DEPARTMENT
OF REGIONAL
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EXPANSION



# THE CANADA LAND INVENTORY

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# THE ECONOMICS OF PLANTATION FORESTRY IN SOUTHERN ONTARIO



The Canada Land Inventory
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# THE ECONOMICS OF PLANTATION FORESTRY IN SOUTHERN ONTARIO

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# RÉSUMÉ

Les peuplements artificiels qui, depuis une époque reculée, recouvrent toute la potentialité de la surface des terres, sont le fruit d'un aménagement forestier très poussé; leur production de bois tend à atteindre un rendement maximal possible des terres. Le bois des peuplements artificiels est produit à un coût très compétitif et la plupart des pays du monde produisent, de cette façon, une part croissante du bois dont ils ont besoin. Il faudrait donc, relativement à l'aménagement des terres à des fins forestières, déterminer le rythme qui permettra de répondre le mieux possible aux besoins de l'économie; car, à une phase ou l'autre du développement, il est vraisemblablement certain qu'on devra avoir recours aux peuplements artificiels.

Comme la demande mondiale de bois dépassera sans doute l'offre avant l'an 2000, on devrait étudier les possibilités d'utilisation des terres très productives et faciles d'accès du sud de l'Ontario. Cette région a une superficie de 23 millions d'acres, dont 11.4 millions sont de vocation agricole, 7 millions, de vocation forestière, (dont 5.8 millions productives), et 4.4 millions se classent dans diverses autres catégories. Depuis 1941, quelque 60 mille acres de terre arable sont laissées en friche chaque année. De plus, dans le sud-est ontarien, la classification "faible revenu" caractérise 20 à 30 p. 100 des fermes, lesquelles pourraient être utilisées à meilleur escient pour la production de bois.

La présente étude fournit des renseignements sur le rendement des peuplements artificiels de pin rouge et d'épinette blanche dans de nombreuses stations de cette région. On établit la valeur des terres consacrées à la culture forestière en tenant compte des frais de plantation et d'aménagement. La comparaison entre la valeur de ces terres et celle des terres de même catégorie affectées à d'autres usages peut servir de critère de décision en ce qui a trait à l'utilisation des sols.

## CHAPITRE 1. Facteurs significatifs dans l'économie de la production du bois

La possibilité de produire du bois dans le sud de l'Ontario, ce qui présuppose des investissements en exploitation forestière, est conditionnée par plusieurs facteurs, dont les suivants:

1. La capacité inhérente du sol lui-même, compte tenu du climat, à produire du bois de diverses essences et de leurs variétés. En général, le climat et le sol du sud de l'Ontario offrent toutes les conditions requises pour une productivité élevée.

2. *Aménagement intensif.* D'ordinaire, cet aménagement ne diminue pas la productivité, pourvu qu'on reboise les terres avec des espèces marchandes. Toutefois, des techniques telles que l'éclaircissage et l'élagage peuvent, en fait, améliorer la qualité et la croissance du bois exploitable. Dans le sud de l'Ontario, il y a de bonnes perspectives pour la commercialisation actuelle et à venir du produit des coupes d'éclaircie.

3. *Accessibilité de la région (réseau routier) et proximité des marchés.* Les facteurs d'accessibilité déterminent en grande partie le coût de la production et de la distribution du produit manufacturé. Dans les deux cas, le sud de l'Ontario présente des avantages particuliers que l'on ne trouve pas ailleurs au Canada.

4. *Disponibilité d'une main-d'oeuvre suffisante.* Du fait que beaucoup de travailleurs du sud de l'Ontario migrent du milieu rural au milieu urbain, on peut s'attendre à une augmentation continue du coût de la main-d'oeuvre. Il faudra mettre au point l'équipement mécanique nécessaire pour l'aménagement et l'exploitation des peuplements et aussi améliorer l'efficacité de l'administration si l'on veut maintenir le coût de la production à un niveau raisonnable.

5. *Droit de propriété et prix des terres.* La plupart des terres qui, dans le sud de l'Ontario, conviennent à l'aménagement des peuplements sont des propriétés privées, qui sont ou ont été jusqu'à récemment consacrées à une exploitation agricole peu rentable. Les prix de vente de ces terres tendent à être élevés à cause de l'intérêt des urbains à se les procurer à des fins récréatives et autres. Le prix des terres monterait en flèche si l'on décidait d'acheter de grands espaces dans certaines régions en vue d'y établir des peuplements artificiels.

6. *Taux des taxes municipales.* Les taxes sont prélevées chaque année sur les terres boisées, même si dans le cas des peuplements artificiels, il n'y a pas de revenu pendant plusieurs années. De telles taxes, auxquelles s'ajoutent les taux d'intérêt courants, peuvent représenter une charge trop élevée à déduire du revenu au moment de la récolte. Les données quantitatives obtenues grâce à cette étude fourniront le moyen d'évaluer la possibilité d'utiliser les terrains pour la production de bois. En révisant le régime fiscal, il serait possible d'alléger le fardeau des taxes jusqu'à la perception du revenu.

7. *Taux d'intérêt.* En comparant les divers usages possibles des terres, on devrait utiliser des taux inférieurs d'intérêt pour que la compensation soit plus réaliste. Le tableau 7-4 démontre l'incidence des divers taux d'escompte sur la valeur de la terre pour la production du bois.

## CHAPITRE 2. Évaluation du potentiel physiographique des stations

Le potentiel de production de bois d'une région, c'est-à-dire la productivité de terres entièrement boisées, dépend du climat, du sol et des propriétés du sol telles que la texture, la pétrographie, la profondeur du sol de surface et le régime d'humidité du sol. Le système de classement des terres en Ontario est double d'après les régions (essentiellement, régions climatiques), et d'après les stations (topographie). Le système d'évaluation comprend une échelle de cinq classes de productivité dans chaque région, pour chaque essence commerciale, dans laquelle chaque station type peut être classifiée.

Cette étude, bien qu'elle fût restreinte à certaines stations, — surtout celles à sols sablonneux d'une même région climatique, — comporte toute l'échelle des régimes d'humidité dans les peuplements où ces essences sont communément cultivées; il en résulte donc une vaste gamme de classes de productivité potentielle. On a échantillonné trois de ces classes de productivité qui figurent en tête de liste pour chaque essence; les stations classifiées dans les deux catégories inférieures n'avaient pas, en général, de peuplements assez denses pour qu'un échantillonnage y soit possible.

Le rendement de chaque essence pour les classes de productions potentielles 1 à 3 figure aux tableaux 2-2 et 2-3. Le rapport entre la station type et le rendement était évident pour le pin rouge, un peu moins pour l'épinette blanche, dû en partie aux variations parmi les arbres d'un peuplement. Les deux essences ont donné leur meilleur rendement en terre très fraîche (figure III-1).

On dresse actuellement, par grands secteurs, la carte du sud de l'Ontario et chaque secteur représente une mosaïque ou un ensemble de stations types. Le pourcentage des terres, dans chacune des classes de productivité potentielle, peut être évalué pour chaque secteur; les données sur le rendement provenant de cette étude peuvent servir à déterminer pour ce secteur la quantité de bois qui pourrait être produite si le secteur était occupé par des forêts aménagées. L'évaluation des secteurs de moindre importance, celle des fermes par exemple, exige que l'on détermine à quelle station type ils correspondent pour qu'on puisse les inclure dans la bonne classe de productivité potentielle pour les essences en question.

Les rendements rapportés ici représentent la production totale du bois, y compris celle des arbres morts prématurément et le produit des coupes d'éclaircie; les classes de possibilités des sols de l'Inventaire des Terres du Canada se fondent sur le volume de bois marchand produit en une révolution. Pour plusieurs raisons, le lien entre ces deux valeurs est difficile à établir. Pour les relier, il faut donc faire un certain nombre d'hypothèses: *a)* que les meilleures stations échantillonnées dans le sud de l'Ontario correspondent à la classe 1 des possibilités des sols de l'Inventaire des Terres du Canada; *b)* que le pin rouge est l'espèce idéale pour ces stations; donc des peuplements exceptionnels de pin rouge dans le classe 1 de productivité potentielle ont été placés dans la classe 1 des possibilités des sols de l'I.T.C. et l'ensemble de la classe de productivité potentielle 1 dans la classe 2 de l'I.T.C. *c)* que, si on utilisait comme indice le taux de croissance de l'épinette blanche dans les meilleures stations (environ de 25 p. 100 moindre que celui du pin rouge), la même station entrerait dans la classe 3 de l'I.T.C. Le tableau 2-4 indique la relation qui existe entre les classes de productivité potentielle et les classes des sols selon leurs aptitudes à la production forestière, comme les définit l'I.T.C.

Pour un grand nombre de stations types, on ne dispose pas de renseignements sur le rendement. Toutefois, dans le cas du pin rouge, lorsque la station abrite des arbres dont rien n'est venu retarder la croissance, le rapport hauteur-âge est un indice approprié de la classe de productivité potentielle à laquelle la station appartient. On n'a jamais cherché à établir la validité de ce rapport pour l'épinette blanche.

## CHAPITRE 3. Tableaux de rendement du pin rouge et de l'épinette blanche dans les peuplements du sud de l'Ontario

Les tableaux de rendement, qui sont essentiels dans toute étude économique de l'aménagement intensif, ont été établis pour deux essences de peuplements artificiels (tableaux 3-2 et 3-7) en utilisant des données relevées dans des placettes échantillons. Pour les arbres de moins de 40 ans, on s'est servi des données réelles obtenues dans les placettes. Dans le cas des arbres de 40 à 70 ans, on ne disposait que de très peu de données; aussi, les valeurs se fondent-elles sur les projections à partir des rendements observés chez les peuplements plus jeunes.

On a établi trois catégories de rendement, coïncidant avec les classes de productivité potentielle 1, 2 et 3, qui représentent les classes 1 à 4 de l'I.T.C., établies selon les possibilités de croissance du pin rouge.

Ces tableaux présupposent un peuplement complet depuis son établissement, et, pour le pin rouge, des coupes d'éclaircie à intervalles réguliers. Lorsqu'on ne fait pas d'éclaircies, il y a pertes par suite de la mortalité. Pour l'épinette blanche, dont les éclaircies risquent d'être moins rentables que celles du pin rouge, on doit s'attendre à un certain pourcentage de mortalité. Alors que le pourcentage de mortalité est imprévisible à cause de l'absence de vieux peuplements pour servir de mesure, on a tenté de l'évaluer (annexe V) et ce chiffre figure dans les tableaux de rendement pour l'épinette.

## CHAPITRE 4. Marchés pour le pin rouge et l'épinette blanche de peuplement artificiel

Bien qu'on ait constaté que certaines propriétés physiques du bois de pin rouge de peuplement artificiel sont inférieures à celles du bois de peuplement naturel, ces déficiences ne sont pas critiques. Le pin rouge est une essence aux multiples emplois, pâte et papier, placages et contreplaqués, bois d'oeuvre, poteaux et pieux. La demande actuelle et future de ces produits dans le sud de l'Ontario, ou pour l'exportation, semble être très forte.

Comme les ressources naturelles de bois deviennent de plus en plus inaccessibles et comme le pin rouge se prête à bien des usages, on est assuré que la demande pour cette espèce ne cessera de croître.

On ne dispose pas suffisamment de bois d'épinette blanche, essence plantée en moins grande quantité que le pin rouge, dans le sud de l'Ontario, pour qu'il vaille la peine d'en pousser la vente dans la région pour le moment. En outre, elle s'élague lentement en conditions naturelles, elle pousse assez lentement dans la plupart des stations, n'absorbe pas facilement les antiputrides et n'a pas de propriétés qui lui soient particulières. Sauf pour la production de pâte à papier, qui lui donne une valeur exceptionnelle, l'épinette blanche comporte des avantages fort limités sur le pin rouge. Cependant, sa croissance rapide en stations humides et la qualité supérieure de la pâte à papier qu'on en fabrique, peuvent justifier son implantation dans une aire restreinte du sud de l'Ontario.

## CHAPITRE 5. Valeur du bois sur pied

La valeur du bois sur pied est la valeur des arbres marchands destinés à être transformés en un produit primaire, bois de sciage ou bois à pâte, par exemple. On la détermine en soustrayant de la valeur du produit commercial le coût de la récolte, du tronçonnage et du transport, les frais généraux de l'entreprise et le profit de l'exploitant. Ainsi la valeur du bois sur pied est une valeur résiduelle.

A cause de ses conditions favorables d'accessibilité, le bois du sud de l'Ontario a un avantage quant à la valeur du bois sur pied sur la plupart des autres régions de l'Amérique du Nord. A ce titre, la terre dans cette région a une valeur plus élevée pour la production du bois que celle d'autres régions, pourvu qu'on ne doive pas la réserver à une forme d'utilisation plus importante.

On dispose de renseignements limités sur la détermination de la valeur sur pied du bois de peuplement artificiel. Les tableaux 5-1 et 5-3 donnent des valeurs approximatives fondées sur le montant du produit de la vente du bois de quelques peuplements artificiels et des tarifs de vente actuels du bois de peuplements naturels; ces valeurs sont inférieures à celles qui s'appliqueraient aux peuplements artificiels denses.

## CHAPITRE 6. Valeur des terres et coût de l'aménagement

L'objectif premier de cette étude est d'établir quelle valeur aurait une terre d'une productivité donnée si elle était utilisée à d'autres fins. L'une d'elles est l'exploitation agricole, qui est rarement rentable dans certains sols comme les sols sablonneux et secs. En se fondant sur les prix payés pour les terres forestières qu'il ne serait guère rentable d'exploiter à des fins agricoles, une analyse indique que le prix de $12.20 l'acre n'est certainement pas trop bas pour de telles terres; même à ce prix, l'exploitant agricole ne réalise pas beaucoup de bénéfices une fois sa mise de fonds et le coût de la main-d'oeuvre déduits. De cette analyse, on peut déduire que, si les terres destinées à l'exploitation forestière sont évaluées à $12.20 l'acre et que l'on prévoit un revenu suffisant pour le capital investi et le coût de la main-d'oeuvre, alors l'exploitation forestière sera beaucoup plus rentable que celle de l'agriculture.

On se fonde sur le calcul des divers frais relatifs à la plantation et à l'aménagement de peuplements dans le sud de l'Ontario pour déterminer la valeur des terres consacrées à la production de bois.

## CHAPITRE 7. Évaluation des terres et application des résultats de l'étude

Pour les peuplements artificiels destinés à la production de bois, les valeurs immobilières sont fondées sur les données de revenus et de dépenses établies aux chapitres précédents. Ces renseignements touchaient trois classes de productivité potentielle des terres pour le pin rouge et l'épinette blanche. L'influence du taux d'intérêt sur la valeur de la terre est illustrée au tableau 7-4 et à la figure 7-1.

L'intérêt que rapporteront les investissements dans les peuplements dans le sud de l'Ontario n'attireront probablement pas beaucoup de capital. Toutefois, les revenus des terres, de la main-d'oeuvre et du capital, réalisés à partir de l'agriculture marginale, sont considérablement moins élevés. Il semble donc que le gouvernement, en subventionnant l'établissement de peuplements artificiels, pourrait améliorer les revenus de vastes étendues, présentement consacrées à l'agriculture, et en même temps accroître une source de matières premières qui favoriserait, pour les années à venir, l'industrialisation de cette région.

Il est assez évident que dans toutes les zones du sud de l'Ontario, sauf les zones humides ou mouilleuses, le pin rouge constitue un meilleur investissement que l'épinette blanche. Toutefois, si l'on plante de l'épinette, cela devrait être en quantité suffisante pour alimenter un marché potentiel. En outre, le gouvernement pourrait trouver avantageux de favoriser l'établissement de grands peuplements d'épinette afin de susciter un marché pour le bois à pâte de haute qualité.

Il serait intéressant d'étudier les régions qui ont de vastes zones de terres agricoles sous-marginales, ceci en vue de constater s'il est possible de regrouper assez de terres pour permettre une administration efficace des forêts et pour une exploitation industrielle rentable.

Une usine de pâte et papiers moderne a besoin d'un minimum de 200,000 cordes ou de 17 millions de pieds cubes de bois par année. S'il s'agit du pin rouge, le bois ne devrait pas être transporté sur une distance supérieure à 100 milles. L'épinette, bois à pâte plus précieux, peut être transportée sur de plus grandes distances. Si l'on approvisionnait l'usine seulement en produits d'éclaircissage de pin rouge (en supposant que la productivité moyenne des terres soit telle qu'on puisse les faire entrer dans la classe 2), on aurait besoin de 650,000 acres; si l'on utilisait toute la production des peuplements artificiels de pin rouge pour la fabrication de pâte, on aurait besoin de 126,000 acres et, si les peuplements étaient composés d'épinette et ne servaient qu'à alimenter l'usine, on aurait besoin de 200,000 acres.

Regrouper une telle étendue de terrain n'est pas une mince tâche et cela nécessite beaucoup de données précises, comme celles que fournissent l'Inventaire des Ressources forestières et les Inventaires des Terres de l'Ontario et du Canada. Il est bien possible que ce regroupement puisse se faire à partir des 60,000 acres de terres agricoles abandonnées chaque année. Les avantages de la propriété publique, ou de la propriété privée, appuyée par les stimulants adéquats de la part du gouvernement, devraient être considérés, ainsi qu'un compte détaillé du coût de l'acquisition des terres et des frais de plantation et d'aménagement selon des conditions précises.

# THE ECONOMICS OF PLANTATION FORESTRY IN SOUTHERN ONTARIO

## INTRODUCTION

The peak of intensity in the management of forest land in Canada is the plantation—the man-created forest. If man-made forests are created at such density that the land is fully occupied by the stand at an early age (1/5 to 1/4 rotation age), the volume production of the plantation represents the practical potential of the area for that species, subject only to increase through irrigation, fertilization, or genetic selection. Operations, such as fertilization, may often be justified in plantations and where more effective use of land and capital resources can be shown to result they should be applied. However, due to the unlimited variations possible, this study makes no allowance for such operations.

Recovery of the volume potential of the land by intensive management may be a worthy objective for countries in which available land is the limiting factor in raw wood production. In Canada, where capital rather than land is the limiting factor of production, land should be classified and assessed for its productive capacity under different levels of intensity of use so that, under management, the land may make its best contribution to the economy of the country.

The plantation level of forest land management will be justified when the returns from the expenditures for plantation management are at a level which will attract capital from alternative investments, including those involved in the extensive use of land for timber production[1]. However, where the industrial development associated with the harvesting and manufacturing of wood products is an important segment in the country's economic development, the direct returns from either plantation management or extensive management of natural stands may be of little national significance. In such circumstances the benefits of the industrialization may justify state subsidization of the raw wood production. The problem then becomes one of selecting among the alternatives for wood production, one of which may be plantation management.

[1]"Production" as it relates to wood or timber in this report means the *growing* of wood as opposed to the production of primary and secondary wood products through harvesting and manufacturing.

Plantations produce concentrations of wood volume effecting reduced costs in harvesting and transportation. Size and species consistency can mean cost advantages in harvesting and manufacturing also. Costs and returns applicable to plantation wood should be compared to those which are likely to apply to natural stands supplying the same future markets. Forest policies determining the level of forest land management based on such analyses will contribute to a more effective use of available resources.

It is evident that policies determining the means of producing the raw wood for industry involve complicated economic problems. It must be recognized that it is not only a matter of providing the required physical volume but this volume must be so located and be of such quality that it can compete with producers in other regions of the earth. The extent to which other countries are producing the highly competitive plantation wood and the degree to which this may interfere with present trading patterns in wood products should influence policies respecting plantation establishment in Canada.

The two principal markets for Canadian wood products are the United States and Europe. These are also the prime producers of wood products and, although net importers, these regions contain Canada's severest competitors in world markets.

To 1963, 14 million acres of land had been planted in Europe, and in the United States 22 million [6]. In the five-year period, 1963-1967, about five million acres were planted in each of these regions.

Present levels of production of wood products in the United States and Europe are met largely from sustained yield natural forests. Expansion of the wood products industries in the future will be greatly influenced by the availability of wood from plantations in these and other regions.

Recent discussions respecting world reserves of wood suggest that, by the year 2000 or before, current sources of supply will not satisfy demands in the regions where markets are now most active, i.e., North America and Europe [4, 6]. Increasing prices for raw wood material are therefore anticipated. However, the increase in price is likely to encourage the extension of supply lines into presently inaccessible reserves to a lesser extent than it will encourage the more intensive use of productive accessible lands [26]. If Canada is to maintain a satisfactory position in world markets, the possibilities of using accessible lands for plantation management must be under constant review; plantation development must take place where the opportunity for competitive investment is evident.

Southern Ontario[2] comprises an area of some 23 million acres of land which ranges widely in suitability for economic utilization in the myriad of uses to which it could be put. According to the 1961 Census of Canada the area of improved farm land in this region is 11.4 million acres. The total forest land is 7.0 million acres (5.8 million acres productive) and the remaining 4.4 million acres is made up of grass, meadow, wooded pasture and unclassified (settled area, roads, etc.) land [7].

The area of improved farm land in the region has been decreasing steadily from 12.6 million acres in 1941 to 11.4 million acres in 1961—a decrease of 1.2 million acres in 20 years, a rate of 60,000 acres per year.

In addition to this withdrawal of land from agricultural use, it is of importance to note that within the region of Southern Ontario, from Peterborough east, with the exception of a small area around Ottawa, some 20 to 30 percent of the farms are classed as low income farms[3]. Many of these farms must be classed as marginal[4] and some are undoubtedly sub-marginal for agricultural use today. The possibility of increasing acreages of land being released from agricultural use in the eastern part of Southern Ontario is very real.

In the present study an attempt has been made to provide quantitative yield information for lands of a range of levels of ability to produce red pine (*Pinus resinosa*) and white spruce (*Picea glauca*). This information has been converted from a rate of physical production in cubic feet per acre per year to net financial return through the application of appropriate input-output data. The interest return on capital invested in plantation management has been calculated for different classes of land. By this means the returns from the use of land and capital for the creation of plantations may be compared to returns from alternate uses of the same resources.

Because land prices in much of Southern Ontario reflect demands for recreational space rather than agricultural or silvicultural productivity, few properties will attract private capital for investment in plantations. However, where the cost of the land may be charged to recreational use or where prospective future development indicates probable appreciation of land values, investment of private capital in plantations may prove attractive. In the interests of future industrialization in the harvesting and manufacturing of wood products the state may well find it advantageous to undertake plantation development on its own lands and subsidize similar investments on private lands.

This report covers the study as it relates to red pine and white spruce; additional work has been done on the intensive management of heavy hardwoods. A separate report will be prepared for the latter species group.

Work on the study commenced in 1964 when 141 red pine plots were established and measured, and soil and site information recorded. In 1965 the work was extended to include white spruce and tolerant hardwoods. The data for red pine and white spruce were collected in plantations and those for hardwoods in natural stands.

The species most widely used for planting in Southern Ontario are red pine, white spruce and Scotch pine (*Pinus sylvestris*). Of these, red pine and white spruce appear to have greater economic potential than Scotch pine. These species have been planted under a wide range of conditions and in sufficient quantity to provide a reasonable estimate of their potential in plantations in the region. For these reasons, red pine and white spruce were singled out for first consideration.

[2]For the purposes of this report Southern Ontario comprises the area within the six most southerly administrative districts of the Department of Lands and Forests, i.e., Districts of Kemptville, Tweed, Lindsay, Lake Simcoe, Lake Huron and Lake Erie.

[3]Information from "Economic and Social Disadvantage in Canada —some graphic indicators of location and degree", Map No. 3. Low Income Farm—capital value of less than $24,950, gross annual sales of agricultural products of less than $2,500 and off-farm work by the operator of less than one month per year.

[4]Marginal land—land from which it is doubtful whether a specified form of management can produce an income in excess of the costs of such management under given economic conditions.

## Chapter 1

# SIGNIFICANT FACTORS IN THE ECONOMICS OF WOOD PRODUCTION

The production of wood by investment in management operations is influenced by many factors which include the following significant items:

Productive capacity of the lands under management.
Intensity of management—recovery of thinnings, degree of stocking of the stands and rotation ages.
Accessibility of the region—physical accessibility of the land and market accessibility of the products.
The quality and availability of labour in the region.
Ownership of the land and the price of land.
Municipal assessment, land value and taxation.
Interest rates, i.e., the cost of capital.

### Productivity of the land

In agriculture the ability of the land to produce crops may be greatly modified by drainage, irrigation and the use of fertilizers. In the production of forest crops the same is theoretically possible. However, the availability of relatively cheap productive land tends to discourage this intensity of management in timber production at the present time. For practical purposes, therefore, the land may be said to have an inherent productivity for a given species under a specified program of management. The more favourable climate and the abundance of deep fertile soils of Southern Ontario give this region an ecological advantage over most other regions in Canada.

Certain species exhibit a considerable range of genetic qualities and variations in production on a given site could be a reflection of the strain as well as the environment. Red pine, however, is inclined to be genetically very stable and uniform. The species is not subject to great modification and self-pollination exhibits little or no inbreeding effect [13]. For these reasons it may be said that a given site under a given program of management has an inherent capacity for red pine production. The level of this capacity will be one of the most important factors in determining the economic feasibility of using the land for growing red pine timber.

White spruce, unlike red pine, is a species of great genetic variability [19], and variations in plantation yields between sites due to genetic differences is entirely possible. However, since little control over seed source or geographic distribution of nursery stock existed at the time at which the plantations measured for this study were established, the results in terms of volume yields may be assumed to represent a genetic average, but this may account for much of the deviation from the average condition observed on many site types. Growth in white spruce plantations could be greatly improved through genetic control of planting stock [19, 20].

### Intensity of management

In the analysis of the economics of plantation management in Southern Ontario it is assumed that the stands will be created by the planting of cleared land or land from which vegetation, which could cause serious competition to the planted stock, has been eliminated.

The total production of wood from an acre of plantation is not greatly influenced by the degree of intensity of management as this relates to thinnings, provided full stocking has been attained at an early age [27]. In other words, whether a stand is thinned or not will have little influence on the rate of production (see Appendix I, Figure I-3). The usable or utilized proportion of the total production over the rotation will, of course, be much greater in the thinned stand (provided the thinnings are marketable) since there will be far less mortality. In addition, a greater proportion of the total production will be in larger sized trees. The proportion of waste in the individual tree and for the total production from the acre will be greatly reduced where regular thinnings are utilized.

Virtually all of the area comprising Southern Ontario is now or will very soon be within the timbershed[1] of pulp mills which can use thinnings from plantations.[2] After one or two pulpwood thinnings a large proportion of the wood

[1]The area from which timber funnels toward a buyer or group of buyers.

[2]Efforts are now being made at one pulp mill in Southern Ontario to effect technological improvements that will make possible the increased use of red pine for groundwood pulp.

removed from red pine plantations can be used for poles, sawlogs or veneer logs which produce higher direct returns than pulpwood. In the region under consideration, good markets exist for poles and piling and red pine veneer logs will undoubtedly be in high demand when available in sufficient quantity to warrant the establishment of a plant and marketing facilities.

White spruce has less proven versatility in use than red pine. However, in the pulp market it has superior qualities and plantations of this species may well be developed on a short rotation, unthinned, for pulpwood production only. Naturally-grown white spruce has been used for many years for sawn lumber with excellent results and more recently the species has been used commercially for veneer.

It is presumed, therefore, that any production of plantations of red pine and white spruce in the region of Southern Ontario can be marketed except for the normal loss of about 15 percent in tops and stumps which could not practically be utilized in any market at the present time.

Under the intensity of management visualized for this region, planting may be assumed to provide full stocking of the areas taken under management. Unfavourable climatic conditions — particularly drought — may cause an unacceptable reduction in stocking in the first or second year following planting, but on all commercial sites this would be corrected by replanting or filling. Allowance for the extra costs involved in such replacement may be made in the average planting cost.

The rotation ages to which the plantations will be grown are variable depending upon the species, the productive capacity of the land and the products for which the plantations are being managed. Subsequent analysis of the information available respecting these items will lead to suggested optimum rotations.

## Accessibility of the region

The physical accessibility[3] of the land in Southern Ontario is very favourable due to the dispersal of settlement throughout the area and the intermixture of land uses, including agriculture, timber production, and recreation which will ensure a continuing high level of accessibility. This accessibility attributes to the region an economic potential for timber production which is unique in Ontario.

Because of the concentration of population in Southern Ontario, the market accessibility of the region is also much more favourable than most other areas of the Province. Where export markets are visualized this region is once again in a very favourable location, being within easy reach of the Northeastern and North-central United States and close to a commercial waterway for world trade.

In comparing rates for the transportation of newsprint from Northern Ontario and from Southern Ontario to destinations in the United States, Michalowicz[4] shows the following:

| | |
|---|---|
| From Northern Ontario to New York, N.Y., 887 miles rail haul at 2.50¢ per ton mile; cost per ton | $22.20 |
| From Southern Ontario by rail haul to New York, N.Y., 472 miles at 3.051¢ per ton mile; cost per ton | $14.40 |
| From Southern Ontario by water-carriers, including loading, unloading and port charges; cost per ton | $11.60 |

This water transportation cost applies within the Great Lakes region for a distance of approximately 900 miles.

Thus Southern Ontario possesses a marked advantage over Northern Ontario as far as the major transportation costs are concerned. The transportation advantage is at least $8.00 per ton and could be in excess of $10.00 per ton where water transportation is feasible.

## Quality and availability of labour

The movement of population from the rural areas to the cities and improved working conditions of farm labour have seriously reduced the labour supply for forest management work. Recent contracts for the harvesting of the timber crop in Agreement Forests[5] have included increases in wage rates (now at a level of $1.75 per hour) and increases in contract prices.

As far as the planting and maintenance operations in the plantations are concerned some of the work can be done under contract at a specified piece rate. Fire guard maintenance, planting and pruning have been done under contract with considerable success. Much of the maintenance work is seasonal and can best be done under contract where circumstances permit. The labour rate for time work is $1.38 per hour for tree planting and similar management operations.

Rising labour costs in the economy generally indicate that increased mechanization in all aspects of management and harvesting is necessary. Insufficient effort has been directed in the past to the study of mechanization in plantation management. To avoid the economically damaging effects of extended rotations, partial cutting methods are now required to produce the high value specialty

[3]"Physical accessibility" means the accessibility to the land provided by roads as opposed to "market accessibility" which refers to the geographic location of the land relative to markets.

[4]Michalowicz, A.Z. 1963. Interregional comparison of the transportation costs of newsprint. M.Sc.F. thesis, Faculty of Forestry, University of Toronto.

[5]"Agreement Forest" is the term applied to land owned by municipalities in Ontario and under the management of the Ontario Department of Lands and Forests.

products. This means that the large modern machines developed for the clearcutting of natural stands cannot be employed in the plantations except for the final cut. The partial cutting operations are now done with the aid of horses or farm machinery; in many situations it is probable that efficiency could be considerably improved by the use of specialized equipment developed for the purpose.

There has been considerable variation in the quality of labour, the quality of supervision, or in the problems of management in the operation of the Agreement Forests of Southern Ontario. A study of the costs[6] covering 14 of these forests over the period of their management revealed a variation in average annual costs per acre (in 1960 dollars) of from $1.53 to $5.64 with a weighted average (weighted by 1960-61 area) of $3.05.

## Ownership and price of land

Of the total land area of the region (23.0 million acres), 21.1 million acres are in private ownership and 16.0 million acres of this are classified as non-forested land. As previously noted, land previously used for agriculture was abandoned at the rate of 60,000 acres per year between 1941 and 1961. The present total area of Agreement Forest land in the Province, which is practically all located in Southern Ontario, is about 180,000 acres accumulated over a period of more than 50 years. Therefore, practically all of the land which might be considered for development for red pine and white spruce production is at the present time in private hands.

Although much of the land in certain parts of the region is submarginal for agricultural purposes, land prices are at a relatively high level. This is due in part to the shifting of farm population from the vicinity of cities and towns, where their land has been sold at a high price for urban development, to rural areas. The high prices obtained for development land encourage purchases in less accessible rural areas at higher prices than would ordinarily prevail. In addition, many urban dwellers, especially professional people and business executives, have purchased land in rural areas for recreational purposes. The nature of these demands has tended to maintain a relatively high price even for land which is marginal for agricultural production.

An analysis of the price paid for land acquired for the County Forest scheme revealed an average price of from $5.00 to $10.00 per acre from 1940 to 1960. A comprehensive analysis of land purchases of the Ontario Department of Lands and Forests in the year 1965-66 for County and River Valley Authority ownership is shown in Table 1-1.

[6]Love, D.V. 1964. The economics of the timber-growing operations of the Ontario Department of Lands and Forests. [Unpublished report.]

The average price paid by the Department for nearly 10,000 acres of land in 1965-66 was $15.40 per acre which included the estimated timber value of $3.20 per acre leaving a land value of $12.20. All but one of the 91 properties purchased were acquired in the Southern Ontario region as defined by this report. Purchases were well distributed throughout the area.

The highest land prices ($25.00 to $50.00 per acre) are in the southwest and central areas of the region where farm incomes are generally high [2] and, in the case of the central area, where the demand for land for recreational use is strong. The lower values ($5.00 to $25.00 per acre) are not only associated with low farm income regions [2] but they generally apply in counties where large areas of land have been abandoned for agricultural use [23]. From this study it appears that land prices for the acquisition of property for timber production are still quite reasonable in the low farm income areas. However, if an attempt were made to assemble a large acreage in any specific location the price would undoubtedly increase rapidly.

Although there is great variation among forest districts in the proportion of the properties under plantation and swamp cover (see Table 1-1), the proportions of open land and woodlot are remarkably uniform. Considering the range in geographic location of the properties and the variation in agricultural development of the different areas from which they were chosen one might expect a wider range in the ratio of cleared to forested land.

These properties were virtually all purchased with a view to some forest use, including timber production, water conservation and recreational use with the last two usually secondary in importance. There may, therefore, have been some intent in selecting the areas to strive for a suitable balance between cleared and forested land. However, it seems more likely that the purchases were determined by the availability of land for purchase and farms having a high proportion of the area in forest cover (average 57 per cent) fell into the sub-marginal agricultural classification at this stage in the development of the rural economy of the region.

The use of land for the production of red pine and white spruce in plantations will be entirely compatible with recreational use in much of Southern Ontario. In addition, where alternative uses are not evident the exclusive use of the land for plantations will produce a more favourable economic return than exclusive agricultural use in many parts of the region. Detailed economic analysis of this situation will be dealt with in a later chapter.

## Municipal assessment and taxation

When bare land is placed under forest production there is a relatively long time interval from investment in the

## Table 1-1. AVERAGE SIZE, VALUE AND VEGETATIVE COVER OF PROPERTIES PURCHASED BY THE ONTARIO DEPARTMENT OF LANDS AND FORESTS, 1965-66

| Location<br>County<br>Forest District | No. of Prop-erties | Average Area per Property | Average Value per Acre | | | Acreage of Vegetative Cover per Property | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Timber | Land | Land & Timber | Open Land | | Natural Forest | | Plantation | | Swamp | | Total | |
| | | (acres) | $ | $ | $ | Acres | % | Acres | % | Acres | % | Acres | % | Acres | % |
| Norfolk and Others | 6 | 69 | 10 | 35 | 45 | 20 | 29 | 41 | 59 | 8 | 12 | – | – | 69 | 100 |
| Lake Erie District | 6 | 69 | 10 | 35 | 45 | 20 | 29 | 41 | 59 | 8 | 12 | – | – | 69 | 100 |
| Grey | 14 | 107 | 7 | 9 | 16 | 29 | 27 | 57 | 53 | (0.5) | – | 21 | 20 | 107 | 100 |
| Bruce | 4 | 129 | 9 | 9 | 18 | 31 | 24 | 97 | 76 | 0.5 | – | – | – | 129 | 100 |
| Others | 4 | 36 | 11 | 41 | 52 | 2 | 6 | 18 | 50 | – | – | 16 | 44 | 36 | 100 |
| Lake Huron District | 22 | 98 | 8 | 11 | 19 | 25 | 26 | 57 | 58 | – | – | 16 | 16 | 98 | 100 |
| Simcoe | 7 | 69 | 1 | 31 | 32 | 39 | 57 | 28 | 40 | 2 | 3 | – | – | 69 | 100 |
| Ontario | 7 | 106 | — | 26 | 26 | 25 | 24 | 63 | 59 | 3 | 3 | 15 | 14 | 106 | 100 |
| Others | 3 | 70 | — | 22 | 22 | 11 | 16 | 37 | 53 | – | – | 22 | 31 | 70 | 100 |
| Lake Simcoe District | 17 | 84 | — | 27 | 27 | 28 | 33 | 44 | 53 | 2 | 2 | 10 | 12 | 84 | 100 |
| Durham | 2 | 33 | 36 | 11 | 47 | 8 | 24 | 9 | 27 | 16 | 49 | – | – | 33 | 100 |
| Victoria | 9 | 142 | 2 | 6 | 8 | 27 | 19 | 107 | 75 | 1 | 1 | 7 | 5 | 142 | 100 |
| Lindsay District | 11 | 122 | 3 | 7 | 10 | 23 | 19 | 89 | 73 | 4 | 3 | 6 | 5 | 122 | 100 |
| Hastings | 7 | 114 | 1 | 5 | 6 | 25 | 22 | 68 | 60 | – | – | 21 | 18 | 114 | 100 |
| Lennox & Addington | 4 | 343 | 1 | 8 | 9 | 74 | 22 | 243 | 70 | – | – | 26 | 8 | 343 | 100 |
| Tweed District | 11 | 197 | 1 | 7 | 8 | 43 | 22 | 131 | 66 | – | – | 23 | 12 | 197 | 100 |
| Prescott | 3 | 78 | — | 14 | 14 | 38 | 49 | 40 | 51 | – | – | – | – | 78 | 100 |
| Grenville | 10 | 118 | — | 7 | 7 | 57 | 48 | 36 | 31 | – | – | 25 | 21 | 118 | 100 |
| Lanark & Leeds | 4 | 117 | 1 | 8 | 9 | 58 | 49 | 50 | 43 | 2 | 2 | 7 | 6 | 117 | 100 |
| Russell & Stormont | 6 | 55 | 4 | 9 | 13 | 22 | 40 | 30 | 55 | 3 | 5 | – | – | 55 | 100 |
| Kemptville District | 23 | 96 | 1 | 8 | 9 | 46 | 48 | 37 | 39 | 1 | 1 | 12 | 12 | 96 | 100 |
| Renfrew | 1 | 100 | 2 | 8 | 10 | 40 | 40 | 60 | 60 | – | – | – | – | 100 | 100 |
| Pembroke District | 1 | 100 | 2 | 8 | 10 | 40 | 40 | 60 | 60 | – | – | – | – | 100 | 100 |
| Average for Province | 91 | 108 | 3.20 | 12.20 | 15.40 | 32.6 | 30.1 | 61.5 | 56.7 | 1.8 | 1.7 | 12.4 | 11.5 | 108.3 | 100.0 |
| Total for Province | 91 | 9,833 | 31,033 | 120,119 | 151,152 | 2,961 | | 5,598 | | 164 | | 1,122 | | 9,845 | |

establishment of the crop to the recovery of the first revenue against which accumulated costs may be charged. This elapsed time may well exceed 30 years on some sites and during this period taxes have to be paid on an annual basis. It is obvious, therefore, that the level of municipal taxation will be a significant factor in the economics of plantation forestry.

For purposes of assessment in Ontario, rural land is evaluated on the basis of the "productivity" of the land [1]. There are at least two major problems associated with the determination of the land productivity as a basis for assessment.

The first point as noted above is the waiting period before the plantation will yield any net revenue. If the assessed value is based on the annual revenue that the plantation will produce in the future, when the land is covered with trees of suitable ages to produce continuous revenue, it will be too high. The land will be overvaluated and property taxes will be confiscatory.

The second difficulty develops from the problems of anticipating future yields, both in terms of physical volume units and in terms of revenue. Very little work has been done in Canada to produce value assessments in forestry comparable to the same assessments in agricultural production. The current study should be helpful in this respect but much additional work is required if realistic assessed values for land under forest use are to be forthcoming.

In addition to these problems, which should not be insurmountable given sufficient study, there is the apparent reluctance on the part of municipalities to recognize the low level of productivity of the sub-marginal agricultural area. The very term sub-marginal, which is applicable to much of the area of Southern Ontario as evidenced by the abandonment of land for agricultural use, suggests a negative land value where agricultural use prevails, i.e., if the farmer were receiving the going rate of return for the labour and capital which he devotes to the operation of his sub-marginal farm, his net annual return would be a deficit.

Municipalities, however, faced with the need to provide services for the rural population, seek to support the highest possible land values and thus attain the highest possible assessed values. In the absence of adequate property tax revenue to provide the necessary services the municipality seeks provincial grants. To the extent that these grants provide services to the land — road construction, maintenance and protection — the grants benefit all land uses present including agriculture, forestry and recreational use. However, to the extent that the grants support services to the rural agricultural population, the grants are subsidizing the agricultural sector. In the absence of such grants the sub-marginal agricultural land would perforce be abandoned to purposes which would more effectively utilize the available resources.

A detailed study of rural taxation in six townships in Ontario[7] was undertaken in 1965-66 by the Ontario Economic Council [5]. This study revealed the fact that in all six townships provincial grants to the township exceeded the value of taxes paid by farmers. In one township the provincial grant of $155,000 was more than twice the gross income from the land of $69,000. This type of subsidization has the undesirable feature that it supports inefficiency in land use and encourages dependence on subsidies. Also, an increase in subsidies is necessary as the sub-marginal agricultural land (sub-marginal even with subsidization) falls into disuse and assessments diminish.

Subsidization of the forest use of land if intelligently applied will create an appreciating asset. Benefits in the form of expanded wood-products industries should increase rural employment opportunities and expand the tax base.

In situations where forestry and agriculture are being compared on the same class of land, it is necessary to recognize the effects of agricultural subsidization on the apparent land value. A true comparison of the agricultural and forestry potential involves stripping both alternatives of advantages created by subsidization.

## Discount rates

The interest rate is of considerable significance since it is used to discount future returns from the land. When the land, under the particular use for which a value is to be determined, produces a uniform annual net revenue, the value of the land is obtained by the following formula:

$$V_0 = \frac{a}{(1+p)^t - 1} = \frac{a}{p} \qquad (1)$$

where, $V_0$=present land value

$a$=the annual net revenue

$p$=interest rate expressed as a decimal fraction.

If the same land under another use produces a uniform net revenue at regular periodic intervals (usually more than one year), the land value will be determined by the formula:

$$V_0 = \frac{A}{(1+p)^t - 1} \qquad (2)$$

where, $V_0$=present land value

$A$ =the periodic net revenue, the first coming "t" years hence

$p$ =interest rate expressed as a decimal fraction

$t$ =interval between receipts of "A".

When higher interest rates are used in the valuation calculation the interest factor in formula (2) is disproportionately increased compared to (1) and the $V_0$

[7] The six townships included in the study are, Monteagle, Carlow, Lindsay, Harley, Brethour and McCrosson-Tovell.

value correspondingly reduced. Thus the valuation of an annual income of $1.00 at 3 percent discount is $\frac{1.00}{0.03} = \$33.33$, and the value of $5.00 coming every 5 years at 3 percent discount is $\frac{\$5.00}{1.03^5 - 1} = \frac{\$5.00}{1.159 - 1} = \$31.45$. The comparable values at a discount rate of 6 percent are $16.67 and $14.80. At the 3 percent discount rate the value of the delayed income is 94.4 percent of the capitalized annual income, i.e. $\frac{\$31.45}{\$33.33} = 94.4$ percent. The comparable figure at the 6 percent rate is 88.8 percent. It is evident, therefore, that the higher discount rates penalize uses of land which involve a time delay in realization of revenue compared to those uses which produce an annual revenue.

Land values at various interest rates are presented in Chapter 7 and the effect of changes in the rate can be readily observed in Table 7-4. Where alternative uses of the land are being compared on the basis of calculated land values, more realistic results will be developed where rates of 3 to 4 percent are used in the capitalization of income. The same rate of discount must be used, of course, for each of the alternative land uses being compared.

# Chapter 2

# ASSESSMENT OF PHYSIOGRAPHIC SITE POTENTIAL

## Classification and evaluation of physiographic sites

The potential production of a given land area for any timber species may be defined as the maximum rate of wood volume production that can reasonably be expected of that species on that land over a specified period. This implies that the management of the area has achieved maximum stocking from an early age; the plots chosen for this study met this standard. A quantitative expression of potential production in terms of cubic feet per acre (per year) over a stated rotation provides a most useful measure where management of the land for wood production is the primary objective. An important aspect of the present study has been the measurement of yield in 115 plots in red pine and 30 in white spruce. These plots represent a good range of potential production for red pine and for white spruce, even though they were found on a limited range of physiographic site types.

Forest site research conducted by the Ontario Department of Lands and Forests has made three major contributions which make possible the interpretation of the quantitative data by providing a framework in which all land areas may be placed, and thereby given a position relative to the sites actually sampled. This permits any land area to be evaluated without the presence of a stand, which means that the potential production of the site may be reliably estimated before the land is forested. The three contributions are as follows:

(a) A forest site classification based on physiographic (climate and soil) features significant to the production of forest crops and providing a system of classes or types (physiographic site types) based on combinations of these significant features [15]. Any uniform small plot of land may be placed in one physiographic site type.

(b) A system of forest site evaluation which places physiographic site types on a scale of potential production for each tree species, as well as on scales of other features pertinent to forest management [18].

(c) A mapping system which provides for the mapping of land areas at various levels of intensity to suit various management purposes. The land type component is usually of the order of size of the single farm unit or forest compartment, and provides fairly specific information about soil materials, soil moisture regime, and other features, and is useful for the management of the compartment [24]. The land unit and landscape unit are broad units incorporating patterns of site types having ascending degrees of complexity, and are useful for planning purposes within a county or forest district [17].

The classification system provides, first of all, for thirteen broad regions for Ontario called forest site regions [16]. These are essentially climatic regions, and are characterized by the natural distribution of tree species on a range of specified landform situations. They could also be characterized by the potential production of given species on specified landforms. Differences in these characteristics between regions reflect to a large extent differences in regional climate.

The site regions are, therefore, regarded as basic units, and all forest site research conducted by the Ontario Department of Lands and Forests is done within the framework of the site region. The various scales used in the classification and evaluation systems have been set up separately for each site region, to represent the range of values which might be found *in that region.*

The physiographic site types are based on significant combinations of such features as texture, petrography and depth or soil materials, soil moisture regime, and local climate. The combination of features within each type determines its potential production as well as other factors pertinent to management. The physiographic site type thus provides a logical basis for studies in site evaluation.

The present study has been conducted within a fairly narrow range of physiographic sites in Ontario, in that most plots were located in one site region, namely 6E, with only a few taken in 7E. The findings will, therefore, be directly applicable only in these regions. Further interpretation and study will be required to provide similar information for other regions. Most of the plots were located on deep sandy soils, having a range of petrography; a few plots were on other soil materials, and a few on shallow soil over bedrock. The red pine plots were located in somewhat dry (0) to somewhat moist (4) moisture regime classes, the white spruce on a wider range from somewhat dry (0) to very moist (6).

The physiographic site type was determined for each plot by preparing soil pits within the plot. The pits were deep enough to permit observation of the features significant to tree growth. These pits ranged from two to twelve feet in depth, depending on the soil features found there. For each plot the physiographic site features were recorded in considerable detail.

The concepts developed in site evaluation provide for the recognition of a range of potential production for a given species on the range of sites possible within a site region. This range is divided somewhat arbitrarily into five classes. While suitable stands for measurement are not always available for all site types requiring assessment, a forester who has learned to recognize physiographic site types and who understands the influence of the various site features on wood production can do an acceptable job of placing the various types in the correct potential production classes without the aid of a large number of tree measurements.

Much evaluation of site types has been done in the site research program in Ontario with a minimum amount of stand measurement by applying value judgments to visual observations of stands. The present study provides a body of detailed measurements which can be placed within the framework of potential production classes for site region 6E and to a lesser extent for 7E. With proper interpretation they may be used at least tentatively in placing a quantitative evaluation of potential production of any physiographic site in those regions, whether or not the site type was included in the sampling.

Using the moisture regime as the independent variable, the total production associated with various levels of moisture has been analyzed in the Appendix and summarized in Table 2-1. The analysis for red pine indicates that, *within the range of sandy soils sampled in site region 6E* between somewhat dry (0) and somewhat moist (4) moisture regimes, there appears to be a significant relationship between moisture regime and observed production, the most favourable moisture regime apparently lies between very fresh (3) and somewhat moist (4) with reduced production on the dry side and probably also on the wet side of this level of moisture. Lack of suitable plantations for sampling on the moist sites precluded quantitative yield values, but the presence of plantations of unsatisfactory growth indicated that these sites are not productive of red pine.

TABLE 2-1: RELATIONSHIP BETWEEN MOISTURE REGIME AND PLANTATION YIELDS
(See Appendix III)

| Moisture Regime | Yield at 50 years (Total production in 1,000's of cu. ft. per acre) | |
|---|---|---|
| | Red Pine | White Spruce |
| 0 somewhat dry | 5.8 | 4.2 |
| 0+ | 6.7 | 4.9 |
| 1− | 7.5 | 5.5 |
| 1 somewhat fresh | 8.1 | 6.1 |
| 1+ | 8.7 | 6.5 |
| 2 fresh | 9.4 | 7.3 |
| 3 very fresh | 10.2 | 7.7 |
| 4 somewhat moist | 10.3 | 7.2 |
| 5 moist | — | 6.1 |
| 6 very moist | — | 4.7 |

Note: The entire range of moisture regime likely to be present in any Site Region is divided into 11 classes, using $\theta$ (theta) at the dry end, and the digits 0 to 9, 9 being the wettest. The three values, 0+, 1− and 1+, are transitional values considered useful in this study.

Further analysis is desirable to establish the relationship between yield and other site features. For example, it is likely that differences in liminess of parent soil materials and in shallowness of some soil profiles, will cause variations in production. Also, it is well known that texture of soil material, as well as structure of finer materials, influences production.

The relationship between yield and physiographic site (as indicated by the moisture regime) seems less well defined for spruce than for red pine. This is probably because the analysis for spruce included fewer plots although the data for the latter cover a greater range of moisture regimes. The most favourable moisture regime for spruce appears to be very fresh (3) as shown in Table 2-1.

The comparison of red pine and white spruce shown in Table 2-1 indicates that, on a 50-year rotation with the present methods of planting and with present genetic strains, red pine is a vastly higher producer of wood volume than white spruce on those sites on which both species grow well. Because of the absence of suitable plantations of red pine on the moist sites (M.R. 5-6), these sites cannot be assessed by the methods of measurement used in this study, nor does red pine generally constitute a suitable species for timber production on such sites. White spruce is apparently less limited by wetness, moisture regimes 5 and 6 being productive for this species although at a reduced level.

Having established potential production ratings for each species on a range of physiographic site types, and yield data to characterize each potential production class, this information may be applied to sizeable areas in Southern Ontario by proper interpretation of maps presently being made using the system described. As already mentioned, the landscape units, as well as units of intermediate size being mapped in this region, are patterns of individual physiographic site types and are described and rated in terms of these patterns. By consulting these descriptions, along with the ratings of the various types within each mapping unit, the potential of the unit or of portions of it for red pine and white spruce production may be calculated, using values that arise from this study.

The application of yield information to a small area, for example, a single forest compartment or farm unit, depends on a specific knowledge of site types in the area at the landtype component level, in which the site types present are described in somewhat more specific terms than for the landscape unit. Landtype component maps are available for only a few areas in Southern Ontario, for example, in unpublished form for many of the Agreement Forests. For other areas, information necessary for the management of farm units or forest compartments must be determined by the extension or management forester, with the proper local interpretation of such aids as the description of the landscape units, soil maps published by the Ontario Soil Survey, aerial photographs, and by using his own intimate knowledge of his area.

From the foregoing discussion it appears imperative that the forester in management or extension work acquaint himself thoroughly with the site classification, with specific reference to the kinds of land occurring in his area, and the means of identifying them in any location. He must also be familiar with the various aids mentioned above, and their interpretation in his area. Finally, he must have some knowledge of the range which is included in the five potential production classes for each species and the ability to place each physiographic site type into the proper class.

## Interpretation of yield measurements

This study is aimed at evaluating sites in terms of total stem production over an acceptable rotation age. This value is used rather than any expression of merchantable volume for two reasons (1) total stem production is more closely related to the capacity of the site, and (2) any change in the degree of utilization would tend to invalidate figures based on current utilization standards. It is more useful to give total production, and to permit the local forester to convert this to merchantable volume using standards in effect locally. Determination of total wood production over such a period is complicated by several factors which are outlined in the following paragraphs.

(a) Stands at rotation age may not be available for analysis. For this study, 20- to 40-year-old stands were fairly plentiful, and their yields were measured. However, it is well known that the rate of production changes as the stand grows older, and a suitable method is needed to assess present production in terms of yield at a designated rotation age. In this study, this was done by means of Backman's projection[1] which is explained in Appendix I. For both red pine and white spruce, estimates of total production were projected to an age of 50 years using this method. Although a rotation age in excess of fifty years might be desirable, this age was chosen to minimize any inaccuracies due to applying a projection over a longer period.

(b) The yields of most natural stands and many plantations do not represent the potential production level of the land on which they are growing. Many stands are incompletely stocked; many have suffered severe mortality or are made up of trees that have been suppressed, or damaged by insects, disease, or some other agency. Yields of many stands therefore fall far short of potential production, i.e., the best that can reasonably be expected under intensive management.

The plots used in this study were located with considerable care to exclude openings or damaged trees. The production measured in these plots was therefore considered to approach fairly closely the potential production of the sites on which they were located.

(c) In most plantations on a 6′ x 6′ spacing that are more than 20 years old, some mortality has almost certainly occurred, so that the volume on the ground is likely to be less than the total wood produced to date. Inasmuch as the plantations used in this study were planted in rows with regular spacing, mortality up to 40 years tends to be small and any dead trees that had attained any significant size could be located. It was found that the volume represented by dead trees was not great in most cases; the details concerning mortality are shown in Appendix V. Except in the older plantations of red pine, thinned stands were not generally used because of the difficulty in estimating the volume of wood removed in the thinnings. Where thinned stands were used, the volume of thinning was included as part of the total production.

The range of sites sampled was restricted by the availability of suitable plantations for measurement. There were no red pine plots measured on the extremely dry sites characterized by shallow soils. The sites which were sampled probably included the best in the region for red pine production. Of the five potential production classes, therefore, it appears that the three highest classes were sampled, with some individual plots falling into the fourth class for reasons other than moisture regime. The deep sands even when composed of coarse material are not drier than a somewhat dry moisture regime (M.R. 0). Because of the limited number of plots available in moisture regimes of 4 and wetter, there is no conclusive evidence that production is lower in this range. However, indications are that productivity for red pine decreases

[1]Kleist, A. 1961. Considerations concerning the natural laws regulating the internal structure of even-aged white and red pine stands. University of Toronto, M.Sc.F. thesis.

with increasing soil moisture at moisture regimes in excess of 4. For these reasons, the data collected were considered to fall in the top three of five potential production classes for red pine in the region.

Similarly, for white spruce, within the range of the sampling it is assumed that the best sites were represented, hence the three production classes for white spruce into which the data were classified represent the top three of five potential production classes.

Tables 2-2 and 2-3 show for red pine and white spruce the yields to be expected for each potential production class and the moisture regime and dominant heights associated with each class.

Further study is desirable to confirm the relationship between the classes and yields presented, and to confirm the placing of certain physiographic site types in the respective classes. Also, it is most desirable that the management or extension forester using this information have some measurements of plantations in his own area, to provide local checks on, and local demonstrations of, the site-production relationship. Suitable stands covering the range of physiographic sites as fully as possible should be measured in each management unit.

### Relationship between Potential Production Classes and the Forest Use Capability Classes of the Canada Land Inventory

The Canada Land Inventory provides a national scale of seven classes of forest use capability, embracing nearly all the land of Canada, with special provision for certain highly productive areas. Each class is characterized by a range of mean annual increment (m.a.i.), based on volume of merchantable wood of a suitable indicator species that can be expected from managed stands at rotation age [22]. This scale is recognized and used in most provinces, and it seems reasonable to relate the values from the present study to this scale.

Such a conversion seems to require a reliable ratio between merchantable volume at rotation age, as specified for the national scale, and total production through the rotation, as used in this study. Since the factor to make this conversion is quite variable, an indirect approach has been used. As already mentioned, the three yield classes represent three of five potential production classes for the region. Among the values in the top classes were some outstanding ones, considerably higher than the average for the class.

To relate these potential production classes to the national scale of forest use capability, it was assumed, in the light of knowledge of ecological conditions across Canada, that if all land, excluding a few outstanding areas, were divided into seven classes of timber use capability, at least a small part of the range of sites in Southern Ontario would fall into the top class, and thus should be in Class 1 of the Canada Land Inventory.

Next it was assumed that red pine is a species with an inherent growth rate that best expresses this capability in this region. It is therefore a suitable indicator within the meaning of the Canada Land Inventory. The outstanding red pine stands should therefore fall in Class 1 on the national scale, and the remainder of Yield Class 1 in national Class 2. Yield Classes 2 and 3 could then be placed in national Classes 3 and 4 respectively, and the less productive sites, not represented by yield classes, would fall in national Classes 5, 6, and 7.

The study in spruce confirmed common observation that in the more productive sites spruce yield is less than that of pine — the quantitative estimates indicate 25 percent less. This means that if the same sites were evaluated using white spruce as an indicator, they would fall into a lower capability class than using red pine.

Since all land falling in a given site type within any site region will fall in one capability class regardless of its present cover, the species indicating the highest capability should be used as the indicator. Thus red pine would be used in preference to white spruce on dry and fresh sites (M.R. 0-3) in Southern Ontario. On moister sites (M.R. 4-6) white spruce is probably a more suitable indicator. Accordingly, Potential Production Class I for white spruce would indicate a class at least one class lower on the national scale than that of red pine for the same site type.

Table 2-4 shows the relationship between Yield Classes and Potential Production Classes for the two species, and the national Forest Use Capability Classes, derived in this manner.

It is noted that there are two m.a.i. values given for each species, and a discrepancy between them, in the case of red pine of about 2:1. Two main factors contribute to this:

(a) The present study was based on total production, including mortality, stumps and tops, whereas the national class is based on merchantable volume on the ground at rotation age. The discrepancy between these two may be considerable, the stumps and tops generally being considered to represent about 15 percent of the total stem volume and mortality accounts for 35 to 40 percent over a rotation of 50 to 60 years.

(b) The plantations observed were much more fully stocked than most of the natural stands available for the derivation of the national scale.

### Use of height growth of individual trees as a measure of site quality

It frequently happens that plantations are not fully stocked, or have had unknown volumes removed in the past through thinning. One also frequently finds rows of

Table 2-2. RELATIONSHIP BETWEEN POTENTIAL PRODUCTION CLASSES, MOISTURE REGIME, VOLUME PRODUCTION AND DOMINANT HEIGHT—RED PINE

| Potential Production Class* | Moisture Regime** (deep sands of Site Region 6E) | Total Volume Production (cu. ft. per acre at 50 years) | Dominant Height at 50 years — Site Index — Calculated (feet) | Rounded |
|---|---|---|---|---|
| I | 2— to 4 | 10,000 | 77 | 80 |
| II | 1— to 2— | 8,000 | 68 | 70 |
| III | 0 to 1— | 6,000 | 60 | 60 |

*The lower two classes (IV and V) of the five-class potential production classification may be extrapolated from the three measured classes.

**Applicable only to the deep sandy soils of Site Region 6E, although a small proportion of the plots were located on other soil materials.

Table 2-3. RELATIONSHIP BETWEEN POTENTIAL PRODUCTION CLASSES, MOISTURE REGIME, VOLUME PRODUCTION AND DOMINANT HEIGHT—WHITE SPRUCE

| Potential Production Class* | Moisture Regime** (deep sands of Site Region 6E) | Total Volume Production (cu. ft. per acre at 50 years) | Dominant Height at 50 years — Site Index — Calculated (feet) | Rounded |
|---|---|---|---|---|
| I | 2— to 4+ | 7,750 | 64 | 65 |
| II | (0+ to 2—)&(4+ to 6—) | 6,250 | 59 | 60 |
| III | (0 to 0+)&(6— to 6+) | 4,750 | 52 | 50 |

*The lower two classes (IV and V) of the five-class potential production classification may be extrapolated from the three measured classes.

**Applicable only to the deep sandy soils of Site Region 6E, although a small proportion of the plots were located on other soil materials.

Table 2-4. RELATIONSHIP BETWEEN YIELD CLASSES, POTENTIAL PRODUCTION CLASSES, AND THE FOREST USE CAPABILITY CLASSES OF THE CANADA LAND INVENTORY

| C.L.I. Capability Class | Defined M.A.I. (merch. at rotation) cu. ft. | Yield Class | Potential Production Class | Total Volume Production (50 years) cu. ft. | M.A.I. (total-50 years) cu. ft. | Approximate Ratio Merchantable to Total M.A.I. |
|---|---|---|---|---|---|---|
| | | | Red Pine | | | |
| 1 | over 110 | (exceptional) | I | 13,000 | 260 | 1:2 |
| 2 | 90 – 110 | 1 | I | 10,000 | 200 | 1:2 |
| 3 | 70 – 90 | 2 | II | 8,000 | 160 | 1:2 |
| 4 | 50 – 70 | 3 | III | 6,000 | 120 | 1:2 |
| 5 | 30 – 50 | | IV | | | |
| 6 | 10 – 30 | | IV | | | |
| 7 | 0 – 10 | | V | | | |
| | | | White Spruce | | | |
| 1 | over 110 | | | | | |
| 2 | 90 – 110 | | | | | |
| 3 | 70 – 90 | 1 | I | 7,750 | 155 | 1:1.9 |
| 4 | 50 – 70 | 2 | II | 6,250 | 125 | 1:2.1 |
| 5 | 30 – 50 | 3 | III | 4,750 | 95 | 1:2.7 |
| 6 | 10 – 30 | | IV | | | |
| 7 | 0 – 10 | | V | | | |

red pine or white spruce in a mixed plantation; or there may be plantations suitable for measurement but where time and resources to conduct the detailed measurements are lacking.

In many of these cases a number of dominant, free-growing trees may be found, the height and age of which may be accurately determined. Such trees can be used for site evaluation purposes, since it is generally accepted that the height-age relationship of dominant trees is a reasonably reliable indicator of potential production for the species concerned. It is expressed as the estimated dominant height at a specified age, and this value is called the "site index". Site index in this study was based on an age of 50 years. Dominant heights were recorded for red pine and projected to give site index values using Backman's projection method. Relationships between dominant height and age for red pine and white spruce are shown in Appendix IV. A sufficiently close relationship was found between site index and potential production in red pine to justify use of the former as an index of potential production in stands where yield cannot be measured.

Projected heights at 50 years were also determined for white spruce from the trees cut down for stem analysis and the values obtained appear in Appendix IV, Table IV-3. While these values show a fairly good relationship between site index and either yield or moisture regime, it is not nearly as striking as that found for red pine, partly because of the irregular nature of spruce plantations, and partly because of the small number of measurements available for analysis.

The site index values for red pine and white spruce corresponding to the yield values for each potential production class are shown in Tables 2-2 and 2-3. Also, since site index is not a precise measurement, these values were rounded to a multiple of five feet; the rounded values taken to correspond to each production class are also shown. It is of interest to note that the total volume production corresponding to the three classes given are roughly proportional to the square of the site index (S.I.), i.e., yield at age 50 is roughly 1.7 times $(S.I.)^2$ for red pine, and 1.8 times $(S.I.)^2$ for white spruce.

There are many red pine plantations in the 10- to 20-year-age range in Southern Ontario. These may be used for site evaluation where older stands are not available. A measure frequently used elsewhere as an index in such stands is the five-year-intercept, that is, the length of the five internodes immediately above breast-height [12]. This involves a very short part of the tree's growth pattern, and it uses height growth at a time when this may be affected by such things as grass or shrub competition evidence of which is no longer observable. However, the intercept can easily be measured in red pine, and it has been found effective as a rough guide, usable, with some reservation, where more reliable measurements are not available. A number of five-year intercepts collected in a separate study suggest the following values for each potential production class:

| Potential Production Class | Intercept (5-year height growth above b.h.) |
|---|---|
| I | 12 feet |
| II | 10 |
| III | 7 |
| IV | 4 |
| V | 2 |

A similar guide has not been prepared for white spruce. The difficulty of identifying the nodes in this species reduces the usefulness of the method for white spruce.

## Chapter 3

# YIELD TABLES FOR RED PINE AND WHITE SPRUCE PLANTATIONS IN SOUTHERN ONTARIO

## Red pine yield tables

A yield table is designed to show, for given sites, the progressive development of the stand at periodic intervals covering the greater part of its useful life. It usually includes average diameter and height, basal area, number of trees and final yields, and may include thinnings. The yield table is essential to any assessment of the economics of intensive management where investment in the creation of forests is contemplated.

Most of the required material for the development of red pine plantation yield tables has been assembled in this study. However, because of the limited area of older plantations available for examination (only four plots exceeded 40 years, one of which exceeded 50 years), the construction of the table to 70 years involves extrapolation from approximately 40 years. Extension of the table to 70 years is deemed desirable since rotations of maximum financial yield may well exceed 60 years and should be tested to 70 years if possible.

In preparation of these yield tables (Tables 3-1, 3-2, 3-3 and 3-4), certain arbitrary but, it is believed, realistic assumptions respecting land productivity classes and the management of the plantations have been made. These are described in some detail below.

### *Potential Production Classes*

(a) As mentioned in Chapter 2, within Southern Ontario five classes of potential production are recognized and three of these were included in the sampling. Interpolation between classes and extrapolation to Classes IV and V are possible but the range and precision of the work at this stage does not justify a more elaborate presentation.

(b) The total production, mean annual increment, moisture regime and dominant height of the Potential Production Classes recognized are shown in Table 3-1, taken in part from Appendices III and IV.

### *Planting density and thinning schedules*

(a) Trees will be planted and refilled (where necessary) to create a stand of 1,000 trees per acre at 15 to 20 years of age.

(b) Thinning will be made for pulpwood at or about 25 years of age which will remove about one-third of the trees (probably row thinning of one in three).

(c) Thinnings will be made for commercial products including pulpwood at ten-year intervals from age 25.

(d) All thinnings, after the first, will be on a selection basis well distributed through the stand.

(e) Thinnings will tend to remove the smaller trees although "wolf" trees and any damaged trees will be taken. The average diameter of the material removed in thinnings will be less than that of the residual stand (except the first thinning where row thinning is practiced) and will therefore tend to increase the average diameter of the stand, i.e., the average diameter of the residual stand following cutting will be higher than that of the entire stand prior to the thinning.

It is appreciated that, under certain market conditions, the manager may wish to take advantage of an available market and remove a larger proportion of large trees in early thinning. In this case, the anticipated financial position resulting from this decision must be compared with that which is anticipated by the somewhat more conservative approach visualized here; where financially attractive current markets exist, the liquidation of the larger immature trees may be justified. As long as the growing stock is not depleted beyond that shown in the tables, and provided it is in a healthy condition, the gross cubic foot yields indicated in the tables should be realized; values will be influenced by the sizes of the trees maintained in the residual stand.

(f) The accumulated volume of all thinnings at age 70 is about 40 percent of total production at that age, i.e., about 60 percent of total production will be on the ground as the main stand at 70 years.

(g) No appreciable mortality will result provided thinnings are taken as indicated and cutting is well distributed throughout the plantation.

## TABLE 3-1. RED PINE PRODUCTION CLASSES

| Potential Production Class | Total Volume Production at 50 years (1,000's cu. ft. per acre gross total volume) | | Mean Annual Increment (cu. ft. per acre at 50 years) | | Moisture Regime* | Dominant Height at 50 years (feet) | |
|---|---|---|---|---|---|---|---|
| | Range | Average | Range | Average | Range | Range | Average |
| I | 9.1–11.0 | 10.0 | 180–220 | 200 | 2— to 4 | 74–82 | 78 |
| II | 7.1– 9.0 | 8.0 | 140–180 | 160 | 1— to 2— | 66–74 | 70 |
| III | 5.1– 7.0 | 6.0 | 100–140 | 120 | 0 to 1— | 59–66 | 62 |

*On deep sand, in Site Region 6E

## TABLE 3-2. RED PINE PLANTATION YIELD TABLES—POTENTIAL PRODUCTION CLASS I

| Age (years) | Dom. Ht. (feet) | Volume (cu. ft./acre) | | | Number of Trees | | Vol./Tree (cu. ft.) | | Avg. Diam. (inches) | | Approximate Basal Area (sq. ft.) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Total Prod. | Re-moved | Main Stand | Re-moved | Main Stand | Re-moved | Main Stand | Re-moved | Main Stand | Main Stand |
| 20 | 32 | 2,100 | | 2,100 | | 1,000 | | 2.1 | | 5.2 | 150 |
| | | | 1,200 | | 330 | | 3.6 | | 5.8 | | |
| 30 | 52 | 5,100 | | 3,900 | | 670 | | 5.8 | | 6.8 | 170 |
| | | | 1,480 | | 290 | | 5.1 | | 6.5 | | |
| 40 | 66 | 7,700 | | 5,020 | | 380 | | 13.2 | | 9.0 | 170 |
| | | | 1,320 | | 120 | | 11.0 | | 8.0 | | |
| 50 | 77 | 10,000 | | 6,000 | | 260 | | 23.1 | | 11.0 | 170 |
| | | | 700 | | 45 | | 15.5 | | 8.5 | | |
| 60 | 84 | 11,600 | | 6,900 | | 215 | | 32.1 | | 12.0 | 170 |
| | | | 300 | | 15 | | 20.0 | | 9.5 | | |
| 70 | 88 | 12,600 | | 7,600 | | 200 | | 38.0 | | 12.8 | 180 |

## TABLE 3-3. RED PINE PLANTATION YIELD TABLES—POTENTIAL PRODUCTION CLASS II

| Age (years) | Dom. Ht. (feet) | Volume (cu. ft./acre) | | | Number of Trees | | Vol./Tree (cu. ft.) | | Avg. Diam. (inches) | | Approximate Basal Area (sq. ft.) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Total Prod. | Re-moved | Main Stand | Re-moved | Main Stand | Re-moved | Main Stand | Re-moved | Main Stand | Main Stand |
| 20 | 28 | 1,700 | | 1,700 | | 1,000 | | 1.7 | | 4.8 | 125 |
| | | | 960 | | 330 | | 2.9 | | 5.4 | | |
| 30 | 45 | 4,080 | | 3,120 | | 670 | | 4.7 | | 6.7 | 165 |
| | | | 890 | | 250 | | 3.6 | | 5.5 | | |
| 40 | 58 | 6,200 | | 4,350 | | 420 | | 10.4 | | 8.6 | 165 |
| | | | 900 | | 110 | | 8.2 | | 7.3 | | |
| 50 | 68 | 8,000 | | 5,250 | | 310 | | 16.9 | | 9.9 | 165 |
| | | | 750 | | 60 | | 12.5 | | 8.4 | | |
| 60 | 76 | 9,350 | | 5,850 | | 250 | | 23.4 | | 11.0 | 165 |
| | | | 650 | | 35 | | 18.5 | | 9.5 | | |
| 70 | 82 | 10,400 | | 6,250 | | 215 | | 29.0 | | 11.6 | 160 |

## TABLE 3-4. RED PINE PLANTATION YIELD TABLES—POTENTIAL PRODUCTION CLASS III

| Age (years) | Dom. Ht. (feet) | Volume (cu. ft./acre) | | | Number of Trees | | Vol./Tree (cu. ft.) | | Avg. Diam. (inches) | | Approximate Basal Area (sq. ft.) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Total Prod. | Re-moved | Main Stand | Re-moved | Main Stand | Re-moved | Main Stand | Re-moved | Main Stand | Main Stand |
| 20 | 25 | 1,300 | | 1,300 | | 1,000 | | 1.3 | | 4.8 | 125 |
| | | | 740 | | 330 | | 2.2 | | 5.4 | | |
| 30 | 39 | 3,100 | | 2,360 | | 670 | | 3.5 | | 6.2 | 140 |
| | | | 880 | | 260 | | 3.4 | | 5.6 | | |
| 40 | 50 | 4,800 | | 3,180 | | 410 | | 7.7 | | 8.0 | 140 |
| | | | 530 | | 80 | | 6.6 | | 6.9 | | |
| 50 | 60 | 6,000 | | 3,850 | | 330 | | 11.7 | | 8.7 | 140 |
| | | | 600 | | 70 | | 8.6 | | 7.2 | | |
| 60 | 69 | 7,000 | | 4,250 | | 260 | | 16.3 | | 9.7 | 135 |
| | | | 510 | | 35 | | 14.6 | | 8.8 | | |
| 70 | 74 | 7,800 | | 4,540 | | 225 | | 20.2 | | 10.5 | 135 |

## White spruce yield tables

Markets in Southern Ontario for white spruce appear to be considerably more limited than for red pine. With the possible exception of the pulpwood market, red pine could be substituted for white spruce without serious reduction in quality standards for most products. Since white spruce is less productive on most sites than red pine, there appears to be little justification for the growing of white spruce on sites which can produce red pine. However, due to its favoured position in the pulp market, it may be feasible to produce white spruce for the exclusive use of this market. In plantations, white spruce develops a heavy, persistent foliage on the lower branches which remains as a dense underbrush long after the lower branches have died. For this reason, the pruning of white spruce is much more costly than the pruning of red pine and partial cutting is extremely difficult and expensive.

Although total production of wood in a plantation is not materially increased by thinning, the degree of utilization is improved where commercial thinnings are taken, by reducing mortality; this is particularly true where close spacing is practiced in the original planting. However, in view of the difficulties of partial cutting in white spruce plantations, it is suggested that wider spacing be used in planting, probably 8′ x 8′ or 6′ x 10′ and the plantations be grown on a short rotation so that mortality does not become excessive. Clearcutting with no thinnings being taken at any point in the development of the stand is the suggested method of management.

If this procedure is followed in the management of white spruce plantations the significant factor in the analysis of the economics of production will be the volume yield, i.e., the volume of live timber on the ground at various ages. Since it is not visualized that spruce will be used extensively for sawtimber or veneer, there will be little need for the determination of numbers of trees per acre or average diameters at various stand ages. If efforts are made to develop mechanical equipment for clearcutting spruce plantations, some thought would have to be given to tree sizes but such investigations lie outside the scope of this report.

The most serious source of error in estimating future yields from clearcutting is in making proper allowance for mortality. An attempt has been made to assess this loss, the details of which are described in Appendix V. Assuming that the mortality allowance is correct, the estimates of production from the white spruce plantations in Site Region 6E are shown in Tables 3-5, 3-6, and 3-7, for three potential production classes for which stands suitable for measurement occurred.

Tables 3-5, 3-6, and 3-7 have been developed from the data collected in plantations which were planted in most cases on 6′ x 6′ spacing or closer (trees planted per acre varied from 796 to 1,927 and averaged 1,450[1], while 6′ x 6′ spacing produces 1,200 trees per acre). Under these circumstances the land would be fully occupied by the stand at an earlier age than would be the case with wider spacing (8′ x 8′ spacing produces 680 trees per acre), mortality however would be greater. The net result of the wider spacing would probably be to produce about the same standing volume at ages of 40 years or more but with a lower total production, a lower mortality, a higher average diameter and some reduction in the specific gravity of the wood produced.

A check on the above assumptions was made against a 57-year-old white and black spruce (*Picea mariana*) and balsam fir (*Abies balsamea*) plantation located in Paipoonge Township in Northwestern Ontario. This plantation of 0.9 acres is in a completely different site region from the area being studied and hence is of limited value as a check. However, being an older plantation, it gives some idea of the development to that age.

It is estimated[2] that the plantation originally consisted of about 275 trees per acre which were moved from the natural forest to a farm field. The present volume on the ground is estimated to be 4,300 cubic feet per acre of gross merchantable volume or over 5,000 cubic feet of gross total volume and an estimated gross total production (including mortality) of about 6,200 cubic feet per acre with an average dbh of white spruce (85 percent of the present total volume is in this species) of 14.4 inches. Many of the black spruce and balsam fir originally planted have died or been blown over (in all 74 trees per acre averaging 8″ to 9″ dbh) so that production has not been at the maximum throughout the period.

Considering the difference in climatic conditions, the site of this stand would probably correspond to Potential Production Class II although, for reasons noted above, the production is somewhat less than that indicated by this production class. The significant point concerning this stand is the high average diameter of the white spruce associated with the wide spacing. At the spacing of the plots measured in Southern Ontario the average dbh at 57 years would appear to be in the neighbourhood of 8″ to 9″.

Under the assumptions made above, the specifications of the various white spruce potential production classes are shown in Table 3-8, taken in part from Appendix III.

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[1]Although the number of stems averaged 1,450, the actual number of trees planted may have been less since spruce has a tendency to fork at the seedling stage and develop multiple stems. In addition, when planting stock is small, as is often the case with spruce, two trees may be planted in one hole.

[2]Personal correspondence from R. J. Burgar who measured the plantation for the authors in 1962.

TABLE 3-5. WHITE SPRUCE PLANTATION YIELD TABLES—POTENTIAL PRODUCTION CLASS I

| Age (years) (n) | Dom. Ht. (feet) | Volume (cu. ft./acre) Total Prod. | Mortality | Standing Timber (V) | M.A.I.* (cu. ft./acre/year) | C.A.I.* (cu. ft./acre/year) | Rate of Volume Increase** |
|---|---|---|---|---|---|---|---|
| 20 | 29 | 1,250 | — | 1,250 | 62 | | |
| | | | | | | 205 | 10.2 |
| 30 | 44 | 3,450 | 150 | 3,300 | 110 | | |
| | | | | | | 180 | 4.4 |
| 40 | 56 | 5,800 | 700 | 5,100 | 128 | | |
| | | | | | | 130 | 2.3 |
| 50 | 64 | 7,750 | 1,350 | 6,400 | 128 | | |
| | | | | | | 100 | 1.5 |
| 60 | 71 | 9,400 | 2,000 | 7,400 | 123 | | |
| | | | | | | 60 | 0.8 |
| 70 | 76 | 10,600 | 2,600 | 8,000 | 114 | | |

TABLE 3-6. WHITE SPRUCE PLANTATION YIELD TABLES—POTENTIAL PRODUCTION CLASS II

| Age (years) (n) | Dom. Ht. (feet) | Volume (cu. ft./acre) Total Prod. | Mortality | Standing Timber (V) | M.A.I.* (cu. ft./acre/year) | C.A.I.* (cu. ft./acre/year) | Rate of Volume Increase** |
|---|---|---|---|---|---|---|---|
| 20 | 25 | 750 | — | 750 | 37 | | |
| | | | | | | 165 | 12.3 |
| 30 | 39 | 2,500 | 100 | 2,400 | 80 | | |
| | | | | | | 160 | 5.2 |
| 40 | 50 | 4,500 | 500 | 4,000 | 100 | | |
| | | | | | | 120 | 2.7 |
| 50 | 59 | 6,250 | 1,050 | 5,200 | 104 | | |
| | | | | | | 90 | 1.6 |
| 60 | 65 | 7,500 | 1,400 | 6,100 | 101 | | |
| | | | | | | 60 | 1.1 |
| 70 | 70 | 8,450 | 1,750 | 6,700 | 96 | | |

TABLE 3-7. WHITE SPRUCE PLANTATION YIELD TABLES—POTENTIAL PRODUCTION CLASS III

| Age (years) (n) | Dom. Ht. (feet) | Volume (cu. ft./acre) Total Prod. | Mortality | Standing Timber (V) | M.A.I,* (cu. ft./acre/year) | C.A.I.* (cu. ft./acre/year) | Rate of Volume Increase** |
|---|---|---|---|---|---|---|---|
| 20 | 22 | 400 | — | 400 | 20 | | |
| | | | | | | 110 | 14.1 |
| 30 | 34 | 1,550 | 50 | 1,500 | 50 | | |
| | | | | | | 140 | 6.8 |
| 40 | 44 | 3,150 | 250 | 2,900 | 72 | | |
| | | | | | | 125 | 3.6 |
| 50 | 52 | 4,750 | 600 | 4,150 | 83 | | |
| | | | | | | 105 | 2.3 |
| 60 | 58 | 6,100 | 900 | 5,200 | 87 | | |
| | | | | | | 80 | 1.4 |
| 70 | 64 | 7,100 | 1,100 | 6,000 | 86 | | |

*Calculated for standing volume only.
**Compound annual rate of standing volume (V) increase from $V_n$ to $V_{n+10}$.

TABLE 3-8. WHITE SPRUCE PRODUCTION CLASSES

| Potential Production Class | Total Volume Production at 50 years (1,000's cu. ft. per acre gross total volume) | | Mean Annual Increment (cu. ft. per acre at 50 years) | | Moisture Regime (for deep sands, Site Region 6E) | Dominion Height at 50 years (feet) | |
|---|---|---|---|---|---|---|---|
| | Range | Average | Range | Average | | Range | Average |
| I | 7.01–8.50 | 7.75 | 140–170 | 155 | 2— to 4+ | 62+ | 64 |
| II | 5.49–7.00 | 6.25 | 110–140 | 125 | 0+ to 2— and 4+ to 6— | 56–62 | 59 |
| III | 4.00–5.50 | 4.75 | 80–110 | 95 | 0 to 0+ and 6— to 6+ | 48–56 | 52 |

## Chapter 4

# MARKETS FOR PLANTATION-GROWN RED PINE AND WHITE SPRUCE

### Suitability of plantation-grown red pine for commercial use

Evidence of the potentialities of red pine for afforestation prompted investigations into the strength and related factors of red pine which might influence its commercial utilization. In 1963 studies were undertaken by the Forest Products Research Branch of the federal Department of Forestry — these have been reported upon recently[1, 2] [11].

Strength tests[2] show that values for specific gravity, modulus of rupture and modulus of elasticity are significantly lower for plantation-grown timber than for naturally grown red pine trees. However, specific gravity determinations along selected radii of the test material indicate a strong radial gradient in density increasing toward the bark. The trees from which specimens were taken for this analysis were 36 years old; if the gradient referred to above persists in older trees, density and strength factors for rotation age trees (probably 50 to 60 years old) would closely approximate those of the naturally grown trees.

In many of the products for which red pine may be well suited, the mechanical strength of the wood is not a critical factor. For example, in the manufacture of pulp and paper the length of the fibre and the density and colour of the wood will be characteristics of major significance. In veneer and plywood used for decorative panels and construction work, the strength of the plantation-grown red pine would be well within normal requirements.

The market situation respecting red pine timber requires additional study. The summary contained here covers certain highlights of recent investigations which appear to have some relevance to red pine production in Southern Ontario. A brief statement is included for each of the products for which red pine would logically be produced.

[1]Calvert, W.W. 1965. Kiln-drying of red pine lumber from plantation-grown trees. Department of Forestry of Canada, Forest Products Research Branch. [Unpublished progress report.]

[2]Jessome, A.P. 1966. Strength studies on plantation-grown red pine. Department of Forestry of Canada, Forest Products Research Branch. [Internal Report.]

#### *Pulp and paper*

From a technological viewpoint the coniferous species, being of greater fibre length, are favoured over deciduous species for the production of pulp and paper. In the industrialized countries, therefore, the pressure for utilization of the coniferous species far exceeds that of the hardwoods. Within the Tennessee Valley Authority watershed, for instance, softwood utilization is up to the allowable cut, whereas raw material potential exists for six new hardwood pulp plants within the T.V.A.

Coniferous raw material located close to markets or on deep water ports is particularly attractive to industry due to expanding international trade in pulp products. Thus recent developments on both the east and west coasts of Canada have taken advantage of accessible coniferous wood and suitable plant locations on tidewater. As world demand for pulp products increases, red pine timber adjacent to the St. Lawrence Seaway will become increasingly attractive to the pulp and paper industry.

Estimates of future pulpwood requirements in the United States, Europe and Canada indicate a tremendous increase in utilization. In Canada it is estimated that consumption will be 70 percent higher in 1975 than in 1960, and Western Europe and the developing countries around the world are showing higher rates of increase in utilization of paper. The estimated wood requirements for paper and paperboard in the developing countries of Latin America, Asia and Africa in 1970 is 32.3 million cubic metres, which is 2.3 times the 1957-59 utilization of 13.8 million cubic metres [28].

Red pine pulpwood from plantations set out in 1966-70 would not be available in quantity until about 1990. Barring major economic or social upheavals, there is evidence to suggest that the market for coniferous pulpwood in the Great Lakes area will be very strong by that time.

#### *Plywood and veneer*

World production of plywood is presently more than five times that of 1938 and there is ample evidence that demand will be strong in the future. Plywood consumption in Europe increased from 2.8 million cubic metres in

1960 to 3.7 million cubic metres in 1965 and in North America from 9.5 million to 14.7 million in the same period. In Europe this means an increase from 6.1 cubic metres per 1,000 people in 1960 to 7.7 cubic metres in 1965. In North America the corresponding figures are 48.0 cubic metres and 64.3.

The increase in use within countries and the difference in rate of consumption per capita between countries indicate a strong likelihood that the demand for plywood and for suitable stumpage will continue into the forseeable future. It is estimated that consumption on a per capita basis in Canada will increase by 45 percent between 1959-61 and 1975 which will double the total requirements by 1975.

Economies of scale are not so pronounced in the plywood and veneer industry as in pulp and paper. Economies in the industry could be achieved if pulp and paper plants were designed to use the thinnings and residue from the manufacture of more valuable wood products.

### *Lumber*

Although the per capita consumption of lumber is decreasing in Canada (from 192 board feet in 1959-61 to an estimated 161 board feet in 1975), total requirements are increasing. For timber suitably located relative to the market, the demand will undoubtedly be high. However, the production of sawlog material requires relatively long rotations to gain the sizes required for efficient conversion.

A study of the kiln-drying of red pine lumber carried on by Calvert[3] revealed a serious weakness in the younger plantation-grown red pine used for lumber. Lumber sawn from logs taken from a 36-year-old plantation showed the following characteristics. About 90 percent of the lumber sawn from the sapwood met established standards of assessment, half of the sap/heart boards were satisfactory but virtually none of the material containing a high proportion of heartwood, commonly called juvenile core, was satisfactory.

With longer rotations the proportion of juvenile core will be diminished which will lead to better average quality outturn from plantation-grown material. Alternatively, a plan of utilization that will direct the low quality heartwood to products other than lumber will improve the use of red pine in this field.

In view of the increasing use being made of plywood and the expected future demand for this product, it is believed that management of red pine should be oriented to the production of veneer rather than lumber. However, the program of management is virtually the same for both products except for the length of the rotation (which may be shorter for veneer). Since economies of scale are not decisive in the sawmilling industry, the decision to produce lumber rather than veneer may be made as the raw material matures. In fact, with the integration of pulp and paper, veneer and lumber, many advantages would be realized; under such a plan the requirements of the pulp plant would dictate the minimum scale of planting operations as discussed in Chapter 7.

[3]Op. cit.

### *Poles and piling*

An analysis of the market situation for these products in North America suggests a declining per capita utilization of about 5 percent per year. However, opportunity for the export of these products surely exists and with a more aggressive approach in this area a continuing or even expanding market could be developed. Nevertheless, although the material produced in red pine plantations is particularly well suited for these products, no great expansion of the market was visualized in the determination of stumpage values.

The possible adaptation of plantation material to cottage construction could lead to improved market conditions. Because of the uniformity of size of red pine plantation wood (see Appendix VI), new commercial uses may well be developed. In the absence of any historical trends of utilization in special uses such as those indicated above, no projection of future markets in these areas is possible.

## Summary of the market situation for red pine

Future strong demands for red pine in the Southern Ontario region are evident as raw material for pulp and paper, veneer and plywood and sawlogs and a present lucrative market exists for poles and piling. This latter market may well continue for the favourably located plantation material.

Virtually all of the timber now being used in Canada is obtained from the liquidation of natural stands. In the process of moving into more remote areas to acquire this material, or in the development of techniques for the utilization of less desirable but more accessible material, increasing costs will be incurred.

In view of the versatility of red pine timber in commercial utilization, it appears almost certain that it will be in high demand in the Southern Ontario region or for export in manufactured form to the U.S.A. and Europe. If produced in the region, its favourable physical and market accessibility will guarantee stumpage returns in all markets considerably in excess of those applying to the natural stands. The effect of these high returns is to justify the investment in plantations under certain conditions. These conditions are examined in Chapter 7.

## Suitability of plantation-grown white spruce for commercial use

No tests of the mechanical properties of plantation-grown white spruce from Ontario have been undertaken.

However, on the samples taken for the current study a graduate student at the University of Toronto[4] has undertaken a detailed investigation of the effect of growth rate and other factors on the specific gravity of white spruce wood. From this investigation it appears that the specific gravity of the plantation-grown wood at 0.33 is significantly less than that of natural stands which is 0.35. This will be a matter of some importance in the use of plantation-grown white spruce for pulpwood.[5]

White spruce, having been much less widely planted in Southern Ontario than red pine, suffers from a lack of adequate local concentrations of volume to justify market development in the region at the present time. Furthermore, since it prunes slowly under natural conditions, does not accept preservatives readily and has no unique mechanical qualities which impart exceptional value, white spruce satisfies no specific timber requirement justifying its movement to distant markets except as pulpwood.

As a pulping species, spruce — both black spruce and white spruce — is superior to other species in central North America as indicated by the prices paid for various species shown in Table 4-1 [21].

[4]Chang, C. 1966. Specific gravity variation of plantation-grown white spruce.

[5]As in the case of red pine it is expected that specific gravity will increase with plantation age.

TABLE 4-1. MAXIMUM PRICES PAID FOR MICHIGAN-PRODUCED PULPWOOD

| Species | Prices (Per Cord) Delivered Maximum | |
|---|---|---|
| | Rough | Peeled |
| Spruce | $30.00 | $35.00 |
| Balsam fir | 28.00 | 30.00 |
| Pine | 16.50 | N.A. |
| Hemlock | 16.50 | N.A. |
| Aspen and white birch | 13.00 | 22.50 |
| Miscellaneous hardwoods | 13.00 | N.A. |

Although pulpwood is generally a low value product which is rarely moved more than 50 miles, spruce pulpwood has qualities which justify movement for much greater distances. Rail shipment of spruce for distances in excess of 200 miles is not uncommon. In this market, therefore, the species has special value which may justify its management in plantations under certain conditions, the economics of which will be examined in Chapter 7.

## Chapter 5

# STUMPAGE VALUE OF TIMBER HARVESTED

### Determination of stumpage value

The stumpage value of timber may be defined as the value of the timber as it stands in the forest ready for conversion to sawlogs or pulpwood. It is determined by subtracting from the value of the commercial product the costs of harvesting, manufacturing and transporting the timber, the overhead costs of the business, and an allowance for profit to the operator, i.e., the stumpage value is a residual value. An example of the calculation is shown in Table 5-1.

In the conversion of standing trees of a given species to lumber or veneer, two factors, within the limitations imposed by the given accessibility conditions, influence the stumpage value. These factors are log or tree size and timber quality. The latter is influenced by the size, straightness and extent of defect and by the number and size of knots present. The log size influences the costs of harvesting and manufacturing and determines the proportion of waste. The timber quality determines the grade of the product that will be produced.

Many of the red pine trees in the Agreement Forests have attained commercial size not only for pulpwood (the product with the least rigid size and form specifications), but for poles, piling and sawlogs. The prices that have been paid for these products and the harvesting costs provide the most reliable source of information from which to determine stumpage values for this material. In using the data from existing plantations, however, it must be appreciated that most of the material cut from these plantations is quite young compared to the optimum age for utilization and values on a unit-volume basis will, therefore, be low.

### Stumpage values for red pine in plantations

A study has been made of the prices and costs that apply to plantation material utilized for pulpwood, poles and piling. These data cover the operations on Agreement Forests in 1965-66 and indicate stumpage values as shown in Table 5-1.

Table 5-1 illustrates the tremendous range of stumpage values associated with the different products produced.

TABLE 5-1. THE DETERMINATION OF CURRENT STUMPAGE VALUES FOR PLANTATION-GROWN RED PINE TIMBER

| | Pulpwood | | | | Poles | | Piling* | |
|---|---|---|---|---|---|---|---|---|
| | Roadside** | | Stumpage† | | Roadside** | | Stumpage† | |
| | Per Cord ($) | Per cu. ft. ($) | Per Cord ($) | Per cu. ft. ($) | Per Piece ($) | Per cu. ft. ($) | Per Piece ($) | Per cu. ft. ($) |
| Roadside Price | 12.50 | 0.147 | — | — | 2.36 | 0.436 | — | — |
| Harvesting Costs (including supervision) | 10.40 | 0.122 | — | — | 0.91 | 0.168 | — | — |
| Stumpage Price | — | — | 1.70 | 0.020 | — | — | 4.56 | 0.410 |
| Supervision Cost | — | — | 0.62 | 0.007 | — | — | — | 0.007 |
| Stumpage Value†† | 2.10 | 0.025 | 1.08 | 0.013 | 1.45 | 0.268 | — | 0.403 |

*These rates are based on a small sale of 3,000 pieces and must be considered high for all but specialty products.
**Products harvested by the Department of Lands and Forests and sold at the roadside.
†Timber sold on the stump.
††Net price realized for standing timber.

Where specifications are not rigid, as in the case of pulpwood, the rate is low — from 1.3 to 2.5 cents per cubic foot; where special dimensions and quality (straightness) are required, rates are considerably higher — from 27 to 40 cents per cubic foot. In the latter categories, markets tend to be somewhat limited although new uses for round construction material especially for agricultural buildings could greatly expand this market.

No price data were available for sawlogs or veneer logs cut from Ontario plantations. Although a small amount of material is sold for sawlogs, the reduction of lumber grade in seasoning[1] discourages the use of the younger trees for this purpose. In older and larger trees where a smaller proportion of the volume is in juvenile core, the production of lumber will be practical.

Stumpage rates applying to plantation timber used for sawlogs and veneer logs will be influenced by two important factors. The physical accessibility of the land and the accessibility of the region to markets will increase the value of the stumpage in Southern Ontario over that applying to the more remote naturally-grown timber elsewhere in Canada. Also, since most of the timber cut for these markets will have been pruned at an early age, it will produce clear grades of lumber and veneer and therefore will command higher rates.

In projecting stumpage rates to obtain estimates of future returns from presently immature plantations or from plantations which are now being established, the trend of value changes should be recognized. There is evidence to suggest that the long-term trend indicates rising timber values in North America in constant dollars [8] at the rate of 2 percent per year. However, recent stumpage prices in National Forests in the United States [14] indicate fluctuating rates with no short-term trend of increasing rate for any species except Douglas-fir (*Pseudotsuga taxifolia var. glauca*).

The suitability of red pine for specialty products (poles and piling, etc.) and its potential for veneer and plywood combine to indicate that this species will, in future, enjoy relatively high stumpage rates in areas where it may be grown in Southern Ontario. For these reasons the current rate of $0.27 per cubic foot for the small poles presently being cut has been used for all non-pulpwood material. This rate must be considered as a conservative figure since it does not recognize the long-term trend of increasing timber values, nor the increasing size of poles and piling that will be available in future from the older plantations and which will command higher prices per unit volume.

As a basis for comparison of rates, an estimate of future timber value, using present stumpage rates for naturally-grown saw-timber ($15.00 to $20.00 per M

[1]Calvert, W.W. 1965. Kiln-drying of red pine lumber from plantation-grown trees. Department of Forestry of Canada, Forest Products Research Branch. [Unpublished progress report.]

TABLE 5-2. GRADE-PRICE RELATIONSHIP IN LUMBER AND LOGS

| Product | Grade | Price ($) | Comments |
|---|---|---|---|
| Red Pine Lumber | D Select | 190 per M fbm | High proportion of these grades from pruned trees. |
| | No. 1 | 132 | |
| | No. 2 | 102 | High proportion of these grades from unpruned trees. |
| | No. 3 | 87 | |
| | No. 4 | 72 | |
| | No. 5 | 55 | |
| Douglas-fir Logs* | Peelers No. 1 | 135 per M fbm | |
| | Standard Sawlog No. 2 | 80 | The absence of log markets in Eastern Canada precludes the reference to a more appropriate species. The relationship between quality and price applies in all species used for veneer and lumber and quality is greatly reduced by the presence of knots. |
| | Peewee Sawlog | 67 | |
| | Pulpwood | 30 | |
| Spruce Logs* | High grade peelers | 97 per M fbm | |
| | High grade | 92 | |
| | Peelable | 65 | |
| | Merchantable | 57 | |
| | Pulpwood | 47 | |

*A. W. Rafter. Economic use of wood in British Columbia. Woodlands Review, March 1966.

fbm) with an assumed 2 percent annual increase in value, is shown in Table 5-3.

A rate of $0.27 per cubic foot applied to sawlogs and veneer logs may appear high until it is appreciated that pruning effects an important change in product values as indicated in Table 5-2.

## Stumpage values for white spruce in plantations

As previously noted, from the point of view of volume production, there seems little justification for the planting of white spruce in preference to red pine on any but the moister sites (M.R. 5 and higher) in Southern Ontario. However, as is obvious from the relative prices paid for pulpwood (Tables 4-1, 5-2), spruce has a high value for pulp production. If the species may be considered essential for the maintenance of a strong pulp and paper industry in the region, what stumpage rate should be applied to justify the use of certain lands of Southern Ontario for the growing of spruce in preference to red pine? The lands which would logically be used for spruce would be those where spruce more nearly approaches the level of the red pine production, namely on the drier sites (M.R. 0 to 1 —). Such sites are not good for either species but the difference in yield (gross total production) at 1,250 cubic feet at 50 years (see Tables 3-4 and 3-7) is less on the drier than on the more productive sites.

On a 50-year rotation, the yield of merchantable volume for the red pine (Table 3-4) would be 5,000 cubic feet net merchantable (6,000 cubic feet gross total), of which 1,830 cubic feet (net volume in the first three thinnings) would be at the pulpwood rate of $2.00 per

TABLE 5-3. NON-PULPWOOD STUMPAGE RATES AT VARIOUS PLANTATION AGES.
(Assuming a 2% annual stumpage increase from current rates applicable to naturally grown saw-timber.)

| Age (years) | Escalator Factor 2% per Year | Base Rate $15.00 per M bd. ft. | | | Base Rate $20.00 per M bd. ft. | | |
|---|---|---|---|---|---|---|---|
| | | Rate per M bd. ft. | Rate per merchantable cu. ft. | | Rate per M bd. ft. | Rate per merchantable cu. ft. | |
| | | | Average dbh of Stand* up to 8" | 8" and over | | Average dbh of Stand* up to 8" | 8" and over |
| | | ($) | (¢) | (¢) | ($) | (¢) | (¢) |
| 20 | 1.49 | 22.40 | 10.1 | 11.2 | 29.80 | 13.4 | 14.9 |
| 25 | 1.64 | 24.60 | 11.1 | 12.3 | 32.80 | 14.8 | 16.4 |
| 30 | 1.81 | 27.20 | 12.3 | 13.6 | 36.20 | 16.3 | 18.1 |
| 35 | 2.00 | 30.00 | 13.5 | 15.0 | 40.00 | 18.0 | 20.0 |
| 40 | 2.21 | 33.20 | 15.0 | 16.6 | 44.20 | 19.9 | 22.1 |
| 45 | 2.44 | 36.60 | 16.5 | 18.3 | 48.80 | 22.0 | 24.4 |
| 50 | 2.69 | 40.40 | 18.2 | 20.2 | 53.80 | 24.2 | 26.9 |
| 55 | 2.97 | 44.50 | 20.0 | 22.2 | 59.40 | 26.8 | 29.6 |
| 60 | 3.28 | 49.20 | 22.2 | 24.6 | 65.60 | 29.6 | 32.8 |
| 65 | 3.62 | 54.30 | 24.5 | 27.1 | 72.40 | 32.6 | 36.2 |
| 70 | 4.00 | 60.00 | 27.0 | 30.0 | 80.00 | 36.0 | 40.0 |

*Thinnings are presumed to be suitable for products other than pulpwood where the average dbh of the material is 7.6 inches or more. For average dbh's of 8.0 inches or less, a conversion of 222 merchantable cubic feet per M fbm is used; for average dbh's of over 8.0 inches, 200 merchantable cubic feet per M fbm is used. The volume unused for sawlogs or veneer logs will be largely usable as chips, but no value has been assigned to this volume.

cord, and 3,170 cubic feet at the non-pulpwood rate of $0.27 per cubic foot. The total value of production from the red pine would therefore be $892.00. Ignoring any interest charges that may develop from differences in the time of recovery of yield, the value of the spruce pulpwood at age 50 would have to be $892.00 per acre if the use of the area for spruce production was to be competitive.

At 50 years the estimated standing volume of spruce is 4,150 cubic feet gross total, or 41.5 cords net merchantable. The competitive stumpage value for spruce would therefore have to be $21.50 per cord. This is a highly unrealistic stumpage value by present-day standards. Based on prices for pulpwood shown in Table 4-1, there now exists a differential between spruce and pine of $13.50, if a stumpage price of $2.00 is applied to the pine then, for timber of equal accessibility, a rate of $15.50 for spruce stumpage would be justified. It is obvious that this is somewhat of an oversimplification of the case but it does indicate that the $21.50 per cord competitive rate for spruce is presently out of line with pulpwood rates for other pulpwood species. If it is felt that spruce must be provided in the future through plantations, it appears that state subsidization will have to account for at least $6.00 per cord ($21.50—$15.50) and probably much more.

Stumpage rates for spruce in the Central Region of North America range from $1.75 to $8.75 per cord and probably average $7.00 per cord [21]. At this stumpage rate, spruce, with its lower yields and limited market potential, cannot compete with red pine for any of the sites for which production data are available.

## Chapter 6

# LAND VALUES AND COSTS OF MANAGEMENT

### Land value for marginal land under agricultural use

The method of analysis applied in this report will produce an estimate of the prices which could be paid for lands of different productive capacity, at specified interest returns on the cost of the land and the costs of planting and management under forest use. These calculated prices will be compared to the market price of abandoned sub-marginal agricultural land (see Table 1-1) to indicate the potential of forestry use compared to that of agriculture.

An analysis of the purchases of land made by the Ontario Department of Lands and Forests for the Agreement Forest program in 1965-66 shows the following distribution of vegetative cover on the typical property of 108 acres (Table 1-1). Thirty percent of the purchased property is open land[1], much of which would be immediately suitable for tree planting without further treatment. The natural woodland area, covering 57 percent of the property, would not normally be suited to plantation development, although some could be so used after an expenditure for site preparation. The remaining 13 percent is either swamp (11 percent) or it is already in plantation (2 percent).

From the survey of marginal agricultural land in six townships in Ontario conducted by the Ontario Economic Council [5], it appears that agricultural production from cleared land produces a gross income averaging between $16.00 and $24.00 per acre per year. An average price of $12.20 per acre for such land (Table 1-1) would mean, at 7 percent return (current commercial interest rate), an anticipated net revenue of $0.85 per acre (0.07 x $12.20) and a value for the farmer's services and return on capital invested in buildings and machinery of $24.00 —$0.85 = $23.15 per acre (assuming an annual gross return of $24.00 per acre). For the typical property with 32 acres cleared, the farmer's income from labour and capital input would be $740.00 (32 x $23.15) per year —well below the minimum standard of $2,500 gross annual income of marginal farmers prescribed by ARDA [2]. If a higher price is visualized for the land (assuming that the cleared land is more valuable than the forested area), the return to labour and capital is reduced. It would seem, therefore, that the average price per acre of $12.20 for the typical property is not too low for the cleared land under agricultural use. In fact this analysis adds strength to the observation of the Ontario Economic Council [5], "That . . . these acres continue in use [for agriculture] may be more related to habit patterns than to economics."

[1]Of six townships analyzed by the Ontario Economic Council, open land occupies 21 percent of the total area [5].

### Costs of forest management

The costs of management, assumed here to be equal where applicable for red pine and white spruce, may be separated into two categories. The first class includes the "one time" operations, such as planting and pruning; the second class includes the annual cost of maintenance and protection. The first class of management operations may be accomplished through contract work, in which case the overhead cost will be very small consisting only of assessment of the adequacy of the work. For annual maintenance some permanent staff is necessary and additional casual staff is required at certain periods of the year.

In making allowance for these costs in the calculation of land values, the two classes of costs may be handled differently—the first class appearing as a capital expenditure at a specific time, and the second as a uniform annual cost of management.

#### *Planting and pruning costs*

Considerable variation exists in the cost of tree planting, depending upon whether the work must be done by hand or whether planting machines may be used[2]. For much of the sub-marginal agricultural land, machine planting is practical so the rate applicable to this method has been used. Assuming that 1,000 trees per acre are

[2]Excessive degrees of steepness, stoniness or wetness and the presence of stumps and slash may hinder or preclude the use of machines and thus necessitate more expensive hand planting methods.

TABLE 6-1. PLANTING COST AT ROTATION AGE (AT 4% INTEREST)

| Rotation (years) | Interest Factor | Red Pine 1,000 trees/acre @ 2.84¢ = $28.40 Cost at Rotation Age ($) | White Spruce 700 trees/acre @ 2.84¢ = $20.00 Cost at Rotation Age ($) |
|---|---|---|---|
| 40 | 4.801 | 136 | 96 |
| 50 | 7.107 | 202 | 142 |
| 60 | 10.520 | 299 | 210 |
| 70 | 15.570 | 442 | 311 |

planted, the machine cost of planting varies from $8.45 to $18.40 per acre according to figures collected in the county forests for 1964. To allow some latitude for refilling the plantations where trees have been killed by drought or other causes, the higher of these figures will be used, namely $18.40 per acre for red pine and $13.00 (700 trees per acre) for white spruce. To the cost of planting must be added the price of trees which at current rates is $10.00 per thousand trees.

The cost of planting, including the cost of trees (total, 2.84 cents per tree), will be assumed to be the same for all site classes and the amount of this cost at 40, 50, 60, and 70 years is shown in Table 6-1 for red pine and white spruce.

Pruning costs applicable only to red pine have been estimated on a per tree basis at the rate of 20 cents per tree to 17 feet, the recommended height for pruning if the butt log is to be used for sawlogs. It has been suggested that where the trees are being pruned for use as veneer a pruned height of 18.5 feet to produce two peeler logs would be desirable.

A study by Farrar [9] of the annual sheath of wood laid on living red pines yielded some valuable information respecting the foliage which should remain after pruning to avoid reductions in the annual growth. It appears that seven or eight whorls of branches should be left on the tree. This means that the earliest practical time for pruning to 18.5 feet (or 17 feet) would be after seven or eight whorls have been grown above the 18.5 foot point.

In Potential Production Class I the height at 20 years is 32 feet and the average annual height growth is 1.6 feet; the length of the unpruned crown must therefore be at least 7.0 x 1.6 = 11 feet. Since at 20 years the height of dominants is 32 feet, the live crown of 11 feet means that pruning could be undertaken at, or somewhat before, 20 years of age.

By similar reasoning, it can be determined that Potential Production Class II may be pruned at 20 years and Potential Production Class III at 25 years without seriously restricting the growth of the stand. The average dbh of the stand at time of pruning for all classes would therefore be about 5 inches. Not all stems would be pruned and those that were pruned would tend to be slightly larger than the average—an estimate of 5 inches dbh at time of pruning will therefore be conservative.

Fedkiw [10] shows that for trees growing at the rate of 10 rings per inch (6 inches of dbh growth in 30 years) the rate of return on investment in pruning white pine (*Pinus strobus*) is at least 7 percent compound interest. The rates for red pine may be somewhat lower than those for white pine where lumber value only is considered due to somewhat lower lumber prices in certain grades. However, the veneer potential of red pine justifies the assumption that an equal or better return could be expected for that species.

It may be assumed, therefore, that it will be profitable to prune, on Potential Production Class I land, all trees that will be 11 inches dbh or over (5 inches at time of pruning, plus 6 inches of growth in 30 years) at 50 years —the total is 260 according to Table 3-2 but only a portion of these will exceed the 11-inch minimum at this age. If the stand is maintained to 70 years, virtually all of the 200 trees in the stand at that age would exceed 11 inches. Allowing 10 percent for losses it is believed that on this site about 220 trees per acre should be pruned.

For Potential Production Class II the 11-inch diameter is reached at 60 years, hence a lower interest return will be recovered on pruning undertaken in stands of this productivity class. Since the average diameter at 70 years is 11.6 inches, more than half of the trees will exceed 11 inches so the pruning of about 150 trees (140 plus 10 percent for losses) in this class of land would be justified.

For Potential Production Class III, where pruning cannot be undertaken until age 25 and where average dbh at age 70 is less than 11 inches, less than half the trees in the stand at 70 years could profitably be pruned, probably about 100 per acre, and these would have to be given preferential treatment in thinning to encourage continuous rapid growth.

On the basis of these assumptions, it will now be possible to estimate the costs of pruning for the different land classes—these estimates are summarized in Table 6-2.

***Annual maintenance costs***

An estimate of annual maintenance costs could be derived from the existing Agreement Forest records by deducting such items as planting and pruning costs from the total, which to date amounts to $3.05 per acre per year. This estimate would be affected by the relatively large overhead and small size of these forests. They range in size from a maximum of 24,000 acres to less than 1,000, and many of the properties making up the forests are scattered over large areas. Such a figure would require adjustment to serve as a base for estimating maintenance costs of a forest established under ARDA.

The cost of management of 23.06 million acres of private land in the southern United States has been esti-

TABLE 6-2. PRUNING COSTS PER ACRE BY SITE CLASSES

| Potential Production Class | Trees Pruned per Acre (number) | Age when Pruned (years) | Cost per Acre @ 24¢ per tree ($) | Capital Value at 4% 60 years ($) | Capital Value at 4% 70 years ($) |
|---|---|---|---|---|---|
| I | 220 | 20 | 52.80 | 254 | 375 |
| II | 150 | 20 | 36.00 | 173 | 256 |
| III | 100 | 25 | 24.00 | 95 | 140 |

mated [3] at $32.61 million for an average cost of $1.41 per acre. This includes the cost of planting and pruning and covers a wide range of size in forest ownership. It would therefore seem to be a reasonable figure for suitable units that could be set up in Ontario. To allow some latitude, it will be assumed that the annual management cost of $1.40 per acre does not include planting and pruning.

In addition to the direct costs of management (fire protection, fencing, supervision, etc.), there are overhead costs in the form of municipal costs for roads, welfare and education. For the six townships[3] analyzed by the Ontario Economic Council [5] these costs averaged $1.62 per acre. In the management of the land for timber production there would be a lower cost for municipal roads (forest road maintenance is already included in the $1.40 mentioned above) and there would be fewer people engaged in sub-marginal agriculture, reducing the need for welfare payments. However, certain costs presently represented by municipal taxes would have to be covered. Under forest management, it is assumed that municipal expenses could be cut in half. A total management cost of $\$1.40 + \frac{\$1.62}{2} = \$2.21$ per acre, therefore, will be allowed to cover all regular annual costs. The amounts to which these annual costs accumulate at 4 percent to various rotation ages are shown in Table 6-3.

TABLE 6-3. ANNUAL MANAGEMENT COSTS AT ROTATION AGE (AT 4% INTEREST)

| Rotation Age (n) (years) | Interest Factor $(1.04^n-1)$ | Costs at "n" Years $\frac{2.21}{0.04}(1.04^n-1)$ ($) |
|---|---|---|
| 40 | 3.801 | 210 |
| 50 | 6.107 | 337 |
| 60 | 9.521 | 525 |
| 70 | 14.571 | 805 |

[3]Monteagle, Carlow, Lindsay, Harley, Brethour and McCrosson-Tovell.

# Chapter 7

# ESTIMATES OF LAND VALUE AND THE APPLICATION OF THE FINDINGS OF THIS STUDY

## Land value determination for red pine

In these calculations, an estimate will be made of present bare land value based on the estimated future net returns that the planting of red pine would produce.

The data have been worked up for the three potential production classes for which yield tables were produced, and the results are summarized in Tables 7-1, 7-2, and 7-3 for rotations of 50, 60 and 70 years.

In the calculations of land value in these tables the following assumptions were made.

(a) With respect to Class I (Table 7-1) it was assumed that

(i) thinnings at 25 and 35 years would be saleable only as pulpwood; in fact a fair proportion of thinnings in this class of stand at 35 years will produce poles at rates of $0.27 per cubic foot and more; the value of thinnings estimated is, therefore, conservative;

(ii) all of the merchantable volume in thinnings at 45, 55 and 65 years would be saleable as poles or sawlogs; in fact, this is an overly optimistic view but the rate of $0.27 per cubic foot which is applicable for small poles is too low for most of the material that would be produced in thinnings at 45 years and over where the average dbh exceeds 8.0 inches;

(iii) no increase in value takes place as a result of increasing tree size as the timber approaches maturity; this is a decidedly conservative approach and allows considerable latitude for physical losses and changes in the markets for wood; present stumpage rates for larger material are as high as $0.40 per cubic foot for thinnings from stands 40 years old.

(b) With respect to Class II (Table 7-2) it was assumed that

(i) thinnings at 25, 35 and one-half the volume at 45 years would be suitable only for pulpwood; with an average dbh of 7.3 inches at 45 years the thinnings would be suitable in large measure for poles or sawlogs, so this assumption is believed to be realistic;

(ii) the assumptions respecting value at 55 and 65 years are valid because of the points made in (a)(ii) above;

(iii) see (a)(iii) above.

(c) With respect to Class III (Table 7-3) it was assumed that

(i) thinnings were suitable only for pulpwood except one-half of the thinnings at 55 years and those at 65, which would be suitable for poles or other quality products. Again the sizes would appear to justify this assumption;

(ii) and (iii) see explanations (a)(ii) and (a)(iii) above.

Since pruning cost has been allowed for 60- and 70-year rotations only, it may be argued that the non-pulpwood stumpage rate for these rotations should be higher than that for the 50-year rotation. In fact, a forest covering a range of potential production classes would be managed to produce the small poles and piling from thinnings from all classes of land and from the harvest cut of the poorer land classes. The timber from the harvest cut of the better land classes would be directed to the sawlog and veneer log market and to larger poles. Under such a scheme, all classes of land would receive a proportion of the higher value markets. It is assumed that such a program of management would be applied on land acquired for red pine plantations under ARDA and a uniform rate is therefore justified for rotations of 50, 60 and 70 years.

Because of the market situation, it is assumed that a rotation of 60 years for red pine would be more realistic than the 50-year rotation indicated by the higher land value under this rotation. It is believed that the 50-year rotation would provide an over-production of small sized material especially if applied on large areas of Class III land. The longer rotation provides for a better return on pruning investment and produces a more versatile raw material.

The values per acre (see Tables 7-1, 7-2 and 7-3) are rather high, using the 4 percent interest rate which is, of course, quite low compared to commercial rates. As

TABLE 7-1. LAND VALUE DETERMINATION FOR RED PINE, POTENTIAL PRODUCTION CLASS I (VALUATION AT 4% INTEREST)

| | Thinnings | | | | | |
|---|---|---|---|---|---|---|
| Year | Merch. Volume* (cu. ft.) | Value (¢/cu. ft.) | Total Value ($) | Rotation Age (Years) | Interest Factor | Value at Rotation ($) |
| 25 | 1020 | 2.4 | 24 | 50 | 2.666 | 64 |
| | | | | 60 | 3.946 | 95 |
| | | | | 70 | 5.841 | 140 |
| 35 | 1260 | 2.4 | 30 | 50 | 1.801 | 54 |
| | | | | 60 | 2.666 | 80 |
| | | | | 70 | 3.946 | 118 |
| 45 | 1120 | 27.0 | 302 | 50 | 1.217 | 368 |
| | | | | 60 | 1.801 | 544 |
| | | | | 70 | 2.666 | 805 |
| 55 | 595 | 27.0 | 161 | 60 | 1.217 | 196 |
| | | | | 70 | 1.801 | 290 |
| 65 | 255 | 27.0 | 69 | 70 | 1.217 | 84 |

| Item | Unit | Rotation Age (Years) | | | | | |
|---|---|---|---|---|---|---|---|
| | | 50 | | 60 | | 70 | |
| Revenue | | | | | | | |
| Merch. Volume of Harvest | cu. ft. | 5100 | | 5865 | | 6460 | |
| Value per cu. ft. | ¢ | 27 | | 27 | | 27 | |
| Total Value of Harvest | $ | 1380 | | 1584 | | 1744 | |
| Value of Thinnings | $ | 486 | 1866 | 915 | 2499 | 1437 | 3181 |
| Costs** | | | | | | | |
| Planting | $ | 202 | | 299 | | 442 | |
| Pruning | $ | – | | 254 | | 375 | |
| Annual Expenses | $ | 337 | 539 | 525 | 1078 | 805 | 1622 |
| Net Revenue | $ | | 1327 | | 1421 | | 1559 |
| Factor† $(1 + 0.04)^n - 1$ | — | 6.107 | | 9.521 | | 14.571 | |
| Land Value per acre†† | $ | | 217 | | 149 | | 107 |

*Merchantable volume = 85% of gross total.
**Planting @ $28.40/acre (Table 6-1),
Pruning @ 24¢/tree (Table 6-2),
Annual expenses @ $2.21/acre (Table 6-3).
†Where n = rotation age.
††Land value per acre = $\frac{\text{Net Revenue}}{\text{Factor}}$

indicated in Chapter 1, the lower interest rate tends to make comparisons of alternatives more equitable. Thus in comparing the forestry use of Potential Production Class I land on a 60-year rotation with annual agricultural or recreational revenue from the same area, the value of $342.00 per acre would be equivalent to a net annual revenue of $342 x 0.03 = $10.25 per acre. The same class of land evaluated at a 6 percent rate produces a land value in forest use of $5.50 equivalent to a net annual output of $5.50 x 0.06 = $0.33. The disparity illustrated by this example indicates the desirability of using nominal interest rates as the basis for calculating land values where a long delay in the recovery of revenue is involved. There is no thought here that low rates of interest should be used in evaluating the forestry potential and high rates for other uses, but rather that more realistic comparisons will result if lower rates (3 or 4 percent) are used throughout for all possible alternatives requiring comparison.

To show the influence of the interest rate on land values at the recommended rotation age of 60 years, land values were determined for Potential Production Classes I, II and III for interest rates of 3 to 6 percent inclusive. A summary of these calculations, shown in Table 7-4 and Figure 7-1, indicates that Potential Production Class I land will yield a 6 percent return on all costs of management, including the purchase price if it is acquired for $5.50 per acre; if a 5 percent return is considered

TABLE 7-2. LAND VALUE DETERMINATION FOR RED PINE, POTENTIAL PRODUCTION CLASS II (VALUATION AT 4% INTEREST)

| | Thinnings | | | | | |
|---|---|---|---|---|---|---|
| Year | Merch. Volume* (cu. ft.) | Value (¢/cu. ft.) | Total Value ($) | Rotation Age (Years) | Interest Factor | Value at Rotation ($) |
| 25 | 815 | 2.4 | 20 | 50 | 2.666 | 53 |
| | | | | 60 | 3.946 | 79 |
| | | | | 70 | 5.841 | 117 |
| 35 | 755 | 2.4 | 18 | 50 | 1.801 | 32 |
| | | | | 60 | 2.666 | 48 |
| | | | | 70 | 3.946 | 71 |
| 45 | 380 | 2.4 | 112 | 50 | 1.217 | 136 |
| | 380 | 27.0 | | 60 | 1.801 | 202 |
| | | | | 70 | 2.666 | 298 |
| 55 | 640 | 27.0 | 173 | 60 | 1.217 | 210 |
| | | | | 70 | 1.801 | 312 |
| 65 | 550 | 27.0 | 149 | 70 | 1.217 | 181 |

| Item | Unit | Rotation Age (Years) 50 | | 60 | | 70 | |
|---|---|---|---|---|---|---|---|
| Revenue | | | | | | | |
| Merch. Volume of Harvest | cu. ft. | 4460 | | 4970 | | 5310 | |
| Value per cu. ft. | ¢ | 27 | | 27 | | 27 | |
| Total Value of Harvest | $ | 1200 | | 1340 | | 1430 | |
| Value of Thinnings | $ | 221 | 1421 | 539 | 1879 | 979 | 2409 |
| Costs** | | | | | | | |
| Planting | $ | 202 | | 299 | | 442 | |
| Pruning | $ | — | | 173 | | 256 | |
| Annual Expenses | $ | 337 | 539 | 525 | 997 | 805 | 1503 |
| Net Revenue | $ | | 882 | | 882 | | 906 |
| Factor† $(1 + 0.04)^n - 1$ | — | 6.107 | | 9.521 | | 14.571 | |
| Land Value per acre†† | $ | | 144 | | 93 | | 62 |

*Merchantable volume = 85% of gross total.
**Planting @ $28.40/acre (Table 6-1),
Pruning @ 24¢/tree (Table 6-2),
Annual expenses @ $2.21/acre (Table 6-3).
†Where n = rotation age.
††Land value per acre $= \frac{\text{Net Revenue}}{\text{Factor}}$

adequate a price of $55.00 per acre could be paid.

Class II land by comparison will produce a 5 percent return if the land is acquired for $23.00 per acre. Class III land will produce a return of 4 percent if a cost of acquisition of $29.00 is attributed to the management.

The figures in Table 7-4, shown graphically in Figure 7-1, may have some value in indicating prices which could be paid for land where different rates of return on investment are prescribed. However, the real value of the analysis set out here is the opportunity that it provides to make comparisons between alternatives in which one alternative produces a net annual return and the other (forestry) produces a periodic annual return, i.e., a net revenue every rotation of 50 to 70 years. The alternative showing the highest capitalized value of the annual or periodic return (as the case may be) should be the selected land use alternative, other things being equal.

Overruling, to some extent, the results of a comparison of individual acres, as indicated above, is the overall objective of land management within the region under consideration. The general status of land use or potential land use must be assessed in the light of realistic objectives. If, for instance, it appears reasonable to develop a region for ranching, the selection of small units of land within the region for red pine or spruce development would probably be highly impractical even though the actual acres involved showed superior values in plantation use.

TABLE 7-3. LAND VALUE DETERMINATION FOR RED PINE, POTENTIAL PRODUCTION CLASS III (VALUATION AT 4% INTEREST)

| Thinnings | | | | | | |
|---|---|---|---|---|---|---|
| Year | Merch. Volume* (cu. ft.) | Value (¢/cu. ft.) | Total Value ($) | Rotation Age (Years) | Interest Factor | Value at Rotation ($) |
| 25 | 630 | 2.4 | 15 | 50 | 2.666 | 40 |
| | | | | 60 | 3.946 | 59 |
| | | | | 70 | 5.841 | 88 |
| 35 | 750 | 2.4 | 18 | 50 | 1.801 | 32 |
| | | | | 60 | 2.666 | 48 |
| | | | | 70 | 3.946 | 71 |
| 45 | 450 | 2.4 | 11 | 50 | 1.217 | 13 |
| | | | | 60 | 1.801 | 20 |
| | | | | 70 | 2.666 | 29 |
| 55 | 255 } 255 } | 2.4 } 27.0 } | 75 | 60 | 1.217 | 91 |
| | | | | 70 | 1.801 | 135 |
| 65 | 430 | 27.0 | 116 | 70 | 1.217 | 141 |

| Item | Unit | Rotation Age (Years) 50 | | 60 | | 70 | |
|---|---|---|---|---|---|---|---|
| Revenue | | | | | | | |
| Merch. Volume of Harvest | cu. ft. | 490§ 2790 | | 3610 | | 3850 | |
| Value per cu. ft. | ¢ | 2.4 27 | | 27 | | 27 | |
| Total Value of Harvest | $ | 765 | | 975 | | 1040 | |
| Value of Thinnings | $ | 85 | 850 | 218 | 1193 | 464 | 1504 |
| Costs** | | | | | | | |
| Planting | $ | 202 | | 299 | | 442 | |
| Pruning | $ | — | | 95 | | 140 | |
| Annual Expenses | $ | 337 | 539 | 525 | 919 | 805 | 1387 |
| Net Revenue | $ | | 311 | | 274 | | 117 |
| Factor† $(1 + 0.04)^n - 1$ | — | 6.107 | | 9.521 | | 14.571 | |
| Land Value per acre†† | $ | | 50 | | 29 | | 8 |

*Merchantable volume = 85% of gross total.
**Planting @ $28.40/acre (Table 6-1),
Pruning @ 24¢/tree (Table 6-2),
Annual expenses @ $2.21/acre (Table 6-3).
†Where n = rotation age.
††Land value per acre $= \frac{\text{Net Revenue}}{\text{Factor}}$
§It is estimated that 15% of the stand at age 50 would be suitable only for pulpwood.

## Land value determination for white spruce

Under the conditions of management visualized for white spruce there would be no intermediate cutting. Rotations would be kept as short as possible having in mind the minimum size of harvestable pulpwood and the rate of volume production on the various land classes.

Tables 3-5, 3-6 and 3-7 show m.a.i. culminating at approximately 40, 50 and 60 years for Potential Production Classes I, II and III respectively. At these ages the increases anticipated on the present volumes of the stands over the next decade read from the last column of Tables 3-5, 3-6, and 3-7 are at the rate of 2.3, 1.6 and 1.4 percent per annum for Classes I, II and III respectively. As these returns are well below that which would normally be considered desirable, it would seem that shorter rotations should be adopted. However, at these ages the average dbh based on the measured plots (which were planted at close spacing — over 1,400 trees per acre average) would be approximately 6.5-7.0 inches for all Classes, and there would be a considerable loss in undersized material if managed on these rotations. Planted on an 8′ x 8′ spacing (700 trees per acre approximately), however, the trees should be considerably larger in average diameter (probably 9.0 to 9.5 inches) at the ages indicated. In spite of the relatively high standard deviation around the average diameter (see Appendix VI), there would be relatively little volume lost in under-

TABLE 7-4. BARE LAND VALUES ON A ROTATION OF 60 YEARS AT VARIOUS INTEREST RATES, POTENTIAL PRODUCTION CLASSES I, II AND III — RED PINE

| | Potential Production Class I | | | | Potential Production Class II | | | | Potential Production Class III | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Interest Rate | | | | Interest Rate | | | | Interest Rate | | | |
| | 3% | 4% | 5% | 6% | 3% | 4% | 5% | 6% | 3% | 4% | 5% | 6% |
| Value of Thinnings | $ 788 | $ 915 | $1068 | $1254 | $ 468 | $ 539 | $ 624 | $ 730 | $ 184 | $ 218 | $ 262 | $ 319 |
| Harvest at 60 years | 1580 | 1580 | 1580 | 1580 | 1340 | 1340 | 1340 | 1340 | 975 | 975 | 975 | 975 |
| Total Revenue | 2368 | 2495 | 2648 | 2834 | 1808 | 1879 | 1964 | 2070 | 1159 | 1193 | 1237 | 1294 |
| Accumulated Costs | 699 | 1078 | 1683 | 2658 | 645 | 997 | 1564 | 2485 | 594 | 919 | 1443 | 2299 |
| Net Revenue | 1669 | 1417 | 965 | 176 | 1163 | 882 | 400 | —415 | 565 | 274 | —206 | —1005 |
| Interest Factor | 4.892 | 9.520 | 17.679 | 31.988 | 4.892 | 9.520 | 17.679 | 31.988 | 4.892 | 9.520 | 17.679 | 31.988 |
| Land value/acre | $ 342 | $ 149 | $ 55 | $ 5.50 | $ 238 | $ 93 | $ 23 | Neg. | $ 115 | $ 29 | Neg. | Neg. |

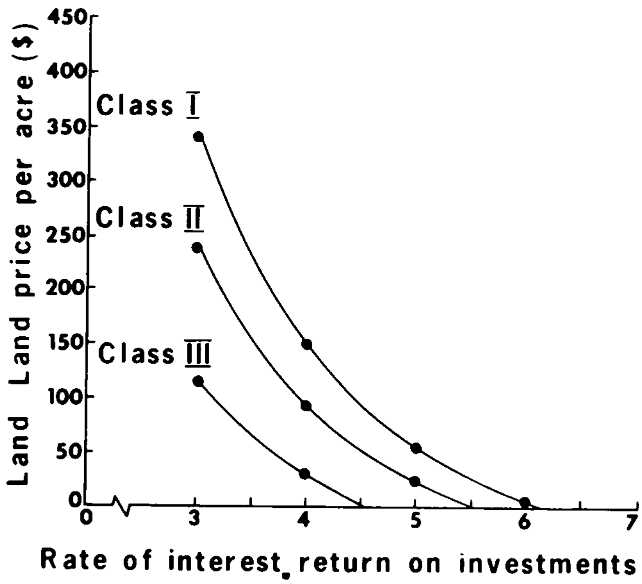


FIGURE 7-1: Relationship between the price paid for land per acre and the return on investments in red pine plantations on a 60-year rotation on various potential production classes of land in Southern Ontario.

TABLE 7-5. LAND VALUE DETERMINATION FOR WHITE SPRUCE (VALUATION AT 4% INTEREST)

| Potential Production Class | I | II | III |
|---|---|---|---|
| Rotation Age (n) (years) | 40 | 50 | 60 |
| Merchantable Volume/Acre | | | |
| cu. ft. | 4,350 | 4,400 | 4,400 |
| cords | 51 | 52 | 52 |
| Value of Harvest Cut ($7.00/cord) | $357.00 | $ 364.00 | $ 364.00 |
| Costs of Production | | | |
| Annual Expenses ($2.21/acre/year) | $210.00 | $ 337.00 | $ 525.00 |
| Planting ($20.00/acre) | $ 96.00 | $ 142.00 | $ 210.00 |
| Total Costs | $306.00 | $ 479.00 | $ 735.00 |
| Net Revenue | $ 51.00 | $−115.00 | $−371.00 |
| Interest Factor ($1.04^n - 1$) | 3.801 | 6.107 | 9.521 |
| Land Value | $ 13.50 | Negative* | Negative* |

*Negative values here indicate that, for the given productivity, revenue and cost conditions, the land will not provide the interest return (4%) on the investment.

sized material on an 8′ x 8′ spacing. This view is supported by the experience with the 57-year-old plantation at the Lakehead (275 trees planted — present average diameter 14.4 inches). It is reasonable to suppose, therefore, that, with 8′ x 8′ spacing, virtually all of the standing volume would be merchantable (assuming proper allowance for stump and unused top) at the ages indicated (40, 50 and 60 years for Classes I, II and III respectively). Little opportunity exists, however, for reducing the rotations below these levels because of size requirements for efficient harvesting and processing.

The present stumpage rate for spruce pulpwood in Michigan at about $7.00 per cord would appear to be a reasonable rate to apply to plantation-grown white spruce in Southern Ontario. This rate would apply, however, only if plantations were large enough to provide a supply of raw material that would justify local market development. If small quantities only were available it would have to be shipped considerable distances and stumpage rates would be reduced.

Under the assumptions described, the land value of the various potential production classes may be calculated as shown in Table 7-5.

Based on these assumptions and observations the land of Class I productivity for spruce would, under spruce plantation, earn a 4 percent return if the land could be acquired for $13.50 per acre. Classes II and III would yield at a considerably lower rate.

Land of Class I productivity for red pine would, under red pine plantation, earn 5.8 percent on the investment at a purchase price of $13.50 per acre.

It may be argued that many of the markets assumed for the red pine could be applied to the spruce, thus increasing its gross cash return. This is, of course, true but, as previously noted, the spruce has no peculiar qualities which render it more valuable than the red pine except for pulpwood and, at reasonable stumpage rates for this product, the spruce is unable to compete with the red pine except on moist sites where red pine is excluded.

## Application of the findings of this study

Since the land in Southern Ontario is now largely privately owned but may be acquired by government for one reason or another, it is evident that the findings of this study should be of interest to both the private and public sectors of the economy.

### *The private sector*

The analysis of returns on investment indicate that the private investor is not likely to be attracted to investment in land for the purposes of plantation management. Even the best red pine land will yield only 6 percent return where the cost of land is $5.50 per acre and, in most cases, the cost of the land in plantation must be considered to be higher than this. In determining the cost of the plantable land it must be recognized that only rarely will all of the land in a property be open for planting and only a part of the open land will normally meet the Potential Production Class I standards. In the typical property purchased by the Department of Lands and Forests in 1965-66, only 30 percent of the land was open land. If the cost of the naturally forested land and the swamp land could not be covered by production from such lands, then it must be assumed that the cost of the plantable land is increased.

However, if land is being held for recreational purpose or as a private estate so that there is no land cost applicable to the plantation, the owner may find it financially attractive to put the better classes of land under plantation management. Under such circumstances the best red pine land would yield in excess of 6 percent on the investment in management and Class II would yield about 5½ percent.

Where governments are prepared to subsidize forest management by reducing or eliminating property taxes or by paying the cost of planting, the returns on investment over the rotation could be attractive to the private investor. Short of subsidization or improved marketing methods so that better prices are obtained for the raw material, it is doubtful if much private capital will be directed to the acquisition and management of land for plantations.

### *Public sector*

In the interests of industrial or social development, governments frequently find it expedient to make investments which do not produce a *direct* return which justifies the expenditure. Investments in roads and education are examples of this type of public investment. It is this characteristic of certain governmental investments which is of interest in considering investments in plantations in Southern Ontario.

This analysis shows quite conclusively that, where the land class is suitable, red pine produces a much higher return on investment than white spruce. It might be concluded, therefore, that no white spruce should be planted except on the wetter sites where red pine will not grow. Such a policy rigidly applied could produce difficulties in the marketing of spruce due to the small volume that would be produced unless sizeable areas too moist for agricultural production or for red pine become available.

As noted elsewhere in this report, the costs to society of raw material production may be relatively unimportant when compared to the benefits of industrial development made possible by the availability of the raw material. In the case of pulp and paper where the value of the final product may be $140.00 a ton, the cost of producing the cord and a half of wood required — $10.00 to $15.00 (depending upon the interest rate used) — may be unimportant considering the derived benefits.

Thus, although the economic potential for spruce is very low in terms of direct return, its peculiar advantages in the production of pulp and paper may justify the planting of it on government land or the subsidization of the species for private planting.

In this regard, it should be noted that, due to the lower yield of spruce on typical sites in the region compared to that of red pine, the spruce would logically be planted only for pulpwood, the product for which it has unique qualities. For maximum efficiency in product use, the planting should be closely oriented to a plan for the development of a concentration of volume that will justify industrial development.

Red pine, on the other hand, due to its market versatility and high productivity may be planted in relatively small concentrations without fear of serious difficulties at marketing time. It is a fact that, if the thinnings of the red pine plantations are to be utilized effectively, the red pine must also be oriented to pulp and paper manufacturing development. The pulpwood thinnings, however, represent a small proportion of total value. Provided the thinning operations can be carried on as a silvicultural investment at reasonable cost, the computed land value (or a close approximation thereto) may still be realized, even if the pulpwood thinnings are not marketed.

As a supplement to this study, it is proposed that a region in Southern Ontario, in which it is known that agricultural use under present methods is sub-marginal, be studied with a view to prescribing forest management units of a size and of suitable productivity to meet certain practical requirements. These requirements include the following:

(a) That sufficient land can be brought together in contiguous, or at least concentrated blocks (either as private land under some supervised plan of management or as municipal or provincial land under more or less complete provincial control) to establish management units that can be protected and administered efficiently.

(b) That the long term reservation of the land for forestry will not interfere with the best development of the region for possible future alternative uses. In this respect, it would seem reasonable that specific areas taken under management should generally be reserved for forest use for at least one rotation, possibly 50 to 70 years, from the time of planting.

(c) That the accumulation of production from the units within one timbershed will be sufficient to attract effective units of industry at the time when a regular annual output of wood can be harvested.

### Area of plantation required

Four possibilities exist respecting the area of plantation required to supply a modern pulp mill[1]. These alternatives are as follows: (a) where no spruce is planted and early red pine thinnings only are used for pulpwood; (b) where no spruce is planted but all red pine production is directed to the pulpwood market; (c) where a mixture of red pine and spruce plantations is visualized providing greater versatility in the use of the raw material — in this case it is assumed that early red pine thinnings only will be used for pulpwood, the remainder of the pine being directed to more lucrative markets; (d) where no red pine is visualized as being available for pulpwood, the entire mill requirements being provided from spruce plantations.

(a) Plantations of red pine where early thinnings only are utilized for pulpwood.

Except on the best sites, most of the material produced in the first two thinnings of red pine plantations is suitable only for pulpwood. If a market is to be provided for these thinnings, therefore, the plan of management must be oriented to the requirements of the pulp and paper industry.

If it is assumed that Potential Production Class II represents the average productive capacity of land planted to red pine, and if it is further assumed that the first two thinnings would be pulpwood, an estimate can be made of the acreage of land required to keep a modern pulp mill supplied with raw material. The gross total production from two thinnings is 1,850 cubic feet; this volume estimate is conservative since there would be additional volume in tops and malformed trees liquidated in subsequent cuts. On a 60-year rotation a conservative estimate of mean annual increment of *pulpwood only* would be $\frac{1850 \times 0.85}{60} = 26$ cubic feet per acre per year of merchantable pulpwood volume (allowing 15 percent reduction in gross volume to account for waste in stumps and tops). Production of 200,000 cords (17,000,000 cubic feet) would require 650,000 acres if the plantation *thinnings only* were to be the source of raw material. In fact, there would probably be other species utilized so that this acreage planted over a 60-year period would provide for minimum requirements. To provide a pulpwood market for red pine thinnings, the average annual area planted should be not less than 10,000 acres within the timbershed of a suitable mill location on the St. Lawrence Seaway.

(b) Plantations of red pine where all production was utilized for pulpwood.

If red pine plantations were to be grown solely for the production of pulpwood on a 50-year-rotation (m.a.i. 160 cu. ft. gross total production — 135 cu. ft. gross merchantable production) the area required would be much less; a total area of 126,000 acres on a 50-year-rotation or an average of 2,500 acres per year would be adequate. In order to provide a sufficient quantity at the time of first thinning, a larger area would have to be planted at the beginning of the program or arrangements made to provide some of the raw material from other sources.

(c) Plantations of red pine and spruce.

Red pine and spruce may be used separately or in combination in a wide range of pulping processes to produce commercial paper products. The proportion of the different species depends upon the process and the qualities desired in the product. No definite proportions may be stipulated at this stage of development. However, a spruce proportion of less than 20 percent would seem to be too small to be significant. On the basis of mean annual increment for pulpwood production (red pine 27 cubic feet per acre and white spruce 104) the acreage of each species required to provide raw materials for pulp and paper industrial development would be calculated as follows:

| | |
|---|---|
| Total output required 17,000,000 cubic feet | |
| Proportion of red pine 80% or 13,600,000 cubic feet | |
| Proportion of white spruce 20% or 3,400,000 cubic feet | |
| Acreage of red pine required at 27 cu. ft. per acre per year | 500,000 |
| Acreage of white spruce required at 104 cu. ft. per acre per year | 33,000 |
| Total Acreage Required (Minimum) | 533,000 |

[1]Because of the importance of scale in pulp manufacture, the pulp mill dominates all other manufacturing operations in planning for plantation development in a situation such as this.

(d) Plantations of spruce utilized solely for pulpwood.

If white spruce is grown exclusively for pulpwood and yields equivalent to that of Potential Production Class II are realized, an estimate may be made of the acreage needed to provide the full requirements of a mill located in Southern Ontario as was done for red pine. On the assumption that the entire yield from the spruce plantation would be used as pulpwood, the area required to supply a 200,000-cord-per-year mill on a 50-year rotation would be 200,000 acres or an average of 4,000 acres per year. However, because the value of spruce as pulpwood is high, it enjoys wider pulpwood market opportunities than red pine and small quantities (buyers are not usually interested in less than 1,000 cords at one concentration point) may be saleable at any location within the Southern Ontario region. The need for orientation of the spruce planting to a specific plan of use is therefore not as necessary as in the case of red pine thinnings.

In comparing the pulpwood potential of spruce and red pine on the same area it is necessary to note that whereas the red pine thinnings would commence 25 years after planting, the spruce, grown on the shortest pulpwood rotation feasible, would probably not be harvestable for 35 to 40 years.

The detailed application of the results of these studies will involve the use of the land inventory maps prepared by the Land Inventory Unit of the Ontario Department of Lands and Forests under arrangement with the Canada Land Inventory, as well as the forest cover maps of Forest Resources Inventory to determine the acreage of land of various production classes which may be available for development. It is obvious that the putting together of a plantation of some 560,000 acres suitable to attract pulp and paper development will be a major operation; initially the annual requirements will be about 25,000 acres diminishing to an average of 9,300 acres over a 60-year period.

Thinning from red pine plantations are presently being transported up to 100 miles to the mill and spruce may be transported much farther than 100 miles. A 100-mile radius encompasses a timbershed of over 20 million acres (31,416 square miles) provided the plant is located in the centre. If the plant is located so that only a semicircle of land is available for development (as in the case of a plant located on Lake Ontario), then 10 million acres would be within the timbershed. The selection of 560,000 acres out of this area would involve the allocation of 5.6 percent of the available area to plantations.

In the Southern Ontario region generally there are 5.8 million acres of productive forest land and 1.2 million acres of abandoned agricultural land for a total of 7.0 million acres, a significant part of which must be considered as a backlog suitable immediately for plantations, although some investment in site preparation would be required on much of this area. In addition, if abandonment of land used for agriculture continues at the 1941-61 average of 60,000 acres per year, a substantial portion of the annual requirements could be acquired out of current abandonment. In short, the statistics on available land suggest that the acquisition of sufficient area to establish the production required for at least one pulp mill of 200,000 cords capacity is well within the physical limitations of selected locations in the Southern Ontario region.

An extension of this study should be undertaken which would prepare estimates of the cost of land acquisition and/or costs of extension work and subsidization involved in the promotion of this type of land use on privately owned land.

This additional study should include the cost of land and the costs of planting, protection, and management under specific conditions in an area suitable for development. It should include estimates of labour and capital requirements to implement an effective program and should make an assessment of the contribution that current investments in land and wages would make to the economy of suitable areas. The final assessment would be an evaluation of the contribution that the harvesting and manufacturing operations would make to the forest economy that would exist in the selected region when regular production from the plantations justified the establishment of permanent units of industry. A recent report on the Tweed Forest District [25] illustrates in part a method of adapting this type of information to a specific situation.

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## Appendix I

# THE PATTERN OF VOLUME PRODUCTION OF RED PINE IN SOUTHERN ONTARIO

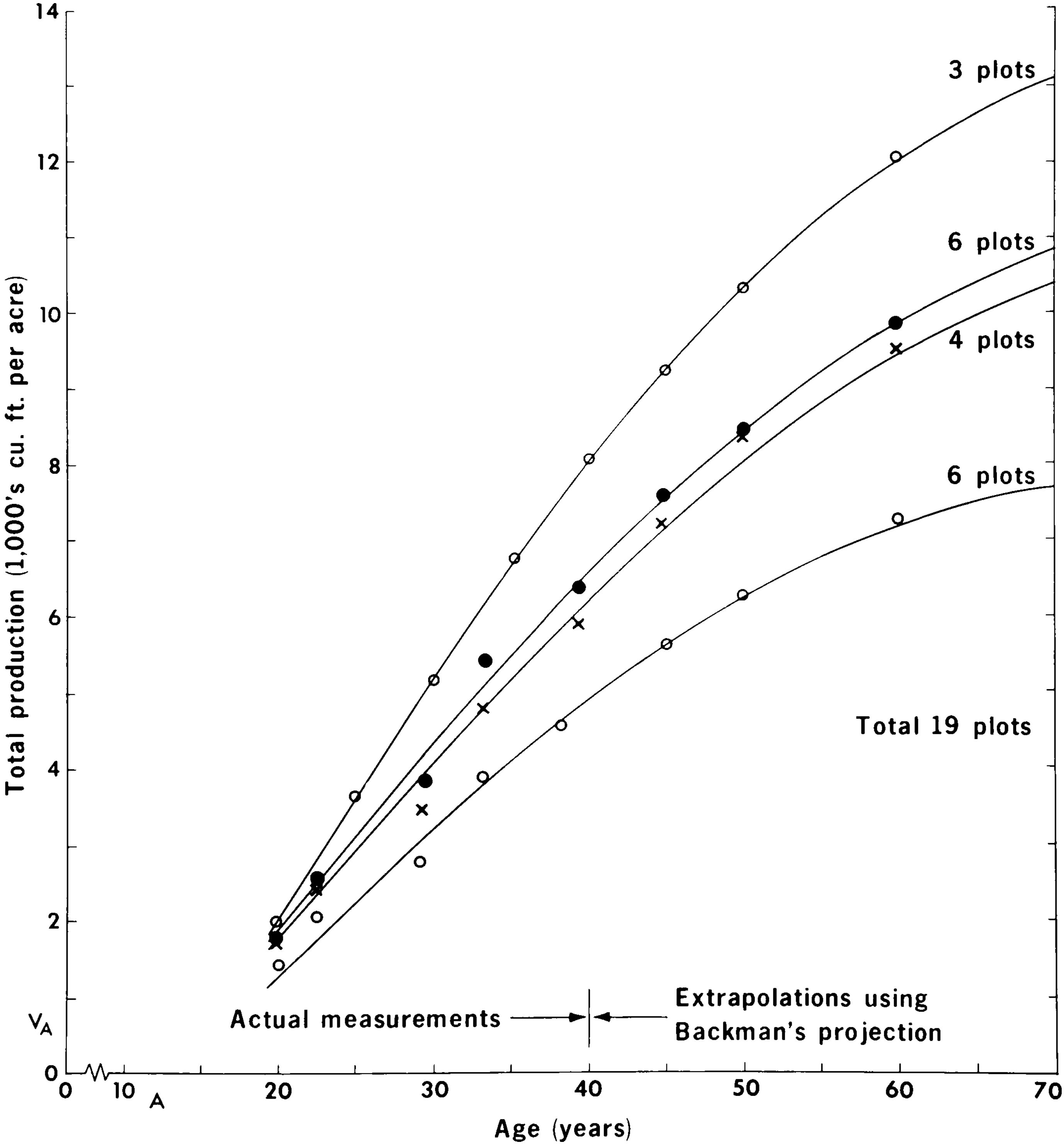


FIGURE I-1: Pattern of volume growth of red pine in Southern Ontario.

Nineteen permanent sample plots located in York County and Simcoe County forests were analyzed in detail to establish the pattern of volume production of red pine in Southern Ontario. Four measurements had been made of these plots at five-year intervals between ages 25 and 40. The trends of growth of four different classes of land represented by these plots are shown in Figure I-1. Volumes[1] at ages beyond 40 years were obtained by the use of Backman's projection[2].

In this projection method the sigmoidal pattern of total volume production over age is accepted. This pattern indicates a period of slow but increasing annual volume growth in the early years of the stand development and a decreasing annual growth as the stand approaches maturity. The pattern of annual growth resembles the probability curve, therefore, with a characteristic bell shape but tending to be skewed to the right since the decrease in growth in the older age is less rapid than the increase at the early age. By placing the typical growth pattern graph on a logarithmic scale of time, the skewness tends to be corrected due to the compressing effect of the logarithmic scale which increases as the age increases.

The graph of annual or periodic growth which, with logarithmic correction, now closely approximates the probability curve may be converted to a straight line by plotting on probability paper as indicated in Figure I-3 where the development of volume in the Rockland Plantations has been plotted. The practical use of this method involves the estimation of an ultimate volume which the stand would attain at time of death due to overmaturity and the calculation of the percentage of this ultimate value attained at various ages. These percentages prescribe a straight line on log probability paper where appropriate ultimate values have been selected.

From the growth patterns defined in Figure I-1 the relationship between total volume production at specified ages ($V_A$) and total volume production at 50 years ($V_{50}$) was established as shown in Figure I-2.

[1]Stiell, W.M. and F.W. von Althen. 1964. Revised taper curves and volume tables for plantation red pine. Department of Forestry of Canada Publication No. 1075.

[2]A description of this technique is contained in an M.Sc. thesis entitled "Considerations Concerning the Natural Laws Regulating the Internal Structure of Even-aged White Pine-Red Pine Stands" by A. Kleist, Faculty of Forestry, University of Toronto.

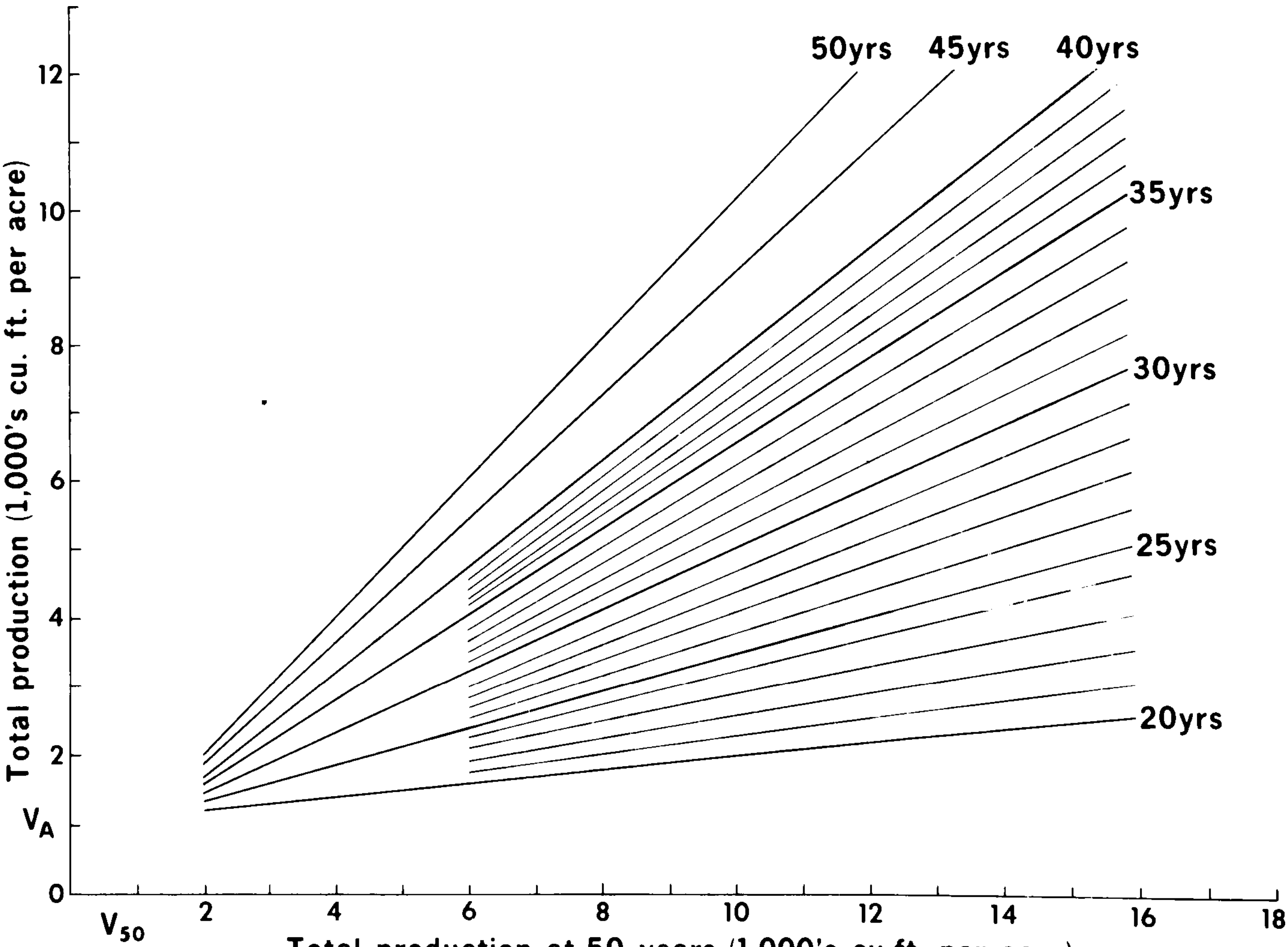


FIGURE I-2: Relationship between actual volume at specific age ($V_A$) and volume at 50 years ($V_{50}$).

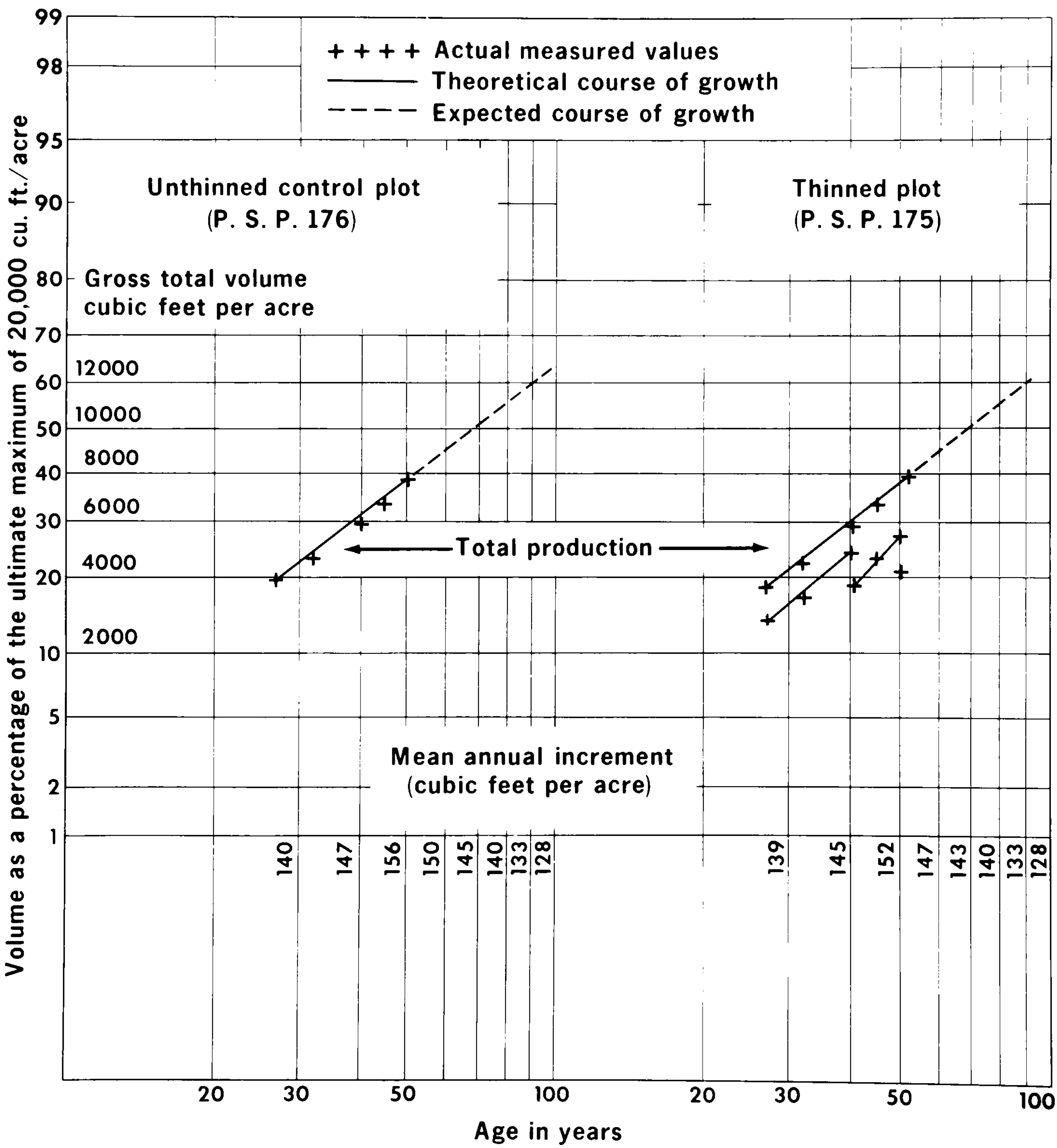


FIGURE 1-3: Rockland plantation red pine volume production.

## Appendix II

# COMPILATION OF WHITE SPRUCE VOLUMES

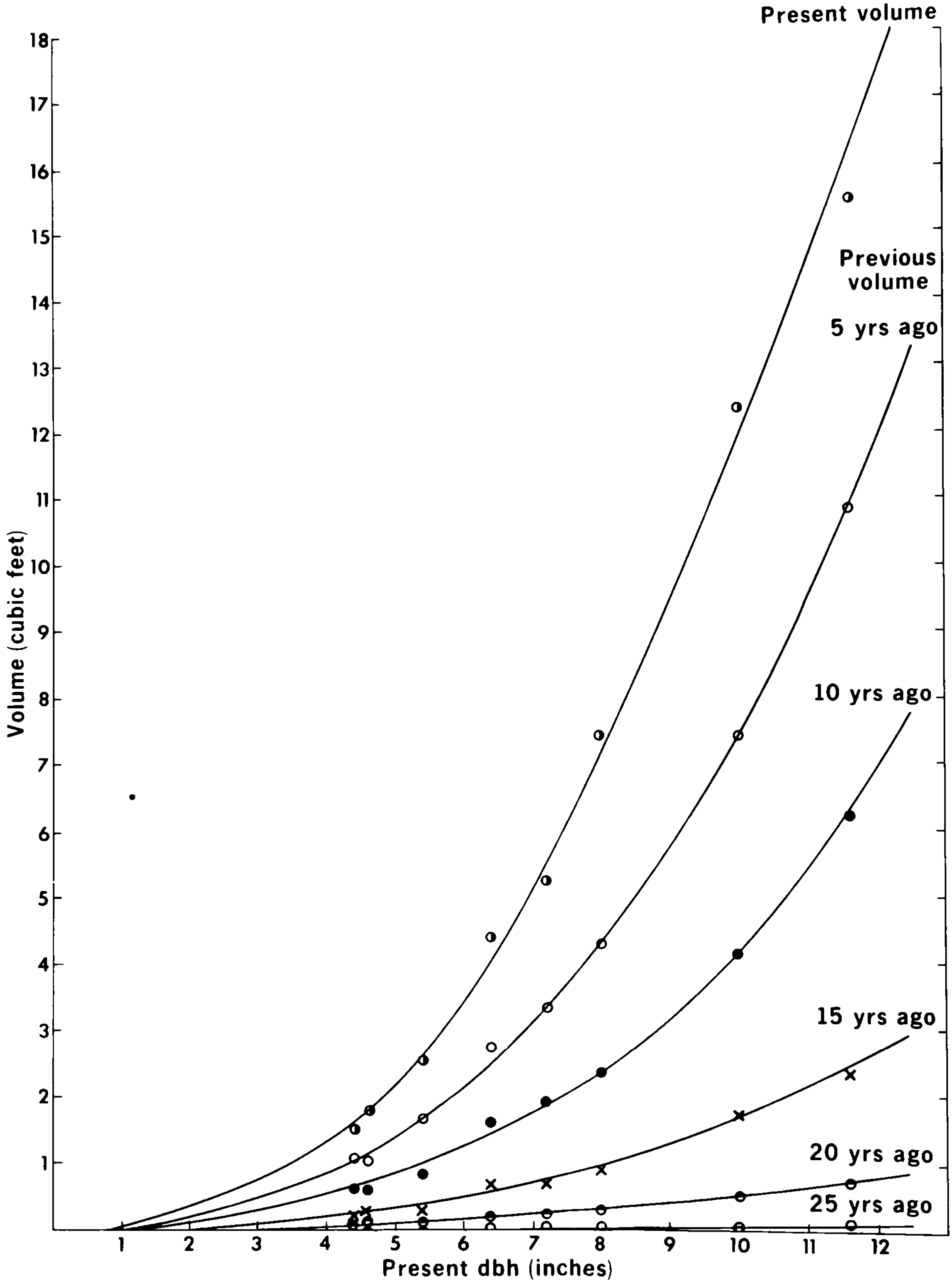


FIGURE II-1: White spruce volume tables, Plot No. 14. Present age of plot 36 years.

Because of a scarcity of white spruce plantations from which to take measurements, the procedure used for the determination of the relationship between physiographic site and yield differed from that used for red pine. For the white spruce, 30 plots were established and on each plot the same physiographic site data were recorded as on the red pine plots; the tree measurements, however, were quite different.

A tally was taken of all trees on the plot (the location of each tree and its diameter to one-tenth inch was recorded) and a number of trees (usually 7 to 12) were cut down and cross sections taken at four-foot intervals. The sections were shipped to Toronto where diameters were taken at five yearly intervals on each cross section over the life of the tree.

Cards were punched and a computer program written for the computation of the volume in each tree at the present time and at five yearly intervals over the life of the tree.

After the computation of the volume of the tree as described above, a series of curves were prepared for each plot in which volume in cubic feet was plotted over *present* dbh as shown in Figure II-1. These curves represented local volume tables for the plot at five yearly intervals over its life.

Using the plot tally of trees by present dbh and the volumes read from the curves, the volume of the plot in gross total cubic feet was determined at five yearly intervals over the life of the stand. The pattern of growth defined by this volume development of the stand was plotted on log-probability paper (Backman's projection) and projected to age fifty (Figure II-2) to provide a gross total production at this age as a basis for the comparison of plot yields.

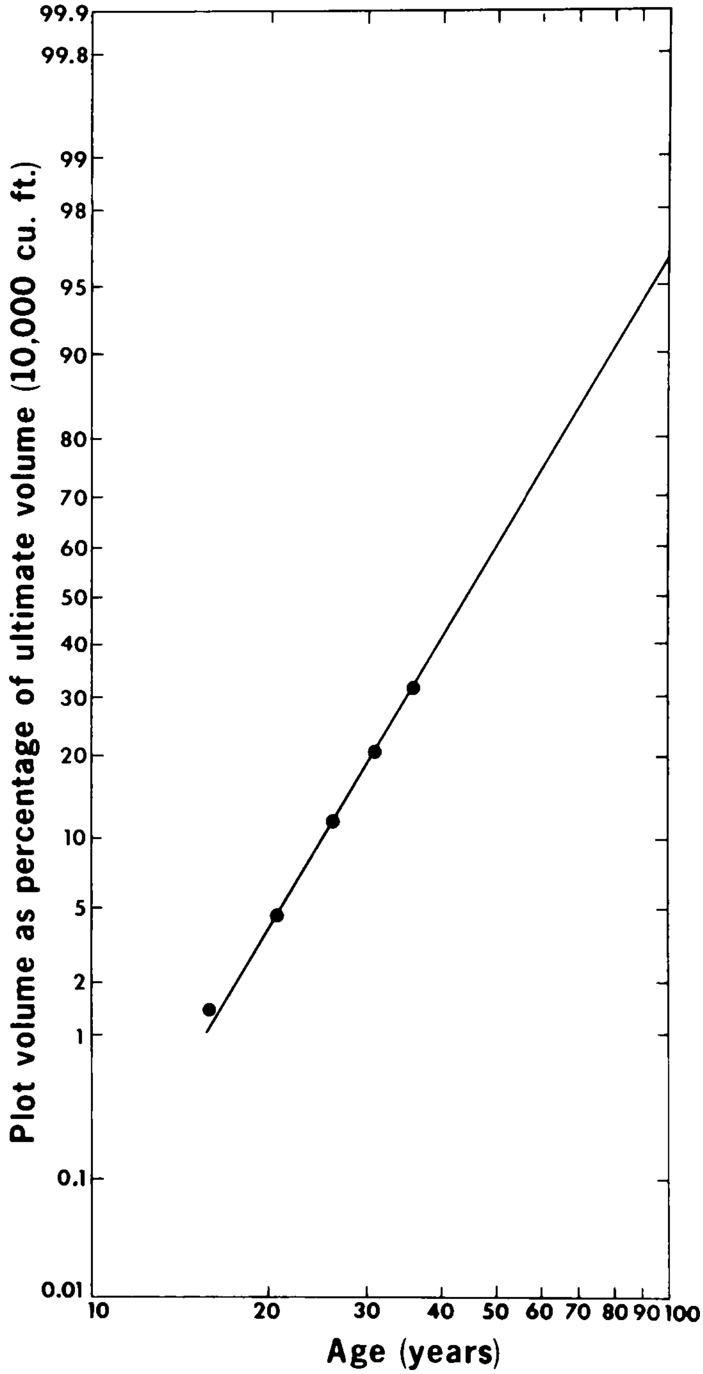


FIGURE II-2: White spruce volume development with age, Plot No. 14.

## Appendix III

# RELATIONSHIP BETWEEN MOISTURE REGIME AND POTENTIAL PRODUCTION—RED PINE AND WHITE SPRUCE

### Red pine

For each of 115 plots measured for this study, the total volume production at age 50 years was estimated using the pattern of volume development established in Appendix I. This was done by locating in Figure I-2 the position of each plot based on its present age and total volume production to that age. The graph provided the basis for estimating total volume production at 50 years ($V_{50}$). Using the moisture regime of the plot as the independent variable, the total volume production at 50 years associated with each moisture regime class was averaged and plotted as shown in Figure III-1. A freehand curve was drawn to approximate the relationship between the two variables which appears reasonably reliable on the drier end of the moisture regime scale. Table 2-1 was read in part from this curve.

The range of production values measured was taken to represent the upper three of five potential production classes for the species (see Chapter 2). The appropriate moisture regime range was read from Figure III-1 for the various potential production classes.

### White spruce

The total volume production at age 50 years established for each of the 30 plots measured as described in Appendix II was averaged for each moisture regime category. The latter was used as the independent variable as in the case of the red pine analysis. The averages resulting from these calculations were plotted as shown in Figure III-1.

The relationship between total volume production at 50 years and moisture regime appears less well defined for spruce than for red pine. This may be accounted for in part by the limited number of measurements available for the spruce. It is also quite possible that the uncertain development of spruce plantations in their early years and genetic differences may be the cause of variations in potential production ($V_{50}$) within a moisture regime class.

In the same manner as for red pine, the range of production for white spruce was taken to represent the upper three of five potential production classes.

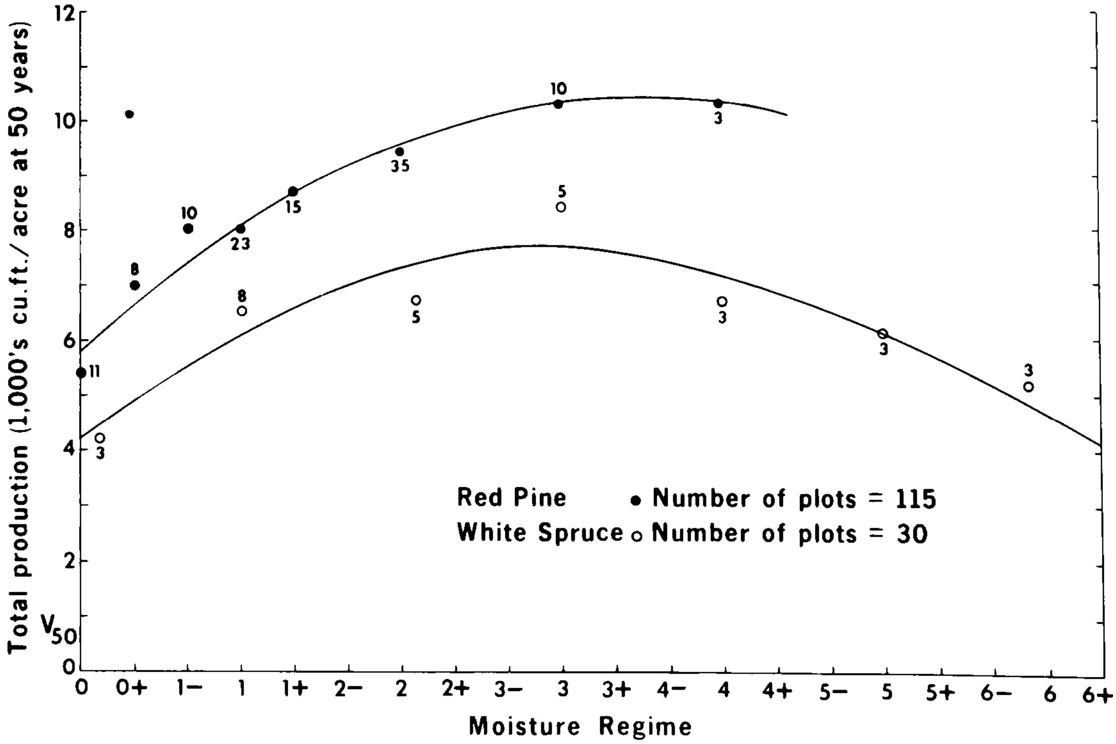


FIGURE III-1 — Relationship between total production and moisture regime.

## Appendix IV

# RELATIONSHIP BETWEEN DOMINANT HEIGHT AND POTENTIAL PRODUCTION—RED PINE AND WHITE SPRUCE

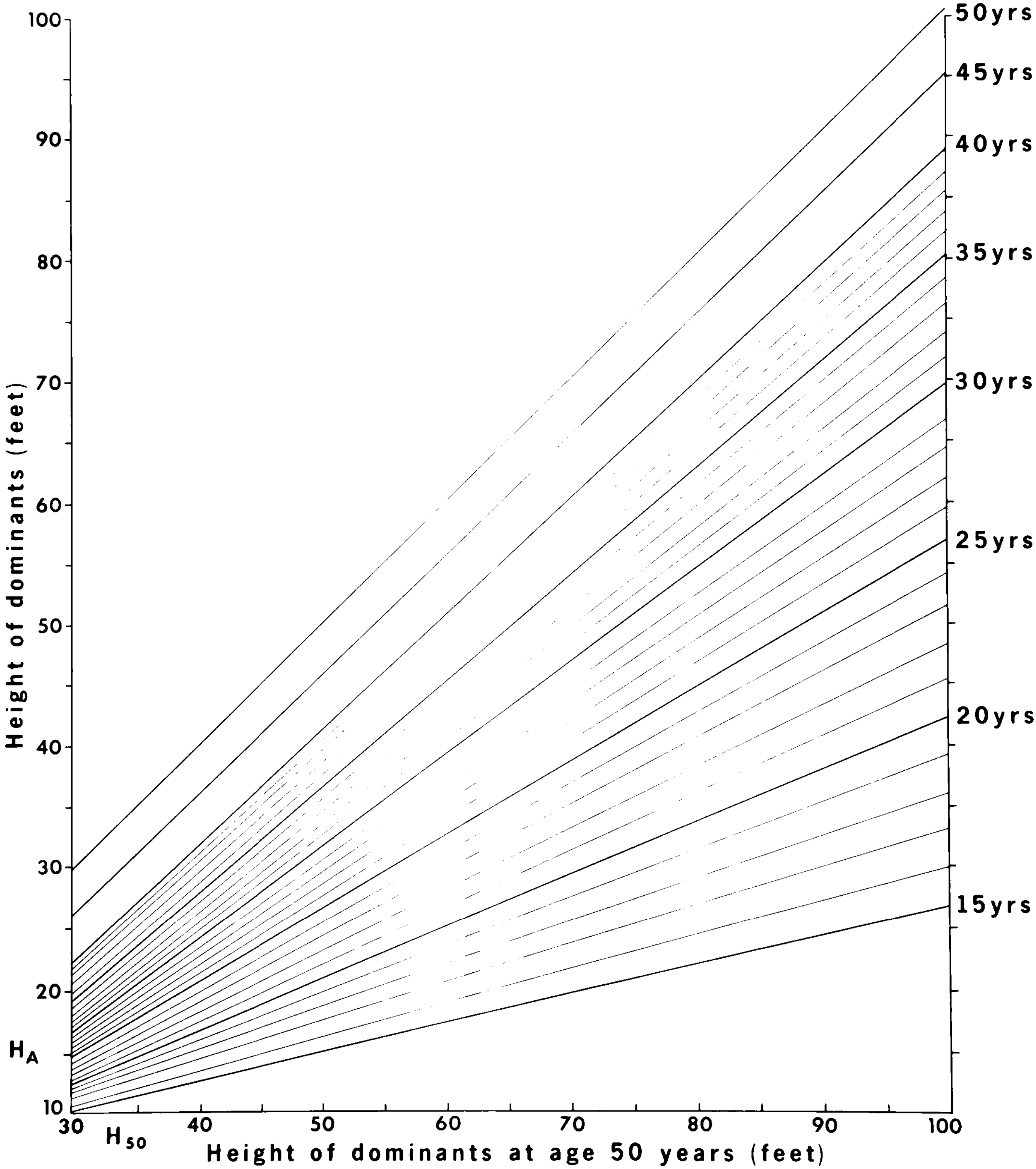


FIGURE IV-1: Relationship between actual dominant height at specified age ($H_A$) and dominant height at 50 years ($H_{50}$). Red Pine.

## Red pine

The pattern of analysis of the relationship between dominant heights and potential production follows that used to analyze the relationship between moisture regime and potential production. The pattern of height development for various classes of land productivity was established using the 19 permanent sample plots of the Ontario Department of Lands and Forests previously mentioned.

From this pattern of development a series of graphs showing the relationship between heights at known ages and heights at 50 years was established (Figure IV-1). By means of these graphs the height at 50 years was established for 115 plots measured for the study.

The relationship between dominant height at age 50 years ($H_{50}$) and total volume production at age 50 years ($V_{50}$) is shown graphically in Figure IV-2. In this analysis the $V_{50}$ was designated as the independent variable and the average dominant height for each production class was determined.

Figure IV-2 was read at the mid-point of the potential production class to establish the average height of dominants for each class. The result is shown in Tables 2-2 and 3-1.

## White spruce

Based on the analysis of volume production (see Appendix III) and the $V_{50}$ established for each plot, it was possible to identify plots as Potential Production Class I, II or III; the 30 plots were classified accordingly.

From stem analysis carried out on trees cut from each plot, the pattern of height development of the taller trees (usually 3 to 5 trees per plot) in the plot was established. This pattern of height development was established for each plot and averaged for all of the plots in each production class. A pattern of height development was thus established from these data and, using Backman's projection, was extended to age 50 years. The height-age development for the production classes (I, II and III) and the height of the dominant trees in each plot at time of cutting is shown in Figure IV-3. The scarcity of samples and irregularity in stand development probably accounts for the rather wide dispersion of the points about the assumed trend of growth. These curves provided the estimates of dominant height for Tables 3-5, 3-6 and 3-7 (yield tables) and for Tables 2-3 and 3-8. No separate analysis of the relationship between total production ($V_{50}$) and height ($H_{50}$) was undertaken for the white spruce.

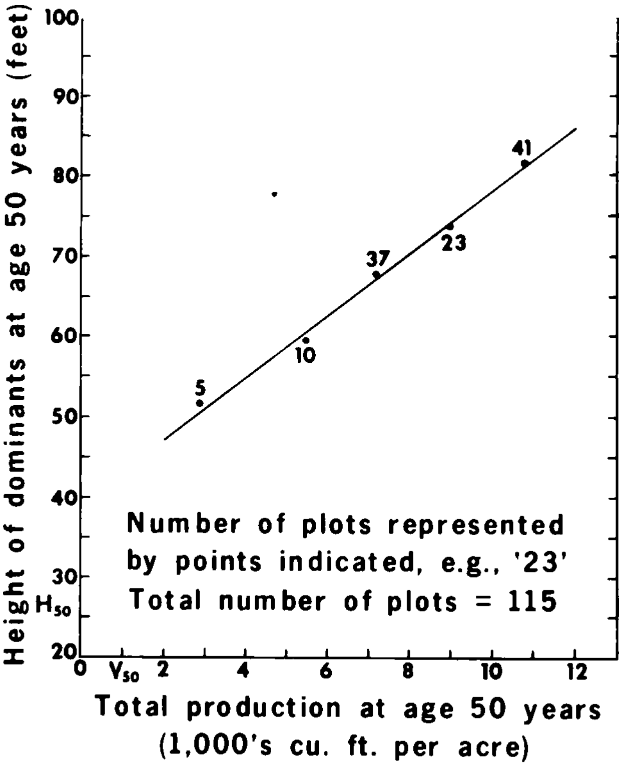


FIGURE IV-2: Relationship between dominant height ($H_{50}$) and total production ($V_{50}$). Red Pine.

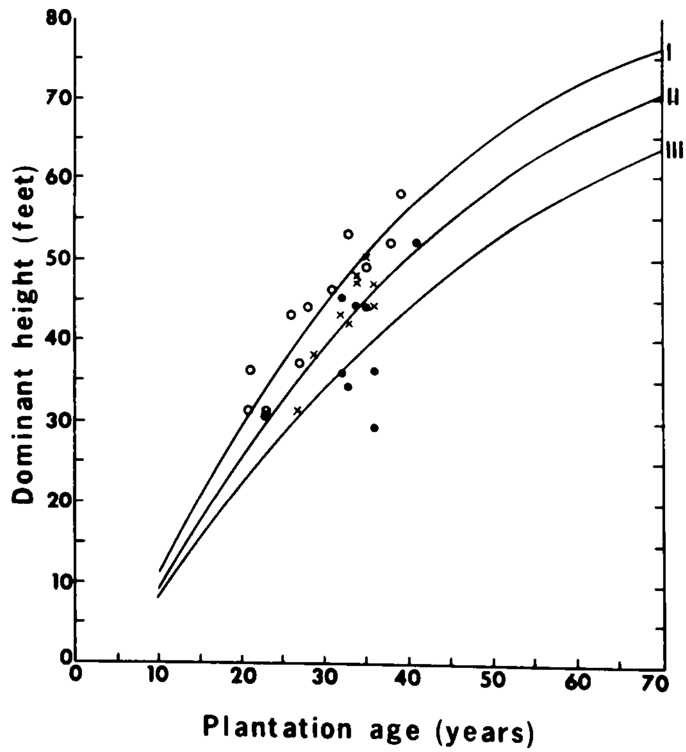


FIGURE IV-3: Dominant height development for white spruce, Potential Production Classes I, II, III.

## Appendix V

# MORTALITY ALLOWANCES IN UNTHINNED WHITE SPRUCE PLANTATIONS

The management procedures visualized for red pine require that thinning will be undertaken at 10-year intervals and, assuming that the cutting is well distributed throughout the stand, mortality will cause no significant loss of volume. Mortality in most of the red pine plots was found to be negligible at 20-40 years. The situation with respect to spruce is quite different; no thinning of spruce stands is anticipated and losses due to mortality are to be expected.

Mortality losses in the spruce plots measured varied from nil to 11 percent with only six of the 30 plots showing mortality in excess of five percent. As previously noted, the stems in the measured plots are closely spaced and mortality would be greater for these plots than would be the case under the wider spacing (8′ x 8′) recommended. However, the measured plots are quite young, varying in age from 21 to 41 years, so that the full effect of over-crowding has not yet been felt.

Although the more productive sites will support a greater volume on the ground than the less productive, they also produce wood at a more rapid rate. Overcrowding must be expected on the better sites and as a result a larger proportion of the volume will be lost.

The primary control on the build-up of live volume, if the height limitations of the site are accepted, is the basal area. The highest basal area observed on the 30 plots measured was 207 square feet per acre and this for a plot 39 years old with a 10 percent mortality. Basal area of the live stand may be expected to increase slightly above this level as the stand increases in average diameter and the number of trees diminishes. The basal area of the 57-year-old plantation at the Lakehead is 155 square feet per acre but, as previously noted, this probably does not represent full use of the site.

Based on this evidence, the gross total production for white spruce as previously determined (Appendix III) was reduced to live standing volume by the application of mortality percents of 25, 20 and 15 for Potential Production Classes I, II and III respectively. With this allowance for mortality the basal area of the standing volume (see Tables 3-5, 3-6 and 3-7) approximates 210, 190 and 180 for the three production classes.

## Appendix VI

# DEVIATION OF DBH ABOUT THE MEAN—RED PINE AND WHITE SPRUCE

Uniformity of tree size can be a matter of some significance in determining the commercial use to which the timber may be put and the amount of material which may be lost in harvesting (either thinnings or final cut) due to its failure to meet minimum size specifications. To determine the relative importance of this feature the standard deviation of dbh was determined for each of the 30 white spruce plots; 30 red pine plots were selected matching as nearly as possible the spruce plots as to average dbh and moisture regime. The results of these calculations are compared in Table VI-1 and summarized in Table VI-2.

There is no obvious tendency to increasing standard deviation of dbh with size for either species as might be expected, partly because of the narrow range of age and dbh included in the study. The greater spread of dbh about the mean for white spruce must be considered a disadvantage from the point of view of harvesting and utilization. Greater efficiency in handling and greater standardization in manufacturing methods are possible where size is consistent. In addition, where clear cutting at an early age is desirable (as in the case of white spruce) the greater the dispersion about the mean dbh the greater the loss in volume due to undersized material.

A fact which may be of significance in the comparison of spruce and red pine plantations concerns maximum sizes for a given average dbh. In almost all cases the spruce shows trees of larger dbh than the pine. It must be appreciated, of course, that this larger size is attained at a considerably older age. The difference between the spruce and pine in average age for equal average dbh's emphasizes the superiority of red pine over white spruce for both volume and quality production where quality is associated with size.

TABLE VI-1. DEVIATION OF DBH ABOUT THE MEAN

| White Spruce | | | | | Red Pine | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Plot No. | Age | $\overline{\text{Dbh}}$ | Dbh Range | S.D.* | Plot No. | Age | $\overline{\text{Dbh}}$ | Dbh Range | S.D.* |
| 1 | 36 | 4.32 | 1-10 | 1.85 | 78 | 23 | 4.66 | 1-8 | 2.19 |
| 2 | 35 | 4.67 | 1-8 | 1.73 | 110 | 24 | 4.89 | 3-7 | 1.01 |
| 3 | 35 | 4.87 | 1-9 | 1.62 | 48 | 22 | 5.00 | 2-7 | .97 |
| 4 | 31 | 5.28 | 1-9 | 1.54 | 56 | 25 | 5.28 | 2-9 | 1.44 |
| 5 | 29 | 4.40 | 1-8 | 1.61 | 77 | 20 | 4.75 | 1-8 | 1.23 |
| 6 | 32 | 4.35 | 1-9 | 1.80 | 113 | 25 | 4.71 | 2-7 | 1.12 |
| 7 | 21 | 4.07 | 1-9 | 1.91 | 28 | 21 | 4.62 | 3-6 | 0.75 |
| 8 | 23 | 4.00 | 1-7 | 1.28 | 34 | 19 | 4.39 | 2-6 | 0.65 |
| 9 | 21 | 4.52 | 1-9 | 1.82 | 1 | 21 | 4.72 | 2-7 | 0.87 |
| 10 | 21 | 4.79 | 1-12 | 1.99 | 124 | 28 | 4.94 | 2-7 | 1.22 |
| 11 | 23 | 4.16 | 1-8 | 1.66 | 31 | 30 | 4.65 | 2-6 | 0.91 |
| 12 | 26 | 4.94 | 2-8 | 1.52 | 74 | 19 | 4.94 | 1-7 | 1.08 |
| 13 | 36 | 3.97 | 1-7 | 1.47 | 32 | 27 | 4.24 | 1-6 | 0.97 |
| 14 | 36 | 5.31 | 1-12 | 2.22 | 37 | 24 | 5.30 | 3-8 | 1.02 |
| 15 | 34 | 5.91 | 1-10 | 1.64 | 79 | 22 | 5.94 | 3-9 | 1.26 |
| 16 | 33 | 5.54 | 1-10 | 1.48 | 66 | 20 | 5.54 | 2-9 | 1.51 |
| 17 | 34 | 5.63 | 3-11 | 1.71 | 139 | 40 | 5.63 | 3-9 | 1.27 |
| 18 | 38 | 5.33 | 1-11 | 2.31 | 114 | 23 | 5.34 | 2-8 | 1.18 |
| 19 | 39 | 6.71 | 2-12 | 2.03 | 131 | 51 | 6.76 | 4-9 | 1.35 |
| 20 | 35 | 4.55 | 1-9 | 2.34 | 135 | 26 | 4.81 | 1-8 | 1.23 |
| 21 | 34 | 4.92 | 1-9 | 1.56 | 5 | 25 | 5.12 | 2-8 | 1.26 |
| 22 | 27 | 4.81 | 1-8 | 1.47 | 121 | 21 | 4.87 | 2-8 | 1.53 |
| 23 | 27 | 4.32 | 1-8 | 1.46 | 2 | 21 | 4.67 | 2-7 | 1.25 |
| 24 | 28 | 5.66 | 1-10 | 1.94 | 50 | 35 | 5.67 | 3-8 | 1.14 |
| 25 | 32 | 4.60 | 1-9 | 1.96 | 26 | 26 | 4.83 | 3-7 | 1.84 |
| 26 | 32 | 3.83 | 1-9 | 1.86 | 16 | 32 | 4.19 | 2-7 | 1.70 |
| 27 | 33 | 3.21 | 1-8 | 1.77 | 93 | 21 | 3.97 | 1-8 | 1.86 |
| 28 | 36 | 6.06 | 3-9 | 1.39 | 82 | 29 | 6.03 | 3-9 | 1.31 |
| 29 | 33 | 6.19 | 1-11 | 2.28 | 120 | 28 | 6.20 | 4-9 | 1.24 |
| 30 | 41 | 5.52 | 2-11 | 2.42 | 23 | 27 | 5.51 | 2-8 | 1.31 |

*Standard Deviation.

TABLE VI-2. DEVIATION OF WHITE SPRUCE AND RED PINE DBH ABOUT THE MEAN

| Dbh Class | Number Plots | | Average Dbh | | Standard Deviation Average | | Average Age | |
|---|---|---|---|---|---|---|---|---|
| | White Spruce | Red Pine | White Spruce | Red Pine | White Spruce | Red Pine | White Spruce | Red Pine |
| 3 | 1 | – | 3.2 | – | 1.8 | – | 33 | – |
| 4 | 9 | 4 | 4.2 | 4.2 | 1.7 | 1.3 | 29 | 25 |
| 5 | 12 | 18 | 4.9 | 4.9 | 1.9 | 1.2 | 31 | 24 |
| 6 | 7 | 7 | 5.8 | 5.8 | 1.8 | 1.3 | 34 | 29 |
| 7 | 1 | 1 | 6.7 | 6.8 | 2.0 | 1.3 | 39 | 51* |

*This is an unthinned control plot which accounts for the small average dbh at this age.