bur oak	132	126	131
White oak	130	131	–
Hawthorn	–	126	132
White ash	132	126	132
Norway maple	–	128	132
Bitternut hickory	142	135	135
Honey locust	140	137	136
Shagbark hickory	149	137	137
Sycamore	143	–	140
Catalpa	–	138	142
Kentucky coffee tree	150	142	144

(Species are listed in the order of leafing in 1960. The data were collected in the Ottawa area.)

Table 2. Variations in date (day of the year) of flushing from year to year

Plot	Species	1940	1941	1942	Plot description
1	Balsam poplar	126	108	110	Altitude 4,450 feet, slope 10%, aspect N40W.
	Trembling aspen	129	116	120	
2	Willow	109	86	–	Altitude 4,700 feet, slope 35%, aspect N65W.
	Trembling aspen	130	107	115	
	White birch	127	109	110	
	Lodgepole pine	135	112	118	
	White spruce	140	124	144	
	Douglas fir	140	125	144	
3	Willow	–	86	96	Altitude 4,475 feet, slope 20%, aspect N70W.
	Balsam poplar	129	119	125	
	Trembling aspen	133	122	125	
	Lodgepole pine	132	119	117	
	White spruce	139	122	138	
	Douglas fir	155	122	141	
4	Willow	109	86	87	Altitude 4,600 feet, slope 10%, aspect N15W.
	Balsam poplar	129	121	114	
	Trembling aspen	134	–	131	
	Lodgepole pine	134	122	121	

(Five trees per species, per plot, were tagged and observations were made on the same trees each year. The day when leaf buds were bursting is recorded. The data was collected at Kananaskis, Alberta, by N.V. German, O.G. Larsson and H.A. Parker.)

Table 3. Variations in date (day of the year) of flushing in the same general area

Year	Species	Plot 1	Plot 2	Plot 3	Plot 4
	Tamarack	–	–	129	129
	White birch	137	135	135	137
1939	Trembling aspen	140	135	142	142
	Red maple	137	135	142	142
	Wire birch	140	149	156	156
	Tamarack	–	–	124	127
	White birch	130	132	123	122
1940	Trembling aspen	136	130	134	127
	Red maple	128	133	126	131
	Wire birch	125	136	134	134
	Tamarack	–	–	119	117
	White birch	125	125	121	117
1941	Trembling aspen	130	122	122	122
	Red maple	121	121	121	128
	Wire birch	125	127	125	135
	Plot description	Moist, low-lying, slope slight, N.W. exposure.	Moist, low-lying, slope slight, S.W. exposure.	Dry, near top of ridge, slope moderate, S.E. exposure.	Dry, near top of ridge, slope moderate, S.E. exposure.

(Day of the year when leaf buds burst on four plots in the area of the Acadia Forest Experiment Station, New Brunswick. Data collected by W.B.M. Clark and H.D. Long.)

Table 4. Frequency of colouring and leaf fall (number of times)

Period (Days of the year)	Colouring begins	Peak of fall colouring reached	Significant leaf-fall begins	Most leaves fallen
236-240	–	–	–	–
241-245	3	–	–	–
246-250	3	–	–	–
251-255	1	–	2	–
256-260	–	–	–	–
261-265	–	1	2	–
266-270	–	1	3	–
271-275	–	4	–	–
276-280	–	1	–	1
281-285	–	–	–	4
286-290	–	–	–	2
291-295	–	–	–	–

Dates of leaf colouring and leaf-fall during a seven-year period are roughly indicated. This table was derived from phenological observations made at Chalk River, Ontario. The main species involved are sugar maple, yellow and white birch, aspen, beech, basswood and red maple.

The data were collected by members of the Fire Protection Section of the Department of Forestry.

Table 5. Conversion of day of the month to day of the year

Day of the month	Day of the year				
	April	May	June	September	October
1	91	121	152	244	274
2	92	122	153	245	275
3	93	123	154	246	276
4	94	124	155	247	277
5	95	125	156	248	278
6	96	126	157	249	279
7	97	127	158	250	280
8	98	128	159	251	281
9	99	129	160	252	282
10	100	130	161	253	283
11	101	131	162	254	284
12	102	132	163	255	285
13	103	133	164	256	286
14	104	134	165	257	287
15	105	135	166	258	288
16	106	136	167	259	289
17	107	137	168	260	290
18	108	138	169	261	291
19	109	139	170	262	292
20	110	140	171	263	293
21	111	141	172	264	294
22	112	142	173	265	295
23	113	143	174	266	296
24	114	144	175	267	297
25	115	145	176	268	298
26	116	146	177	269	299
27	117	147	178	270	300
28	118	148	179	271	301
29	119	149	180	272	302
30	120	150	181	273	303
31	–	151	–	–	304

(Note: For leap-years add 1 to day of the year figures shown.)