AN ECONOMIC APPRAISAL OF SUSTAINED YIELD FOREST
MANAGEMENT FOR BRITISH COLUMBIA

by

DAVID HALEY
B.Sc., (Forestry), University of Aberdeen, 1961
M.F., University of British Columbia, 1964

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of
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We accept this thesis as conforming to
the required standard

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M.F., The University of British Columbia, 1964

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Sustained yield forest management has been widely accepted as a major objective of forestry. It implies continuous production of forest crops with the aim of achieving, at the earliest practicable time, an approximate balance between net growth and harvest, either by annual or somewhat longer periods. The concept, introduced to North America by European foresters at the end of the 19th century, has become an important component of public policy for forestry and conservation.

History of sustained yield forest management, its role in conservation philosophy, and its economic advantages and disadvantages, as well as alternatives, are discussed. Evolution of sustained yield management and its application in British Columbia are described.

Many advantages have been claimed for sustained yield forest management as an alternative to unregulated liquidation of resources. Yet preservation of forests for the benefit of future generations, amelioration of uncertainty in forestry enterprises, protection of social values, stabilisation of communities, and provision of regular incomes, cannot, themselves, justify unconditional acceptance of sustained yield.

Sustained yield forest management emphasizes stability and continuity of production but neglects economic values of the resource. It may even retard economic growth and development. By using physical rather than economic criteria to set goals for forest management, sustained yield often causes the net present worth of the forest resource to fall short of its maximum potential value. Although sustained yield policy aims at stability, the inability of entrepreneurs to respond to cyclical changes in economic activity may actually lead to instability in stumpage prices and forest revenues.

The rational forest owner should only practise sustained yield forest management if it will achieve his objectives in the most efficient manner. Forest owners should always consider alternatives to sustained yield. Benefits must be analysed in relation to costs. Forest management planning also can be improved by linear programming and decision theory techniques as illustrated herein.
It is suggested that in British Columbia sustained yield forest management has become so firmly established that alternative policies are seldom considered. Rigid application of sustained yield principles forms an effective barrier to maximization of the social value of the Provincial forest resource. Opportunities for expansion of lumber and plywood industries are being curtailed, and inadequate attention has been given to planning of the transition from old growth to second growth stands of Douglas fir. Despite its emphasis on "perpetual yields of wood of commercially usable quality from regional areas in yearly or periodic quantities of equal or increasing volume", forest management in British Columbia has neglected urgent needs for improved reforestation.

After a thorough examination of its implications for British Columbia, it is concluded that sustained yield must be rejected as a universal goal of forest management. Sustained yield forest management should always be compared to other alternatives and be fully justified on economic and social grounds before it is accepted.

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Many advantages have been claimed for sustained yield forest management as an alternative to unregulated liquidation of resources. Yet preservation of forests for the benefit of future generations, amelioration of uncertainty in forestry enterprises, protection of social values, stabilization of communities, and provision of regular incomes, cannot, themselves, justify unconditional acceptance of sustained yield. Many of the benefits claimed for sustained yields are not dependent on the production of equal annual, or periodic, harvests but are the result of continuous forest production.
Sustained yield forest management emphasizes stability and continuity of production but neglects economic values of the resource. It may even retard economic growth and development. By using physical rather than economic criteria to set goals for forest management, sustained yield often causes the net present worth of the forest resource to fall short of its maximum potential value. Although sustained yield policy aims at stability, the inability of entrepreneurs to respond to cyclical changes in economic activity may actually lead to instability in stumpage prices and forest revenues.

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Foreword

Sustained yield is one of the fundamental concepts of forest management and is synonymous, in the minds of many professional foresters, with "good" forest practice. Many leading foresters have identified professional forestry with sustained yield management. For example, Hiley (1931) stated:

"The fundamental conception of forestry, as opposed to lumbering, is the principle of sustained yield. So long as this principle is followed a forest may be said to be undergoing forest management. The antithesis of forest management is devastation. (my emphasis)"

and Davis (1954) said:

"the idea of maintaining forest productivity distinguishes forestry as a profession from forest liquidation, no matter how skillfully the latter may be accomplished." (my emphasis)

Sustained yield has become an integral part of the philosophy of the forestry profession and would appear to be regarded, by many, as an infallible creed to be followed at all costs. Great moral significance is sometimes attached to the pursuit of sustained yield, and there is a tendency to regard anyone who opposes the doctrine as unethical.

Sustained yield is widely accepted by public forestry agencies as the most important goal of forest management (Greeley, 1952; F. A. O., 1950, 1953). The
validity of such a policy is rarely questioned and its faults are seldom examined. Chapman (1925) said that:

"sustained yield is the goal of all rational forest management." (my emphasis)

To blindly accept sustained yield forest management is extremely dangerous. Before any management plan is adopted, forest managers should be sure that it is compatible with their overall policy objectives and will achieve these objectives in the most efficient manner.

In this thesis the concept of sustained yield will be critically examined and an attempt will be made to put it into perspective, vis a vis other management alternatives. Although much of the discussion is general, particular attention will be given to sustained yield forest management as it is practised in British Columbia.

The concept of sustained yield forest management is discussed in Chapter One and its history in France, Germany, the United States and Canada is summarised in Chapter Two. Chapter Three presents an economic view of conservation and resource use, and in Chapter Four the rationale of sustained yield is critically examined. An economic critique of sustained yield forest management in Chapter Five is followed, in Chapter Six, by a discussion of management techniques which could be used by forest managers to facilitate decision making. Chapter Seven describes the history of forest
management in British Columbia, and critically appraises the implementation of sustained yield forest policy in the Province.
1. Definition of Sustained Yield Forest Management

Sustained yield is one of the most fundamental concepts of forest management. Forestry literature abounds with discussions of sustained yield practices but few authors have felt the need, or have been able, to provide a concise definition of the policy. Sustained yield might be simply interpreted as continuous forest production. That is, it could be said that a country, or region, is practising sustained yield forestry if regeneration is encouraged following logging. To most forest managers, however, sustained yield forest management implies that a balance is maintained between the growth and harvest of the forest, thus ensuring the maintenance of an even-flow of forest products. Davis (1954) stated that:

"Sustained yield management, as the term is most accurately and commonly employed, means continuity of harvest. Whether reckoned by years or more commonly by longer periods, the purpose is to obtain a sustained flow of products. ....... The term 'sustained yield' is sometimes rather broadly employed separately from the word 'management' to mean maintenance of forestry productivity generally,
whether growth, harvest or both. To do so, robs the term of its more specific meaning as applied to the management of a property."

The Society of American Foresters has defined sustained yield as:

"A method or plan of forest management which implies continuous production with the aim of achieving, at the earliest practicable time, an approximate balance between net growth and harvest, either by annual or somewhat longer periods. (Society of American Foresters, 1958)

and the British Columbia Royal Commission on Forest Resources, 1945, defined it as:

"A perpetual yield of wood of commercially usable quality from regional areas in yearly or periodic quantities of equal or increasing volume." (Sloan, 1945)

In this thesis, sustained yield forest management will be interpreted as: the management of a forest area in such a way that an equal, or near equal, volume of merchantable wood can be harvested annually, or periodically, in perpetuity.

2. The Normal Forest

A forest regulated for sustained yield production has a characteristic structure and is known as a normal forest. The origin of the term normal forest has been discussed by Dwight (1965). The "Normale", according to
Dwight, was the term used in Austria in the 18th Century for a set of standard instructions prescribing the method to be used for the valuation of forested lands owned by monasteries, convents and entailed estates. The "Normale" prescribed the forest structure necessary for the forest to maintain a sustained yield in perpetuity. It contained a table showing the nature of this structure and made it clear that the presence of a definite quantity of wood—the normal growing stock—was a necessary result.

The Society of American Foresters has defined a normal forest as follows:

"A standard with which to compare an actual forest to bring out its deficiencies for sustained yield management. An ideally regulated or organized forest with normal increment, normal age classes in area and distribution and normal growing stock" (Society of American Foresters, 1944)

This definition is rather tautological and, perhaps, a better description of a normal forest is that given by Brasnett (1953):

"A normal forest is an ideally constituted forest with such volumes of trees of various ages so distributed and growing in such a way that they produce equal annual volumes of produce which can be removed continuously without detriment to future production."
The normal forest is an extremely important concept in traditional forest management and may best be understood through a simple hypothetical example. Consider a forest which is to be managed on a fifty year rotation and produces 5000 cubic feet of timber per acre at rotation age. The mean annual increment at rotation age will be 5000/50, or 100, cubic feet per acre per annum. If the forest consists of 1000 acres which are homogenous as regards site quality and stand density and the forest manager wishes to equalize output for every 5-year period throughout the rotation, the normal structure for the forest will consist of 10 five-year age classes, each age class occupying an area of 100 acres. Thus, in every 5-year period 100 acres of the forest, yielding 500,000 cubic feet of timber, will be cut and regenerated. This ideal structure is illustrated diagrammatically in Figure 1. This figure is, of course, a schematic representation of the normal forest structure. The true relationship between age and stand volume is not linear but has a sigmoid form. In Figure 1 the small shaded squares represent the average increment (1) on 100 acres of the forest during the 5-year period. The 0-5 year age class carries a growing stock, at the end of 5 years, of 50,000 cubic feet and had an average growing stock during the 5-year period.

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1 The rotation is the time which elapses between the regeneration and the final felling of the forest crop.
Figure I: Schematic representation of a forest ideally regulated for sustained yield management.
period of 50,000/2, or 25,000, cubic feet. Similarly, the 5-10 year age class carried an average growing stock of 75,000 cubic feet during the preceding 5-year period, and so on up to the 45-50 year age class which had an average growing stock of 475,000 cubic feet during the preceding 5-year period. The total increment for the 5-year period, on all the age classes represented in the forest, is known as the normal increment of the forest and is that volume which can be cut from the forest during each cutting period, in perpetuity (i.e. the sustainable yield of the forest). In this example the normal increment is equal to 500,000 cubic feet, which is the volume represented by the sum of the shaded squares or the total volume in the 45-50 year age class, in Figure 1. The normal growing stock of the forest is that growing stock which will yield the normal increment in perpetuity. In this example the volume of the normal growing stock is represented in Figure 1 by the area of the triangle ABC, that is 2.5 million cubic feet. The volume of the normal growing stock may be calculated by multiplying the normal increment by half the number of cutting periods in rotation.

The normal forest is the acme of traditional forest management. It is the ideal towards which, according to the literature, all forest managers must strive:
"As in every business there is an ideal, a standard in conduct and condition, which the manager more or less consciously recognizes and follows, or seeks to establish, yet, on account of uncontrollable circumstances can never quite attain, so is the ideal of the forester never quite attainable, although it is his obligation to attempt and approach it as far as practicable. The ideal conduct of the management 'for annual sustained yield' is possible only under the ideal condition which the forester recognizes in the 'normal forest', the standard by which he measures his actual forest and to which he desires, as nearly and as quickly as circumstances permit, to bring his actual forest. The latter will usually be found abnormal in some one direction or in several directions and hence make ideal conduct impossible. The object of forest regulation, then, is to prepare for the change of an abnormal forest into a normal forest." (Fernow, 1902)

Discussions on how to achieve the normal forest have dominated forest management literature for over 150 years and, even today, the principal task of most forest managers is to regulate the yield of the forest in such a way that a normal distribution of age classes will eventually be attained.

The relationship between the eventual sustained yield capacity of the forest and the allowable annual, or periodic, cut during the transition period to normality, will usually depend on the distribution of age classes in the unregulated forest and the speed of transition. The earliest method of yield regulation was based entirely on area and was first
practised in France during the 14th Century (Brasnett, 1953). Methods of yield regulation gradually became more sophisticated and more attention was given to regulation by volume rather than by area. Great emphasis was placed on formulating methods which would give approximately equal annual yields during the transition period. Many of the most successful methods were complementary to a specific silvicultural system or were designed for a particular region.

Methods of yield regulation are dealt with in all the standard textbooks of forest management and will not be pursued here. Brasnett (1953), described most of the principal methods of yield regulation used in Europe and traced their historical development in some detail. Smith (1958) made a survey of allowable cut determination in the United States and Canada.

3. Maximum Sustained Yield

It should be emphasized that sustained yield and yield maximization are not necessarily joint policy objectives, but they seem to be inseparable in the opinion of many foresters. For example, Chapman (1931) stated that:

"In a normal forest the current net increment will coincide approximately with the mean annual increment and, for this reason, will also coincide with the amount cut annually. Mean or average increment has a definite value as an aid in determining the value of the annual cut. Were each
stand to be cut at rotation age, the volume cut, when divided by the age of the stand would coincide with this maximum mean annual increment.' (Chapman, 1931) (my emphasis)

The United Nations Food and Agriculture Organization has endorsed the policy of 'maximum sustained yield'. In a publication entitled World Forest Policy, Law and Administration it stated:

"National forest policy must include the principles of sustained and maximum yield.------ They need not, of course, always be regarded as rules immediately applicable, but they must exist at least as ideal objectives which define and sum up the policy." (F. A. O., 1950) (my emphasis)

Davis, Breigleb, Fedkiw and Grosenbaugh (1962) made a review of timber management planning procedures and objectives in the United States. They cited as one of the main "technical objectives of sustained yield timber management" the maximization of yield of all timber products.

In a forest perfectly regulated for sustained yield management, the yield which can be sustained in perpetuity, is equal to the mean annual increment of the forest. The yield of the forest can be maintained at any desirable level. Given a certain site productivity and standard of utilization, the level at which the yield of the forest is maintained will depend on the length of the rotation. To a point, the longer
the rotation the greater will be the mean annual increment and, hence, the sustainable yield. Eventually, the mean annual increment will reach a maximum and will then decline. Proponents of maximum sustained yield believe that the rotation should be of such a length that the mean annual increment and, therefore, the sustained yield capacity of the forest is maximized.
CHAPTER TWO

History of Sustained Yield Forest Management

In order to understand how the concept of sustained yield has become so firmly entrenched as a doctrine of forest management, it is necessary to explore the history of forestry in Europe, particularly France and Germany, and in the United States and Canada.

Throughout the ages, forest policy, in most western nations, has been shaped by the economic and political atmosphere of the times. In forestry, present policies are greatly influenced by the past. Because it is a long term business, decisions, once made, are difficult to reverse and a strong link exists between one generation of foresters and the next. The forestry profession tends to attract men of a conservative nature and traditions and old ideas die hard. It is not surprising, therefore, to find that many of the policies first formulated in Europe centuries ago, still influence forest management throughout the world.

The concept of managing a forest in such a way that, each year, a volume of timber may be cut which is equal to the annual growth of the forest is extremely old. The earliest written record of continuous forest management is contained in Pliny's 17th book of about A. D. 500 where he describes the cultivation of Spanish chestnut, in Ancient
Gaul, on a three to five year rotation for vine stakes (Brasnett, 1952). Throughout Europe from medieval times to the industrial revolution, and in some cases beyond, towns and villages managed coppiced stands on a strict sustained yield basis for fuelwood. The concept of carefully regulated sustained yield on a national scale, however, was not introduced until the 18th century. Modern sustained yield policy had its origins in Germany and France and forest practices in these two countries have had a profound influence on forest policy throughout the western world.

1. France

In parts of France local scarcity of forest products caused the introduction of legislation to control the annual cut, as early as the 14th century, in both coppice and high forest areas. Such legislation was localized, and usually of a temporary nature. Deforestation continued steadily, throughout most of France, until the mid 17th Century as the expanding population raised the demands for industrial wood and for agricultural land. In 1669, an elaborate series of forest laws was put into force, designed to control forest devastation. The chief proponent of these laws was Jean Baptiste Colbert. Colbert (1619-1683) was the minister of finance under Louis XIV. He had a deep interest in forestry

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2 This discussion is mainly based on Greeley (1952); and Brasnett (1953).
and, prior to his political career, had managed the large estate of Cardinal Mazarin.

Colbert was the chief exponent in France of the economic doctrine which later became known as Mercantilism. Indeed, this policy is actually called Colbertism by the French (Soule, 1952). The Mercantilists regarded the nation as an individual merchant. The nation, they believed, could grow rich by exporting more than it imported. Great value was put on large stores of gold and silver and any policy was encouraged which would raise the nation's store of bullion. Imports were discouraged by imposing high tariffs, and an attempt was made to make the nation self sufficient in primary resources. Colonies were exploited for the benefit of the colonizing countries. Every effort was made to extract natural wealth from the colonies, as cheaply as possible, and transport it to the mother country. (Soule, 1952)

The forest legislation of 1669, which became known as the Code Colbert, was just one manifestation of Colbert's economic philosophy. The Code reorganized the forest administration. It dealt with all aspects of forest management and prescribed strict silvicultural systems and cutting procedures designed to ensure the continuance and improvement of the French woodlands. Other laws of this period severely restricted the import of wood and other forest products.
The Code Colbert was the basis of forestry in France until the revolution. Following the revolution, during the decade 1791-1801, forest owners had complete rights of exploitation but, in 1801, Napoleon reorganized the forest service and tried, without much success, to reimpose the controls of Colbert. Before long, however, timber shortages became apparent, accentuated by the Napoleonic wars, and in 1827 a law was passed which established the National Service of Waters and Forests.

During the 19th Century forestry in France became a subject of serious study and scientific research. In 1824 the French State Forest School was opened at Nancy under Lorentz who had studied in Prussia and was a close follower of German management practices. Lorentz, and his immediate successor, Parade, advocated the uniform system of forest management in which natural regeneration is encouraged by gradually removing the forest canopy by means of a series of regeneration fellings. For purposes of yield regulation, each forest was divided into a number of Periodic Blocks. One of these Blocks was regenerated during each regeneration period. Thus, if regeneration took 20 years to accomplish and the rotation was 120 years, the forest would consist of 6 Periodic Blocks. The annual allowable cut was calculated by dividing the growing stock in the regeneration Block by
the number of years in the regeneration period and adding the average increment, on the growing stock of the forest, during the regeneration period.\(^3\) By the middle of the 19th Century, this method of management was obligatory throughout most of France and is still in use today in some areas (Brasnett, 1953).

Towards the end of the 19th Century, the uniform system gave way to the selection system of management, in the more mountainous regions of the country, with yield regulation by size class. The most famous method of size class yield regulation was the so called, "French Method of 1883", which was introduced by Melard (Brasnett, 1953).

Today, in France, the practice of sustained yield is strictly observed on practically all the forest area. The Single Periodic Block Method of yield regulation with the uniform system of forest management is still practised throughout large areas of the French forests. In the mountainous regions selection forests are the rule but yield regulation by size class has largely given way to Biolley's Methode du Controle (Knuchel, 1949).

Tradition plays a major role in French forest management. In some cases, management plans which originated in the 19th Century are retained for sentimental reasons. The attitude of the French towards forest management was

\(^3\) This method of yield control was first formulated by Heinrich Cotta, the founder of the Saxon School of forestry. Parade was a pupil of Cotta (Brasnett, 1953).
summed up by Greeley (1952) as follows:

"The conception of an allowable cut fixed by growth of a 'normal exploitation' or possibilite is almost universal in French woods­men of all degrees. It is the interest, as distinct from the capital, which is sacred to all Frenchmen. Forestry is part of a national talent for conserving and managing wealth."

2. Germany

German forestry, prior to the middle ages, was dominated by the concept of the 'mark' and the 'ban'. The 'mark' forests were areas of common land surrounding the settlements. Every free man could use them for hunting, forage, fuel and timber. The 'ban' was the right of the state to restrict and control forestry practices. The 'ban' was first used to limit hunting but was later extended to cover all aspects of forest use. During the middle ages, forest ownership gradually became concentrated in the hands of princes, noblemen and the church. The area of 'mark' forests diminished but the peoples' right to use the forests had become so deeply rooted, as part of the traditional heritage, that it survived. The first 'ban' to deal directly with cutting rights was in 1165 (Fernow, 1907).

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4 This discussion is mainly based on Fernow (1907); Heske (1938); Greeley (1952); and Brasnett (1953).
During the sixteenth century most German states enacted ordinances designed to control the removal and use of timber. In some localities there was fear of timber famine and in others it was deemed necessary to protect timber supplies of local industry, particularly mining.

"This crisis (timber famine) was reached in the more densely populated parts of Germany between the thirteenth and sixteenth centuries. It was during this period that the first attempts were made to regulate timber cutting and improve forest conditions, this may be designated as the first sprouts on earth of sustained yield forest management."

(Heske, 1938) (my emphasis)

Laws were passed which prohibited the cutting of trees below certain diameter limits; leaving seed trees of desirable species became mandatory in some localities, and grazing was restricted. In some areas attempts were made to control timber utilization; the number and height of buildings allowed in each village was prescribed and only certain woods could be used for fuel. There was no absolute shortage of wood at this time but lack of transportation facilities and the political fragmentation of the country led to local scarcities. Heske (1938), commenting on this situation, stated:

"Largely as a result of these difficulties of communication, Germany was split into many small independent economic and political units each walled about by its own customs barriers. In Prussia alone there were, in 1812, sixty different customs boundaries. Intercourse was
restricted to the locality and local consumption depended on local production. The peculiar conditions of the period strongly affected the development of sustained yield forestry in two ways: directly through the primitive communications and the consequent difficulty of transporting bulky goods of comparatively low value, such as wood, for long distances; and indirectly through the spirit of division, rationing and control which ruled the economic and cultural life of the times. Every wood consuming centre which did not happen to be situated on a navigable or drivable stream was dependent on the wood produced in the immediate neighbourhood. When, therefore, the wretched condition of the forests forced the public authorities to take action to prevent a wood famine, their objective could be attained only by a strict regulation of cutting so that the forest would always produce an equal annual yield. At first, various practical measures were tried as a means of accomplishing this. Later, the theory of the ideal forest was worked out scientifically under the name of 'normal forest'. This term, normal forest, is very characteristic, because the need for sustained production was the normal thing in the whole economic life of those times."

During the 16th and 17th centuries, forest laws in Germany

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Heske's interpretation of the term "normal forest" is incorrect. The true derivation of the term, as described by Dwight (1965), is given on page 5.
became even more stringent and, following the Thirty Years War, state control of the forests became absolute.

Following the French Revolution a wave of liberalism swept Europe which affected German forest policy. In France the Physiocrats attacked the doctrine of Mercantilism and advocated the economic freedom of \textit{laissez-faire}. In Germany there was a movement towards democratic government and the autocratic powers of the nobility were gradually removed. The whole structure of forest administration underwent radical change. Under the rule of the German princes the administration had been carried out by a group of civil servants known as cameralists. The cameralists had little knowledge of forestry and their rule, although very harsh, was technically poor. The successors to the cameralists were true professional foresters.

During the 19th Century forestry in Germany became a subject of academic study and research. Several contesting theories of forest management developed and bitter arguments ensued. It was a time of new conceptions in forestry practise and it was during this period that sustained yield management was systemized and put into serious operation. During the first half of the 19th Century the German state forests, and most of the private and communal forests, were surveyed and organized for sustained
yield management. A great deal of attention was paid to methods of regulating the cut. Implementation of detailed yield regulation formulae helped to impress on the German forests their characteristic sustained yield structure.

In South Germany a method of yield regulation became popular which distinguished between the 'normal' and 'actual' growing stock of the forest. The basic concept was that a forest managed for sustained yield must have a 'normal' timber stand, which must be maintained as capital growing stock. Only the increment on this 'normal' growing stock should be cut. The theoretical 'normal' growing stock was determined and compared with the 'actual' growing stock. The 'actual' was then brought to equality with the 'normal' by reducing the annual cut, in the case of a deficit, or by increasing it, in the case of a surplus. This method of yield regulation was first used in Austria during the 18th Century and is usually referred to as the Austrian method.

In the mid-19th Century, German forestry was affected by the industrial revolution. New methods of transportation became available and wood could be shipped over greater distances. Local timber shortages declined in importance because communities were no longer dependent on wood produced in the immediate vicinity. Sustained yield management of small forest units was no longer considered essential. Coal was discovered and mined in many localities and industries became independent of wood fuel supplies.
These conditions led to the formation of a new school of thought in German forestry which considered the forests as an economic, rather than a purely physical, resource. The founder of this school was Professor Pressler of Tharandt (Heske, 1933). The most marked difference between this school, and its contemporaries, was concerned with the financial goals of forest management. The traditional foresters advocated rotations which would maximize the annual net income (Waldrente) from the forest, regardless of interest charges against the forest capital. They retained the forest crop until the marginal rate of return to the forest capital was zero. The new school of forest economists favoured a rotation length which would maximize the net revenue from the forest, discounted to the present at a predetermined rate of interest (Bodenrente). In 1849, Faustmann published a paper in which he showed how the Bodenrente might be calculated (Faustman, 1849).

The new school also advocated the abandonment of sustained yield policy for, they argued, the annual cut should no longer be determined by the annual growth on the working unit but should simply be the sum of the volumes of the individual stands which, at any time, had to be liquidated for financial reasons. Although the new economic principles were taught in the forest schools they were not
put into general forestry practice:

"In practice, foresters could not bring themselves to introduce the short rotations which the soil rent (Bodenrente) theory demanded and actually reduce the growing stock in accordance with such a shortening of the rotation, or to give up sustained yield to the extent dictated by purely financial reasoning. German forestry probably affords the only instance where the ideal of sustained management, in accordance with the long term interests of the people as a whole, was developed before the start of the capitalistic era and, with few exceptions, was unwaveringly followed while life was dominated by liberal capitalism and laissez faire philosophy. ----- A lively controversy arose as to the theoretical soundness and practical applicability of this doctrine of soil rent and for decades occupied the attention of the leading spirits of European forestry science and forestry practice. It was settled in Germany only when the principles of liberal capitalism ceased to dominate economic thought." (Heske, 1938)

As fuelwood became less important to the German economy and the demand for industrial lumber increased, the old stands of beech and oak and the mixed stands of broad-leaved and coniferous species gave way to pure stands of spruce and pine which could be managed more profitably for lumber production.

Towards the end of the 19th Century there was a
reaction in Germany against "artificial" forestry. The movement was led by Gayer, professor of silviculture at Munich. He believed that it was wrong to cultivate pure stands and regulate the forest according to mathematical formulae. The slogan of his movement was "Back to Nature" and he advocated mixed, unevenaged stands of broadleafed and coniferous species, with natural regeneration instead of artificial seeding and planting. Gayer had a great influence on German silviculture and management and even today, in Germany, the natural school has many followers. Gayer's ideas were followed throughout southern Germany and in the German speaking cantons of Switzerland where they gave rise to the Swiss Fémelshlag, or irregular shelterwood system of management, and Biolley's Méthode du Controle.

During the 19th Century the forest schools of Saxony and Prussia attracted students from many countries. They had a profound influence on forest management practices throughout Europe and, as will be seen in the next section, the United States and Canada. Today, throughout much of the western world, the German forests are still looked on as a model of "good" forest management and German management criteria are emulated in many countries. The regular sustained yield structure of the German forests, with their regular gradations of age classes and carefully calculated allowable annual cuts, have survived to the present day over
much of the country.

3. United States

The United States inherited the concept of sustained yield forest management from Europe. The first professional forester to head a public forest agency in the United States was Dr. Bernhard Fernow, a German who had studied forestry under Heyer in Prussia and was an ardent advocate of sustained yield. Fernow was appointed head of the Division of Forestry in 1886 (Rodgers, 1951). Gifford Pinchot, the first American-born forester, who succeeded Fernow in 1898, was a great admirer of German forest management. He was trained at the French forestry school at Nancy but was greatly influenced by Dr. Dietrich Brandis, a German forester of the 'old school' and the founder of the British Indian Forest Service (Pinchot, 1947).

For 250 years the forest economy of the United States was dominated by the existence of 'free land'. As westward expansion took place, millions of acres of new land became available and the 'free land' policy of the government was designed to encourage settlement and rapid development. Ninety-one million acres were granted to aid the construction of railways, canals and roads. Thirty-seven million acres of forest land were given to newly-
formed states in the west. The Pre-emption Acts of 1820 and 1841 and the National Homestead Act of 1862 gave free land to legitimate settlers. The Timber and Stone Act of 1878 enabled any citizen to acquire 160 acres, without requiring residence or improvements, for a cost of $2.50 per acre (Greeley, 1952).

To the farmer, rancher and homesteader the forest was a hindrance and large areas were cleared, often by burning. The rapidly expanding economy of the country gave rise to a high demand for lumber and a large lumber industry developed. Until the mid-nineteenth century the lumber industry was centred on the Eastern States. After the Civil War the industry moved to the Lake States and about 1880 turned to the Southern Pine region. Since about 1915 the main centre of lumber production has been the Northwestern States.

The free land policy and low stumpage rates of the 19th Century led to a great deal of land speculation and many personal fortunes were amassed. In 1907, the Bureau of Corporations found that 436 billion board feet of western stumpage was owned by only 20 corporations. One quarter of the timber in the whole country was owned by only 131 concerns (Ise, 1920).

The lumber industry was a migratory industry; many
of the sawmills were small and portable and could be easily moved to new areas when the surrounding timber had been liquidated. It followed the main paths of expansion and was usually the first industry into a newly settled area, providing employment and cheap building materials for further growth. In many cases new frontiers were pioneered by the industry. Lumbermen provided railways and roads into undeveloped regions and were followed by homesteaders who cultivated the newly cleared land.

During the 18th and 19th centuries there were fears of local timber shortages and several attempts were made to control the alienation and use of forest land. As early as 1762, William Penn, the founder of Pennsylvania, stipulated that for every 5 acres of forest cleared, one acre of trees should be reserved (Fernow, 1899).

About 1870, there began in the Eastern States, a movement which deplored the 'desecration' of the country's natural resources, particularly the forest resource. This movement was influenced by several writers of the period who were concerned about man's relationship to his physical environment. The most important work in this field was Man and Nature by G. P. Marsh. The main theme of Marsh's book was that man, although an integral part of the natural
environment, has developed such a high degree of intelligence and technical skill that it is within his power to modify the environment. Man, wrote Marsh, is "everywhere a disturbing influence" and eventually, unless checked, he will destroy himself by wasting the natural resources upon which his very existence depends.

In 1870, for the first time, forests were included in the United States Census. Between 1867 and 1887, 10 states named commissioners to study the extent of forest destruction and recommend necessary action. Carl Schurz, Secretary of the Interior, forecast, in his annual report of 1877, that there was only a 20 year supply of timber left in the country (Ise, 1920).

At the 22nd meeting of the American Association for the Advancement of Science, in 1873, a paper was presented by Franklin B. Hough entitled "On the Duty of Governments in the Preservation of Forests". This paper stressed the need to educate the public and forest land owners as to the importance of forests in relation to timber supply, climate, erosion and runoff. In 1876, Hough was appointed, by the Commissioner of Agriculture, to investigate all aspects of forestry in the United States and in 1881 a Division of Forestry was formed in the Department of Agriculture with Hough at its head. Hough was replaced as chief of the
Division in 1883, by Nathaniel H. Egleston. In 1886, Congress granted statutory recognition to the Division of Forestry and Fernow became its chief(Dana, 1956). A law was passed in 1897 which authorized the government to sell the timber on reserves without alienating the land and gave protection to the forest from fire and theft. This act marked the beginning of a true national forest policy.

Concern, during the late 19th century, for the nation's forests, was mainly responsible for the birth of one of the most important political movements in the United States history, the Conservation Movement. This was a political reform movement. Its chief architect was Gifford Pinchot, the first American-born professional forester, who took over from Fernow as head of the Division of Forestry in 1898. Pinchot, in his autobiography, described how the idea of a new policy for the control of natural resources came to him in 1907 while riding through Rock Creek Park, near Washington, "in the gathering gloom of an expiring day". In this often quoted passage he described how he thought on:

"the forest and its relation to streams and inland navigation; to water power and flood control; to soil and erosion; to coal and oil and other minerals; to fish and game and man's other possible use or waste of natural resources.——-Suddenly the idea flashed through
my head that there was unity in this complication. Here was no longer a lot of different, independent and antagonistic questions each on its own separate little island, as we had been in the habit of thinking. In place of them was one single question with many parts. Seen in this new light all the separate questions fitted into and made up one great problem of the use of the good earth for the good of man. ------ It took me time to appreciate that here was the makings of a new policy, not merely nation wide but world wide in scope, important because it involved not only the welfare but the very existence of men on earth."

(Pinchot, 1947)

Soon Pinchot took his ideas to his good and powerful friend Theodore Roosevelt:

"Very soon after my own mind was made clear enough to state my proposition with confidence, I took it to T. R. And T. R., as I expected, understood, accepted and adopted it without the smallest hesitation. It was directly in line with everything he had been thinking and doing. It became the heart of the administration. ------ Having just been born the new arrival was without a name. Both Overton (Overton Price) and I knew that large organized areas of government forest lands in British India were named Conservancies, and the foresters in charge of them Conservators. After many suggestions and long discussions, either Price or I proposed that we apply a new meaning to a word already
in the dictionary, and christen the new policy Conservation." (Pinchot, 1947)

Pinchot was a dedicated evangelist for the preservation of natural resources, almost fanatical in many of his views. His writings are full of emotion and he appealed to the nationalistic sentiments of the people.

"The Conservation of natural resources is the key to the future. It is the key to the safety and prosperity of the American people and all the people of the world for all time to come. The very existence of our nation, and of all the rest, depends on conserving the resources which are the foundations of life. That is why Conservation is the greatest material question of all." (Pinchot, 1947)

These were strong words, the sort which politicians can make much of. The Roosevelt administration made full use of the Conservation ideal and turned it into one of the most significant political movements in American history. Prior to the rise of the Conservation Movement, Roosevelt had established a reputation as a staunch anti-monopolist and land reformer and had created many forest reserves. In his first message to congress he stated, "Forestry is the preservation of the forests by wise use" and by 1907 he had created 105 million acres of National Forest Reserves. Roosevelt's opposition to big business fitted in well with
the Conservationist ideals. Monopolists and big businessmen were, to the Conservationists, vampires living on the life blood of the American people. Monopolists, it was said, wantonly destroyed natural resources, wasting non-renewable resources and failing to replace those which could be renewed (Pinchot, 1910).

In 1908 the governors of all the states and territories were summoned to the White House to confer with President Roosevelt, and with each other, upon the conservation of natural resources. Many papers, on all aspects of natural resources, were presented to the governors and the conference concluded with the submission of a lengthy declaration of objectives and recommendations. This declaration is an explicit statement of the philosophy of the Conservation movement and is worth repeating in part:

"We the governors of all the states and territories of the United States of America, in conference assembled, do hereby declare the conviction that the great prosperity of our country rests upon the abundant resources of the land chosen by our forefathers for their homes and where they laid the foundation of this great nation. We look upon the resources as a heritage to be made use of in establishing and promoting the comfort, prosperity, and happiness of the American people, but not to be wasted, deteriorated or needlessly destroyed."
We agree that our country's future is involved in this, that the great natural resources supply the material basis upon which our civilization must continue to depend, and upon which the perpetuity of the nation itself rests. We agree that the forests which regulate rivers, support industries, and promote the fertility and productivity of the soil should be preserved and perpetuated." (Van Hise, 1921)

In 1909, Roosevelt called a North American Conservation Conference which was attended by representatives of Canada, Newfoundland and Mexico.

Conservation became the watchword of progressive politics during the Roosevelt administration and many people lost sight of its original purpose:

"The Conservation Movement ultimately moved from natural resources to doctrine and policies on immigration, anti-industrialization, trust busting, pure food laws, child labour, Anglo Saxon supremacy and so on. The clues as to how this happened are to be found in the fact that it was a successful political movement; architects and managers of a developing political programme are rarely consistent in their thoughts or actions. Further-like all successful political movements - the Conservation Movement was dominated by its leaders and flavoured by their personalities, rather than intellectually led and constructed with scholarly rigour." (Barnett and Morse, 1962)
The Conservationists attached great significance to an ecological system undisturbed by man. They believed that there existed a unique balance of nature at a high level of physical productivity. Such views find their counterpart in much of the European forest literature of the late 19th Century. Conservationists saw natural resources as finite entities which were being rapidly depleted. They were convinced that excessive current use of natural resources, would reduce the productive potential of society in the future and they were very conscious of their obligation to unborn generations. Physical scarcity of natural resources was identified with economic scarcity. They made elaborate estimates of the physical quantities of all natural resources present in the United States and devised methods by which they could be eked out. Probably their greatest concern was over the 'wasteful' use of the forests. Ordinary people could see this taking place around them and the results were clearly demonstrated by the rapid disappearance of the forests in the Eastern and Southern states.

"The five indispensable essential materials in our civilization are wood, coal, water, iron and agricultural products------. We have timber for less than thirty years at the present rate of cutting. The figures indicate that our demands upon the forest have increased twice as fast as our population." (Pinchot, 1910) (my emphasis)
The obvious answer to the problem of forest conservation was the imposition of a maximum sustained yield system of management. Although sustained yield became the official doctrine of the Forest Service, it could not be imposed on the private forest owners who then controlled more than 90 per cent of the United States timber supply.

When the administration of Theodore Roosevelt came to an end, the popular appeal of the Conservation Movement subsided. Taft, Roosevelt's successor, was not sympathetic to the Conservationist ideals of the previous administration and proceeded to sell timber in the National Forest Reserves. The fight for Conservation and sustained yield forest management continued in the ranks of the Forest Service, however.

Following the First World War, the United States Forest Service and the Society of American Foresters began separate drives to bring about the public regulation of cutting in privately owned forest lands. In 1919, Gifford Pinchot wrote:

"The need for governmental control of private timber lands is now self evident: because without such control the general practise of forestry in this country will never become a reality and because unless enough forestry is practised to prevent forest devastation the danger to our prosperity in peace and safety in war will grow steadily worse. The field is
cleared for action and the lines are plainly drawn. He who is not for forestry is against it. The choice lies between the convenience of the lumbermen and the public good." (Pinchot, 1919)

Much controversy took place over whether regulations governing private forest land should be exercised by the Federal government or the State Governments but no legislation, pertaining to this problem, was enacted. The main proponent of sustained yield, during the 1920's and 30's, was David T. Mason. Mason, and many others in the Forest Service, saw sustained yield as the answer to all the ills of the forest industry during the early days of the depression.

Mason (1927) expressed the belief that the main problems of the American forest industry were: a rapidly diminishing supply of saw timber; too many small inefficient mills; overproduction in the lumber industry; and instability throughout all the forest product industries. He calculated that if softwood depletion continued at the 1927 rate the supply would only last for 37 years, and he predicted that, due to a world shortage of timber, future imports to the United States would be limited. He believed that British Columbia, with an annual cut of 2.6 billion board feet, had already surpassed the sustained capacity of its forests and its imports to the United States would diminish.

Mason concluded that the United States must grow within its borders all its timber requirements, or go without
and that this objective could only be achieved through sustained yield management. Sustained yield, said Mason, would restrict supply and raise lumber prices thus giving the mills, remaining in the industry, a greater margin of profit. Larger, more efficient mills would develop as permanent supplies of timber became available but the number and capacity of the mills would be controlled by the forest manager. He considered that the most important result of a sustained yield policy was the stabilization of communities.

"From a community point of view we want the lands which are principally valuable for tree growing used for that purpose permanently, in an organized way, to their full capacity. We want this so that dependent industry may run steadily at capacity, furnishing the maximum permanently in employment, in payrolls, in local markets, and in traffic. We want relatively large units of production which can afford to utilize closely, can develop by-product plants, and which will develop good sized towns which can furnish more of the satisfactions of life than the little towns of 'hay wire' operators. In other words we want sustained yield, for this is it; and nothing else is an acceptable substitute."

(Mason, 1927)

During the administration of Franklin D. Roosevelt there was renewed interest in the Conservation Movement. In 1933 a vast public works programme commenced which included
forestry, soil conservation, river valley development and flood control. Between 1934 and 1938, 50 million dollars were allotted by the federal government for the purchase of forest land.

In 1933, a report was published by the United States Department of Agriculture entitled *A National Plan for American Forestry* which became known as the Copeland Report (United States Government, 1933). This report consisted of over 1650 pages and presented a plan for the co-ordinated utilization of forest land in the United States. The report recommended the extension of public ownership of forest land and more intensive management of publicly-owned land. It endorsed sustained yield policy as follows:

"If our forests are to do their part in maintaining permanent, prosperous communities, they must be handled in such a way that a continuous supply of timber is assured for each dependent community; that is, under the principle of sustained yield by comparatively small economic units. In this way unhealthy 'boom' development can be avoided, overproduction of lumber and other forest products can be prevented, all of indirect benefits from the forests can be retained and increased, and all our forests can take their place permanently as one of the basic natural resources upon which regional and national prosperity is founded." (U.S. Government, 1933)
In 1938, President Roosevelt recommended the appointment of a joint committee to study the forest problem, especially the need for the public regulation of yield from private forest land. The committee was formed and reported to Congress in 1941. One of the committee's main recommendations was for legislation authorizing the establishment of co-operative sustained yield units.

In 1944, the Sustained-Yield Forest Management Act was passed which authorized the formation of co-operative sustained yield units consisting of Federal forest lands and private forest lands combined; and Federal sustained yield units consisting entirely of public forest land. Only one co-operative sustained yield unit has been established, under the 1944 Act, this being near the town of Shelton in the State of Washington.

During the 1940's the States began to bring more pressure to bear on private forest owners to improve their cutting practices and many private owners began, voluntarily, to introduce yield regulation measures. In 1941, the American Tree Farm programme was started, sponsored by American Forest Products Industries. This programme began in the Pacific North West and has since spread throughout the country. A tree farm is defined as:

"An area of privately owned forest land devoted to the continuous growth of merchantable forest products under good forest practices."

(Dana, 1956)
The purpose of the tree farm programme is to encourage forest owners to adopt sustained yield management and improved forest practices, by public recognition of their efforts. To qualify as a tree farm a forest must meet specific management standards and be approved by a certifying agency.

The Multiple Use-Sustained Yield Act was passed in 1960, which requires the maintenance of National Forest productivity to insure perpetual, optimum level, annual, or periodic, output of all the various products of the United States forest resource.

In 1958 a major review of the forest resource situation in the United States was concluded by the United States Forest Service (U. S. Dept. of Agriculture, 1958). In this review the demand for, and supply of, timber in the United States were projected to the year 2000. Demand projections were made at three levels based upon different population, Gross National Product, and price projections. It was concluded that the forest resource of the United States could not sustain demands, at the lowest assumed level, to the end of the century. It was assumed that, by the year 2000, timber harvests would be balanced by projected growth estimates in all the major regions. This would call for a relative increase in the volume of eastern hardwoods
harvested annually and a relative decrease in the annual harvest of eastern and western softwoods. It was emphasized that substantial expansion and intensification of forest management would have to take place in the United States if future timber shortages are to be avoided.

A reappraisal of the timber situation and outlook in the United States was published in 1965 (U. S. Dept. of Agriculture, 1965). The broad conclusions were similar to those made in the 1953 study. However, it was shown that earlier reports had underestimated the volume of timber in the west and that this region is capable of maintaining its present cutting level to the year 2000. It was estimated that timber growth and inventories in the United States would be sufficient to meet projected demands to 1990, provided current trends in management intensification continue and increasing use is made of hardwood species. By the year 2000, it was estimated, projected supplies will fall short of projected consumption by about 16 per cent, or 13 billion board feet. In 1962, there was a 60 per cent surplus of growth over cut. By 1990, it was estimated, growth will balance cut, and that by the year 2000 there will be a growth deficit of 20 per cent.

Both the reports discussed above were dominated by sustained yield concepts. A great deal of emphasis was placed on the need to bring timber removal into balance
with growth, as quickly as possible, by region and species. It was implied that, if timber shortages in the United States are to be avoided in the future, consumption patterns must be modified and forest management must be intensified.

It would appear that one of the main objectives of the United States forest policy is to achieve a high level of national self sufficiency in sustained timber production. Large increases in imports of forest products are not envisaged even though increases in domestic production can only be achieved at a very high cost.

The views expressed by the United States Forest Service have been severely criticized. Smith (1965 b) pointed out that with extensive Canadian forests easily available, it does not seem reasonable to accept the view that there will be a major timber shortage in the United States by the year 2000. Zivnuska (1964) could foresee no shortages of timber in the United States in the future and suggested that there is no urgent need for forest management intensification programmes. Zivnuska (1965 b) emphasized the dominant role played by Canada in supplying United States forest product imports and expressed the view that this trade will increase in the future. In 1963, Canada supplied more than 99 per cent of the United States pulpwood imports, 99 per cent of softwood lumber imports, 96 per cent of newsprint imports, 88 per cent of wood pulp
imports, 43 per cent of hardwood lumber imports, 26 per cent of paper and board product imports, and even 4 per cent of hardwood plywood imports. Only in tropical hardwoods does the United States have an important degree of import dependency on any nation other than Canada.

4. Canada

The history of forest management in Canada is, in many ways, similar to that of the United States. It differs from the United States in one important respect, however. In Canada, since Confederation in 1867, control of the forest resources has been, almost exclusively, the domain of the Provinces.

Forest history in each of the Provinces has been extremely diverse and it is not the purpose of this chapter to deal with each Province in detail but merely to indicate the main trends in Canadian forest management. The history of forest management in British Columbia will be dealt with in some detail in a separate chapter.

Canadian forests were first used commercially in the 17th Century to provide ship building material for the navies of Britain and France. After the American Revolution, British demands for masts and ship timbers led to the rapid development of lumber industries in the Maritimes and Quebec. The first exports of lumber and industrial timber from Canada
took place during the Napoleonic wars when Britain was cut off from its traditional Baltic supplies.

During the 19th Century the population of Canada grew rapidly and there was vast westward expansion. At first, there were no restrictions on forest exploitation and the only revenue derived by the Crown, from the forest industry, took the form of Crown Dues on felled timber. In 1826, legislation was enacted in Quebec which authorized the granting of timber leases. This was the earliest attempt in Canada to bring the forest resource under public control. The Crown Timber Act, of 1849, authorized the granting of Timber Licences in upper and lower Canada which restricted cutting to certain areas, for a limited time. The licences were usually of one year duration but could be renewed indefinitely, provided the licencee did not default in the payment of his licence fee.

Under the British North America Act, of 1867, the Dominion of Canada was created and control over management and sale of all public lands, including the timber, was given to the Provinces. Only in the Prairie Provinces were substantial areas of forest land retained by the Federal Government.

During the latter part of the 19th Century, although the Provinces retained the forest land in the ownership of
the Crown, no moves were made to control the rate of forest exploitation. Concern over the future of the forests did exist, however. In 1871, Sir John A. Macdonald wrote to the Premier of Ontario:

"The sight of the immense masses of timber passing my windows every morning constantly suggests to my mind the absolute necessity there is for looking at the future of this great trade. We are recklessly destroying the timber of Canada and there is scarcely the possibility of replacing it. The quantity of timber reaching Quebec is annually increasing and the fires in the woods are periodically destroying millions of money. What is to become of the Ottawa region, after the timber is cut away, one cannot foresee. It occurs to me that the subject should be looked in the face and some efforts made for the preservation of our timber. The Dominion Government, having no lands, has no direct interest in the subject, but it seems to me that it would be a very good thing for the two Governments of Ontario and Quebec to issue a joint commission to examine the whole subject and to report:- 1st. As to the best means of cutting the timber after some regulated plan, as in Norway and the Baltic; 2nd. As to replanting so as to keep up the supply, as in Germany and Norway; and 3rd. As to the best way of protecting the woods from fires." (Pope, 1921)

The Conservation Movement in the United States also affected the public attitude towards natural resources in
Canada. Towards the end of the 19th Century, the Provinces all passed laws which strengthened the control of the Crown over the forest lands and improved the protection from fire given to the forests. In 1900, the Canadian Forestry Association was founded. During the latter part of the 19th Century and the early 1900's the Dominion Government was responsible for the creation of many forest reserves across the country. By 1905, Dominion timber reserves covered an area of almost 10 million acres (Rodgers, 1951).

In 1906, a forestry conference was held at Ottawa at the request of the Prime Minister, Sir Wilfred Laurier, and under the auspices of the Canadian Forestry Association (Canadian Journal of Forestry, 1906). The conference was addressed by many leading North American foresters including Pinchot and Fernow. Among the recommendations of this conference the following were, probably, the most important: that a general forest policy be inaugurated in Canada; that forest reserves be established by the Dominion and Provincial governments which would eventually "embrace all lands suited for the production timber"; that the reserves be administered in a way commensurate with the aim of sustained production; that Forest Services be established in each province; that provincial forest inventories be intensified; and that timber licences and mill capacity should be limited in relation to the available stumpage.
In 1912, a Commission on Conservation was set up by the Federal Government. The Commission conducted several studies of Canada's natural resources, the most significant contributions being: *The Forests of British Columbia* (Whitford and Craig, 1918); and *Forest Conditions of Nova Scotia*, (Fernow, 1912). The Commission was disbanded in 1922.

In 1923, a Royal Commission was appointed to examine the pulpwood situation in Canada (Canada, 1924). The Commissioners did not consider that pulpwood shortages were of immediate concern but recommended that steps should be taken to reduce losses suffered from fires, insect attacks and decay. They did not consider it was necessary to hoard supplies of timber or introduce sustained yield management but they stressed the importance of protecting immature second growth.

During the Second World War there was concern, across Canada, about the adequacy of existing timber supplies to support the rapidly developing forest industries. Royal Commissions were named in three Provinces, Ontario, Saskatchewan and British Columbia to investigate the forest situation and in five other Provinces less formal investigations were made. In all cases, these bodies recommended the continuance of the policy of public forest ownership and the implementation, as rapidly as possible, of
legislation that would ensure a perpetual, or sustained, yield of forest products.

In Saskatchewan, the Royal Commission (Saskatchewan, 1947) recommended that the annual cut, on all timber licences, be restricted to 5 per cent of the standing mature timber on the licence. The aim was to remove white spruce, in an orderly manner, over a 20-year period, and then revise the rate of cutting to take into account the available second growth.

The Ontario Royal Commission (Ontario, 1947) recommended the adoption of a rigid sustained yield plan to protect the forest operators "against their own folly in wasting forest resources which are the life blood of their industries". One of their main recommendations was for a scheme by which all the loggers and manufacturers in a certain area would form a single company, managing their joint forest holdings on a sustained yield basis. Each participant would be allocated a number of shares in the company proportional to his consumption of wood.

The British Columbia Royal Commission (Sloan, 1945) differed in its recommendations from the other two in that it favoured a completely new form of forest tenure. The Commission proposed the formation of Forest Management Licences, dedicated to sustained yield, which would be
issued on a perpetual basis provided certain contractual obligations were fulfilled.

The major recommendations of the Royal Commissions in Saskatchewan and British Columbia were implemented by subsequent legislation.

Today, most of the Canadian Provinces pursue a policy of sustained yield forest management in some form. The actual level of development of planned forest management varies widely, however, from Province to Province. Good summaries of the regulation of Crown forest land across Canada have been given by Moore (1957) and Sisam (1961). Moore conducted a comprehensive survey of forestry tenures and taxes in Canada, for the Canadian Tax Foundation, and included in his work several comments on forest management practices.

5. Summary

In this brief history of the development of sustained yield forest management policy, there are several important points which should be emphasized:

a) Sustained yield developed originally in northwestern Europe, principally in France and Germany. The policy was forced on individual communities by local timber shortages, aggravated by poor communications and the inherent difficulties of transporting such a bulky material as wood.
b) Sustained yield lent itself admirably to the mercantile policies, which dominated European economic thought during the 17th Century. Laws enforcing sustained yield, on a national scale, were first implemented by the mercantilists.

c) The wave of economic liberalism, which swept Europe in the wake of mercantilism, produced many opponents to sustained yield policies. The strict government control over forest lands, which sustained yield demanded, was in every way contrary to the principles of *laissez faire*. The practise had become firmly entrenched, however, and traditionally conservative foresters were loathe to change their policies.

d) The industrial revolution brought about unprecedented forest exploitation and renewed fears of timber famine weighed heavily on the side of the sustained yield proponents.

e) The "art" of managing a forest on a sustained yield basis reached its peak in Germany during the latter half of the 19th Century. Forest management techniques were developed in minute detail and applied rigorously.

f) The concept of sustained yield management was introduced to North America from Europe. Fernow, one of the founding members of the United States Forest Service, was of German origin and an ardent supporter of
traditional management policies.

g) The chief architect of the Conservation Movement in the United States, Gifford Pinchot, was a European trained forester. Sustained yield was adopted as the cornerstone of the Conservationists' plan for the nation's forest resources.

h) Forestry in Canada has been greatly influenced by the traditional policies of Europe and the Conservationist policies of the United States.
Economics of Conservation and Resource Use

1. Economics of Conservation

In the previous chapter, it was shown that the policy of sustained yield forest management is an integral part of the philosophy of resource conservation. In order to discuss the implications of sustained yield management within an economic framework, it is first necessary to examine the premises of the Conservation Movement and discuss the economist's attitude towards conservation. It is not the purpose of this dissertation to carry out a comprehensive economic appraisal of conservation policies and what follows is merely a brief description of the major issues involved.

The ultimate aim of economic policy is the maximization of human welfare and one of the fundamental purposes of economic theory is to examine how scarce resources must be allocated in order to meet this end. It is clear, therefore, that any policies which seek to control the use of resources, such as the proposals of the Conservation Movement, must be considered in an economic context. Conservationists, do not usually attempt to analyze the economic implications of the policies they advocate and the exact
nature of the underlying economic philosophy of the movement is not made clear in their writings. In recent years, several attempts have been made to draw economic inferences from the Conservationist literature and to use these inferences to investigate the economic ramifications of public policies, designed to conserve natural resources. Such policies have been closely scrutinized and, in many cases, severely criticized. The major works in this field are: *Resource Conservation Economics and Policies* by Ciriacy-Wantrup (1952); *Natural Resources: The Economics of Conservation* by Scott (1955); and *Scarcity and Growth* by Barnett and Morse (1963). The bulk of the material in this section is based upon these three contributions.

An excellent anthology of readings in conservation and resource management has been presented by Burton and Kates (1965).

The Conservationists appear to base their philosophy on the following assumptions (Goundrey, 1960):

a) Natural resources are necessary for production.
b) The productive processes use up natural resources.
c) If the rate of use, of renewable resources, exceeds the rate of renewal, the supply of these resources will be reduced.
d) Stock resources (non-renewable resources) are in fixed supply.
e) As the stock of natural resources is reduced in quantity or quality, the labour/capital ratio, in the industries concerned, will increase, the real cost of production will rise and the real income per capita will fall to subsistence level.

f) Society has an obligation to future generations which is not provided through the market.

Conservationists believe that private individuals, left to their own devices, will use stock resources at a faster rate than is socially desirable and will fail to invest sufficiently in renewable resources. They advocate, therefore, government intervention and control over the natural resource industries.

Scott (1955), cited three main reasons why the Conservationists believe that the aims of private individuals do not satisfy the needs of society in the use of natural resources. Firstly, there are many "external" social costs and benefits connected with the use of natural resources. Consequently, it is unlikely that the maximization of private benefits, on the part of the individual, will also maximize the benefits to society. Secondly, profit maximization, on the part of entrepreneurs, will only result in the maximization of social welfare in a perfectly competitive economy. There are in reality, however, certain market imperfections which prevent this process taking place. Thirdly, the going market
rate of interest might be too high from a social point of view and the use of natural resources should, perhaps, be controlled by a 'social rate' of interest, somewhat lower than the market rate.

Economists, on the whole, have shown little sympathy towards the principles of the Conservation Movement. They do not believe that natural resources should be treated differently from other forms of social capital and they can find no evidence to support the proposition that resource use will necessarily lead to a fall in per capita income (Barnett and Morse, 1962). On the contrary, resource conservation may impair economic growth and development. Economists point out that the Conservationists make two vital mistakes in arriving at their conclusions. Firstly, they identify absolute scarcity of resources with economic scarcity and, secondly, they fail to consider the effects of technological change and innovation on resource supply.

To the economists, it is the stream of goods and services which are produced from resources which are important and not the resources themselves. Natural resources are not necessarily 'used up', in any true sense, but can be converted into more efficient forms of social capital and into consumer goods which contribute to human welfare. Scott (1955) stated:
"We can, without serious error, draw one conclusion: that both capital goods and our natural resources are indeed constituents of our social capital. ------ We can also conclude that what is directly important to society is the stream of services we can draw from these resources, not the physical nature of the resource itself. In fact, if we take cognizance of our material progress at all, we cannot help but reflect that most of this progress has taken the form of converting natural resources into more desirable forms of wealth. If man prized natural resources above his own product, he would doubtless have remained a savage, practising 'conservation'."

Zimmerman (1951), pointed out that resources are often regarded as being static and fixed where as they are actually dynamic and in a constant state of flux, expanding and contracting in response to human effort and behaviour. They reflect every change in the aims and structure of society. What may be regarded as a resource in one society, under a certain set of circumstances, may be completely neutral in another context. All materials, organic and inorganic, are potential resources which may one day be made productive by the ingenuity of man.

The development and expansion of resources is largely dependent on economic pressures. As a resource is depleted its real production cost increases and the supply price rises. The users of the resource economize on its use
and substitute other inputs in its place. Innovation takes place and completely different production processes may emerge which do not utilize the depleted resource. As supplies of the resource become more valuable, there is an incentive for the producers to make fuller use of the resource. Grades of lower quality will be used, there will be less physical waste in the extractive process and new improved methods of extraction may be devised. In the case of stock resources, such as minerals and oil, there will be an incentive for firms to seek new supplies of the material. Capital, to finance exploration, will be drawn into the industry by the prospect of high returns. In the case of renewable resources, such as timber, more investment will take place and greater supplies of these resources will be created. If the depletion of the resource is foreseen, the reactions mentioned above will precede the actual supply crisis. In addition, speculators will stockpile the resource in anticipation of high prices in the future. The effects of resource depletion will thus be ameliorated by the actions of entrepreneurs stimulated by the profit motive.

There are many examples of resource development and recession in response to cultural and economic stimuli. One which is often cited is the case of rubber. Although the rubber of the Amazon basin had been known to the people of the civilized world for many centuries, it could not be
utilized until the process of vulcanization was invented by Goodyear in 1839. Rubber then became a resource. Business men began to manufacture and sell articles made of rubber. The prices which people were willing to pay for rubber goods determined the price which could be paid for the raw material, thus fixing the area which could be economically tapped. As the demand for rubber increased there was a strong incentive to produce it more cheaply. Improved strains of the wild rubber tree were produced and grown in plantations in Malaya and Indonesia. The cost of producing rubber fell drastically and the Brazilian rubber industry, being unable to compete, was gradually forced to reduce production. Thus, due to a change in technology, in response to human demands, the wild rubber of Brazil ceased to be an important resource. In a similar manner, the increasing use of synthetics threatens to render obsolete the rubber resources of the far east.

Many conservationists, while admitting that in the past technical innovation has offset the effects of resource depletion, believe that technical ability itself is subject to diminishing returns. There are good indications, however, that technical knowledge and cultural progress are cumulative. Each new discovery opens the way to several different paths of advance. Each generation has an inheritance of knowledge and experience on which to build.
"There has been a certain tendency to regard technological advance as a chancy phenomenon, a bit of luck that is sure to run out sooner or later. The view that improvement must show a diminishing return is implicit in the thought of those who regard the more optimistic opinion as 'cornucopian'. Yet a strong case can be made for the view that the cumulation of knowledge and technological progress is automatic and self-reproductive in modern economies, and obeys a law of increasing returns. Every cost reducing innovation opens up possibilities of application in so many new directions that the stock of knowledge, far from being depleted by new developments, may expand geometrically." (Barnett and Morse, 1962)

One of the main premises of the conservationist philosophy is the belief in the obligation of the present to future generations. It is doubtful, however, whether the needs of future generations are best served by the conservation of natural resources. It is far more important to leave, to the future, a legacy of knowledge, cultural institutions and capital instruments than a large body of untouched physical resources. Resource conservation may retard current development and growth and reduce the capital base on which the next generation has to build.

"The Conservationist who urges us to 'make greater provision for the future' is in fact urging lesser provision for posterity. For the provision is already being
made, composed not of natural resources, but of those capital goods which today's individuals believe are the most profitable source of future income and output." (Scott, 1955)

2. Economic Theory of Resource Use

   a. Conditions for Optimum Resource Allocation in a Market Economy

   The ultimate aim of economic policy is the maximization of human welfare. It will be assumed that, as far as society is concerned, resources are being used in an optimum manner when the marginal social benefit derived from using the last added unit of a resource is just equal to the marginal social cost of using the unit. This optimum can only be achieved in a market economy provided certain conditions are fulfilled. Firstly, there must be perfect competition in both the factor and product markets; secondly, there must be no discrepancies between private and social values; and thirdly, each entrepreneur must behave in a way which is designed to maximize profits.  

   The conditions which must hold for optimum resource allocation in a market economy have been admirably expressed by Lerner in the form of an identity which has become known as "Lerner's Rule" (Lerner, 1946). "Lerner's Rule" may be expressed as follows:

   \[
   \text{M.S.B.} = \text{V.M.P.} = \text{M.P.R.} = \text{M.P.C.} = \text{V.M.F.} = \text{M.S.C.}
   \]

   where:

   \[
   \begin{align*}
   \text{M.S.B.} & = \text{marginal social benefit} \\
   \text{V.M.P.} & = \text{value of the marginal product} \\
   \text{M.P.R.} & = \text{marginal private revenue} \\
   \text{M.P.C.} & = \text{marginal private cost}
   \end{align*}
   \]
The above is a spatial rule for optimum resource allocation. We now turn to the optimum use of resources over time. How should natural resources be used in order to maximize their net contribution to human welfare?

\[ V.M.F. = \text{value of the marginal factor} \]
\[ M.S.C. = \text{marginal social cost} \]

The conditions under which these equalities will hold are as follows:

\[ M.S.B. = V.M.P. \quad \text{This implies} \quad \text{that the benefit derived by society from the last added unit of the resource is truly represented by the value of the product of this last added unit of the resource in the market place, or, in other words, there are no discrepancies between the private and social benefits of resource use.} \]

\[ V.M.P. = M.P.R. \quad \text{This implies that there is perfect competition in the product market. In an imperfect product market, marginal private revenue would be less than the value of the marginal product.} \]

\[ M.P.R. = M.P.C. \quad \text{This implies that entrepreneurs are seeking to maximize profits.} \]

\[ M.P.C. = V.M.F. \quad \text{This implies that there is perfect competition in the factor market. In an imperfect factor market the marginal private cost would be greater than the value of marginal factor.} \]

\[ V.M.F. = M.S.C. \quad \text{This implies that the cost of employing the last added unit of factor input is truly representative of the full social opportunity cost of employing this unit of input, or, in other words, there are no discrepancies between private and social costs.} \]
It has been shown that there is no economic difference between natural resources and other forms of economic wealth. Economists have, therefore, turned to the theory of capital in order to answer the question of natural resource allocation over time (Scott, 1964).

b. Stock Resources

The decision to postpone the utilization of a stock, or non-renewable, resource is analogous to a decision to invest. In both cases, the individual makes a decision to incur a current cost in order to secure a gain in the future. The return which the resource owner expects to obtain from using his resource in the future, is the opportunity cost of forgoing current consumption. The resource owner should only postpone resource utilization if the opportunity cost exceeds the revenue he could obtain from current consumption. If the net revenue, which the marginal unit of the resource could earn today, is less than it could earn in some future period, it will pay the entrepreneur to postpone the production of that unit.

In order to maximize the present worth of the resource, therefore, the resource owner should use it in such a way that the discounted net revenue, accruing to the last unit of the resource used in any period, does not fall short of the net revenue which that unit could earn in any period. The present worth of the resource will be maximized
when there is no possibility of increasing revenue by switching units of the resource from one period to another. 7

c. Renewable Resources

In the case of renewable resources, investment can take place through the postponement of consumption, as described above, or by creating new supplies of the resource. The resource owner, seeking to maximize the present worth of his enterprise, should invest in a renewable resource as long as the present value of the stream of net revenues, expected from the resource in future periods, exceeds the

The conditions under which the present worth of a stock resource is maximized may be expressed as follows:

\[
V.M.P_0 = \frac{V.M.P_t}{(1/p)^t} = \frac{V.M.P_{2t}}{(1/p)^{2t}} = \frac{V.M.P_{nt}}{(1/p)^{nt}}
\]

where:

\[
V.M.P_0 = \text{Value of the marginal product in the current period. (The value of the marginal product is the physical product of the last added unit of input during the production period, multiplied by the unit product price)}
\]

\[
V.M.P_t = \text{Value of the marginal product in period } t.
\]

\[
V.M.P_{nt} = \text{Value of the marginal product in the } n\text{th period}
\]

\[
p = \text{The resource owners' alternative rate of return expressed as a decimal fraction}
\]
initial investment cost.\(^8\)

In a perfectly competitive market economy, in which there are no discrepancies between private and social values, resources will be used in an optimum social manner if each entrepreneur behaves in the manner described above. If we admit the presence of market imperfections and external social effects of resource utilization, rational behaviour on the part of the private resource users will not guarantee that resources are used in an optimum manner from the point of view of society. In such a situation, a government may feel that it has a duty to interfere in the market allocation of resources. This interference may take several forms. The government may attempt to remove the barriers to optimum resource allocation by means of education, liaison, legislation or taxation. Thus, an imperfect product market might be dealt with by such measures as

\[\text{Initial investment cost.}\(^8\)\]

The investment criterion may be expressed as follows:

Invest in the resource if

\[
I \left< \frac{R_t}{(1/p)^t} \right< \frac{R_{2t}}{(1/p)^{2t}} \right< \ldots \right< \frac{R_{nt}}{(1/p)^{nt}}
\]

where:

\[
I = \text{Initial investment cost}
\]

\[
R_t = \text{Net revenue from the resource in period } t
\]

\[
R_{nt} = \text{Net revenue from the resource in the } n\text{th period}
\]

\[
p = \text{The resource owners' alternative rate of return expressed as a decimal fraction}
\]
anti-trust and combines legislation; or a discrepancy between the private and social costs of resource use might be removed by taxing or subsidizing the private entrepreneur in such a way that his costs are adjusted to the social level. The government may, however, choose to take complete control of any resource industry, in which it believes there are serious barriers to the maximization of social benefits through the market and administer it in a way designed to achieve the social objectives. The methods by which governments may control the natural resource industries have been discussed by Ciriacy-Wantrup (1952) and Scott (1955).
APPENDIX TO CHAPTER THREE

The Discount Rate

1. Purpose of the Discount Rate

A discount rate is necessary to make revenues, accruing in different planning periods, comparable in time. It is imperative that the criteria used in deriving a rate of discount are sound and lead to maximum economic efficiency.

2. Criteria for Time Discounting

Resource managers and economists find it difficult to agree on discounting criteria and the literature on the subject abounds with contradictory statements. A brief discussion of some of the principal issues may help to resolve the matter.

Reference may be found in the literature to five main criteria for discount rate determination. These are:

a) The going market rate of interest.
b) The marginal rate of interest at which the entrepreneur can borrow.
c) The marginal rate of interest at which the entrepreneur can lend.
d) The entrepreneur's personal rate of time preference.
e) The social rate of time preference.
The market rate of interest is determined by the demand for, and supply of, money in the economy. In a perfect capital market the interest rate would be the same throughout the economy and all individuals would be able to lend and borrow money at the same rate. Scott (1955) said that in a perfect capital market, the market rate of interest should prevail as the individual resource owner's rate of discount. Ciriacy-Wantrup (1952) supported the use of the market rate of interest, for discounting future revenue, if the market for the resource owner's assets was perfect.

"Market rates would be relevant for individual resource users if they could easily exchange on the market their expected future net revenues discounted on the basis of such rates." (Ciriacy-Wantrup, 1952)

This argument implies a perfect capital market, because the current market for assets, yielding future returns, would only be perfect if the discount rate were the same for everyone in the economy.

Within a perfect capital market, the resource owner would not use a discount rate higher than the market rate, for discounting future returns, for by so doing he would fail to maximize the present worth of his resource. Rather than resort to a higher rate of resource exploitation it would pay him to either sell the resource at its capitalized market value or borrow money at the going rate.
Similarly, the resource owner, in a perfect capital market, would not use a rate of discount lower than the market rate for, rather than do this, it would pay him to capitalize the resource and lend the money, thus realized, at the going market rate of interest.

Capital markets are not perfect and differential lending and borrowing rates usually prevail throughout the economic system. In an imperfect capital market, at what rate of interest should the resource owner discount future returns?

Hirschleifer, Dehaven and Milliman (1960), in discussing water resources, stated that, even in an imperfect capital market, the going market rate of interest should be used to discount future returns.

"We can scarcely believe that those responsible for making water investment decisions can do better than to accept the, admittedly imperfect, market rates of interest as their guide to relative intertemporal values of goods and services." (Hirschleifer et. al., 1960)

Ciriacy-Wantrup believed that, in an imperfect capital market, the individuals' rate of time preference should be used as a rate of discount. He defined the rate of individual time preference as:
"a ratio between the present marginal utility of pecuniary net revenues in more distant future intervals and the present marginal utility of the same amount of money in intervals nearer to the present and reduced by unity; it may be expressed in per cent and per unit of time." (Ciriacy-Wantrup, 1952)

Because time preference is a marginal concept, individual time preferences are affected by the level of income:

"economists generally accept the theorem that a unit of income - a dollar - becomes less and less effective in influencing economic decisions as income increases. ------
In time economics, we are interested in the ratio between the effectiveness (in influencing economic decisions) of the identical amount of income in different planning periods. If the theorem is approximated, this ratio must also decrease progressively with increasing income levels." (Ciriacy-Wantrup, 1952)

He also used the fact that the rate of time preference decreases as income increases to show why large corporations and government agencies tend to be more conservative in their approach to natural resource planning than small private firms and individuals.

The rate of time preference is not necessarily
connected to the interest rates prevailing in the economy:

"Interest rate is not in itself an expression of time preference. It serves to guide the decision of a person in choosing whether to save or spend. Some would choose to save even if the interest rate were negative (and inflation may make it effectively so); others choose to spend even if the interest rate is very high." (Price, 1958)

Scott (1955) stated that in an imperfect capital market the resource owner's rate of discount must be at least as high as the rate at which he can lend. The rate at which a resource owner can lend is his opportunity cost of capital funds. This criterion appears to be logical, because if the resource owner discounted future returns at a rate less than his lending rate he would fail to maximize the present value of his own assets. The resource owner's discount rate may be higher than his borrowing rate if his alternative investment opportunity yields a higher interest rate than the borrowing rate. If, however, the yield on his next best alternative investment is less than the borrowing rate, and he has a large supply of funds at his disposal, his discount rate may be lower than his borrowing rate. If, on the other hand, the yield on his next best alternative investment is lower than the resource owner's borrowing rate, and he does not have an internal supply of funds, then his borrowing rate must rule his investment decisions.
Thus, large corporations or government agencies will usually be faced with a low borrowing rate but will have several good alternative investment opportunities and will be ruled in their investment decisions by the opportunity cost of their capital assets. A small individual resource owner, however, will usually be faced by a high borrowing rate and may use this rate as the discount rate on his future revenues. An individual resource owner may have a much higher short run, than long run, discount rate. He may periodically have an urgent need for liquid funds to settle current accounts or purchase a major item for current consumption. The interest rate which he would have to pay on a loan at short notice will usually be higher than his normal borrowing rate and thus his discount rate will be consequently higher. This view was expressed by Scott (1955):

"if his (the resource owner's) wealth is locked up in a natural asset, which he is unable to divide physically or to borrow against, he may be personally so short of liquid funds that he is willing to pay a very high interest for money, or, what comes to the same thing, to sell the asset at a price which represents its future earnings capitalized at a very high rate. This will particularly be the case if his need for liquidity arises at short notice relative to the time needed by lenders to appraise the investment and the risks connected with it."
3. Social Rate of Interest

One aspect of time discounting, over which much controversy has taken place, is whether or not projects of social significance should be discounted at a lower rate of interest than private projects. Some writers (Pigou, 1932; Marglin, 1963; and Feldstein, 1964) have suggested that social time preference attaches more weight to the future than private time preference, and that it is the former which is relevant for determining the allocation of society's resources over time.

They say that the market determination of values between present and future goods and services neglects the claims of the future. Unborn generations are not represented in the current market place and, therefore, decisions concerning the future are bound to be one sided. Pigou believed that society, left to its own devices, would base its intertemporal investment decisions on an "irrational" time preference. In a much quoted section of his book entitled The Economics of Welfare he stated:

"There is widespread agreement that the State should protect the interest of the future in some degree against the effects of our irrational discounting and of our preference for ourselves over our descendents." (Pigou, 1932)

Marglin (1963) suggested that each individual's preference
for current consumption might be less (i.e. his discount rate might be lower), if there was a government-organized programme, for imposing sacrifices on a large section of the population, than if the discount note was left to individuals in the market place.

On efficiency grounds the concept of a social rate of interest is open to severe criticism:

"Assuming that the private and public spheres are divided, the adoption, say, of a 3 per cent discount rate in the public sphere and a 6 per cent discount rate in the private sphere for investments of comparable risk means that there will be investments in the private sphere not undertaken because they will not be justified. Meanwhile, however, projects yielding only 3 per cent are being adopted in the public sphere. On efficiency grounds, the disparity of interest rates will lead to the adoption of public projects that are less productive than private projects which are not being adopted. Note that the question of the claims of the future versus the present do not enter into the conclusion. The disparity of interest rate means that, given the aggregate amount of present sacrifice less is provided for the future when less productive investments are undertaken." (Hirschleifer et al., 1960)

Hirschleiffer et al. went on to suggest that inefficiency might be avoided if the government took steps
to push down market rates of interest to the social rate, so that all investments, whether in the public or private sectors, would be carried out on the same basis.

Scott (1955) pointed out the difficulties of administering a system incorporating two discount rates. Who, for example, should decide which projects should use the lower discount rate and which the higher? Practically all industries could present a legitimate claim on the lower rate and, Scott suggested, the government may eventually have to enforce, throughout the whole economy, a rate of interest lower than that which would prevail otherwise. Scott appealed to Keynesian analysis to show that a lower rate of interest could increase aggregate demand and an inflationary situation would result. Increased aggregate demand would mean greater investment in capital equipment and stock resources, required for capital formation, would be depleted at a greater rate than under higher interest rates, thus defeating the major objective of a low interest policy.

A common argument used in favour of lower discount rates for public projects is that government agencies are in a position to take into account future social benefits and costs whereas private entrepreneurs are only interested in private values. For example, the United States Department of agriculture (1964) stated:
"A number of considerations are arguments for holding the Federal rate for timber growing below such a level as 5 or 6 per cent. One is the existence of fringe benefits of Federal timber management: benefits from non-timber values and from pursuance of the national conservation policy to alter resource use in favour of future generations. Among fringe benefits may also be included that of helping to secure the national raw material supply, a benefit to society analogous to what the integrated private firm enjoys, and similarly serving to lower the guiding rate of interest."

While it is true that public agencies should be aware of the social benefits and costs of resource management, such considerations do not necessarily justify lower discount rates. Social considerations will modify the future net revenues, accruing to a project, but once these social factors have been identified there seems to be no reason for modifying the discount rate. If a government agency used a lower discount rate for all its projects this would be tantamount to assuming that all projects bestowed an equal benefit on society. This is simply not so. Many projects undertaken by government agencies may have no social significance, whatsoever. Social values should be appraised by government agencies as thoroughly as private values but both should be discounted at the same rate.
4. Effect of Risk on the Interest Rate

In the capital market it is generally assumed that the riskier an investment is, the higher must be its rate of return. If, for example, the average rate of return on a risk-free investment in the economy is 5 per cent, then an investment in which there is a 50 per cent chance of default in payment, must yield at least 10 per cent, if investors are to be attracted. That is, the expected long run yield on the investment must be at least as high as the yield on a risk-free investment. Of course, there may be some people who obtain satisfaction from gambling and are willing to accept a lower rate than 10 per cent. A gambler may prefer a 50 per cent chance of obtaining a 7 per cent return to a certain return of 5 per cent. Similarly, there will be investors who are risk avoiders and will require a higher rate than 10 per cent. It has been put forward (Krutilla and Eckstein, 1957) that governments and large corporations can spread their risks and can, therefore, base their discount rate on the statistically determined expected return on their investments. Small firms and individuals, on the other hand, will require a risk aversion premium, over and above the long run expected returns of their investments, and will, therefore, have a higher rate of discount on the future.

From the foregoing discussion it would appear that
the degree of risk to which an investment is exposed, must influence the discount rate used in evaluating that investment. The degree of risk is usually cited as one of the main determinants of the operative discount rate for a project:

"The owner's guiding rate of interest for forestry is influenced by his judgement of the relative risks (and uncertainties) in forestry as compared with the alternative objects of investment and spending. The higher the risks in forestry relative to other enterprises, the higher the guiding rate of interest; that is, the more the forest enterprise has to earn in order to be comparatively attractive."

(United States Department of Agriculture, 1963) (Similar views have been expressed by Duerr (1960).

In recent years, there has been a tendency for natural resource economists to treat risk in a different manner. It has been pointed out (Hirschleifer et al., 1960) that to include a risk factor in the discount rate is to assume that risk is a compounding function of time, like interest. In fact, risk may be irregularly variable over time and to discount at higher rates may give risk too much weight in the decision making process. It has been suggested that, instead of incorporating a risk allowance in the discount rate, future benefits and costs should be weighted by their probability of occurrence. For example, if there
is a 75 per cent probability that net benefits of a project, 10 years hence, will be $1000 and a 25 per cent probability that they will be zero, the net benefits should be evaluated in present terms by discounting the expected net return, that is $1000 \times 0.75$ at the risk free discount rate. This method of dealing with future risks has been discussed by Krutilla and Eckstein (1958); Hirschleifer et al. (1960); and Sewell et al. (1961).

In the light of the above discussion, therefore, it would appear that the most efficient and objective criteria for choosing a discount rate are as follows:

(a) Discount future net revenues and costs at a rate representative of the decision maker's expected rate of return on his next best alternative investment.

or, if the yield on the decision maker's next best alternative investment is lower than his borrowing rate and, in addition, he does not have access to a supply of internal funds then:

(b) Discount future net revenues and costs at a rate representative of the price which the decision maker must pay for access to liquid funds i.e. his borrowing rate.
CHAPTER FOUR
Advantages Claimed for Sustained Yield Forest Management

Prior to discussing problems raised by sustained yield management, a critical appraisal will be made of the rationale for the policy. What motivates foresters to advocate and practise the policy of sustained yield? There are many facets to this question and there is a danger of being too sophisticated in seeking an answer. The main motives for the adoption of sustained yield appear to be as follows:

1. Preservation of the Forest Resource for Future Generations

The argument that foresters are under an obligation to pass the forest resource to future generations, in an unimpaired or improved state, has a strong emotional appeal and is probably one of the strongest motives for the adoption of sustained yield policies.

Two main reasons exist to support the above argument. The first has ethical overtones and the second is economic.

Firstly, there is a feeling on the part of many foresters, and laymen, that the practise of forestry per se
is desirable and should be encouraged regardless of cost. They believe that forestry is intrinsically good and that forests enrich a society regardless of their contribution to the social product.

The intrinsic value of natural resources has always been one of the cornerstones of conservationist philosophy and has its roots in the Judaeo-Christian teachings of western thought (Glacken, 1956). Man is viewed as the trustee of an earth created by a divine power and has, therefore, to treat the resources of the earth with respect and use them wisely and carefully.

It is difficult to criticize such motives for sustained yield policy for they are outside the realm of economics. The most the economist can do is to bring to the attention of society the costs of its actions.

The second basis for the argument, that forests should be passed on unimpaired to future generations, is purely economic. Proponents of this view believe that forests are a scarce resource and that if they are depleted, by the present generation, the productive capacity and economic welfare of future generations will be impaired.

This view is open to severe criticism (see Chapter Three). In order to justify sustained yield on the grounds that it is necessary to protect the future economic well being of society, one has to assume that the demand for
timber in the future will be similar to the demand today and that if the present generation fails to provide posterity with a sufficiently large endowment of timber, then future generations will suffer because wood will always be an indispensable part of the social capital. Clearly, this position is untenable for, as pointed out in the previous chapter, scarcity is an economic rather than a physical phenomenon and there are always forces at work in the economy which tend to ameliorate the effects of physical resource depletion.

The fear of timber scarcity was a more valid argument for the practice of sustained yield during the 17th and 18th Centuries when the policy was developed in western Europe. It was legitimate, at that time, to consider that wood was an indispensable resource. Wood was the primary fuel; the principal building material; and was necessary for the development of industries such as mining and iron smelting. Maritime nations were entirely dependent on wood for ship building. Wood had played a major role in the economic life of most communities for thousands of years and there was no reason to believe that patterns of demand would change in the future. In addition, communications were poor and the high weight: value ratio of most forest products made their transportation uneconomic. The mercantile philosophy of the times also favoured sustained
yield management. The mercantilist believed in national self sufficiency and raised high tariff barriers against the importation of raw materials (Gould, 1964). Under these circumstances, foresters were probably justified in assuming that, unless forest management made provision for the future, the livelihood of future generations would be threatened. Today, however, in highly developed economies, conditions are completely different (Walters, 1965). It cannot be assumed that consumer demand is static. In many countries population and per capita income are growing at unprecedented rates and consumer tastes and preferences are being influenced by a countless number of external factors. Wood is no longer an indispensable commodity. It has a multitude of competitors in all its traditional uses and every year new, competitive products are being created. Some of these products are technically superior to wood and much cheaper to produce. Improved communications and transportation systems allow wood to be shifted in bulk over great distances, quickly and efficiently, at relatively low cost. Local timber shortages are no longer important. Economically developed countries are no longer dependent on timber supplies within their own frontiers and international trade in forest products is growing annually. Most governments subscribe, at least in principle, to free trade practices.
Absolute world shortages of timber are not anticipated. Throughout most of the world, forestry could be classified as a primitive industry. Timber is harvested from virgin stands and most technological innovations are directed at the extensive margin. Only a small portion of the world's total forest resources has been exploited and intensive silviculture is restricted to Western Europe, the Southern United States, Australia, New Zealand, South Africa, and parts of Asia which have been subject to European influences. Even in these areas, silvicultural practices are rudimentary and there is a great deal of scope for technological improvement.

2. Risks and Uncertainties of Forestry Enterprises

The high degree of risk and uncertainty which surrounds any forest enterprise is often cited as a motive for the practise of sustained yield forest management. It is said (Chapman, 1950; Davis, 1954), that sustained yield management decreases the risks attached to forestry enterprises and, therefore, encourages investment in the forest resource.

The distinction between risk and uncertainty was first made by Knight (1922). Knight defined risk as a situation in which the outcome is not certain but the probability distribution of alternative outcomes is known,
or can be estimated in an objective manner. Uncertainty, is defined as a situation in which the unknown outcomes cannot be predicted in probabilistic terms.\textsuperscript{9}

In forestry, risks are usually a physical nature and uncertainties of an economic nature. The chance that the forest crop will be lost through fire or disease should be classified as a risk and the chance that, in the long run, there will be a downward trend in the demand for, and prices of, forest products, should be classified as an uncertainty. Physical risks tend to influence forest management decisions less than uncertainties. There is generally sufficient knowledge about the physical risks of growing timber to allow large companies and government agencies to insure themselves against such losses, internally, and, in some places, insurance companies provide small private forest owners with adequate coverage against physical loss. Market uncertainties, on the other hand, are uninsurable.

Market uncertainties, which may influence the decision to practise sustained yield forest management, may be divided into two categories. Firstly, there are uncertainties surrounding the future demand for forest

\textsuperscript{9} Knight arrived at this distinction as a logical explanation to the existence of profits in a competitive economy. He believed that profit is the entrepreneurs 'reward' for bearing uncertainty. He argued that if all risks were measurable and, therefore, insurable, there would be no place for profits in the competitive system. The very existence of profits, he said, proves that uninsurable uncertainties exist.
products and secondly, there are uncertainties about the future supply of raw material.

When an entrepreneur begins production he gambles on there being an adequate demand for his product when he is ready to put it on the market. The longer the production period, the more difficult it is to forecast future demand and the greater the market uncertainty. Economic forecasts, which involve the interaction of many complex variables, are difficult to make. In the business world, forecasts for more than three to five years in advance are regarded with extreme scepticism. In forestry, however, in order to choose an optimum management plan, it may be necessary to forecast economic conditions several decades in the future and, therefore, the forest manager is faced with extreme uncertainty. The market uncertainties attached to forestry are alleviated, somewhat, by the nature of the product. In forestry, provided cutting plans are sufficiently flexible, short term cyclical fluctuations in the demand for timber can be largely ignored. Wood is a durable product and can be reserved on the stump until a propitious market appears, without impairing its quality. The real market uncertainty attached to forestry is that there will be a secular downward trend in the demand for forest products.

It is not at once apparent why sustained yield
management should be a reaction to extreme uncertainty. One would expect that a rational forest manager, faced with extreme uncertainty about the future, would choose to maximize the value of his enterprise in the short run and discount the future at a very high rate. The adoption of sustained yield would seem to indicate that the forest owner is not uncertain about the future but is fairly confident that the current demand for his products will continue indefinitely.

It would appear that a forest owner who practices sustained yield, in the face of uncertainty, is unwilling to risk the loss of future markets but is willing to risk future declines in the demand for forest products and the opportunity cost which such declines would entail. To such an owner the utility of having a permanent supply of wood, which will allow him to take advantage, to a degree, of any favourable changes in the market situation, outweighs the utility afforded by a current, relatively risk-free income. This argument may have some validity if one considers the long production period in forestry enterprises. If the forest owner decides, in the face of uncertainty, to harvest his crop as quickly as possible and then finds that the price of forest products is rising, it may be impossible for him to reverse his original decision, and he may sustain a
considerable loss. The forest manager who favours sustained yield is, evidently, not prepared to take this chance. A public forest agency, particularly, may value highly a permanent supply of timber as a hedge against market uncertainties. In the face of uncertainty, therefore, it is impossible to say that a forest owner who chooses to practise sustained yield is wrong, provided he has carefully weighed the alternatives. Any choice involving uncertainty can be considered rational provided it indicates a consistent and systematic ordering of alternatives.

Uncertainties surrounding the future supply of the forest resource may motivate integrated forest companies to practise sustained yield forest management. In the absence of a market for timber, or if the market for timber is imperfect, or otherwise subject to a degree of uncertainty, a private forest company, which operates its own utilization plant, may decide to practise sustained yield on its own forest lands in order to stay in business. It would be quite rational for a company to value the survival of the corporate body above the maximization of profits. It would regard the financial loss, in the form of a revenue forgone, in the forestry sector of its enterprise, as the price it has to pay for insurance against the uncertainties of the open market. This view has been expressed by the United
States Department of Agriculture (1963):

"The typical firm in this class (large scale corporate ownership) looks to its plant investments as its primary source of profits and would like to expect a high rate of return from these investments. From its timber resources it expects a sustaining flow of raw materials, protection from the vagaries of the open market, and thus security in its profit position, but ordinarily only a low intrinsic rate of return."

It would appear, therefore, that in the face of uncertainty, sustained yield forest management might be justified, provided the forest manager is aware of, and has given consideration to, all the possible management alternatives. The comparison of management alternatives and the factors affecting decision making in uncertain situations will be discussed in the next chapter.

3. Provision of a Regular Income

The provision of a regular, or periodic, income is usually cited as one of the main reasons for practising sustained yield forestry. It is said that, if forestry is to be given the same status as other business enterprises, it must provide regular annual, or periodic, returns.

"When forestry is to be practised as an independent industry, it becomes desirable, as in any large mercantile establishment, to plan, organize, and manage the business so as to secure, continuously and systematically, a regular annual income, nearly equal or increasing year by year."

(Fernow, 1902)
Chapman (1926) stated that the main virtue of sustained yield was that it would provide an annual income or dividend which could be gauged, like other businesses, on its relation to the capital invested in the forest and Buttrick (1948) expressed the belief that forestry is only possible as a business if it provides regular annual returns.

An analogy is often drawn between the normal growing stock of a sustained yield forest and the capital equipment of an industrial enterprise. The annual sustainable yield of the forest is likened to the return on this capital. The return on the forest enterprise is found by expressing the value of the sustainable annual yield as a percentage of the value of the normal growing stock. It is said that if forestry can be presented to the public in this form it will be considered a more attractive proposition and the flow of capital into the forest industries will increase.

A forest enterprise organized on a sustained yield basis may appear, at first sight, to be an attractive proposition. This is largely a delusion, however. The only way by which two streams of income, occurring over time, can be compared in a rational manner, is in terms of their total present worth. Each future net income must be discounted to the present at the investor's alternative rate of return. If the total present worth of the sustained yield enterprise is less than the present worth of the forest under some
alternative form of management, then sustained yield must be rejected by the rational forest owner.

It may be argued that some people prefer a regular annual return to an irregular income even though the irregular income has a higher present worth. This is well illustrated in the market for securities where many investors prefer to buy bonds, giving a fixed annuity, rather than the more capricious common stocks. This is largely a risk phenomenon, however, Investors are attracted to bonds because their yield is usually subject to a far lesser degree of uncertainty than the yield of common stocks. There is no reason to believe, however, that future revenues under sustained yield management are any more certain than under any other form of forest regulation and to favour sustained yield, on the grounds that it provides a regular annual income, appears to be completely irrational, if such a system of management fails to maximize the present worth of the forest enterprise.

4. Protection of Social Values

Forests are essentially a multiple use resource. Apart from providing wood products they yield such benefits as recreation, watershed protection, and, in many parts of world, shelter and forage for livestock. The protection of
such values is often cited as one of the main motives for practising sustained yield forest management.

Many of the benefits accruing to the forest resource are of a non-specific nature. That is, they benefit not only the forest resource owner but the whole of society. The non-specific nature of the forest resource is often used to justify government intervention in the forest industry and the enforcement of sustained yield policies. It is argued that the forest owner, seeking to maximize his own profits, will fail to maximize the net social benefits of the resource. He will use the forest resource at some rate other than the social optimum. It is, therefore, necessary for the government to control the rate of forest use in order to insure that social interests are protected.

It is certainly true that, in many cases, there are extreme differences between the social and private objectives of forest management. These discrepancies may often justify government intervention to protect the public interest, but do they justify the adoption of sustained yield management? In order to criticize the rate of private forest use, on social grounds, it is first necessary to show that the social values in question are truly affected by the rate of use. All too often, governments fail to identify or quantify the social values they are striving to protect. It is seldom recognized that there are large
areas of forest land which have no value other than the production of timber and these would best serve society by being managed solely on a profit maximizing basis.

Sustained yield is almost invariably looked upon as the key to good forest management and the most efficient way of protecting the social values of the forest. Sustained yield is, in fact, a method by which the timber production of a forest area is controlled and does not necessarily enhance the production of the non-wood products or protect social values. The protection of social values may, on occasion, be served best by a rate of exploitation either faster or slower than that rate indicated by sustained yield policy. It may often be the case that the production of the non-wood values of the forest is completely independent of the cutting rate. For example, the capacity of a forest to protect a watershed may be independent of the cutting rate provided regeneration is always encouraged following logging.

Alternatives to sustained yield forest management are seldom considered by public forest agencies. Few attempts are made to compare the social benefits and costs under one system of management with those under another. Although many references are made to the multiple purpose nature of forestry by public forest authorities, very few
attempts are made to calculate the optimum product mix of forest areas or to integrate forest uses in a systematic manner.

5. Stabilization of Communities and the Provision of Permanent Employment

Probably the most common argument put forward in favour of sustained yield forest management is that it performs a social service by providing a permanent industry around which can be built a stable community and that by providing an even flow of timber to the forest industries stable income and continuous employment are insured. This motive for the practice of sustained yield is closely related to the social motives cited in the previous section, but is considered important enough to warrant a separate discussion.

If a forest area is dedicated to perpetual production, it is said that permanent public utilities become feasible; workers in the forest industry settle permanently in the locality with their families; schools and other social service centres are built and permanently staffed; and private capital is drawn into the area to provide shops and places of entertainment. The administrators hope that, eventually, secondary industries will be established thus increasing the employment opportunities and leading to further expansion. The eventual outcome will be the
establishment, in a once underdeveloped area, of a permanent community. Great emphasis is put on this aspect of sustained yield management, particularly in countries with large areas of undeveloped wilderness or problems of rural poverty stemming from economic stagnation.

Sloan (1945), in his report on the forestry resource of British Columbia stated:

"A sustained yield policy has, as one objective, the maintenance of forest cover and growth, thus ensuring a perpetual supply of raw material for forest industries with consequent stability of industrial communities and assurance of permanent pay rolls.

---- Continuity of employment has, as its sequel, stable, settled and prosperous communities." (Sloan, 1945)

The use of sustained yield forest management as a vehicle of economic development in rural communities may, of course, be commendable in many cases and may be of very great social significance. Unfortunately, however, the decision to use the forest resource in this way often appears to be one of political expediency rather than economic rationality. Foresters and politicians seem loathe to admit that, in some areas, the best national interest would be served by a 'cut and get out policy' and that communities, in such cases, could be planned on a temporary basis, plant and equipment being amortized over
the period of resource exploitation. Forest administrators only seem to see the social benefits of sustained yield planning and fail to acknowledge the costs which inevitably accompany these benefits. It is naive to assume that a certain policy, because it appears to have some social merit, is necessarily the best plan to follow, until all the costs which accompany the policy have been identified and other alternative plans evaluated.
A Critique of Sustained Yield Forest Management from an Economic Viewpoint

It has been shown above, that sustained yield policies have become such an integral part of traditional forest management dogma that they are usually accepted without question by most foresters. Criticism of sustained yield is rare, but is not entirely lacking. The strongest, and best informed, attacks on sustained yield policies in recent years, have been made by Moore (1957), Guthrie and Armstrong (1961), and Gould (1962, 1964).

Moore conducted a study of forest tenures and taxes in Canada for the Canadian Tax Foundation and, in the course of his work, investigated several basic management concepts. Moore rejected sustained yield policy on the grounds that it was completely without economic justification.

"Deciding the most desirable rate of cut is an economic decision. So long as all benefits and costs are taken into account the most desirable rate of exploitation is the most profitable one; and this can be decided only with reference to changing market values." (Moore, 1957)

Guthrie and Armstrong did not criticize sustained yield as strongly as Moore but raised many interesting questions concerning the policy. They pointed out that the social and private costs of a "cut and get out" policy may
often be far less than the costs of practising sustained yield, and that sustained yield prevents response, on the part of entrepreneurs in the forest industry, to changes in the market demands for timber. Sustained yield, they said, fails to maximise the net returns to the forest resource:

"It (sustained yield policy) does not envisage divergence of cut from the volume obtained through growth, except over the very short run. Any such divergence is considered unwise. The implication of sustained yield, if thus applied, is that eventual gain of other values incurred by adhering to it will always be greater than the immediate gain to society occasioned by departing from it. But such an application is open to question." (Guthrie and Armstrong, 1961)

Gould's main concern was that forester's preoccupation with producing timber on a sustained yield basis causes them to neglect other values of the forest resource, principally recreation. According to Gould, the sustained yield concept, which was developed in Europe, has stifled other ideas in the United States. He pointed out that the economic conditions under which sustained yield policies were first formulated are not applicable in the United States today. He made a plea for more flexibility in forest management.

In the past, the critics of sustained yield policies have been vague in their assertions and have dealt with the subject in general terms. In this Chapter an attempt will be made to discuss the main drawbacks of sustained yield management in a more explicit manner.
1. Sustained Yield Forest Management Fails to Maximize the Present Worth of the Forest Enterprise

The rate of forest use under sustained yield management usually differs markedly from the most efficient utilization rate. It has been shown previously that economists assume, not without justification, that the main objective of a rational resource owner is to maximize the present worth of his enterprise. Forest managers often have a complete disregard for economic factors when considering the rate of forest exploitation. Allowable cuts are usually determined on a physical volume basis. No attempts are made to estimate the value of the proposed cut or to discount the value of future harvests to the present. The main aim of sustained yield policy is to equalise, as nearly as possible, the volume of timber harvested in each cutting period and to perpetuate the forest indefinitely. Usually any resemblance between the harvest rate under sustained yield policy and the most efficient rate of exploitation is purely coincidental.

In the previous chapter, the theory of resource use was described. This theory will now be used, specifically, to investigate the factors which determine the most efficient rate of forest exploitation.

The forest may be regarded as both a stock resource and a renewable resource. Stands of large dimension, old-growth timber, although they are physically renewable, may be regarded as a stock resource from an economic point of view.
Such stands may take over 200 years to mature and to consider investment over a period of this length is meaningless. In a modern economy investments of from 5 to 10 years are considered long term.

a. Old-growth

It was shown in Chapter Three that, in order to maximize the present worth of a stock resource, it is necessary to equate the discounted values of the marginal products for all periods. In the case of the old-growth forest resource, this general rule may have to be modified in one important respect. The old-growth forest may occupy land which could be put to some alternative use. This may be the production of a second-growth forest crop or it may be some use other than forestry. By holding the current old-growth forest crop, the resource owner is foregoing the rent which the land could earn in its alternative use. This additional cost of holding the old-growth timber will cause the forest owner to exploit the resource at a faster rate than would otherwise prevail.\(^\text{10}\)

This argument can be most easily demonstrated in the following manner:

In Footnote 7 (page 65) it was shown that the conditions under which the present worth of stock resource is maximized are as follows:

\[
(1) \quad V.M.P_0 = \frac{V.M.P_t}{(1/p)^t} = \frac{V.M.P_{nt}}{(1/p)^{nt}}
\]

where

- \(V.M.P_0\) = Value of the marginal product in the current period
- \(V.M.P_{nt}\) = Value of the marginal product in the nth period
- \(p\) = The resource owner’s alternative rate or return expressed as a decimal fraction.

In the case of a stock resource, such as the old-growth forest
Throughout the following discussion this additional cost of holding old-growth timber has been assumed away in order to simplify the presentation, but its effect on the old-growth harvest rate should be born in mind.

To the forest owner the value of the marginal product is the net revenue added by the last unit of input during the production period. The production period may be a year or a cutting cycle extending over several years. The volume of timber cut, during a certain period, is at the discretion of the resource owner. He may decide to cut nothing or he may cut all the timber at his disposal. To a certain point, the more he decides to cut, the greater will be the value of the marginal product because there will be economies of scale in production and each additional unit of input will add more to the total product than the previous unit. Eventually, however, as more and more timber is extracted, diminishing

resource, which occupies land having an alternative use; equation (1) should be modified as follows:

\[ (2) \quad V.M.P_o = V.M.P_t - a \frac{t}{(1/p)^t - 1} \]

\[ = V.M.P_{nt} - a_{nt} \frac{t}{(1/p)^{nt} - 1} \]

where

\[ V.M.P_o, V.M.P_t, V.M.P_{nt} \] and \( p \) are as defined above; period \( t \) is one year; and \( a \) is the potential annual rental of the land occupied by the old-growth (i.e. the rental foregone if the old-growth is withheld for an additional year).
returns to scale will usually be encountered and the value of the marginal product will decline.

If the firm is only operating for one period of production and wishes to maximize its return in the short run, it will operate at such a scale that the value of the marginal product is just equal to the value of the marginal factor. That is, the value added by the last unit of input is just equal to the cost of hiring that unit of input. This is illustrated in Figure 2. In this figure, only the declining part of the value of the marginal product schedule is shown, as line BZ. When the factor input is OD units, the value of the marginal product is CD dollars. The point X, indicates the optimum scale of production in the short run. At this point the value of the marginal product XY is just equal to the value of the marginal factor OA. If the firm is operating beyond this point, the marginal contribution to the total revenue of each additional unit of input, is less than the cost of hiring that unit of input. At point Z the marginal contribution to total revenue of the last added unit of input is zero.

11 In this part of the analysis perfectly competitive markets are assumed for all products and factors. The prices obtained for the products and the costs of hiring input factors are the same for all producers and no producer is in a position to influence either the product prices or factor costs.
Figure 2: Profit maximization in the short run.

\[ V \cdot M \cdot F = \text{Value of the Marginal Factor (Unit cost of each additional factor input)} \]

\[ V \cdot M \cdot P = \text{Value of the Marginal Product (Marginal physical product \times Unit product price)} \]
If the entrepreneur expects to remain in business indefinitely, he will be interested in maximizing the present worth of the forest resource in the long run and will have to consider how the value of the marginal product is going to change over time. The main factors affecting the present worth of the marginal product, over a period of time, are the interest rate, changes in the productivity of labour and capital inputs and changes in the price of the product.

The values of the marginal products in future periods must be discounted to the present at the firm's operative discount rate. At any positive rate of interest, provided the value of the marginal product is not increasing over time, it will pay the entrepreneur to increase present production, at the expense of future production, until the present worth of the marginal product is the same for all periods. The only restriction on the scale of production is that the marginal product must not be reduced below the opportunity cost of the factor inputs. That is, below the income which the factor inputs could earn in their next best alternative use.

The higher the interest rate, other things being equal, the greater will be the shift from future production to current production. This principle is illustrated in Figure 3, which shows how resource use should be distributed over three periods, in order to maximize present worth,
Figure 3: Operating in three time periods — for the maximization of present worth.

<table>
<thead>
<tr>
<th>Period I</th>
<th>Period II</th>
<th>Period III</th>
</tr>
</thead>
<tbody>
<tr>
<td>Period I:</td>
<td>Period II:</td>
<td>Period III:</td>
</tr>
<tr>
<td>Value of the marginal product, undiscounted:</td>
<td>Value of the marginal product, discounted at p % for time t:</td>
<td>Value of the marginal product, discounted at p % for time 2t:</td>
</tr>
</tbody>
</table>
assuming that the operative rate of discount is $p\%$ and no changes occur, during the period in question, in product price or factor productivity. The value of the marginal product in period II is discounted at $p\%$ for time $t$ and the value of the marginal product in period III is discounted at $p\%$ for time $2t$. A separate diagram is used to represent each period.

Suppose the resource owner decides to operate at the same scale of production in each period (as would be the case under sustained yield management) and uses OA units of input throughout. In period I the value of the marginal product will be OP dollars; in period II the value of the marginal product will be OQ dollars, that is PQ dollars less than in period I; and in period III, with factor inputs OA, the value of the marginal product will be OR dollars. Clearly, the resource owner could benefit by shifting units of production from the second and third periods to the first, until the value of the marginal product is the same in all periods. In the diagram, the optimum solution is given by a scale of operation of OX in period I; OY in period II; and OZ in period III. The value of the marginal product, which is now the same in all periods, is OT dollars.

If the interest rate was zero, a rise in the marginal productivity of labour and capital or an increase in the price of the product, over time, would cause the
value of the marginal product to rise, and it would pay the resource owner to redistribute production in favour of the future. Conversely, a fall in the productivity of labour and capital or a decrease in the price of the product, over time, would cause the resource owner to increase present production at the expense of future production.

Because old-growth timber is subject to mortality and decay, which reduces its value, over time, it will pay the resource owner to increase current production even if the interest rate is zero and no changes are expected to occur in input productivity or product price.

Normally, the entrepreneur will be faced with simultaneous changes in all the factors which affect the value of the marginal product. For example, if the interest rate, which is used to discount the value of future incomes, is greater than the rate of increase in factor productivity and product price, then there will be an incentive to increase current production and decrease future production. But, if the interest rate is less than the expected rate of increase in factor productivity and product price, then there will be a shift of production to the future.

If the resource is valueless today, but is expected to have a positive value at some future date, production will be postponed, regardless of the interest rate. Similarly, if the value of the resource is expected to fall to zero in the future, present production will be increased until the
value of the marginal product is equal to the opportunity cost of the factor inputs.

If the rate of increase in the value of the marginal product, due to increases in factor productivity and product price, is just equal to the rate of interest, then the time distribution of production, other things being equal, will be immaterial to the resource owner; and, in each period, he will maximize short run profits by equating the value of the marginal product with the value of the marginal factor.

So far, we have been considering the case of a small firm in a perfectly competitive market. In the case of an imperfect market, however, in which a few large firms control a major part of the resource, the analysis, although similar, must be modified. The resource owner, in an imperfect market situation, faces an inelastic demand curve for his product and can influence the price of the product by varying the rate of output. He must take this factor into consideration in arriving at his best course of action. He can no longer maximize profits in the short run by equating the value of the marginal product with marginal factor cost. The value of the marginal product is no longer an adequate measure of the marginal factor's contribution to the total revenue. This may be illustrated by a simple example.

Suppose that in a certain logging and milling operation,
men cut 10,000 board feet per day, which sells at an average price of 50 dollars per thousand board feet, giving a total revenue of 500 dollars. Eleven men cut 11,000 board feet per day, which sells at an average price of 48 dollars per thousand board feet. The value of the marginal product of the eleventh man is \((11 - 10) \times 48\) dollars, that is 48 dollars. However, the marginal contribution of the eleventh man, to the total revenue of the firm, is only \((48 \times 11) - (50 \times 10)\) dollars, that is 28 dollars. This latter value is called the marginal revenue product. The firm in an imperfect market will, therefore, maximize profits, in the short run, by adding units of input until the marginal revenue product is equal to the marginal factor cost (see Figure 4).

In the long run, a firm in an imperfect market will have to consider the effect of its current production on the future price of the product. A low volume of production in the current period, followed by an increase in output in future periods, will mean, other things being equal, a steadily declining product price. Conversely, a high volume of production in the current period, followed by a decrease in output in future periods, will mean a steadily rising product price. In order to maximize the present worth of his enterprise the resource owner should adjust the flow of output so that the marginal revenue product is the same in...
Figure 4: Short run profit maximization in an imperfect product market.

- **V·M·F**: Value of the Marginal Factor (Unit cost of each additional factor input)
- **V·M·P**: Value of the Marginal Product (Marginal physical product x Unit product price)
- **M·R·P**: Marginal Revenue Product (Marginal physical product x Marginal revenue)
all periods. When this is achieved it is impossible to increase the total net revenue by shifting units of output from one period to another.

Whereas old-growth stands must be treated as a stock resource, second-growth stands may be treated as a renewable resource. The supply of old-growth timber is completely inelastic. The decision to be made by the resource owner is whether to cut the timber now or at some future date. The timber which is cut today has gone forever and the volume available for the future has been reduced. It is inevitable that, eventually, all the resource will be used up and this fact dominates the decision making process.

b. Second Growth

In the case of second-growth timber, because it is renewable, the supply is only limited by the area of forest land available and the productive potential of this land. The main decisions to be made by the resource owner are: how much to invest in creating new supplies of timber; and when to harvest the current crop and make it available for consumption?

The rate of use of the second-growth forest resource will depend largely on the resource owner's investment decisions. These include decisions about regeneration
procedures, physical site improvement and cultural practices. For example, in places where natural regeneration is sparse or non-existent a decision will have to be made on whether to create new stands of timber artificially, or not. In areas where natural regeneration is the rule, a decision may have to be made on whether to modify the natural regeneration by artificial means or leave it entirely in the natural state. It may be profitable to encourage natural regeneration by scarification or slash burning, or to control artificially the species composition or spacing of the natural regeneration.

Once a crop is established, decisions have to be made as to the best method of silvicultural management. Should the forest stand be left to develop naturally, or should it be thinned, pruned, fertilized, or otherwise influenced artificially? All these decisions are investment decisions which influence the profitability of the forestry enterprise and the availability of the second-growth forest resource. They should be all subject to some degree of economic appraisal.

The forest owner should invest in measures designed to increase the productivity of his resource if the total value of all future net revenues, attributable to the investment, discounted to the present at the operative discount
rate, exceeds the initial investment cost.\textsuperscript{12}

In the case of an initial investment decision, concerning the artificial regeneration of a forest stand, the total net revenue accruing to the stand during the course of the rotation should be discounted to the present and compared to the regeneration costs. In the case of investment decisions concerned with raising the productivity of the forest crop, once it is established, care must be taken to isolate the true marginal returns to the procedures in question. For example, the marginal returns to fertilization should be calculated by discounting the expected net returns from the forest, with fertilization, and subtracting the discounted net returns expected without fertilization. Only if this value exceeds the cost of fertilization should the procedure be carried out. If artificial regeneration is to be carried out, in an area where natural regeneration can be obtained, the marginal return to the investment should be calculated by subtracting the discounted expected returns of the natural stand, from the discounted expected returns of the artificially regenerated stand.

\textsuperscript{12} The investment criterion can be expressed as follows: Invest in forest improvement measures if -

\[ I < \frac{r_1}{(1/p)^1} - \frac{r_2}{(1/p)^2} - \ldots - \frac{r_n}{(1/p)^n} \]

where:  
\( I \) = initial investment cost  
\( r_i \) = return on investment in period \( i \)  
\( p \) = firm's operative discount rate expressed as a decimal fraction
Forest investment decisions are further complicated by the fact that silvicultural measures, designed to increase the productivity of the stand, will usually affect the length of the financial rotation (the concept of the financial rotation will be discussed below). For example, the financial rotation of an untreated forest area might be 80 years but, if initial spacing control is carried out, it may reduce the financial rotation to 50 years, thus freeing the land, occupied by the stand, 30 years earlier. Therefore, in assessing the present net worth of the operation, the discounted expected net returns without spacing control, should be subtracted from the discounted expected net returns with spacing control plus the discounted maximum total rental which will accrue to the forest land during the 30 year period between 50 and 80 years.

It is clear that investment decisions in forestry require a great deal of speculation about the distant future and are, therefore, subject to a great deal of risk and uncertainty. In order to make forest investment decisions meaningful, risk and uncertainty should be acknowledged and dealt with in a systematic manner. The means by which risk and uncertainty can be accommodated in investment analysis will be discussed in Chapter 6.

A major problem which arises in evaluating forest investment is whether the owner of an integrated forest and
utilization plant should regard the forest and plant as separate enterprises or as a single unit. If the enterprise is regarded as a single unit, the returns on investments in the forest resource will be evaluated in terms of the value of the finished forest products. If, however, the forest resource is managed as an entity separate from the manufacturing plant, the returns on investments in the forest resource will be evaluated in terms of stumpage value of the timber crop. For example, the operator of a lumber mill integrated with a forest, will assess the outcome of a proposed fertilization programme in terms of the increased value of the lumber produced, if he treats his enterprise as a single unit, and in terms of the increased stumpage value of the forest crop, if he treats the forestry enterprise as a separate entity.

The attitude taken by the entrepreneur should depend on the market environment in which the company is operating. If there is a good market for stumpage, the entrepreneur should maximize the returns to each part of his business separately and evaluate forest investment in terms of stumpage values. The stumpage value of his own timber should be imputed as an input cost in the manufacturing sector of his enterprise. If, however, there is no market for stumpage, or if the market for stumpage is subject to a
high degree of uncertainty, it may be legitimate for the entrepreneur to treat his enterprise as a single unit and regard investment in the primary forest resource as a necessary cost of staying in business, or as an insurance premium against the uncertainties of the open market.

Having invested in the forest resource, the second decision facing the forest owner is when to harvest the crop and make it available for consumption. That is, what should be the length of the forest rotation? The criteria to be used in determining the length of the forest rotation have been a centre of controversy among foresters for over a century and there is still little agreement on the problem. To the economist the answer to the rotation problem is relatively simple; namely, that a forest crop should be harvested when the marginal cost of holding the standing timber is just equal to its marginal value growth. This rotation is usually referred to as the financial rotation and it is that rotation which maximizes the present worth of the forest resource. In arriving at the financial rotation both timber and non-timber values of the forest must be considered if the present worth of the resource is to be truly maximized. Financial rotations have been discussed in some detail by: Hiley (1955); Duerr (1960); Gaffney (1960); Haley (1964, 1966); and Pearse (1966) and only a brief outline of the principle will be given here.
There are two main costs involved in holding a standing crop of timber. Firstly, there is the opportunity cost of holding capital tied up in the growing timber stock and, secondly, there is the opportunity cost of the land occupied by the current forest crop. The opportunity cost of holding the growing stock is the income which the capital invested in the growing stock could earn in its next best alternative use. The opportunity cost of the land is the income (rent) which the land could earn in its next best alternative use.

The current forest crop should be harvested when the cost of holding it for another time period, one year or one cutting cycle, is equal to, or greater than, the expected value increment of the stand during this period. This marginal solution can be expressed symbolically as follows:

At the optimum rotation: \[ \text{dg} = \frac{G(p)}{a} \] \hspace{1cm} (1)

where:

- \( \text{dg} \) = annual value growth of the forest stand
- \( G \) = net capital value of the standing timber \((\text{timber value} - \text{harvesting costs})\)
- \( p \) = the forest owner's alternative rate of return expressed as a decimal fraction
- \( a \) = the opportunity cost (rent) per annum of holding the land under the current timber crop.
The determination of the optimum financial rotation is shown graphically in Figure 5.13

If the land occupied by the current timber crop finds its highest use in forestry, the value of 'a' in equation (1) is the maximum annual rental of the land under a forest crop and equation (1) cannot be used, in itself, to determine the financial rotation because the value of 'a' is a function of time and the maximum value of 'a' can only be determined when the optimum financial rotation is known. In order to determine the financial rotation it is necessary to introduce an independent expression for 'a'.

The land opportunity cost 'a' can be derived from the land expectation value, which is the present worth of the bare forest land and is calculated by subtracting the discounted value of all future costs, associated with raising a timber crop on the land, from the discounted value of all future revenues accruing to the land. In its simplest form the land expectation value (Se) can be expressed as follows:14

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13 This useful pictorial representation of the financial rotation problem was originated by Dr. P. H. Pearse of the Department of Economics, University of British Columbia.

14 This is the so-called Faustmann formula, named after the German forester Martin Faustmann who first applied it in 1849 to the determination of optimum financial rotations (Faustmann, 1849).
Figure 5: Determination of the optimum financial rotation.
\[ Se = \frac{G}{(1/p)^r} \cdot \frac{G}{(1/p)^{2r}} \cdot \frac{G}{(1/p)^{3r}} \cdot \ldots \cdot \frac{G}{(1/p)^{nr}} \]

\[ = \frac{G}{(1/p)^{TWF}} - 1 \] 

where:

\[ Se = \text{land expectation value} \]
\[ G = \text{net yield of the forest (timber value - harvesting costs) after a rotation of } r \text{ years} \]
\[ r = \text{length of rotation in years} \]
\[ p = \text{the forest owner's alternative rate of return expressed as a decimal fraction} \]

The annual opportunity cost of the forest land is the annual equivalent of the land expectation value. It is the annual return to the land which the forest owner must forego if he retains the current forest crop, and the highest use of the land is in forestry. Therefore, 'a' may be derived from equation (2) as follows:

\[ a = \frac{G(p)}{(1/p)^r} \cdot \frac{G(p)}{(1/p)^{r-1}} \] 

Substituting the value of 'a' from equation (3) in equation (1) we have:

\[ dg = G(p) \cdot \frac{G(p)}{(1/p)^{r-1}} \] 

which can be solved for the financial rotation 'r':

\[ r = \frac{\log dg - \log (dg - G(p))}{\log (1/p)} \] 

Although equation (5) is a correct mathematical expression for the optimum financial rotation it is usual,
in practise, to derive financial rotations by choosing a maximum land expectation value through a process of trial and error.

The length of the financial rotation is influenced by the volume increment of the forest crop (which is dependant on such factors as site index, stocking and silvicultural treatment); the value of the wood produced; the standards of utilization; the costs of logging; the alternative use of the forest land; and the operable rate of discount. All of these factors are subject to change over time and, therefore, it may be necessary to revise the forest rotation at frequent intervals. The change in the financial rotation may be gradual if, for example, it is caused by a secular change in timber prices, or it may be almost instantaneous if a technological breakthrough increases the growth rate of the crop or changes the economic standards of utilization.

Sustained yield management does not necessarily preclude a realistic policy of investment in the forest resource. For example, in Sweden a great deal of attention is given to the economic evaluation of forest investments within the framework of a National sustained yield policy (see for example Algvere, 1963). A forest owner's decision to invest in stand improvement may not be influenced at all
by the existence of a sustained yield policy. Even if sustained yield policies demand that every acre of forest felled is regenerated, the forest owner is usually free to make a decision as to the kind and timing of reforestation investments.

Sustained yield management may, however, prevent the forest owner from pursuing a rational rotation policy. In a forest regulated for sustained yield, the rotation, once determined, may be difficult to revise without disrupting the sustained yield structure of the forest. In Chapter One, it was shown that a normal forest is so arranged that, each year, the mean annual increment of the forest can be harvested, in perpetuity. If the rotation in such a forest is changed, the mean annual increment will no longer be the same and the age class distribution will have to be modified to return the forest to its normal state. It has been pointed out, however, that optimum financial rotations may change considerably over time and should be revised at frequent intervals.

Sustained yield management plans generally prescribe a single rotation for the whole of the management unit. Financial rotations, however, may differ considerably with site index (Gaffney, 1960; Haley, 1963) and it may be desirable to use different rotations on different sites.
within the same unit.

Sustained yield management demands that a certain volume of timber be produced periodically and, in order to meet these requirements, it may be necessary to designate stands for cutting which have not yet reached financial maturity or leave stands beyond the age of financial maturity. The optimum financial rotation, which maximizes the return to the forest land, is a unique point for a given set of conditions. Any deviation from the financial rotation will reduce the return to the forest land and impose a real cost on the forest owner and on society. This cost may be measured by subtracting the present worth of the forest, under the operative rotation, from the maximum potential present worth under the financial rotation.

2. Management of the Forest Resource for Maximum Sustained Yield

It was pointed out in Chapter One that, although sustained yield and yield maximization are not necessarily joint policies, they are closely associated in the opinion of many foresters, and are commonly used together as a basis for forest management. A critique of sustained yield management would be incomplete without a discussion of the implications of yield maximization.
It was shown in the previous section, that one of the main criticisms of sustained yield forest management, is that it imposes a regular harvest rate, which may be incompatible with the maximization of the present worth of the forest resource. Sustained yield management prescribes that equal, or near equal, volumes of timber be available for harvesting annually, but it does not specify the level at which the yield of the forest must be maintained. It is quite possible, therefore, within a sustained yield framework, to pursue investment and rotation policies which are based upon sound economic criteria.

Under a policy of maximum sustained yield, however, the forest resource must be managed in such a way that it will produce a maximum physical volume of timber annually. In order to pursue such a policy every acre of forest land must be maintained in a productive state regardless of the cost. Rotations are determined on purely physical grounds, the crop being harvested when the mean annual increment of wood, per acre, is maximized. Little thought is given to the value of the wood produced and the costs involved in holding standing timber are ignored. The crop may be held until the rate of return is reduced to zero. Such a policy must lead to a grossly inefficient allocation of resources.

In pursuing a policy of maximum sustained yield,
the forest resource manager is behaving as though wood is the only scarce resource and that the main object of society should be to maximize wood production. He demands that labour and capital be applied to the forest resource until maximum production is achieved, even though the marginal productivity of the factor inputs is reduced to zero. By ignoring the opportunity costs of labour and capital the forest owner implicitly assumes that these factors have no alternative use in the economy or, in other words, all the requirements of society have been completely satisfied except the demand for wood. Clearly, such a position is untenable.

The capitalistic economy treats all resources as scarce. The object of the price system is to allocate scarce resources in such a way that the welfare of society is maximized. As the needs of society change, over time, the price system reallocates resources to meet these changing needs. Under the free market system, factor inputs are employed until the value of their marginal product is the same in all uses. When the marginal unit, of any factor, may be indifferently employed in any use, social welfare is at a maximum provided there are no discrepancies between private and social values. Under such circumstances, it is impossible to shift a factor from one use to another,
without the gain in production value in its new use being more than offset by the loss of production value in its former use.

Capital should be employed in forestry until the rate of return on the last unit of capital added is just equal to the marginal rate of return on capital in any other sector of the economy which is of equal riskiness. If the demand for forest products increases, the price of stumpage will rise and the value of the marginal product of capital, in the forest industry, will increase. Capital will be transferred from other industries to the forest industry until the marginal products are once again equalized. In Figure 6 the distribution of factor inputs between two industries is illustrated. The value of the marginal product for industry A is represented by the line AB and for industry B by line CD. Optimal factor allocation exists when OX units of factor input are used in industry A and OY units of factor input are used in industry B, the value of the marginal product, at this point, being the same for each industry. Suppose that the demand for the product of industry B increases. The price of the product will rise and the value of the marginal product, in industry B, will shift upward to the right, being relocated at EF. The value of the marginal product in industry B is now OT dollars, RT
Figure 6: Optimum factor allocation between two industries.
dollars higher than in industry A. Input factors will move from industry A to industry B, where they can earn a higher rate of return, until the values of the marginal products are once again equalized. That is, when OW units of factor input are used in industry A and OZ units are used in industry B.

Of course, in reality the process of factor allocation leaves much to be desired. Imperfections exist in the factor markets and factors are often indivisible and lack mobility. Even so the price system does tend to move factors towards an optimal position. However, if one resource, such as forestry, is given preferential treatment, optimum factor allocation is impossible. The mechanism through which the preferences of society influence the economic system is broken down and resource allocation becomes arbitrary depending, not upon social choice, but upon political expediency.

3. Sustained Yield Forest Management May Prevent Response to the Cyclical Changes in the Demand for Forest Products

Demand for stumpage is derived from that for forest products. The forest product industries mainly produce capital goods. That is, they produce goods which are not used directly by the consumer but are used for either
capital formation or as inputs in other manufacturing industries. Lumber is mainly used for commercial, industrial and domestic building and in the packaging industries; softwood plywood is used, almost entirely, in construction; and a major part of paper and paper board production is used commercially. Demand for capital goods is particularly susceptible to changes in the level of economic activity, and the demands for all forest products show marked cyclical fluctuations.

The forest product industries do not usually carry large inventories of raw material. Such inventories would be bulky and expensive, and difficult to store, in addition they would represent a considerable investment which would be subject to interest charges and a high degree of risk. Some mills, in areas where the log supply is subject to seasonal fluctuations, may carry inventories of logs to last for several months but, over a period of one to two years, it is usual to find that the volume of timber manufactured corresponds quite closely with the volume cut from the forest. Cyclical fluctuations in the demand for forest products, therefore, bring about similar fluctuations in the demand for standing timber.

The response of price to cyclical changes in demand depends largely on the market structure, the length
of the cycle and the ratio of fixed to variable costs in the industry concerned. If the cycle is (or is expected to be) of very short duration, the rate of output, by the individual firms, may not respond at all. As far as possible, increases in demand will be met from existing inventories, but, if these inventories prove to be inadequate, price may be expected to rise steeply and fall again as demand decreases. If the cycle is expected to be of longer duration adjustments in the quantity supplied will take place. The longer the expected duration of the cycle, the more elastic will be the industrial supply curve and the smaller will be the response of price to changes in demand.

If the ratio of fixed to variable costs in an industry is very small, short run supply adjustments are more easily made than if this ratio is larger. Therefore, the larger the ratio of fixed to variable costs, the more pronounced will price fluctuations be during the economic cycle.

As a rule, those industries that have an oligopolistic or monopolistic structure tend to hold the price line during the course of an economic cycle and meet changes in demand by varying the rate of output. Industries with a more competitive structure tend to maintain the quantity supplied during cyclical changes in demand and the product price is allowed to fluctuate.
In order to maximize profits an entrepreneur should increase the rate of output during an upswing in the cycle when demand and, consequently, the value of the marginal product is rising and decrease the rate of output during a recession when the value of the marginal product is falling. The aim should be to equate the present worth of marginal profits in all phases of the cycle. In many industries this may be impossible to achieve; marginal adjustments in production are often difficult to make due to indivisibilities, institutional restrictions and imperfections in the factor markets. In the forest industry, however, marginal adjustments, in the volume of timber put on the market, are more easily made. Timber on the stump may be regarded as an inventory to be put on the market at the most propitious time. The timber produced, in a certain period, need not be put on the market during that period, but may be retained until some future date. Unlike many agricultural crops which must be marketed annually, the commercial maturity of timber is a relative matter. Stands which are financially immature in a period of low prices, may reach financial maturity as timber prices rise. The rational forest owner, with a reasonable knowledge of the market, should be able to control the amount of timber he puts on the market, in such a way that profit maximization is achieved.
Under sustained yield management, the forest owner is not free to vary the quantity of timber he puts on the market. In its most rigid form, sustained yield management prescribes that the annual cut should exactly equal the annual increment of the forest. The effective supply schedule for forest stumpage is, therefore, completely inelastic. A change in the demand for stumpage does not result in a change in the volume put on the market but is reflected solely in a change in price. The forest owner must supply the same volume of stumpage in a depression as in a boom. During a period of high stumpage prices it may be necessary to withhold stands which have achieved financial maturity and to cut them later in a period of low demand and price. In most modern forest economies, the policy is to balance the cut over a period of years, rather than annually. This may be an improvement, but is not necessarily so if the production period is out of phase with the major economic cycles. Fluctuations in demand are recurrent but are not periodic. Economic cycles differ widely in derivation and are almost impossible to forecast. It would be impossible to set an exact period in which growth and cut should be balanced, and be sure that this period would always correspond to the cycles of economic activity.

The restriction which sustained yield puts on supply adjustments, not only makes profit maximization, on
the part of the forest owner, difficult to achieve, but also may discourage private investment in the forest industry. Because changes in the demand for forest products bring about violent fluctuations in the price of standing timber, a forest enterprise, worked on a sustained yield basis, can anticipate pronounced cyclical instability in income. Investors, however, usually place a high premium on income stability, especially during cyclical contractions.

Of course, not all sustained yield plans are as rigid as envisaged above. Flexibility is often built into sustained yield plans which allows a certain amount of response, on the part of the forest manager, to cyclical demand fluctuations. There may be non-regulated sizes or species which become economic to log as the demand for forest products increases but are not included in the allowable cut calculations. For example, until recently in British Columbia allowable cut calculations did not include lodgepole pine or, in most regions, trees below 12 inches d.b.h. In a period of high demand, however, it may become economically feasible to log lodgepole pine for the manufacture of lumber and the zero marginal tree size may fall well below 12 inches d.b.h. Thus, the actual volume cut from a forest may increase as the demand for forest products increases without contravening the sustained yield restrictions.
4. Sustained Yield Forest Management May Retard Economic Growth and Development

Sustained yield forest policy is founded on a philosophy of economic stability, perhaps even stagnation, and the pursuit of this policy, in a country where forestry plays a major role in the economy, can retard economic growth and development.

Sustained yield, in its most rigid form, involves the imposition of an allowable annual, or periodic, cut on the forest resource and thus sets a physical limit on the size of the forest industry in the economy. This may be relatively unimportant in a country with only a small forest industry but if forestry plays a major role in the economy sustained yield virtually puts a ceiling on economic growth. As the forest industry approaches the capacity set by the sustained yield policy there will be a fall in the rate of increase in forest production and, therefore, a fall in the level of investment in the forest industries. There will thus be a steady fall in aggregate income and chronic unemployment may result. Once capacity level is reached there will be little or no net investment in the forest industries. The only way the economy can achieve a steady growth rate, under such circumstances, is for industries to develop which are not based on the forest resource.

It could be argued that, if sustained policies
were abandoned, a similar situation would result, as the forest resource was dissipated, and the final outcome would be worse because the country would be left with no forest resource base whatsoever. It appears, therefore, that in a country largely dependent on a forest resource, whether sustained sustained yield is practised or rejected, there will eventually be economic stagnation unless investment is diversified and new industries develop. If sustained yield is not practised, however, conditions for the creation of new industries may be more favourable than otherwise. Aggregate income may rise faster and could achieve a higher level than that level possible at sustained yield capacity. There may, therefore, be a greater supply of investable funds available for financing new industries and a better economic climate for industrial expansion. Sustained yield, with its emphasis on a perpetual supply of raw material, may tend to induce complacency amongst the entrepreneurs in the forest industry. If, however, sustained yield is not practised, entrepreneurs will have fewer illusions about the long run supply of raw material and there will be a greater incentive for a diversification of capital investments.

It is often argued, by proponents of sustained yield, that allowable cuts are not rigid but are determined by standards of utilization which, in their turn, are
determined by economic factors. Thus, a rise in the price of certain forest products, or a reduction in harvesting or manufacturing costs, will tend to increase the allowable cut. It is true that, as a rule, allowable cut calculations are subject to modification as economic conditions change. Often, however, allowable cut modifications follow, rather than anticipate, economic changes. That is, allowable cut calculations are based on the current economic limits of merchantability, and are only modified when it becomes apparent that economic conditions have changed and the former criteria for calculating the allowable cut are no longer appropriate. As a result, newly determined allowable cuts are often out of date before they are even introduced. Allowable cut calculations, if they are to be used at all, should anticipate, rather than follow, changes in demand and technology. Current allowable cut estimates should be based on the expected standards of utilization one rotation hence. The questions which forest managers should be asking themselves are: what kind of material should we be planning to produce for the future in stands which are being currently established and how long will it take to grow such material? The maintenance of allowable cuts in the future will not depend, ultimately, on the conservative use of currently mature timber but on sound, intelligent, investment in new
By failing to anticipate technological changes, sustained yield policies may seriously impair the future of the forest industries, by providing the wrong kind of raw material. There are numerous historical examples of this phenomenon. One of the most often quoted examples is that of the oaks planted for the British navy (Walters, 1965). Following the Napoleonic wars, acute shortages of timber, suitable for shipbuilding, caused the British to plant many thousands of acres of oak trees. These oaks are currently reaching a size suitable for shipbuilding, more than half a century after the last wooden warships disappeared from the seas! This mistake may be excused on the grounds that, when the oaks were planted, ships had been built of wood since the dawn of civilization and there was no reason to suppose that this practise would not continue. Today, however, technological change is very much in evidence. We can assume, with near certainty, that the type of forest products

Of course, some attempts have been made to anticipate economic changes in allowable cut calculations. In the United States, for example, the United States Forest Service bases the allowable cuts for National Forests on all trees of 7 inches d.b.h. and over, which is far below the current economic margin of merchantability in most regions. In British Columbia the allowable cut for the latest Sustained Yield Unit to be established (the Finlay S.Y.U.) has been calculated on the basis of trees 7.1 inches d.b.h. and over, in anticipation of the increased demand for pulpwood.
required in the future will differ markedly from those desired today. Forest management should try to anticipate these changes. It is useless to base forest management on a sustained yield plan designed to produce a maximum volume of large dimension sawlogs, in a world where the demand for such material is diminishing yearly. It would be better to capitalize on the large dimension material, while it is available, and allow the transition to smaller sizes to take place naturally.

5. Dedication to Sustained Yield Forest Management May Preclude Optimum Efficiency in Land Use

The whole concept of sustained yield is built around the ideal of perpetual forest management. Consequently, it is necessary to dedicate the area occupied by the forest to continuous timber production. In many countries, in which sustained yield forest management is practised, transfer of land from forest production, to some other use, is specifically forbidden by law. Even if land use changes are not forbidden, however, it is difficult to take away areas of land from forest production, without destroying the sustained yield structure of the forest. Under rigid sustained yield management it is impossible to achieve maximum efficiency in land use.
If there is to be optimum land allocation in a market economy, land must be free to move into its most productive use. The economic cost of using an acre of land, for a certain purpose, is the marginal net revenue which that acre could earn in its next best alternative use. The net revenue which a unit of land can earn, over and above its economic cost, is the economic or differential rent earned by the land. The aim of the profit-seeking land owner is to maximize economic rent. Land use, in the economy, is at an optimum when the rent earned by a marginal unit of land, in any use, is the same. When this distribution of land is achieved, nothing can be gained by shifting a unit of land from one use to another.

It is true that a great deal of land finds its highest use in forest production. Land use patterns and land values change rapidly, however, in an expanding economy. As populations grow, the demand for agricultural land, and land for urban development, increases. Forest owners who, previously, had no other use for their land, may be faced with several alternatives. Conflict between land uses inevitably arises but, given a reasonably free market for land, there is a strong tendency for land to move into its highest economic use. If large areas of land are set aside and dedicated, in perpetuity, to one use, maximum efficiency is impossible to achieve and the favoured industry is, in
effect, being subsidized at the expense of other enterprises in the area.
CHAPTER SIX

Alternative Approaches to Planned Forest Management

In the previous chapters the concept of sustained yield forest management has been examined and critically evaluated. It has been suggested that the policy of sustained yield is unsatisfactory as a universal goal of forest management; a position it currently occupies in most western nations. If sustained yield is to be abandoned, with what is it to be replaced? One often hears the argument that, sustained yield has many faults, but it cannot be replaced because there isn't an acceptable substitute. The time is fast approaching when foresters will not be able to support such a negative policy. Sustained yield policy is not infallible and is not, as has been so often suggested in the past, the answer to all the problems of forest management. It should not be regarded as axiomatic but should be relegated to its rightful position as a management idea to be compared with other alternatives and assessed in a rational manner. In this chapter a framework for a rational forest policy will be developed.

1. An Economic Approach

It will be assumed throughout this discussion that the country, or region, concerned is committed to forestry.
That is, the choice between forestry and non-forestry alternatives has already been made. The question which remains is how to use the forest resource to its best advantage?

The aim of a national forest resource policy should be to use the forest resource in such a way that its contribution to the welfare of society is maximized. In order to achieve this aim two conditions are necessary:

(a) For each management area, or region, that management plan should be chosen, from the possible alternatives, which maximizes the ratio of benefits to costs.\footnote{This is not the only criterion which might be used for choosing between alternative management plans. Other criteria, discussed in the literature, include: the comparison of maximum net benefits; the comparison of net benefit to cost ratios; and the comparison of internal rates of return. For comparing mutually exclusive projects, however, within the confines of a fixed budget; the benefit to cost ratio is considered to be the best criterion (Sewell et al., 1961).} 16

(b) The marginal benefit per unit cost should be the same for each management area, or region, in the forest economy.

The first condition assures the forest manager that, for each management region, a plan is chosen which
maximizes the return to the forest resource, per unit cost. The second condition is an optimising condition which results in an optimum distribution of the total forest budget throughout the forest economy. When this condition is fulfilled it is impossible to increase the net benefits, accruing to the forest resource, by shifting factor inputs from one sector of the forest economy to another.

The benefit-cost technique of project evaluation has been developed by economists and planning engineers and lends itself admirably to the problem of forest management planning. Before proceeding further, therefore, the technique of benefit-cost analysis will be described.

2. Benefit-Cost Analysis

Benefit-cost analysis was first developed in the United States as a method of assessing alternative, multiple use, river basin projects. It has been extensively used by the United States Corps of Engineers for more than half a century (Hammond, 1960). Although benefit-cost analysis was mainly developed for use in the field of water resources, it may be adapted for use in any situation in which a choice has to be made between alternative projects. It is particularly useful when the decision maker is faced with a number of intangible factors. According to Sewell et al. (1961)
"Benefit-cost analysis can provide a logical framework for the evaluation of one or more courses of action. It is also a comprehensive method for dealing with a number of factors some of which may be highly conjectural in nature. Numerous authorities both in industry and government circles have found it to be an excellent tool for the evaluation of alternative projects or programmes, their ultimate purpose being the selection of the one which would be the most suitable under a wide range of circumstances."

One of the most important and difficult steps in any benefit-cost analysis is the identification of all the relevant benefits and costs associated with the projects in question.

Benefits are defined as any advantageous effects accruing to the project, while costs are all those goods and services which society has to give up in order to realize the benefits.

Economists generally divide benefits into three main categories, these are: primary benefits; secondary benefits; and intangible benefits (Sewell et. al., 1961).

Primary benefits are those which accrue directly to those people making use of the goods and services produced by a certain project. In the case of a forestry programme, the value of the timber produced would be classified as a direct benefit.
Secondary benefits, are those which are indirectly associated with a certain project. If, in the course of implementing a forestry programme, roads are built and facilities provided which attract tourists to the area concerned, then the net value of the tourist industry, to the region, may be classed as a secondary benefit.

Intangible benefits, are those which are not normally bought and sold through the recognized market procedures. Many of the benefits which fall into this category are of a social nature. Forestry projects often involve the consideration of many intangible benefits such as the benefits derived from recreation, flood control or watershed protection. Intangible benefits are not, necessarily, unmeasurable. It may be uncommon to market a certain product and, therefore, no market for this product exists. It may be possible, however, to construct a hypothetical market for the product, for purposes of evaluation. This is sometimes the procedure when recreation benefits have to be evaluated. Economists use a market model to determine how much people would be willing to pay for recreation, on a particular area, if the need arose (Trice and Wood, 1958; Clawson, 1959).

Values may also be imputed to intangible benefits by making use of the potential costs of failing to carry out
the project in question. For example, the benefits of flood control may be assessed by considering the costs, which society would have to bear, if the project providing these benefits did not go into operation, or if an alternative plan was put into operation which did not provide such effective flood control.

Many intangible benefits, however, are unmeasurable and cannot be quantified. For example, it is sometimes claimed that recreation benefits not only the individual, but the whole of society. Recreation, it is said, helps produce well balanced, healthy, individuals and results in less mental illness, a happier society and less wastage of productive time due to sickness. Beazley (1961), in discussing the benefits derived by the individual and by society from outdoor recreation stated:

"We as a society, are better off in terms of our general frame of values because of the diffusion of individual's direct benefits of improved mental attitudes, better physical health and deeper education. We suffer fewer cases of poor mental and social health, including crime. There is a range of social complementarity between leisure time and gross national product. An increase in income results from people as a whole being better stimulated and more satisfied, who work better, produce more, innovate more and who are more creative over time, even though many of them may not have engaged in outdoor recreation."
Obviously, it is impossible to quantify such values and attribute them to a particular project. Nevertheless, they can be introduced into benefit-cost analysis in the form of negative or positive factors which are used to modify decisions made on a purely objective basis.

Costs, like benefits, may be divided into three major categories: primary costs; secondary costs; and intangible costs.

Primary costs, consist of those goods and services which must be given up by society in order to release the primary benefits of the project in question. In other words, the primary cost of a project should represent the opportunity cost of the project. The opportunity cost of a factor input is the benefits that factor would generate in its next best alternative use. If an input has no alternative opportunities for employment, there is no true cost associated with employing it in its single available use. If, for example, a forest labourer has no alternative opportunities for employment then the economic cost, measured in terms of alternatives foregone, of employing him in the forest industry is zero.

Secondary costs, are those opportunity costs associated with the production of the secondary benefits of a project.
Intangible costs, are the costs of factor inputs which are not normally priced on the market. For example, the construction of a pulp mill may involve a cost to society, or to individuals, in the form of water or air pollution. Intangible costs, like intangible benefits, may be evaluated by various analytical techniques. The cost of air pollution, for example, may be partly measured by the fall in real estate values in the area affected, or the loss in revenue from fisheries may be used to measure the cost of water pollution. As in the case of intangible benefits, however, such measurement techniques are not entirely adequate. For example, a fall in property values does not measure the effect on people's health and happiness of air pollution and the loss in revenue from fisheries does not take into account the pleasure, taken away from sports fishermen, by the pollution of rivers and streams.

Having identified the costs and benefits associated with each alternative project, the resource manager should compare projects on the basis of their benefit-cost ratios, weighted, if necessary, by a consideration of unmeasurable factors. Benefit-cost analysis may be used to examine the economic feasibility and determine the optimum scale of a single project; to choose between alternative projects; or to determine the optimum product mix when there is a conflict
between resource uses which is to be resolved by integration.

3. Use of Benefit-Cost Analysis in Planning Forest Management

The first step, in the creation of a unified forest management plan, should be to divide the region concerned into working units. This division may be made in a variety of ways:

(a) Geographically - Management units may be formed to correspond to natural geographic features such as a river basin or drainage area.

(b) Strategically - Management units may be formed from areas which supply an existing, or proposed, utilization plant.

(c) Functionally - Management units may be formed on the basis of the primary use of the forest area, such as timber production, recreation or watershed protection.

For each of the working units several alternative management plans should be formulated. The character of these plans will depend on the potential use and situation
of the area in question. For example, if an area is to be used solely for timber production, the alternative management plans might include:

(a) Sustained yield management incorporating a local integrated utilization plant established on a permanent basis.
(b) Management for maximum net revenue (according to the principles described in Chapter Three); shipping all the timber produced to a centrally located manufacturing plant.
(c) Management for maximum net revenue; manufacturing all the timber produced in temporary local mills to be amortized over the period of exploitation.

If an area has a recreation potential, the alternative management plans might include:

(a) Sustained yield management over the whole area incorporating a permanently based forest products
industry, permanent access facilities and permanent community services.

(b) Management for maximum net revenue from timber production over the whole area.

(c) Reservation of select areas for recreation with sustained yield management for timber production on the remaining area.

(d) Reservation of certain select areas for recreation with management for maximum net revenue from timber production on the remaining area.

(e) Reservation and development of the whole area for recreational purposes.

For many working units it would be possible to formulate an infinite number of alternative plans. It is the responsibility of the planner to choose the most relevant alternatives.

For each management alternative a benefit-cost ratio should be calculated which should take the following form:
If there are no immeasurable effects, that plan will be chosen which has the largest ratio of benefits to costs. If there are immeasurable effects, these must be taken into consideration and may influence the decision.

In order to further elucidate the use of benefit-cost analysis, in forest management planning, a simple numerical example will be considered.

Consider an area which is to be managed for the production of timber. The forest manager would like to compare a sustained yield plan, designed to produce a maximum volume of timber annually, with a plan designed to maximize profits by liquidating the timber over a twenty year period. A guide to the best course to follow can be gained by carrying out a benefit-cost analysis. Tables 1 and 2 compare the benefits and costs for the management plans in question.

The primary benefits consist of the net value of the timber produced from the forest area, discounted to the present at an interest rate which reflects the opportunity cost of the forest owner's capital. The primary costs are
those costs associated with the production of the timber product. They differ in content and value for each of the management alternatives.

In the case of the sustained yield plan, there will be an annual regeneration cost and such costs as maintenance, protection, and administration, will be higher than for the 20-year plan. If the sustained yield plan goes into operation, a local utilization plant will be established and transportation charges will be less than under the 20-year plan, in which the timber has to be hauled over a long distance to a centrally located plant. Also included in the primary costs are such things as housing construction and the provision of public utilities. In the case of the sustained yield plan such facilities will be established on a permanent basis. Buildings will be of a permanent nature, major access roads will be paved and proper drainage and sewage facilities will be layed. Under the 20-year plan, however, all buildings will be of a temporary nature and will be either transportable or built of cheap expendable materials. Roads will be largely unpaved and public utilities will be at a minimum.

Under the sustained yield plan, there will be secondary benefits in the form of secondary industries, attracted to the area by the presence of a permanent community based upon the forest resource. Great care has to
be exercised in attributing secondary benefits or costs to a proposed project. The secondary industries have got to be truly dependent on the primary project and could not develop spontaneously, in the absence of the project. It is often argued, for example, that a sustained yield plan will promote the establishment of a permanent utilization plant and the product of this plant is, therefore, cited as a secondary benefit of the sustained yield programme. This is not justified if the utilization plant would have been established in some other location, in the absence of the proposed sustained yield programme. The inclusion of the secondary benefits and costs of a project is more important when the analysis is being carried out from a local point of view rather than on a national scale.

Hypothetical values have been given to all the items appearing in the analysis and on this basis it is found that the sustained yield plan has a benefit-cost ratio of 2.67 and the 20-year plan a benefit-cost ratio of 6.00. Clearly, on the basis of the purely tangible factors, the 20-year plan is far superior. There are, however, several unmeasurable factors which must be considered. If the sustained yield plan is carried out the establishment of a permanent community will give rise to certain private and social intangible benefits. The workers will feel a greater sense of security and enjoy better amenities. They
Table 1 . Benefit Cost Analysis - Sustained Yield Plan

### Tangible Factors

<table>
<thead>
<tr>
<th>Benefits</th>
<th>Million Dollars</th>
<th>Costs</th>
<th>Million Dollars</th>
</tr>
</thead>
<tbody>
<tr>
<td>Present net worth of annual timber harvests in</td>
<td>50.0</td>
<td>Present worth of annual regeneration costs</td>
<td>0.1</td>
</tr>
<tr>
<td>perpetuity---------</td>
<td></td>
<td>Present worth of annual maintenance and protection costs</td>
<td>0.8</td>
</tr>
<tr>
<td>Present worth of future tax payments-</td>
<td></td>
<td>Present worth of future tax payments-</td>
<td>1.6</td>
</tr>
<tr>
<td>Present worth of administration costs for sustained yield unit-</td>
<td></td>
<td>Present worth of administration costs for sustained yield unit-</td>
<td>0.5</td>
</tr>
<tr>
<td>Cost of constructing permanent public utilities and social facilities-</td>
<td></td>
<td>Cost of constructing permanent public utilities and social facilities-</td>
<td>16.0</td>
</tr>
<tr>
<td>Total Tangible Benefits</td>
<td>80.0</td>
<td>Total Tangible Costs</td>
<td>30.0</td>
</tr>
</tbody>
</table>

### Intangible Factors

<table>
<thead>
<tr>
<th>Benefits</th>
<th>Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Social and private benefits of community stabilization.</td>
<td></td>
</tr>
</tbody>
</table>
Table 2 . Benefit Cost Analysis - Twenty-Year Exploitation Plan

Tangible Factors

<table>
<thead>
<tr>
<th>Benefits</th>
<th>Million Dollars</th>
<th>Costs</th>
<th>Million Dollars</th>
</tr>
</thead>
<tbody>
<tr>
<td>Present worth of timber harvested from the area during exploitation period</td>
<td>90.0</td>
<td>Present worth of annual maintenance and protection costs</td>
<td>0.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Present worth of future tax payments</td>
<td>3.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Present worth of administration costs</td>
<td>0.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cost of temporary living facilities and public utilities</td>
<td>11.0</td>
</tr>
<tr>
<td>Total Tangible Benefits</td>
<td>90.0</td>
<td>Total Tangible Costs</td>
<td>15.0</td>
</tr>
</tbody>
</table>

Intangible Factors

<table>
<thead>
<tr>
<th>Benefits</th>
<th>Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Social and Private costs of Community displacement.</td>
</tr>
</tbody>
</table>
will be able to settle with their families and be more content in their jobs. This may lead to less friction between management and labour and greater productivity.

The manager must decide whether the benefits of community stabilization, which accompany the sustained yield plan, outweigh the pecuniary disadvantages of this plan. The manager is faced with a pure value judgment which is outside the realm of economics. The most the economist can do is to make the manager aware of the costs of his alternative actions and place these alternatives into a logical framework.

When plans have been chosen for all the working units in a particular region, on the basis of their benefit-cost ratios, the scale of each plan should be adjusted at the margin, until the marginal benefit per unit cost is the same for all working units. If the budget available for regional development is large enough, each plan should be expanded to the point where its net benefits are maximized (i.e., the marginal benefit-cost ratio is 1:1 for each plan).

This principle is illustrated in Figure 7 which represents the plans chosen for two working units within a management region. For each management plan the average benefit-cost ratio \((E/C)\) and the marginal benefit-cost ratio \((dB/dc)\) have been plotted against total project cost. The plan chosen for Working Unit I has a maximum benefit-cost
Figure 7: Optimizing project scale by benefit-cost analysis.

a. Working Unit I.

b. Working Unit II.
ratio of 4:1 and the plan chosen for Working Unit II has a maximum benefit-cost ratio of 3:1. If the plans are operated at that scale which maximizes benefits per unit cost, their full economic potential, in terms of net benefits, is not being realised and the budget distribution between the two working units is not at an optimum.

If there is no budget constraint, each management plan should be expanded to the point where its net benefits are maximized. Thus, the scale of the plan for Working Unit I—as measured in terms of total cost—would be increased from OA to OB (Figure 7a) and the scale of the plan for Working Unit II would be increased from OC to OD (Figure 7b). At these scales of development the net benefits accruing to the management region would be at a maximum.

If the total budget available for regional development is insufficient to allow the maximization of net benefits, the regional planner, in order to optimise the distribution of the available budget, should adjust the scales of the management plans in such a way that their marginal benefit-cost ratios are equal. For example, under a certain budget constraint, the planner might find it necessary to adjust the scale of the plan for Working Unit I (Figure 7a) to OX and the scale of the plan for Working Unit II to OY (Figure 6b). At these scales of development the marginal benefit-cost ratio for each plan is 2:1. That
is, an additional dollar of expenditure, on either working unit, will give rise to benefits valued at 2 dollars. Under these circumstances, it is impossible, within a budget constraint of \((OX \neq OY)\) dollars, to increase the total net benefits accruing to the management region. There is no advantage, therefore, in any further redistribution of the available budget and an optimum has been achieved.

It cannot be claimed that benefit-cost analysis will provide a perfect answer to all the problems of resource allocation. Indeed, to regard it as an exact scientific method might be dangerous. It does, nevertheless, help the decision maker to see the crux of the problem. It identifies the main issues involved and provides a frame of reference in which to work. As a rule, decisions to practice sustained yield forestry are made without considering, or even recognizing, the costs involved. If methods, as outlined above, were used for forest management planning, the manager would at least know how his proposed plan compared to the possible alternatives, which would be an extremely valuable aid to arriving at a rational decision.

4. Linear Programming

In the previous section, benefit-cost analysis has
been described and it has been suggested that this technique might be used as an aid to forest management planning. The use of benefit-cost analysis in forest management planning raises many difficulties. One of the most important and serious of these is the evaluation of alternative cutting plans. In the example used to demonstrate benefit-cost analysis, cutting for sustained yield was compared to forest liquidation over a 20-year period. How should the cut be distributed in space and time in order to maximize profits, under a particular set of circumstances? What is the potential maximum net revenue under a sustained yield management plan? Unless these questions can be answered no rational comparison of management alternatives is possible.

It was shown in Chapter Three that, in order to maximize the profits of a forestry enterprise, an entrepreneur should behave in such a way that the present values of the marginal products, discounted to the present, are the same for all periods. This is a neat, theoretical way of prescribing entrepreneurial behaviour, but the empirical data necessary to follow such a prescription are rarely available to the forest manager and may be impossible to obtain. It may be very difficult to define the marginal input and it is usually impossible, even for someone adroit in economic analysis, to evaluate the marginal product.
Until recently, comparisons of cutting alternatives, as envisaged above, would have been labourious and expensive operations and would have been impossible to carry out in many cases. The development of high speed electronic computers, however, has made the task much simpler. A whole new field has developed in recent years, known as operations analysis, in which economic and statistical theories are applied to the practical problems facing managerial staffs. It has been discovered that the abstract ideas of the theorist can play an important role in the analysis of applied problems. Techniques of operations analysis have been adopted by the forest products industries but the use of such methods in the management of the primary forest resource has been limited. Forest management has been so completely dominated by traditional sustained yield concepts that the development of new techniques has been stifled.

One of the most powerful tools of operations analysis is linear programming. It is this technique which may be used by the forest manager for the evaluation of alternative cutting plans.

Linear programming is a mathematical technique, largely developed by economists, which finds wide application in a whole range of economic problems.

Basically, linear programming consists of maximizing,
or minimizing, the solution to a multi-linear equation the independent variables of which are subject to a series of constraints in the form of linear inequalities. Any problem which can be reduced to this relatively simple form may be solved by the linear programming technique.

The use of linear programming in forest management has recently aroused attention from forest economists. Arimizu (1958a, 1958b) discussed the application of linear programming to forest yield regulation. Curtis (1962) described the application of linear programming to the management of 22,000 acres of slash pine in Florida and

17 The general form of a linear programming problem may be expressed as follows:

Maximize (or minimize)

\[ z = a_{01}x_1 + a_{02}x_2 + \cdots + a_{0n}x_n \]

subject to:

\[ a_{11}x_1 + a_{12}x_2 + \cdots + a_{1n}x_n \geq K_1 \]

\[ a_{21}x_1 + a_{22}x_2 + \cdots + a_{2n}x_n \geq K_2 \]

\[ \vdots \]

\[ a_{m1}x_1 + a_{m2}x_2 + \cdots + a_{mn}x_n \geq K_n \]

and all \( x_j \geq 0 \)
presented programmes designed to maximize wood tonnage production and the present dollar value of the property. Louks (1964) presented two linear programming models designed to help the forest manager achieve a normal distribution of age classes in the most desirable manner. The first model maximized the volume of timber to be cut periodically, whereas the second minimized the area to be cut periodically, subject to a minimum volume yield requirement, for each period.

Linear programming is extremely flexible and it is this feature which makes it so useful to the forest manager. Forest management decisions may depend on climatic, physiographic and biological variables as well as on economic factors. It is possible, with linear programming, to take all such factors into consideration when searching for the best management alternative.

The main drawbacks of linear programming stem from the assumptions of linearity. The technique of linear programming is based on the assumptions that all the relative production functions are of a linear form and that perfect competition exists in the factor and product markets. That is, it is assumed that there are constant returns to scale in production and that the firm under analysis cannot influence the selling price of the product by varying the quantity it puts on the market and cannot influence its marginal factor cost by varying the quantity of factor inputs.
In order to show how linear programming might be employed to compare alternative cutting plans a simple hypothetical example will be used. Consider a forest area of 10,000 acres which consists mainly of old-growth timber. The owner of this area does not operate a manufacturing plant but wishes to sell the timber produced on the open market. In order to choose the best management plan the forest owner wishes to evaluate three alternative courses of action. These are:

(a) To establish a normal series or age classes with the objective of managing the forest on a sustained yield basis within 80 years.

(b) To remove all the timber during the next decade and abandon the area.

(c) To remove the timber at an average rate of 3,000 acres every 10 years and abandon the area.

The first step is to divide the area into compartments. Each compartment should be as homogeneous as possible as regards species composition, site index and age. The success of the linear programming technique depends upon the
compartments being uniform for it is assumed that there is an equal volume, of equal value, on every acre of each compartment. The compartments used in this example are shown in Table 3. Although this is a hypothetical case, simplified for demonstration purposes, the species and age composition used is similar to many areas on the south coast of British Columbia. The volumes used are based on Barnes' yield tables for typical well stocked stands of Douglas fir and western hemlock (Forest Club, 1959).

Table 3. Stand Composition, Age Class, Site Index and Area of Chosen Compartments

<table>
<thead>
<tr>
<th>Compt.</th>
<th>Species</th>
<th>Age Class</th>
<th>Site Index</th>
<th>Volume/Acre</th>
<th>Area</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Years</td>
<td>Ht. in Ft.</td>
<td>M f.b.m.</td>
</tr>
<tr>
<td>1</td>
<td>Douglas fir</td>
<td>Old Growth*</td>
<td>170</td>
<td>130</td>
<td>2000</td>
</tr>
<tr>
<td>2</td>
<td>Douglas fir</td>
<td>Old Growth</td>
<td>140</td>
<td>90</td>
<td>2000</td>
</tr>
<tr>
<td>3</td>
<td>Douglas fir</td>
<td>80-100</td>
<td>140</td>
<td>58</td>
<td>1000</td>
</tr>
<tr>
<td>4</td>
<td>Douglas fir &amp; Hemlock</td>
<td>Old Growth</td>
<td>140</td>
<td>90</td>
<td>3000</td>
</tr>
<tr>
<td>5</td>
<td>Hemlock</td>
<td>Old Growth</td>
<td>140</td>
<td>100</td>
<td>3000</td>
</tr>
</tbody>
</table>

* Old-Growth-Stands with an Average Age of more than 250 years.

The forest owner may cut the timber on any acre now, or may leave until some future date. The present worth of
future harvests will depend on: the forest owner's rate of return on alternative investments; long run changes in the price of the timber; and long run changes in the cost of logging and transportation. The aim of the forest owner is to maximize the present worth of his enterprise, within the constraints he imposes, and he wishes to distribute the harvest fellings in such a way that this objective is achieved.

He finds that the average cost of harvesting the timber, per M f.b.m., decreases as the rate of exploitation increases, up to a point, and then starts to rise. At an average exploitation rate of 125 acres per annum (alternative (a)) the average harvesting cost is $20 per M f.b.m.; at an average exploitation rate of 300 acres per annum (alternative (c)) the average harvesting cost is $15 per M f.b.m.; and at an average exploitation rate of 1000 acres per annum (alternative (b)) the average harvesting cost is $30 per M f.b.m.

The next step is to evaluate the growing stock in the forest. Table 4 shows the current value per M f.b.m. of the available timber and the net value (gross value - logging costs) per acre, for each management alternative at current market prices.
Table 4 . Current Net Value Per Acre

<table>
<thead>
<tr>
<th>Compt.</th>
<th>Species</th>
<th>Value/M f.b.m.</th>
<th>Value Per Acre</th>
<th>Management Alternatives</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>a</td>
</tr>
<tr>
<td>1</td>
<td>Douglas fir</td>
<td>100</td>
<td>10,400</td>
<td>11,050</td>
</tr>
<tr>
<td>2</td>
<td>Douglas fir</td>
<td>90</td>
<td>6,300</td>
<td>6,750</td>
</tr>
<tr>
<td>3</td>
<td>Douglas fir</td>
<td>70</td>
<td>2,900</td>
<td>3,190</td>
</tr>
<tr>
<td>4</td>
<td>Douglas fir &amp;</td>
<td>80</td>
<td>4,800</td>
<td>5,200</td>
</tr>
<tr>
<td></td>
<td>Hemlock</td>
<td>70</td>
<td>5,000</td>
<td>5,500</td>
</tr>
</tbody>
</table>

It is assumed that the value of the old-growth timber will not change over the exploitation period and that logging costs will remain constant. The value of second growth stands in Compartment 3 will increase over time as the stands increase in volume. The volume growth of Compartment 3 over an 80 year period is shown in Table 5.

Table 5 . Potential Volume Per Acre of Compartment 3

<table>
<thead>
<tr>
<th>Age: Years</th>
<th>90</th>
<th>100</th>
<th>110</th>
<th>120</th>
<th>130</th>
<th>140</th>
<th>150</th>
<th>160</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume/Acre M f.b.m.</td>
<td>63</td>
<td>67</td>
<td>72</td>
<td>81</td>
<td>85</td>
<td>88</td>
<td>90</td>
<td>90</td>
</tr>
</tbody>
</table>
The forest owner decides that the alternative rate of return on his capital is 5 per cent, and this percentage is used to discount the value of future harvests.

In order to demonstrate how linear programming may be used to formulate an optimum management plan for a forest area, the evaluation of the first management alternative will be shown in detail.

Management Alternative a - Establishment of a normal series of age classes over an 80-year period:

Table 6 shows the present worth of one acre, from each compartment, if harvested in the future. Future values are discounted from one to 80 years, at 5 per cent, by 10 year intervals. It is assumed that current timber values and harvesting costs will prevail throughout this period.

Table 6 . Discounted Net Values of Future Harvests

<table>
<thead>
<tr>
<th>Compt.</th>
<th>Period</th>
<th>Dollars Per Acre</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>I</td>
<td>II</td>
</tr>
<tr>
<td>Years</td>
<td>0-10</td>
<td>11-20</td>
</tr>
<tr>
<td>1</td>
<td>8148</td>
<td>5002</td>
</tr>
<tr>
<td>2</td>
<td>4936</td>
<td>3030</td>
</tr>
<tr>
<td>3</td>
<td>2476</td>
<td>1610</td>
</tr>
<tr>
<td>4</td>
<td>3760</td>
<td>2309</td>
</tr>
<tr>
<td>5</td>
<td>3917</td>
<td>2405</td>
</tr>
</tbody>
</table>
The forest owner wishes to distribute his harvest fellings over the 80-year period, in such a way that the present worth of his enterprise is maximized; subject to the condition that no more than 1250 acres must be felled in any ten year period. In order to solve this problem, the data are expressed in linear programming form as follows:

Let - number of compartments = m
number of periods = n
\( a_{ij} \) = the present worth of one acre of compartment i cut in period j.
\( x_{ij} \) = the number of acres cut from compartment i in period j.

The total present worth of the enterprise may be expressed as:
\[
\sum_{i=1}^{m} \sum_{j=1}^{n} a_{ij} \cdot x_{ij}
\]

The problem is to maximize the total present worth subject to the following constraints:

(a) The area cut in any period must not exceed the allowable cut for that period. That is:
\[
\sum_{i=1}^{m} x_{ij} (j = 1\ldots n) \leq A_j
\]
where \( A_j \) is the allowable cut in period j.

(b) The total area cut from any compartment must not exceed the area of that compartment. That is:
\[
\sum_{j=1}^{n} x_{ij} (i = 1\ldots m) \leq C_i
\]
where \( C_i \) is the area of compartment i.
(c) The area cut from any compartment in any period cannot be less than zero. That is:

\[ \text{all } x_{1j} \geq 0 \]

The present problem may be written for purposes of computation as follows:

**Object Function**

Maximize: \[ P.W. = 8148x_{11} \leq 5002x_{12} \leq 268x_{18} \]
\[ \leq 4936x_{21} \leq 3030x_{22} \leq 162x_{28} \]
\[ \leq 3917x_{31} \leq 2405x_{32} \leq 129x_{58} \]

**Constraints**

**Compartment Area Constraints:**

\[ x_{11} \leq x_{12} \leq x_{18} \leq 1000 \]
\[ x_{21} \leq x_{22} \leq x_{28} \leq 2000 \]
\[ x_{31} \leq x_{32} \leq x_{38} \leq 1000 \]
\[ x_{41} \leq x_{42} \leq x_{48} \leq 3000 \]
\[ x_{51} \leq x_{52} \leq x_{58} \leq 3000 \]

**Period Area Constraints:**

\[ x_{11} \leq x_{21} \leq x_{51} \leq 1250 \]
\[ x_{12} \leq x_{22} \leq x_{52} \leq 1250 \]
\[ x_{13} \leq x_{23} \leq x_{53} \leq 1250 \]
\[ x_{18} \leq x_{28} \leq x_{58} \leq 1250 \]

**Non Zero Constraints:** \( x_{11} \text{ to } x_{58} \text{ all } \geq 0 \)
The problem outlined above has been solved herein by the Simplex Method. The Simplex Method is one of the standard techniques for solving linear programming problems and will not be discussed here. A description of the method and its uses was given by Dorfman, Samuelson and Solow (1958).

In Table 7 is shown the optimum cutting schedule for the area under consideration, within the constraints imposed by the first management alternative. This schedule maximizes the present worth of the forest enterprise, subject to the condition that not more than 1250 acres are cut in any decade. The advantage of using this method of production planning is that it shows, not only when harvest fellings should be made, but also where they should be made, in order to maximize profits.

Table 7. Optimum Cutting Schedule for First Management Alternative

<table>
<thead>
<tr>
<th>Compt.</th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
<th>V</th>
<th>VI</th>
<th>VII</th>
<th>VIII</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acres</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>1000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>250</td>
<td>1250</td>
<td>500</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1000</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>250</td>
<td>1250</td>
<td>1250</td>
<td>250</td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>750</td>
<td>1250</td>
<td>1000</td>
<td></td>
</tr>
</tbody>
</table>
Total Present Worth = $18,105,250

Management Alternative b - To Liquidate the Forest at an Average Rate of 1000 Acres per Annum

This management alternative calls for the exploitation of the whole 10,000 acres of the forest during the first decade and would result in a maximum present worth of $37,545,000.

Management Alternative c - To Liquidate the Forest at an Average Rate of 300 Acres per Annum

The cost of logging, at this exploitation rate, is $15 per M f.b.m. In Table 8 is shown the optimum cutting schedule for this management alternative derived by means of the linear programming technique described above.

Table 8 . Optimum Cutting Schedule for Third Management Alternative

<table>
<thead>
<tr>
<th>Period</th>
<th>Compt.</th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
<th>V</th>
<th>VI</th>
<th>VII</th>
<th>VIII</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Acres</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td></td>
<td>1000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>2000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td>1000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3000</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3000</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Total Present Worth = $32,581,000
The number of alternative management plans which can be investigated by means of linear programming is infinite. The effect of different discount rates, changes in the value of the timber and changes in the level of logging costs, over time, may all be examined by using appropriate constants in the object function.

Instead of using area control, as in the above example, the problem may be set up in terms of volume, and cutting plans may be developed which satisfy volume constraints.

The forest manager may wish to reserve a certain number of trees in each compartment for regeneration purposes. This can be achieved by introducing a constraint of the form:

\[
\sum_{j=1}^{n} v_{ij} (i = 1 \ldots m) \leq R_i
\]

where: \( v_{ij} \) = volume cut from compartment \( i \) in period \( j \)

\( R_i = (\text{the total volume in compartment } i) - (\text{the volume to be reserved in compartment } i) \)

The forest manager may wish to give cutting priority to a certain compartment for biological reasons, and may achieve this objective by introducing a constraint of the following form:
This constraint states that the volume cut from compartment 1, during the first three cutting periods, must be equal to the total volume \( V_1 \) of compartment 1. This constraint could just as easily be formulated in terms of area instead of volume. In a similar way a certain species or age class may be given priority or held in reserve.

In the example given above, cutting schedules have been formulated for an 80-year period, in the first case, and for the total life of the forest enterprise, in the second and third cases. Having worked out a long run exploitation policy, the forest manager can use linear programming to establish an optimum cutting schedule for the current working plan period of five to ten years. Such a programme would incorporate a great amount of detail and would indicate to the forest manager where to cut, and how much to cut each year, in order to achieve his short run objectives, which may differ markedly from his long run policy. A forest owner may, for example, be committed to sustained yield in the long run but still pursue maximum profits in each cutting period. The long run schedule will incorporate the secular trends in timber prices and logging costs; it will be flexible and subject to frequent revisions as the expectations of the manager change. The short run
cutting schedule, on the other hand, will be less flexible and will take into consideration short run cyclical fluctuations in costs and prices.

5. Dealing with Uncertainty in Forest Management Decisions

In Chapter Three it was shown, in a theoretical manner, how a rational forest owner, who wishes to maximize the present worth of his enterprise, should behave. In the preceding sections of this chapter, methods by which alternative management plans can be evaluated and compared were discussed and demonstrated with simple examples. It should have become apparent, from these previous discussions, that the overriding factor in choosing an optimum management plan is the decision maker's ability to forecast future events. The forest owner has to base his management plans on such factors as: the future demand for forest products; the type of forest products required in the future; the expected rate of technological change and its impact on the productivity of factor inputs; and the future price of factor inputs.

Clearly, all these factors are subject to a high degree of uncertainty. If the forest manager knew exactly how prices and costs were going to change in the future, then his job would be relatively simple. He would gather
together all the relevant facts and proceed to formulate a plan which would best serve his needs and meet his primary objectives. Predictions cannot be made with certainty, however, and the longer the period involved the more difficult it is to make accurate forecasts. In forestry, predictions may have to be made of economic conditions several decades in the future, in order to formulate an optimum management plan. Any attempt to rationalize decision making in forest management would be incomplete without a discussion of the ways in which uncertainty can be accommodated.

In the past, there has been a tendency for forest managers, and forest economists, to ignore the question of uncertainty. It is not unusual for foresters to assume that current economic conditions will prevail indefinitely. The expression, "let it be assumed that prices and costs will remain constant throughout the period in question" has almost become a cliche with forest economists. The whole concept of sustained yield is based upon a belief in the status quo. The forest manager, who advocates sustained yield management, implicitly assumes that current economic conditions will persist in perpetuity. Attempts are made, of course, to forecast the future demand for, and supply of, forest products. In Canada, the 1957 Royal Commission on Canada's Economic Prospects (Canada, 1957) predicted the demand for all the major forest products of Canada to 1975.
In the United States, several reports have been published which deal, in some detail, with the future demand for, and supply of, forest products. The latest of these reports was published by the United States Department of Agriculture in 1965 (U. S. Dept. of Agric., 1965). These reports are interesting but are inadequate as a guide to decision making in forest management. They give the forest manager estimates of what the demand for his products will be in the future, provided certain rigid assumptions are correct, but fail to examine the degree of certainty which can be attached to these estimates.

Economists have long since realised that uncertainty is such an important part of the economic environment that it must be considered in any theory which attempts to explain human behaviour. A considerable body of theory has evolved which, not only attempts to explain human behaviour in the face of uncertainty, but also prescribes rules for making rational and consistent decisions in uncertain situations.  

The theory of decision making in the face of uncertainty is dominated by two main schools of thought,  

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18 It is beyond the scope of this thesis to pursue this complex and highly specialized subject to any great extent. Some of the more basic works in the field are: The Theory of Games and Economic Behaviour (Neumann and Morgenstern, 1944); The Foundations of Statistics (Savage, 1954); Games and Decisions (Luce and Raiffa, 1957); A Behavioural Theory of the Firm (Cyert and March, 1963); Probability and Profit (Fellner, 1965).
which have been called by Fellner (1965), the "Frequentist" school and the "Subjectivist" school. These schools are divided by their interpretations of probability. Probability is a term which may be interpreted in two major ways. Firstly, probability may be thought of as a measure of long run relative frequency. If a random variable 'E' is a possible outcome of an experiment, then the probability of 'E' is approximated by the relative frequency of 'E'. The greater the number of times the experiment is performed, the closer will the relative frequency of 'E' be to its true probability. At the limit, the relative frequency of 'E' from an infinite number of experiments will be exactly equal to the probability of 'E'. Secondly, probability may be thought of as a measure of the degree of belief in the occurrence of an event. In this interpretation probability is a subjective concept which exists in the mind of the individual. It is impossible to confirm subjective probability distributions, even ex post.

The Knightsian classification of risk and uncertainty was discussed in Chapter Four. A situation is characterised by risk, if objective probabilities can be assigned to the possible outcomes. A risk situation, therefore, must be of a repetitive nature and must possess a frequency distribution from which observations can be drawn and inferences made in
an objective manner. An uncertain situation, on the other hand, is a unique event and does not possess a frequency distribution from which an objective probability distribution can be inferred. Most economic decisions have to be made in the face of uncertainty.

The "subjectivist" school believes that uncertain situations are characterised by a subjective probability distribution, which exists in the mind of the decision maker, and which can be used as a basis for intelligent decision making. The "subjectivists" approach decision making in two major ways. Firstly, there are those who treat subjective probability distributions as though they have exactly the same properties as objective distributions and thereby transform all uncertain situations into risk situations. One of the main advocates of this approach was Savage (1954) who demonstrated that, if individuals obey certain postulates, it is possible to infer from their behaviour a subjective numerical probability distribution. This approach to uncertainty is frowned upon by most game theorists and statisticians. Secondly, there are those "subjectivists" who follow the Bayesian approach to

19 Thomas Bayes' famous paper entitled An Essay Towards Solving a Problem in the Doctrine of Chance was presented to the Royal Society in 1763, two years after his death. An important part of modern decision theory is built on a Bayesian foundation.
decision making in the face of uncertainty and blend subjective probability judgements, with objective density functions, based upon observations of empirical frequencies. A good exposition of the Bayesian approach to decision making has been presented by Hirshleifer (1961).

The "frequentists", on the other hand, believe that subjective probability distributions cannot be defined for uncertain events and that decisions, in uncertain situations, can only be made by the use of "rules of thumb" which presuppose complete ignorance, on the part of the decision maker, as to the future. Shackle (1955) stated:

"Men's knowledge and insight do not usually enable them to specify narrowly what is positively probable, but only discountenance what is impossible and far fetched."

In recent years, there have been isolated attempts, on the part of forest economists, to recognize the important part played by uncertainty in forest management decisions and to deal with it in a rational manner. Dowdle (1962) discussed the effect of uncertainty on forest investment decisions. He pointed out that the major reason for the gap between theory and practice, in forestry, is economic uncertainty and that foresters, who must make management commitments involving the future, must come to terms with uncertainty and unpredictable contingencies. Dowdle based
his discussion on the "expected returns-variance of returns" rule developed by Markowitz (1959) as a guide to efficient portfolio selection. Markowitz' approach is purely "subjectivist" in content and he follows Savage in the belief that individuals behave on the basis of introspective probabilities, exactly as they would on the basis of objective probabilities. The risk associated with each investment alternative was measured by the standard deviation of the expected return estimate. Thus, the greater the risk associated with an investment alternative, the greater would be the standard deviation of the expected outcome of this alternative. Alternatives were compared by plotting the expected present net worth (E), against the discounted expected variance (V) of returns for each alternative. Each point on the resulting graph represented a possible E.V. combination available to the decision maker. Certain of the alternatives could be ruled out directly by examining the E.V. graph. For example, if two alternatives have the same variance (risk), but one has a higher expected return than the other, the one giving the highest expected return will always be chosen by the rational individual. Similarly, if two alternatives have the same expected return but one is subject to less risk than the other, the least risky alternative will always be chosen. In cases, however, where a reduction in risk is associated with lower expected returns,
or vice versa, the choice between alternatives is not straightforward but depends upon the decision maker's attitude towards risk.

A gambler may prefer a risky alternative, with a high expected return, to a less risky alternative, with a lower yield. A very conservative person, on the other hand, may wish to minimize risk even though this may mean sacrificing expected returns. Either view is perfectly acceptable as a rational decision.

This method for ranking alternatives would be admirable, provided the means were available to quantify the standard deviation associated with each expected return estimate. It is, of course, relatively easy to determine the probability distribution and standard deviation associated with physical risks, but great problems arise in dealing with economic uncertainty.

"Generally, investors will not view expected returns on an investment as having a single most likely value, which is assumed in the traditional discounted-net-worth approach to forestry investment analysis. Rather, they visualize a distribution of values around the one believed most likely to occur." (Dowdle, 1962).

Dowdle implied, therefore, that the decision maker must, by some introspective method, describe a theoretical probability distribution for each alternative considered.
It is not enough, in this case, to merely rank alternatives in order of increasing probability. The subjective probability distributions must be quantified in order that their variances can be measured and compared. Dowdle did not discuss the practical difficulties of obtaining such theoretical distributions, and avoided the problem in his empirical example by considering a case, involving physical risk, for which probability distributions could be obtained in an objective manner. He applied the E.V. rule to a problem involving the optimum cutting age of eastern white pine trees. The trees are expected to reach a certain size at a given age, and their expected net realization value is based on their expected size at that age. At any age, however, there will be a variation in tree size, which will affect production cost and the value of lumber recovered, and hence the expected net realization value. The larger the trees, the less the relative variability in their net volume and, hence, in their net value. Therefore, Dowdle reasoned, the desirable cutting age might be beyond that at which expected returns are maximized, if the decision maker is willing to trade expected returns for certainty of returns. The variation in tree size and net realization value, can be evaluated, objectively, for any given age. Dowdle only introduced physical risk into the problem and did not attempt to deal with economic uncertainty, which, in a decision of
this kind, should have been the main object of the exercise.

Dowdle dismissed economic uncertainty as follows:

"Sources of variation on which expected variations-of-returns estimates are based have been selected because they are amenable to empirical investigation. No allowances are made in the expected variation of return estimates to account for future lumber prices or processing cost uncertainty. Allowances for uncertainty would have to be arbitrary, and since the validity of the conditions is not dependent upon making such allowances they are best left to individual interpretation." (my emphasis)

Flora (1964) examined the influence of uncertainty on making of forest management decisions and came to the conclusion that, under normal circumstances, it can be ignored in forest management problems. He divided uncertainty into three main categories which he then proceeded to dismiss, one by one, as irrelevant. The first type, Flora called the "state of the world" and put into this category all factors affecting both forest and non-forest investments. This type of uncertainty, he said, the forest manager could ignore because:

"forest managers, whether in a corporate or governmental structure, are not commonly asked to compare forestry investments to non-forestry alternatives. Legislation or administrative policy has committed the forestry organization to forestry endeavours and thereby removed uncertainty of Type I." (Flora, 1964)

The second type of uncertainty, considered by Flora,
is a product of those factors which principally affect forest investment but which influence all forest investments to the same degree. Such things as property taxes, building cycles and business cycles fall into this category. This type can be ignored, said Flora, because all investment alternatives are affected to the same extent.

Flora's third category of uncertainty bears on some forestry activities more than others. Uncertainty about future demands for various forest products falls into this category. Uncertainties of this type may cancel each other out, said Flora, provided the planning periods involved in the alternative activities are approximately equal. If planning periods are not equal, then greater uncertainty should be attached to the more distant alternative.

The work of Flora is not helpful in solving the problem of economic uncertainty. He avoided the major issues by making general assumptions, most of which are invalid. His final assumption, that uncertainties of the third type may cancel each other out, is arbitrary and without foundation.

If foresters are to pursue a rational management policy, they must devise a method for dealing with economic uncertainty in a systematic manner. Uncertainty cannot be ignored as suggested by Flora, and they cannot rely on
purely subjective probability distributions as implied by Dowdle. The answer to the problem may be found in that branch of statistics known as decision theory.

Decision theory has developed as a natural extension of mathematical game theory. The theory of games was first proposed by the French mathematician, Emile Borel, in 1921, and was developed analytically by John von Neumann. In 1944, Neumann and Morgenstern published their major work on the theory of games in which they developed the theory to deal with competitive situations in economics and warfare (Neumann and Morgenstern, 1944). In game theory the individual seeks to determine a rival's most profitable counter-strategy to his own best moves and thus seeks to formulate the appropriate defensive measures.

Contemporary decision theory follows the Knightsian dichotomy of risk and uncertainty. It has been developed to deal with problems of choice under uncertainty and makes use of many of the tools of game theory but differs from game theory in one important respect. In game theory, it is assumed that each player will do everything he can to get the better of his opponent and, in this respect, the player's actions are predictable. Decision theory, on the other hand, assumes that there is only one player, the decision maker, who, it is said, plays his game against "nature". The "state of nature" is completely unpredictable in
objective terms. In order to describe the decision theoretic approach to forest management problems a simple example will be used.

Consider the case of a forest manager who wishes to maximize the present worth of a stand of old-growth timber with the proviso that the stand is completely harvested within 20 years. It was shown, in Chapter Three, that the optimum rate of old-growth exploitation will depend on the expected changes, over time, in the value of the marginal product. The factors affecting the value of the marginal product are the productivity of labour and capital inputs and the unit selling price of the product. If the forest owner is selling stumpage his cutting rate decision will be mainly influenced by the expected future changes in stumpage prices.

If the forest owner knew how stumpage prices were going to change in the future, it would be relatively simple for him to regulate the cut in a way which would maximize the present worth of the resource. Predictions of future stumpage values are subject to a high degree of uncertainty, however. They depend on such factors as: the future demand for stumpage, as determined by the consumer demand for wood products; the supply of stumpage, as determined by the decisions of other forest owners; and the cost of logging and manufacture, as determined by the state
of technology and the costs of factor inputs. A change in any of these factors would cause a change in stumpage prices. The forest manager wishes to establish the best course of action in the face of this uncertainty. The forest manager decides that the maximum, reasonable rate of increase in stumpage price, which could be expected during the 20 year operational period, is 6 per cent per annum and the lowest, reasonable rate of increase in stumpage price, which could be expected, is -2 per cent per annum (i.e. a fall in stumpage price of 2 per cent per annum). The true state of nature (in this case the true increase in stumpage price) will fall somewhere between these two extremes. In order to simplify the analysis the forest owner decides to investigate the consequences of 5 possible states of nature. The 5 states of nature chosen are average changes in stumpage price, during the 20 year period, of -2 per cent, 0 per cent, 2 per cent, 4 per cent, and 6 per cent. For each of these, the cutting schedule is derived which maximizes the present worth of the forest enterprise. The optimum cutting schedules, which have been arbitrarily numbered 1 to 5, are shown in Figure 9 together with the corresponding states of nature and the maximum potential present worth of the enterprise.
Table 9. Maximum Potential Present Worth of Old-Growth Stand for Five States of Nature

<table>
<thead>
<tr>
<th>State of Nature</th>
<th>Cutting Schedule</th>
<th>Present Worth of Stand</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Increase in Stumpage Value over 20 year period</td>
<td>Thousand Dollars</td>
<td></td>
</tr>
<tr>
<td>%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- 2</td>
<td>1</td>
<td>600</td>
</tr>
<tr>
<td>0</td>
<td>2</td>
<td>750</td>
</tr>
<tr>
<td>+ 2</td>
<td>3</td>
<td>850</td>
</tr>
<tr>
<td>+ 4</td>
<td>4</td>
<td>950</td>
</tr>
<tr>
<td>+ 6</td>
<td>5</td>
<td>1000</td>
</tr>
</tbody>
</table>

Table 9 shows what the forest owner's maximum gain would be, for each state of nature, if he applied the optimum cutting schedule. The forest owner, however, is ignorant of the true state of nature and does not know, therefore, which is the best cutting schedule to adopt. The next step is to calculate the gain to be expected, from each cutting schedule, for every alternative state of nature. For example, what will be the present worth of the resource if the forest owner applies cutting schedule Number 3, which is optimal for a state of nature of +2 per cent per annum, when the actual state of nature is, say, -2 per cent per annum. In Table 10 is shown the present worth of the stand for each cutting schedule, applied under each alternative state of nature. A table such as this is usually referred
to as a pay-off matrix. It will be noted that the maximum potential present worths for each state of nature, which have been tabulated in Table 10, appear as the main diagonal elements of the pay-off matrix.

The decision making procedure would be greatly improved by replacing the monetary values, appearing in the pay-off matrix, with utility values. By expressing the pay-off matrix in monetary terms it is implicitly assumed that the marginal utility of money is constant. For example, if the decision maker applies cutting schedule Number 5, when the state of nature is -2 per cent, his net gain will be $500 thousand and if the state of nature is 6 per cent his net gain will be $1 million. In monetary terms, it is assumed that the decision maker values $1 million twice as highly as $500 thousand. Economists, however, usually accept that the marginal utility of money decreases as an individual's wealth increases. That is, the more money, or assets, a person has, the less he will value an additional unit of wealth. For example, if a person has only $10, he will value an additional dollar more than he would if he had $100. It follows, therefore, that $1 million will not be worth twice as much to the decision maker, as $500 thousand, in terms of utility, and should, therefore, not be given twice the weight in the decision making process. In order to express the pay-off matrix in terms of utility, it would be necessary to define the decision maker's utility function. The derivation of individual utility functions presents many operational difficulties, which will not be pursued here.
Table 10. Pay-Off Matrix (optimum cutting schedule problem)

<table>
<thead>
<tr>
<th>State of Nature</th>
<th>Action (cutting schedule)</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Present worth of stand (thousand $)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>%</td>
<td></td>
<td>600</td>
<td>575</td>
<td>525</td>
<td>500</td>
<td>500</td>
</tr>
<tr>
<td>- 2</td>
<td></td>
<td>450</td>
<td>750</td>
<td>725</td>
<td>700</td>
<td>625</td>
</tr>
<tr>
<td>0</td>
<td></td>
<td>300</td>
<td>650</td>
<td>850</td>
<td>825</td>
<td>750</td>
</tr>
<tr>
<td>/ 2</td>
<td></td>
<td>225</td>
<td>525</td>
<td>600</td>
<td>950</td>
<td>850</td>
</tr>
<tr>
<td>/ 4</td>
<td></td>
<td>150</td>
<td>450</td>
<td>520</td>
<td>800</td>
<td>1000</td>
</tr>
<tr>
<td>/ 6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

From Table 10 the decision maker can see at a glance the potential results of any action he may take, and is in a position to choose the action best suited to his objectives. The action chosen will depend largely on the decision maker's attitude towards risk. Some of the possible strategies he may adopt will now be examined.

a. The Maximin\textsuperscript{21} Criterion - This criterion is one of the techniques of game theory which has been adopted for use in decision theory situations. It is a "rule of thumb" which completely ignores the concepts of probability theory and assumes complete ignorance on the part of the decision maker as to the true state of nature. For each possible action

\[\text{Maximin is a contraction of maximum minimorum.}\]
the decision maker determines the minimum potential pay-off and then chooses that action which maximizes the minimum returns. In this example the decision maker, employing the maximin strategy, would choose cutting schedule Number 3 which gives a minimum return of $520 thousand. The maximin criterion is extremely conservative. It would only be used by a person with an aversion to risk and who always fears the worst.

b. The Maximax\textsuperscript{22} Criterion - This is the corollary of the maximin criterion and, like the latter, is a "rule of thumb" which is completely independent of the decision maker's probability judgments. For each possible action, the decision maker determines the maximum potential pay-off and then chooses that action with highest potential maximum pay-off. In this example, the decision maker, employing the maximax strategy, would choose cutting schedule Number 4 which gives a maximum potential return of $1 million. This approach would be taken by a compulsive gambler who wishes to try for the most glittering prize regardless of the odds.

c. The Minimax\textsuperscript{23} Criterion - Savage (1954) suggested that a decision maker is more interested in the potential loss

\textsuperscript{22} Maximax is a contraction of maximum maximorum.

\textsuperscript{23} Minimax is a contraction of minimum maximorum.
of making a wrong decision than in the potential gain and, if this is so, a possible strategy would be to minimize the maximum potential loss. In order to apply this criterion it is necessary to transform the pay-off matrix into a, so called, regret matrix. The regret matrix indicates the opportunity cost, to the decision maker, of making a wrong decision. For example, if cutting schedule Number 1 is adopted and the state of nature is -2 per cent the decision maker will have maximized the present worth of the stand and will have no regret. If, however, when the state of nature is -2 per cent, the decision maker employs cutting schedule Number 3, the present worth of the stand will not be maximized and the decision maker's regret, in monetary terms, will be $325 thousand\(^{24}\) i.e. the difference between his actual return and the return he would have received if his estimate of the state of nature had been correct ($850 - $525 thousand).

The regret matrix for the current problem is shown in Table 11.

\(^{24}\) As in the case of the pay-off matrix, it would be a great improvement to express the regret matrix in terms of utility instead of pecuniary values. (see footnote No. 20)
Table 11. Regret Matrix (optimum cutting schedule problem)

<table>
<thead>
<tr>
<th>State of Nature $\theta$</th>
<th>Action (cutting schedule)</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>$%$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-2</td>
<td></td>
<td>0</td>
<td>175</td>
<td>325</td>
<td>450</td>
<td>500</td>
</tr>
<tr>
<td>0</td>
<td></td>
<td>150</td>
<td>0</td>
<td>125</td>
<td>250</td>
<td>375</td>
</tr>
<tr>
<td>$\neq 2$</td>
<td></td>
<td>300</td>
<td>100</td>
<td>0</td>
<td>125</td>
<td>250</td>
</tr>
<tr>
<td>$\neq 4$</td>
<td></td>
<td>375</td>
<td>225</td>
<td>250</td>
<td>0</td>
<td>150</td>
</tr>
<tr>
<td>$\neq 6$</td>
<td></td>
<td>450</td>
<td>300</td>
<td>330</td>
<td>150</td>
<td>0</td>
</tr>
</tbody>
</table>

The decision maker, employing the minimax of regret criterion, would choose that action for which the maximum potential regret is minimized. In the current problem, the appropriate minimax strategy would be to apply cutting schedule Number 2, which has a maximum potential regret of $300$ thousand.

d. Bayes Criterion - Unlike the preceding criteria, this criterion makes use of the decision maker's probability judgements and of the full range of outcomes for each action, not just the extreme values. Each outcome, for a certain action, is weighted by its probability of occurrence.
and that action is then chosen which maximizes the weighted average return. This, of course, poses the problem of how to ascribe an acceptable probability distribution to the states of nature. The problem can be approached in two ways. Firstly, there is the classical Bayesian approach. Bayes suggested that, if there is complete ignorance, on the part of the decision maker, as to the true state of nature, use should be made of Benoulli's Principle of Insufficient Reason which states:

"If there is no evidence leading us to believe that one of an exhaustive set of mutually exclusive events is more likely to occur than another, then the events should be judged equally probable."

Using this principle in the present example, an a priori probability of 0.2 would be assigned to each state of nature. The weighted average returns for each action, calculated on the basis of this a priori probability distribution, are shown in Table 12.

Table 12 . Weighted Average Returns: Uniform a priori Probability Distribution

<table>
<thead>
<tr>
<th>Cutting Schedule</th>
<th>Weighted Average Return (thousand dollars)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>345</td>
</tr>
<tr>
<td>2</td>
<td>690</td>
</tr>
<tr>
<td>3</td>
<td>580</td>
</tr>
<tr>
<td>4</td>
<td>755</td>
</tr>
<tr>
<td>5</td>
<td>745</td>
</tr>
</tbody>
</table>
(e.g. Weighted Average Return for Cutting Schedule Number 1 =
\[0.2 \times 600 / 0.2 \times 450 / 0.2 \times 300 / 0.2 \times 225 / 0.2 \times 150 = 345\])

In this case, the decision maker would choose cutting schedule Number 4, which has a maximum weighted average return of $755 thousand.

The second approach to ascribing probabilities to the states of nature is "subjectivist" and is usually referred to as the neo-Bayesian approach. In this method the subjective probability distribution of the individual decision maker is used to weight the possible outcomes of each action. For example, in the problem under consideration here, the forest manager may have a subjective probability distribution for the possible states of nature which is based on a casual observation of historical trends in stumpage prices. If the forest manager examined stumpage prices for the preceding decade and found that they had been rising at an average rate of 3 per cent per annum he might ascribe \textit{a priori} subjective probabilities, to the states of nature appearing in Table 9, as follows:

<table>
<thead>
<tr>
<th>State of Nature $\theta$</th>
<th>Subjective Probability Distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>- 2 per cent</td>
<td>0</td>
</tr>
<tr>
<td>0 per cent</td>
<td>0.1</td>
</tr>
<tr>
<td>$ 2 per cent</td>
<td>0.4</td>
</tr>
<tr>
<td>$ 4 per cent</td>
<td>0.4</td>
</tr>
<tr>
<td>$ 6 per cent</td>
<td>0.1</td>
</tr>
</tbody>
</table>
This subjective probability distribution would then be used to weight the possible outcomes of each action. The weighted average returns for each action, calculated on the basis of the above \textit{a priori} subjective probability distribution, is shown in Table 13. The decision maker would choose cutting schedule Number 4, which has a maximum weighted average return of $860 thousand.

Table 13 . Weighted Average Returns: Subjective Probability Distribution

<table>
<thead>
<tr>
<th>Cutting Schedule</th>
<th>Weighted Average Return (thousand dollars)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>270</td>
</tr>
<tr>
<td>2</td>
<td>590</td>
</tr>
<tr>
<td>3</td>
<td>705</td>
</tr>
<tr>
<td>4</td>
<td>860</td>
</tr>
<tr>
<td>5</td>
<td>802</td>
</tr>
</tbody>
</table>

(e.g. Weighted average return for Cutting Schedule Number 1 = 0.0 x 600 / 0.1 x 450 / 0.4 x 300 / 0.4 x 225 / 0.1 x 150 = 270)

One of the fundamental properties of the Bayesian approach to decision making in the face of uncertainty, is that as more data become available to the decision maker they are used to modify the \textit{a priori} probability distribution for the state of nature.
In the current example, suppose the forest manager investigates the connection between stumpage price and the volume of spending on residential construction and decides that changes in stumpage price are related to changes in the volume of spending on residential construction, as shown in Table 14.

Table 14. The Relationship Between the State of Nature and Changes in the Volume of Spending on Residential Construction

<table>
<thead>
<tr>
<th>State of Nature ( e )</th>
<th>Probability of Observing Upward or Downward Trend in the Volume of Spending on Residential Construction</th>
</tr>
</thead>
<tbody>
<tr>
<td>(-2 \ (e_1))</td>
<td>Upward: 0.2; Downward: 0.8</td>
</tr>
<tr>
<td>(0 \ (e_2))</td>
<td>Upward: 0.5; Downward: 0.5</td>
</tr>
<tr>
<td>(\neq 2 \ (e_3))</td>
<td>Upward: 0.6; Downward: 0.4</td>
</tr>
<tr>
<td>(\neq 4 \ (e_4))</td>
<td>Upward: 0.7; Downward: 0.3</td>
</tr>
<tr>
<td>(\neq 6 \ (e_5))</td>
<td>Upward: 0.9; Downward: 0.1</td>
</tr>
</tbody>
</table>

Table 14 is to be interpreted as follows. If the true state of nature is \(-2\) per cent, the decision maker would expect to observe a rising volume of spending on residential construction 0.2 per cent of the time, and a falling volume of spending on residential construction 0.8 per cent of the
time, and so on for each state of nature.

The decision maker observes that the volume of spending on residential construction is rising. In order to use this knowledge to modify the existing \textit{a priori} probability distribution, for the state of nature, he should make use of the following relationship:

\[
W = P(\theta = \theta_i / Z = Z_1) = \frac{P(\theta = \theta_i \& Z = Z_1)}{P(Z = Z_1)}
\]

Where:

- \(W\) = the \textit{a posteriori} (modified) probability
- \(\theta\) = the true state of nature
- \(Z\) = empirical observation (trend in volume of spending on residential construction)

The \textit{a posteriori} probability for the state of nature, therefore, is represented as a conditional probability. That is, we wish to find the probability that the state of nature is \(\theta_i\) given the empirical observation that \(Z = Z_1\). The terms in the above conditional probability equation can be evaluated as follows. From the preceding analysis the \textit{a priori} probabilities \((w_i)\) are known, these are:

- \(w_1 = P(\theta = \theta_1) = 0\)
- \(w_2 = P(\theta = \theta_2) = 0.1\)
- \(w_3 = P(\theta = \theta_3) = 0.4\)
- \(w_4 = P(\theta = \theta_4) = 0.4\)
- \(w_5 = P(\theta = \theta_5) = 0.1\)

It has been assumed that \(Z = Z_1\) (volume of spending
on residential construction is rising) and, therefore, from Table 14 the following relationships can be derived:

\[ P(Z = Z_1 / \theta = \theta_1) = 0.2 \]
\[ P(Z = Z_1 / \theta = \theta_2) = 0.5 \]
\[ P(Z = Z_1 / \theta = \theta_3) = 0.6 \]
\[ P(Z = Z_1 / \theta = \theta_4) = 0.7 \]
\[ P(Z = Z_1 / \theta = \theta_5) = 0.9 \]

From the definition of conditional probability it is known that:

\[ P(Z = Z_1 / \theta = \theta_1) = \frac{P(\theta = \theta_1 \& Z = Z_1)}{P(\theta = \theta_1)} \]

and therefore:

\[ P(\theta = \theta_1 \& Z = Z_1) = P(Z = Z_1 / \theta = \theta_1) \cdot P(\theta = \theta_1) \]

The right hand side of the latter equation has already been evaluated and therefore:

\[ P(\theta = \theta_1 \& Z = Z_1) = 0 \cdot 0.2 = 0.00 \]
\[ P(\theta = \theta_2 \& Z = Z_1) = 0.1 \cdot 0.5 = 0.05 \]
\[ P(\theta = \theta_3 \& Z = Z_1) = 0.4 \cdot 0.6 = 0.24 \]
\[ P(\theta = \theta_4 \& Z = Z_1) = 0.4 \cdot 0.7 = 0.28 \]
\[ P(\theta = \theta_5 \& Z = Z_1) = 0.1 \cdot 0.9 = 0.09 \]

The probability that \( Z = Z_1 \) can now be easily calculated:

\[ P(Z = Z_1) = P(\theta = \theta_1 \& Z = Z_1) / P(\theta = \theta_2 \& Z = Z_1) / P(\theta = \theta_3 \& Z = Z_1) / P(\theta = \theta_4 \& Z = Z_1) / P(\theta = \theta_5 \& Z = Z_1) = 0 / 0.05 / 0.24 / 0.28 / 0.09 = 0.66 \]
All the data are now available for calculating the a posteriori probabilities ($W_i$) for the five states of nature:

$$W_1 = \frac{0}{0.66} = 0.00$$

$$W_2 = \frac{0.05}{0.66} = 0.076$$

$$W_3 = \frac{0.24}{0.66} = 0.364$$

$$W_4 = \frac{0.28}{0.66} = 0.424$$

$$W_5 = \frac{0.09}{0.66} = 0.136$$

This a posteriori probability distribution may now be used to weight the possible outcomes of each action. The weighted average returns for each action, calculated on the basis of the a posteriori probability distribution are shown in Table 15. Once again the decision maker would choose cutting schedule Number 4, which has a maximum weighted return of $870 thousand.

Table 15 . Weighted Average Returns: a posteriori Probability Distribution

<table>
<thead>
<tr>
<th>Cutting Schedule</th>
<th>Weighted Average Return (thousand dollars)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>262.35</td>
</tr>
<tr>
<td>2</td>
<td>582.65</td>
</tr>
<tr>
<td>3</td>
<td>691.98</td>
</tr>
<tr>
<td>4</td>
<td>870.00</td>
</tr>
<tr>
<td>5</td>
<td>800.27</td>
</tr>
</tbody>
</table>

(e.g. Weighted average return for cutting schedule Number 1 = $0 \times 600 + 0.083 \times 450 + 0.364 \times 300 + 0.424 \times 225 + 0.136 \times 150 = 262.65$)
If more data became available to the forest manager, the probabilities for the states of nature calculated above would provide the a priori basis for calculating a new set of a posteriori or conditional probabilities.

The foregoing discussion of alternative approaches to planned forest management is rudimentary. The objective of this chapter was not to provide the forest manager with detailed prescriptions for forest management but to show that alternative management plans can be evaluated in a systematic and rational manner and that it is not necessary to blindly accept the principle of sustained yield. Use of operations analysis in forest management planning is, of course, a vast, virtually unexplored field and there is much scope for research. Evaluation of the intangible benefits and costs of forest management presents many problems but these problems are not insurmountable. The state of knowledge, in this branch of economics, is rudimentary but progress is being made. However, even with the techniques presently available, answers may be found to many of the problems facing the forest manager.
CHAPTER SEVEN

Application of Sustained Yield Forest Management in the Province of British Columbia

In previous chapters the history of sustained yield forest management has been examined and the concept has been evaluated from an economic point of view. The application of sustained yield forest management in British Columbia will now be considered and the policy will be evaluated in the light of the foregoing analysis.

British Columbia is one of the major producers of forest products in the world and is one of the few regions in the western world which is still largely dependent on old-growth, virgin stands of timber. Forestry is the major industry of the Province and the economic development of the region is substantially affected by the forest policy. The Government of British Columbia has control over more than 90 per cent of the forest area and is in a position to influence all phases of forest management.

1. History of Forest Management in British Columbia

The history of forest management in British Columbia is extremely complex and only the briefest outline can be given here. The major part of this section is based on the work of Sloan (1945, 1956) and Orchard (1964).
Forest management history in British Columbia may be divided into three major periods. The first period began with the colonization of British Columbia at the beginning of the 19th century and ended in 1912. The second period began with the Forest Act of 1912 and ended in 1947. The third, and current period, began with the amendments to the Forest Act of 1947.

a) 1800 - 1912

During the early days of colonization in British Columbia timber had little, or no, value. The early settlers regarded the forests as an obstacle which had to be removed to provide land for grazing and agricultural crops. Some of the timber removed was used for building purposes but the majority was burned.

The first sawmill in the Province was established at Mill Stream, near Esquimalt on Vancouver Island, in 1848, producing mainly rough lumber for local use. The first mill on the mainland was established at New Westminster in 1862 and also produced lumber for local use. In 1863, a mill was established at Moodyville on Burrard Inlet and, in 1865, the Hastings Mill went into operation, also on Burrard Inlet, (Lawrence, 1955). With the opening of the Burrard Inlet mills, exports of lumber to Australia, Chile, Peru and China grew rapidly and timber began to play a significant
role in the Provincial economy.

A law was passed in 1865, enabling the Governor of the Crown Colony of British Columbia to issue forest leases of any extent and at any appropriate fee. This was the first forest legislation enacted in the Province.

The first Timber Act, which was enacted in 1884, was designed to derive a revenue from the cutting of timber on Crown lands. Stumpage was introduced at the flat rate of 15 cents per tree, except Hemlock and Timber Licences were introduced to replace Timber Leases. Unlike the Timber Leases, the Timber Licences were only granted for a period of four years, at an annual fee of $10.00 per acre, and were restricted to a total area of 1000 acres each.

In 1887, the Land Act Amendment Act imposed a royalty of 20 cents per M f.b.m. on timber cut from Crown granted lands. This Act provided that, thereafter, all grants of land must reserve standing mature timber for the Crown. The latter section of the Act was not strictly enforced, however, and timber alienation continued. Royalties were raised to 50 cents per M f.b.m. in 1888, and Hand Loggers Licences were introduced. Timber Licences became Special Timber Licences, which were granted for one year and were renewable but not transferable.

Timber land was defined in 1896 as land containing 8000 f.b.m. per acre west of the Cascade Mountains and 5000
f.b.m. per acre east of the Cascade Mountains. The alienation of such land was forbidden but the Act was not strictly enforced and 'timber lands' continued to pass into private ownership.

In 1901, leases were made renewable every 21 years, and in 1903, the Timber Licence period was lengthened to 5 years. Licences were made renewable every year for a period of 21 years, in 1905, and were made transferable. Existing Licences were made renewable for 16 years after their 5 year term expired. These measures were responsible for the issuance of many more Licences and by 1907 the Province received, from its forest resource, an annual revenue of $1.7 million, compared to $455,000 in 1904, and cutting rights had been issued to 9.5 million acres of forest land. In 1907, the granting of Timber Licences was discontinued.

At this time the doctrines of the Conservation Movement were sweeping the United States. Timber supplies of the Eastern States, Lake States and Southern States had been largely depleted and many 'experts' predicted a serious timber famine within 30 years. Lumber consumption in the United States reached a peak in 1910 of 45 billion f.b.m., a figure not achieved since. Speculators were beginning to turn to the West as the only remaining source of virgin timber on the North American continent and the Government
of British Columbia, with its policy of public forest land ownership, was faced with a great responsibility. Alienation of Crown lands had been prohibited and the licencing system had been suspended. How, the Government wanted to know, was the best way to dispose of standing timber in order that the Province might obtain the maximum benefit from the impending boom in the demand for stumpage? In 1909, a Royal Commission was appointed, under the chairmanship of the Hon. F. J. Fulton K. C., Commissioner of Lands, to enquire into the whole forest question. The Commission submitted its final report in 1910 and made 21 recommendations, many of which had a significant effect on future Government policies.

The Commissioners were concerned that the 21 year time limit on Timber Licences might induce the licensees to wastefully use the forest resource in order that they might harvest the very best of the crop during the restricted time period. They recommended that, in order to make the tenure of the licensees more secure, the licences should be renewable indefinitely on an annual basis. This, they believed, "would tend to the conservation of Crown forests". In addition, they recommended that licence fees and royalty should not be fixed for more than one calendar-year in advance. The Commissioners also recommended that the issuance of Timber Licences be suspended indefinitely and
that no other form of alienation should be introduced. It was proposed that the remaining Crown forest land should be held in reserve. Much concern was expressed by the Commissioners over the low utilization standards being practised, which led to the wastage of wood and loss of public revenue. Certain minimum utilization standards were suggested.

One of the main recommendations of the Commissioners was that a Department of Forestry be established in the Province. To this time the forests had been administered by the Department of Lands. The Commissioners did not make any concrete proposals for the implementation of a sustained yield policy in the Province, but such a policy was implicit in their report in such passages as:

"The natural advantages of our country must remain unimpaired, the public revenue and the lumbering industry must both be protected, in other words, a sound policy of forest conservation must be established."

No recommendations were made for the disposal of Crown timber but it was stated, most emphatically, that no alienation of forest land, either permanent or temporary, must ever again take place.

b) 1912 - 1947

The second phase of British Columbia's forest history began with the passing of the Forest Act in 1912. This Act was based upon the recommendations of the 1910
Royal Commission and embodied all forest law prior to this date. A separate forest administration, in the form of a Forest Branch in the Department of Lands, was established, and a Chief Forester was appointed. One of the most important sections of the Act, was that dealing with the disposal of Crown timber. Between 1907, when the granting of Timber Licences was suspended, and 1912, there was no legal provision for the disposal of Crown timber, with the exception of Hand-logger's licences. The Forest Act of 1912 made provision for the granting of licences to cut Crown timber after cruising, surveying, appraising and advertising had been carried out by the Forest Branch. These licences were referred to as "Timber Sales". The timber was to be sold at not less than the appraised stumpage price plus royalty, cost of cruising, surveying and advertising. An annual rental and forest protection tax had to be paid and the timber had to be removed according to conditions written into the licencing contract.

The Forest Act made no provision for the sustained yield management of the forest resource but, under section 12, provision was made for the creation of Forest Reserves for the "perpetual growing of timber crops and to preserve forest cover which is so necessary for the regulation of stream flow". In 1925, the term Forest Reserve was
dropped in favour of Provincial Forest.

Following the implementation of the 1912 Forest Act, the volume of timber cut in the Province annually increased rapidly. There was a great deal of speculation in timber on the Coast although many operators bought Timber Sales at close to appraised or "upset" prices. Forest practices were poor, on the whole, and new crops failed to regenerate naturally or were destroyed by wild fires following logging in many areas. Artificial regeneration was at a minimum. The logging industry was transient and logging operators, having acquired a Timber Sale, logged it in the specified contractual period and moved on to new areas, the logged-off lands reverting to the Crown.

In the Forest Branch there was concern over the condition of the forests and "overcutting" on the coast was deplored. The Forest Branch was wholly in favour of sustained yield management but the necessary legislation for the implementation of such a policy did not exist. In the 1925 Annual Report of the Forest Branch the following statement was made:

"the object of creating Provincial Forests is to keep the areas permanently productive. Not only must we leave the area in a condition for regeneration but we must also guard against too rapid cutting, or we will have not permanent but periodic production with long lapses of time between one crop and the next. An ideal
regulated forest is one in which only the annual increment is utilized each year." (my emphasis)

The Forest Branch made detailed management plans for many of the Provincial Forests and allowable annual cut estimates were made but it was not possible to regulate the sale of timber in a way which would conform to these plans.

In 1937, the Forest Branch Surveys and Working Plans Division, published a report entitled The Forest Resources of British Columbia (Mulholland, 1937). This report was mainly designed to bring up to date the Dominion Commission of Conservation report on the forests of British Columbia by Whitford and Craig (1918). It also dealt, however, with some major policy issues and made a plea for sustained yield forest management in the Province.

"On the Coast not only is reforestation unsatisfactory, but the rapid expansion of industries is making it apparent that it will be impossible to avoid conflict between the desire of private interests to utilize all the mature stands as quickly as markets can be found for the timber, and the public interest which requires that great basic industries dependent on natural resources should be regulated on a permanent basis. Increased effort should be made to conserve the remaining virgin timber by the reduction of waste, because the Coast forests are now being overcut in relation to the rate of replacement by growth. In the Interior local regulation of the cut is needed, but the more urgent requirement is better protection from fire and insect damage."

(Mulholland, 1937)
In 1943, Chief Justice Gordon McG. Sloan was appointed as a one-man Royal Commission to investigate and report on the forests and forest industries of the Province. In 1945, after lengthy hearings, the final report of the Commission was submitted. In the report many concrete proposals were made. Sloan considered sustained yield to be the only possible form of forest management acceptable in British Columbia:

"We must change over from the present system of unmanaged and unregulated liquidation of our forested areas to a planned and regulated policy of forest management, leading eventually to a programme ensuring sustained yield from all our productive land area." (Sloan, 1945)

Not only was sustained yield advocated but the concept of yield maximization was also endorsed:

"That then must be our objective: To so manage our forests that all our forest land is sustaining a perpetual yield of timber to the fullest extent of its productive capacity." (Sloan, 1945)

Sloan defined sustained yield as:

"a perpetual yield of wood of commercially usable quality from regional areas in yearly or periodic quantities of equal or increasing volume"

he implied, however, in a later passage, that sustained yield policy is not only desirable from the point of view of timber
yield regulation but also enhances the production of other forest products:

"sustained yield policy, perpetuating our forest stands, will not only provide a continuity of wood supply essential to maintain our forest industries, primary and secondary, with consequent regional stability of employment, but will also ensure a continual forest cover adequate to perform the invaluable functions of watershed protection, stream flow and run-off control, and the prevention of soil erosion." (Sloan, 1945)

Sloan believed that the system of forest tenure in British Columbia was largely responsible for "poor" forest practice in the Province:

"Under our present system of temporary alienations of timber lands that revert to the Crown when logged, operators who cut these lands to secure raw material for their own conversion units are offered no encouragement to treat these lands as permanent tree-farms producing continuous crops." (Sloan, 1945)

Sloan recommended the adoption of a completely new system of forest tenures designed to promote sustained yield management. He suggested that Crown timber be allocated to private timber owners in such a way that the resulting unit was suitable for sustained yield management and capable of supporting a conversion plant indefinitely. Owners of revertible licences should be permitted to retain these lands after logging if they were considered best suited for the
purpose of tree farming. In order to ensure the practice of sustained yield on unalienated Crown land, Sloan recommended the creation of public working circles which would be managed by the Government on a sustained yield basis. These areas would provide timber for those segments of the forest industry having small conversion plants but no timber supplies of their own and for independent loggers with neither the means nor the inclination to manage forest areas.

c) 1947 - 1965

The third phase of forest management in British Columbia commenced with the 1947 amendments to the forest Act which were designed to implement the main recommendations of the 1945 Sloan Royal Commission. The most important feature of the 1947 legislation was the creation of a new form of tenure called a Forest Management Licence. A Forest Management Licence, or Tree Farm Licence as it is now called\(^\text{25}\), is a forest area dedicated to sustained yield forest management, in accordance with a working plan which must have Forest Service approval. A licence can be all Crown land, all private land, or a combination of the two. If the licensee owns timber lands within economic logging

\(^{25}\) The name Forest Management Licence was changed to Tree Farm Licence in 1958, (see page 215)
distance of the proposed licence then these privately owned lands must be included in the licence. A utilization plant need not necessarily be associated with the licenced area.

Sloan's recommendation for sustained yield management on unalienated Crown forest land was implemented in 1947 by designating the Provincial Forests, set aside under the provision of the Forest Act of 1912, as Public Working Circles, which were to be managed by the Forest Service on a sustained yield basis. The Provincial Forests, having been established in accordance with the Forest Act, were legally under the administration of the Forest Service. Land outside the Provincial Forests, however, was governed under the provisions of the Land Act. In order to place forests in Public Working Circles, it was first necessary to transfer the land from the Lands Department to the Forest Service for administrative purposes. During the early 1950's the Lands Department voiced objection to any more land being withdrawn from its jurisdiction. In order to overcome this difficulty the Forest Service delineated certain areas of Crown land to be managed on a sustained yield basis and called them Sustained Yield Units. These areas are subject to the provisions of the Land Act but are managed for sustained yield according to working plans developed by
the Forest Service. Since 1956, no distinction has been made between Public Working Circles and Sustained Yield Units. Both are now called Public Sustained Yield Units.

In 1948, legislation made it possible for a farmer to apply for a licence to make use of Crown forest land, adjoining his farm wood-lot, provided he agreed to manage the joint unit on a sustained yield basis, according to an approved working plan. The farmer was offered free assistance in preparing and applying a sustained yield plan.

A new form of tenure was introduced in 1951 by an amendment to the Taxation Act. This legislation made it possible for a private forest land owner to receive tax concessions, provided that he agreed to operate his forest property on a sustained yield basis, according to a working plan approved by the Forest Service. Such areas became known as Certified Tree Farms. Certified Tree Farm land is subject to a property tax of one per cent per annum on the assessed value of the land. The assessed value is based on the present net worth of the land under sustained yield management; all future anticipated revenues and costs being discounted at an interest rate of 12 per cent. Crown granted forest lands which are not classified as Tree Farm Land are either timber lands, or wild lands, and are subject to a property tax of one and one half, or three per cent, respectively, of their assessed value. The assessed value of timber land and wild land is 60 per cent of the current market value of the timber on the land plus one dollar per
acre. The purpose of the Certified Tree Farm classification is to encourage sustained yield on private land, not included in a Tree Farm Licence.

There was much criticism of the new system of tenures. One of the major criticisms was that the system would put small loggers and operators in the Province out of business and concentrate control of the forests in the hands of a few large monopolistic firms (Gibson, 1961). The original Forest Management Licence legislation was designed to make possible a large number of small licenses, held by operators who would sell their timber on the open market. Few small licences were established, however, and control of the forests did tend to pass into the hands of a few large companies. The small, independent logger, had traditionally, been the backbone of the forest industry in British Columbia and there was public indignation that he should be "robbed" of his means of livelihood. Even the introduction of a clause to Forest Management Licence contracts, stipulating that 30 per cent of the allowable annual cut from the Licence must be contracted out, to independent loggers, failed to appease the critics.

Criticism was also levelled at the administration of the licencing system. There was said to be much government favouritism towards the interests of large companies and the honesty of the minister, responsible for the
administration of the Forest Act, was questioned. Some outspoken critics attacked the government's whole concept of forest management and demanded that private companies be given permanent tenure and full control over Crown forest lands (Gilmour, 1949).

In 1955, the Honourable Gordon McG. Sloan was once again appointed as a one man Royal Commission to report on the forests and forest industries of British Columbia. He examined, thoroughly, the new system of forest tenures and heard the points of view of all interested parties. In his final report, Sloan (1956) endorsed the concept of sustained yield and recommended that the existing system of forest tenures be continued with some minor modifications. The most important change he recommended, was that Forest Management licences should not be granted in perpetuity, but should be renewable at either 21 year intervals or when the total volume of timber removed from the licence is equal to the volume of private timber contributed to the licence by the licensee. This measure, said Sloan, would make Government control of the forest resource more evident to the public.

Sloan was very concerned about the loss in volume

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26 This contention was substantiated in 1957 when the Minister of Lands and Forests, the Honourable R. E. Sommers, was convicted on bribery charges in connection with the granting of Forest Management Licences.
of mature stands due to rot and decay and recommended that the rate of old-growth exploitation, especially in the Vancouver forest district, should be increased. He suggested that control in the Vancouver Forest District, during the period of conversion to sustained yield, should be on an area, rather than a volume basis and recommended that 100,000 acres of old-growth timber should be cut annually, for a ten year period, at which time the position should be reviewed. The main objects of forest policy, Sloan believed, should be to establish full increment on all the forest lands and to arrange a normal gradation of age classes.

The name Forest Management Licence was changed to Tree Farm Licence in 1958 and, in the same year, the terms for new licences were reduced from perpetuity to 21 years, with option of renewal on application and subject to the renegotiation of the terms and conditions of the contract.

The Forest Act was amended in 1961 to provide for the establishment of pulpwood harvesting areas in the Interior and, in 1962, the legislation was extended to include the Coastal region. A pulpwood harvesting area may cover several sustained yield units and is designed to encourage the utilization, on a sustained yield basis, of the available raw material which is too small, or otherwise unsuitable, for sawmilling.
The Forest Policy of British Columbia was summarized by Orchard (1964) as:

1. Retain all forest land in public ownership.
2. Protect all forest lands from fire and insects.
3. Maintain and improve progressively a complete inventory of forest resources.
4. Manage every forest acre on a sustained yield basis.
5. Promote the manufacture of forest products in the Province by imposing export restrictions on raw material and by encouraging the establishment and maintenance of forest industry.

By 1964, the total productive forest area committed to sustained yield in British Columbia, under approved working plans, was 68,791,191 acres. The total allowable cut of this area was 1,044,761 cubic feet, which was equivalent to 69 per cent of the Provincial scale. The status of the sustained yield programme in British Columbia, in 1964, is shown in Table 16.

2. Implementation of Sustained Yield Forest Policy in British Columbia

It has been shown above, that the Government of British Columbia has adopted a universal policy of sustained yield forest management. The implementation of this policy will now be examined.
Table 16. Progress of Sustained Yield Programme in
British Columbia, to 1964

<table>
<thead>
<tr>
<th>Type of Managed Unit</th>
<th>Number of Units</th>
<th>Productive Area (Acres)</th>
<th>Allowable Annual Cut (M.C.F.)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Sawlog</td>
<td>Close Util.</td>
</tr>
<tr>
<td>Public Sustained Yield Units</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>In Pulpwood harvesting areas---</td>
<td>33</td>
<td>17,980,621</td>
<td>179,720</td>
</tr>
<tr>
<td>Other Public Sustained Yield Units Sawlog Utilization----</td>
<td>49</td>
<td>37,829,539</td>
<td>377,270</td>
</tr>
<tr>
<td>Close Utilization--------</td>
<td>1</td>
<td>5,150,147</td>
<td>-</td>
</tr>
<tr>
<td>Total Public Sustained Yield Units---------</td>
<td>83</td>
<td>60,960,307</td>
<td>556,990</td>
</tr>
<tr>
<td>Tree Farm Licences-------</td>
<td>39</td>
<td>7,130,067</td>
<td>-</td>
</tr>
<tr>
<td>Tree Farms (excluding those in Tree Farm Licences)------</td>
<td>28</td>
<td>682,553</td>
<td>-</td>
</tr>
<tr>
<td>Farm Wood-lot licences------</td>
<td>55</td>
<td>18,264</td>
<td>-</td>
</tr>
<tr>
<td>Totals</td>
<td>205</td>
<td>68,791,191</td>
<td>-</td>
</tr>
</tbody>
</table>

Source: B. C. Forest Service Annual Report (1964)
a) Goals of Forest Management

The ultimate goal of forest policy in British Columbia, is to bring every acre of forest land under management for maximum sustained yield on a regional basis. That is, eventually, the whole Province will be divided up into a series of public and private sustained yield units. Each unit will consist of a normal series of age classes and will be so arranged that, during each year or period, the maximum mean annual, or periodic, increment of the forest unit can be harvested without detriment to the remaining growing stock.

b) Allowable Annual Cut

In order to achieve the ultimate goal of sustained yield forest management, the forests of the Province will first have to be converted to normality. Few of the sustained yield units in British Columbia have a distribution of age classes which even approach normality. In most units there is a preponderance of old-growth timber, especially in the Coastal region. In 1957, the total area of commercial forest land in British Columbia was approximately 118 million acres. On the coast there were approximately 15 million acres of commercial forest land and in the Interior approximately 103 million acres. On the Coast 74 per cent of the commercial forest area was classified as mature and in the Interior, 56 per cent. (British Columbia Forest Service, 1958)
In devising a method for guiding the forests of British Columbia towards normality, forest managers had two major objectives. Firstly, they wished to assure equal, or near equal, annual or periodic harvests during the period of conversion and secondly, they required that the old-growth timber should last until there is a sufficient volume of second growth to support the existing forest industries. In order to facilitate these objectives they chose to regulate the yield of the forests by means of the Hanzlik formula. The Hanzlik formula is a method of yield regulation based entirely on timber volume. It was proposed by E. J. Hanzlik of the United States Forest Service in 1922, as a rough method of determining the annual allowable cut in forests containing a preponderance of mature age classes, such as occur in the Pacific Northwestern States and British Columbia (Hanzlik, 1922). The British Columbia Forest Service used the Hanzlik formula in their preliminary calculations of the allowable yield from the original Provincial Forests and it was retained for calculating the allowable annual cuts of the Public Sustained Yield Units. The Hanzlik formula has also been adopted by most Tree Farm Licence holders, who use it as a basis for yield regulation in their approved working plans. The Hanzlik formula may be expressed as follows:
\[ Y = \frac{V_m}{r} \left( \frac{G_m - D_m}{2} \right) / G_i \]

where

- \( Y \) = The annual allowable cut
- \( V_m \) = Volume of mature timber
- \( G_m \) = Average annual increment in mature forests
- \( D_m \) = Average annual natural depletion in mature forests
- \( G_i \) = Average annual increment in immature forests
- \( r \) = Number of years in the operative rotation

Allowable cut calculations are usually accompanied by a volume/area allotment check. This consists of projecting the current inventory data for the forest into the future, age class by age class. Starting with the oldest age class in the current period, the future volume of each age class is divided by the annual allowable cut to see how many years it will last. The total theoretical time to cut the forest, is compared to the desired rotation. If the indicated cutting time is longer than the rotation, an increase in the allowable annual cut is called for. If the indicated cutting time is shorter than the rotation, the allowable annual cut is decreased.

c) Elements of the Hanzlik Formula

The rate of removal of old-growth timber in British Columbia is determined by:
The volume of old-growth timber available.
The rate of growth of the immature stands.
The effective rotation age.

The forest managers can influence the amount of timber available annually, or periodically, by changing the basis of any of these variables. At present the following criteria are generally used in British Columbia for determining the allowable annual cut:

(1) The volume of old-growth timber is taken to be that volume which is considered, by the British Columbia Forest Service, to be currently exploitable and merchantable. At the moment this includes the sound wood volume in trees 12 inches d.b.h. and over, to rough standards of utilization, with deductions for wastage and breakage.

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27 Rough utilization, is an estimate of the roughest utilization currently practiced in British Columbia under adverse logging conditions. Stump height is equal to d.b.h., outside bark, with a minimum of two feet. Top diameter, inside bark, is 40 per cent of the d.b.h., inside bark. (British Columbia Forest Service, 1958)

28 Deductions for wastage and breakage vary with species, from 11 per cent for Douglas fir to 19 per cent for western hemlock and 25 per cent for western red cedar. Felling breakage is deducted at a flat rate for all species of 5 per cent. (British Columbia Forest Service, 1958)
on accessible operable sites,\textsuperscript{29} of average or better productivity and excluding lodgepole pine and all deciduous species. (British Columbia Forest Service, 1958)

(ii) The total mean annual increment on immature stands, used in the Hanzlik formula, is calculated by multiplying the mean annual increment per acre of merchantable wood, in trees 12 inches d.b.h. and over, by the number of accessible, operable acres of immature timber on sites of average or better productivity. The mean annual increments per acre are read from empirical yield tables. (British Columbia Forest Service, 1958)

(iii) The rotation age used in the Hanzlik formula by the British Columbia Forest Service, is that age at which the mean annual increment of the forest, measured

\textsuperscript{29} In 1957, only 22.7 million acres, of the 118 million acres of productive forest land in British Columbia, were considered to be currently exploitable. (British Columbia Forest Service, 1958)
in terms of sound merchantable volume, is maximized. This value will, of course, vary with site quality. The Forest Service, however, assumes an average site index of 100 feet at 100 years for the whole Province and, on this basis, uses an average rotation of 100 years on the Coast and 120 years in the Interior.

d) Flexibility of Sustained Yield Policy

Sustained yield forest management, as practised in British Columbia, does not conform to the rigid standards set in Europe. The main sources of flexibility in the sustained yield policy are as follows:

(i) The holders of Tree Farm Licences are not required to comply annually to allowable cut regulations. In any year the actual cut of a Tree Farm Licence need only be within 50 per cent of the allowable cut. Over a 5-year period, the actual yield must be within 10 per cent of the allowable cut and over a 10-year period the actual cut must be equal to the
allowable cut. In the case of Public Sustained Yield Units, there is no definite ruling on the amount of overcut, or undercut, permitted in any period, but the Forest Service appears to be fairly flexible in its approach to yield regulation. For example, in 1963, 60 of the 96 Public Sustained Yield Units in the Province were overcut.

(ii) The British Columbia Forest Service has made provision for the periodic reappraisal of the annual allowable cut. At the moment a reappraisal is made every 10 years.

(iii) If an operator can log species, or sizes, which are not currently included in the allowable cut calculations, he has an opportunity to do so and the yield resulting from such operations is not considered a part of the allowable annual cut sawtimber. This means that, during a period of high demand and high prices when the limits of marginal merchantability fall,
the forest industries have an opportunity to take advantage of the favourable economic conditions without contravening the allowable cut restrictions.

(iv) Tree Farm Licence contracts generally allow the licensee to increase the prescribed allowable cut of his property if he can prove, to the Minister's satisfaction, that he has achieved closer utilization standards, or has improved the productivity of his licence, to a degree which would warrant such a change.

(v) The current rise in pulp production in British Columbia has brought with it a demand for wood which is considered to be too small, or otherwise unsuitable, for sawmilling. In order to accommodate this demand, pulpwood harvesting areas have been delineated in the Interior which include within their boundaries several Sustained Yield Units. In these areas, a guarantee of adequate wood
supply has been made to designated pulp mills. Available wood above this guarantee is distributed to the sawmill industry. Stumpage, below the present standards of utilization for sawlogs, is sold at a flat rate of 55 cents per hundred cubic feet. On the Coast it has been suggested that pulpwood timber sales be established, in timber types currently unsuitable for sawlog production, but this proposal has not yet been implemented. The phenomenal growth of the pulp industry in British Columbia has already given rise to important revisions in allowable cut calculations. The latest Public Sustained Yield Unit to be established, the Finlay Unit north of Prince George, has an allowable annual cut of 100,000 cubic feet, based on the sound wood volume in trees 7 inches d.b.h. and over, to close utilization standards.\textsuperscript{30}

\textsuperscript{30} Close Utilization Standard - The ideal condition whereby almost all the tree stem is harvested. Limits are 1 ft. stump height and top diameter inside bark of 4 inches. (British Columbia Forest Service, 1958)
on accessible, operable sites of average or better site productivity. (British Columbia Forest Service, Annual Report, 1962) No doubt, revision of the allowable annual cuts of established Sustained Yield Units can be expected in the near future. The Provincial Minister of Lands and Forests, the Honourable R. G. Williston, expressed the belief, in a recent address to the Western Forestry and Conservation Association meeting in Vancouver that, largely because of improvements in 'smallwood' utilization, the allowable annual cut of the Province can be raised, immediately, to 3 billion cubic feet. The extent to which this revised attitude will be reflected in increased "quotas" of sawtimber is by no means clear.

3. A Critical Appraisal of British Columbia's Sustained Yield Forest Management Policy

In Chapter Five, the general policy of sustained yield forest management was criticised on economic and social
grounds. The sustained yield forest policy of British Columbia will now be examined in the light of these criticisms.

Most of the criticisms which can be levelled at the forest management policies of British Columbia stem from the fact that, in formulating its policies, the British Columbia Forest Service appears to have had a complete disregard for the economic value of the forest resource. Although sustained yield, as practised in British Columbia, is fairly flexible, it is, nevertheless, considered to be a universal plan of management which is ideal for all regions and all situations. Alternative management plans, apparently, are never given consideration.

Before assessing the sustained yield forest policies of British Columbia, certain assumptions regarding the objectives of forest management in the Province must be made. It will be assumed that the ultimate objective of forest policy in British Columbia is to manage the forests of the Province in such a way that the benefit derived by the people of the Province, from the resource, is maximized. It is doubtful whether any Government would deny such a high objective and there is a general belief that a policy of sustained yield will achieve this aim. Sloan (1956) said:

"The objective of the policy has commonly been defined as sustained yield management, and it worth
repeating that no opposition to this policy has appeared from any quarter. It is important to realize, however, that sustained yield is not an end in itself; more properly it should be regarded as an instrument by which the real purpose of our forest policy may be achieved. This purpose is social and economic rather than technical; it is the use of British Columbia forest for the maintenance of maximum and stable employment and profitable production of manufactured commodities for sale in the markets of the world. To achieve this purpose sustained yield is an essential tool." (my emphasis)

It can be shown, however, that the forest policies currently followed in British Columbia are incompatible with the maximization of the net social benefits from the forest resource.

It was proposed in Chapter Three that, given a perfectly competitive economy, in which there are no discrepancies between private and social costs and benefits, resources will be used in a socially optimal manner if each individual resource owner seeks to maximize the present worth of his enterprise. In British Columbia the Government has a virtual monopoly over the forest resource and should not, therefore, be troubled to any great extent by externalities. Most of the direct benefits and costs, connected with the use of the forest resource, accrue directly to the Provincial Government which manages the forests in the name of the British Columbia people.
It was shown, in Chapter Five, that in order to maximize the social present worth of a forestry enterprise it is necessary to:

(i) Remove old-growth timber in such a way that the discounted values of the marginal product minus the present worth of the annual rentals foregone in lacking the old-growth timber are the same for all periods.

(ii) Remove second-growth stands when their marginal value growth is equal to the marginal cost of holding the standing timber.

Neither of these conditions are met by the management policies currently operative in British Columbia.

a) Rate of Old-Growth Exploitation in British Columbia

It has been shown that the ultimate aim of British Columbia forest policy is to bring every acre of forest land, in the Province, under maximum sustained yield management, and that, during the period of conversion to sustained yield, an allowable annual cut has been fixed by means of the Hanzlik formula. The rate of old-growth exploitation in British Columbia is determined on a purely physical basis and is dependent on several arbitrary factors, such as: the utilization standards assumed; the
operative area; and the rotation age adopted. No attempt is made to consider either the current or the future value of the resource. Although some consideration is given to the social values of forestry, the main aim of the Forest Service is to produce the maximum yield of wood, on a perpetual basis, from all forest land. It is assumed that this objective will automatically create an optimum social balance in forest land utilization.

Sustained yield involving annual, or periodic, harvests of equal volume will only maximize the value of the old-growth forest resource if the value of the marginal product does not change over time and if the land occupied by the old-growth has no alternative use. That is, if either:

(i) The unit value of the product is expected to remain constant; the marginal productivity of factor inputs is expected to remain constant; there is no effective discount rate to consider; and the land occupied by the old-growth has no alternative use.

or

(ii) The discount rate is exactly equal to the rate of increase in the
value of the marginal product due to increases in product price and factor productivity; and the land occupied by the old-growth has no alternative use.

The first of these conditions would apply only in an economy in which the costs of capital and land were zero and no alternative investments to forestry existed. Clearly, this is not the case in British Columbia. The second condition could occur, but the probability of such an occurrence is extremely small, even in a narrowly defined area. It would be impossible for such a condition to prevail throughout the whole Province.

If neither of these conditions hold, then, in order to maximize the present worth of the old-growth forest resource, regular annual, or periodic, cuts are unsatisfactory and the rate of exploitation must be modified.

b) Rate of Second-Growth Exploitation in British Columbia

It is difficult to consider the exploitation of second-growth forest stands entirely separately from that of old-growth stands. It is true, however, in British Columbia, that in dealing with old-growth timber one is dealing with a resource which, although physically renewable, is, economically speaking, a stock resource of fixed dimensions.
Second-growth timber, on the other hand, is definitely a renewable resource.

The forest policy of British Columbia stresses the difference between old-growth and second-growth forest resources but this dichotomy is based upon physical, rather than economic criteria. It is implicit, in the sustained yield forest management policy of British Columbia, that in any management unit, all the old-growth timber must be removed before any second-growth is cut. The reasoning behind this policy is that old-growth is a wasting asset which is being physically depleted by rot and decay, whereas, second-growth timber is increasing in volume and hence in value. Thus, it is argued, unless old-growth exploitation has priority over second-growth, the overall volume recoverable from the forest resource will be reduced:

"The desired end (sustained yield) cannot be reached until our mature timber on the Coast is cut and the area now covered by that old-growth which might just as well be in piles in a lumber yard as in the forest, so far as increment is concerned - is growing a new forest." (Sloan, 1945)

In 1956, Sloan again stressed his belief that mature and overmature forests contribute nothing in the form of growth and should, therefore, be harvested as quickly as possible.

"The rate of cutting in old-growth timber should be related to two objectives. First, it should be
designed to produce an evenly graduated series of age classes in the reforested lands: second, it should remove the old timber soon enough to prevent disastrous losses by insects and fungi-------The losses involved in holding reserves of overmature timber longer than absolutely necessary should not be underestimated." (Sloan, 1956)

This policy appears to ignore the fact that, although old-growth timber is not increasing in physical volume, it may increase in value over time due to the market forces of supply and demand. This value increase may offset the loss in the value of the resource, due to decay and mortality, and may be even greater on a percentage basis than the value increase of the second-growth timber. Under such unusual circumstances, the removal of the old-growth timber prior to the second-growth could only lead to an economic loss.

The results of harvesting all old-growth timber prior to the second-growth, are very apparent in the case of Douglas fir. Haley (1964) discussed the future prospects for Douglas fir and concluded that, from an economic point of view, it is unique amongst British Columbia species. Douglas fir has many traditional trade advantages and enjoys a strong consumer preference, particularly in the United States which currently imports more than 60 per cent of the Douglas fir lumber produced in British Columbia annually.
The current supply of old-growth Douglas fir sawtimber in British Columbia is inadequate to meet the predicted future demands for this species (Haley, 1964). As the supply of old-growth Douglas fir diminishes the stumpage price of this species can be expected to rise. The extent of this rise will depend on the elasticity of demand for Douglas fir stumpage, which will in turn depend, partially at least, on the elasticity of demand for Douglas fir products.

Increases in Douglas fir stumpage prices, over and above those of other species, are already apparent in British Columbia. Prior to 1950, the stumpage price of Douglas fir was on a par with stumpage prices of other major species. Since 1950, however, Douglas fir stumpage has increased at a much greater rate than other species and since 1957 has been approximately double that of the other major species. The differential between the stumpage prices of Douglas fir and other species is much greater on the Coast, where Douglas fir is in particularly short supply and of a higher quality, than in the Interior. In 1964, for example, the average price paid for Douglas fir stumpage in the Vancouver Forest District was $13.52 per cunit, compared to $5.33 per cunit for hemlock and $6.01 per cunit for western red cedar. In the Kamloops Forest District, the average stumpage price paid for Douglas fir was $4.12 per cunit, compared to $1.67 for hemlock, $1.87 for spruce and

Douglas fir products have many substitutes in all their major markets. In Canada, other species are replacing Douglas fir in the lumber market and increasing quantities of "Douglas fir" plywood are being made from other softwood species and faced with a Douglas fir veneer. In the United States, Douglas fir lumber from British Columbia has to compete with domestic Douglas fir as well as other species. The large number of substitutes for Douglas fir suggest that the demand schedules, for products of this species, are fairly elastic. If this is the case, then it is reasonable to suppose that the demand schedule for Douglas fir stumpage will be fairly elastic and a fall in the supply of Douglas fir stumpage may lead to a loss in the total revenue obtained from sales of this species. This is illustrated in Figure 8. As the supply schedule of Douglas fir stumpage shifts from SS to S'S' (Figure 8) the price will rise from P1 to P2 and the quantity demanded will fall from Q1 to Q2. At price P1 the total revenue derived, per unit time, from sales of
Figure 8: Effect of stumpage supply and demand shifts on forest revenue.
Douglas fir stumpage will be $OP_1 x OQ_1$, that is area $OP_1E_1Q_1$. The total revenue at price $P_2$ is $OP_2 x OQ_2$, that is area $OP_2E_2Q_2$. There has thus been a net fall in total revenue of $XE_1Q_2 - P_1P_2E_2X$.

As the price of Douglas fir stumpage rises, the price of Douglas fir products will also rise relative to other species. As the prices of Douglas fir products rise consumers will switch to other species and non-wood substitutes. These changes may result in downward shifts in the demand schedules for Douglas fir products, and hence for Douglas fir stumpage. Such a downward shift would further decrease the total revenue, per unit time, accruing to the Douglas fir resource. In Figure 8 if the demand curve shifts downward from $dd$ to $d'd'$, total revenue will be reduced to $OP_3 x OQ_3$, that is area $OP_3E_3Q_3$.

If the supply of Douglas fir could be increased, rising prices could be controlled and the total revenue, obtainable from the exploitation of this species, maximized.

Palmer (1965) estimated that all old-growth Douglas fir in British Columbia will be liquidated within 20 years. Under current regulations, however, very little second-growth will be harvested for about 40 years. This means that there could be a period of 20 years in which there will be no Douglas fir harvested at all in British Columbia. During this period it is extremely likely that the market
for Douglas fir will either decline in importance, or, even, cease to exist completely. Clearly, under such circumstances, the potential value of the Douglas fir resource, which could be realised without the rigidities of supply imposed by the present policies, will be lost forever.

Douglas fir has been cited here as a special case because of its extreme importance to the forest economy of British Columbia and the current urgency of the problem. The forest policy of British Columbia, however, may lead to similar situations with other species in the future. It is completely unrealistic to demand that all old-growth timber be removed prior to the exploitation of any second-growth. Cutting rate decisions must be made in an economic, rather than a physical, context. The exploitation of second-growth timber must not be governed by arbitrary physical rules but should be integrated with old-growth exploitation in the most economic manner.

c) Investment in Reforestation to Sustain Yield

The British Columbia Government appears to have no sound policy for making investment decisions, as far as the forest resource is concerned. If such a policy does exist it has never been made public and is not apparent in the actions of the Forest Service. As a result, investment in the primary forest resource of British Columbia is misdirected
and inefficient. The Government, in its pursuit of sustained production from every acre of forest land, has adopted the attitude that every acre of forest land, when logged, must be either left in such a state that it will regenerate naturally or must be regenerated artificially.

Steps have been taken to enforce regeneration on privately owned and controlled land in the Province. Section 166 of the Forest Act authorizes the Chief Forester to enter into an agreement with the owner, or occupier, of Crown granted lands, for the reforestation of such lands. The owner of such land is supplied with young trees by the Forest Service, either free or at some nominal cost. Section 167 of the Forest Act authorizes the Minister of Lands and Forests to require the reforestation of alienated land west of the Cascade Mountains that has been classified as unsatisfactorily restocked. Tree Farm licence holders have to reforest all lands, better than site 80 in quality, that were denuded prior to the granting of the licence, at a specified rate, and guarantee to regenerate artificially all lands which are not satisfactorily restocked within seven years after logging, if the land is site index 110 or better, and within 10 years after logging if the site index is between 80 and 110.

In order to have their lands classified as Tree
Farm Lands under the Taxation Act, owners of alienated forest land must undertake a programme of reforestation on all land which is not satisfactorily stocked and must guarantee to keep all their land in continuous production.

In contrast to the stringent regeneration requirements placed upon the private owners of forest land, the reforestation programme of the British Columbia Forest Service appears to be completely inadequate. In 1964, for example, 42 thousand acres of forest land were planted of which only 6 thousand acres, or 14 per cent, were undertaken by the Forest Service on Crown forest land. During this year, approximately 898 million cubic feet of timber were cut from Public Sustained Yield Units and 602 million cubic feet from privately owned or operated forest land. It is impossible to compare the area planted annually to the area logged because the British Columbia Forest Service does not publish reports on areas logged. Since the start of artificial regeneration in British Columbia, about 30 years ago, approximately 336 thousand acres have been planted, 131 thousand acres by the Forest Service on Crown land and 180 thousand acres by private companies, the balance being planted by the Forest Service on Crown granted land.

There has been much concern in the past over the paucity of forest planting in British Columbia and over the very large areas of not satisfactory-restocked (N.S.R.) and
non commercial-cover (N.C.C.) categories of land which now exist. According to the 1957 Continuous Forest Inventory of British Columbia, there were in the Province approximately 18 million acres of forest land which could be classified as N.S.R. or N.C.C., of which 15 million acres were classified as currently accessible. In the Vancouver Forest District, there were 1.9 million acres of N.S.R. and N.C.C. land and it is in this region that the problem is viewed most seriously. In the Vancouver Forest District, forest land, especially on the lower slopes and fertile valley bottoms, is at a premium. Mulholland (1937) estimated that 50 per cent of all land logged annually in this District does not regenerate naturally in a satisfactory manner. Largely because of slash burning and improved fire control, Ker, Smith, and Little (1960) revised this estimate to 25 per cent. The lands which fail to form satisfactory crops after logging are usually the good site lands which are very susceptible to invasion by deciduous scrub species, when cleared. It has been estimated (Sloan, 1957) that good site lands which become covered with deciduous scrub will not return to their original coniferous cover for at least 150 years. Sloan was extremely concerned over the question of N.S.R. and N.C.C. lands and discussed the question at some length in his 1945 and 1956 reports. In 1956, Sloan noted that the area of N.S.R. and N.C.C. land in the Vancouver
Forest District had increased since 1945 and said:

"it appears that the Forest Service should be planting on Crown lands (apart from the economics involved) 12,000 acres a year merely to prevent the present situation form worsening." (Sloan, 1957)

Ker _et al._ (1960) investigated the reforestation needs in the Vancouver Forest District and said:

"There can be little doubt that nearly one quarter of the area logged annually in the Vancouver Forest District during the next few decades will become N.S.R. and N.C.C. unless plans are made now for prompt reforestation. Without prompt reforestation more potential N.S.R. and N.C.C. land will be created annually than has been planted in any one year to date in the Vancouver Forest District."

It does not seem reasonable that members of the Forest Service should insist on behalf of the Government of British Columbia that private forest operators artificially regenerate every acre of forest land, better than site index 80, which does not regenerate naturally, when they themselves appear to be pursuing an inadequate reforestation programme. When confronted, by the 1956 Sloan Commission, with a question as to the criteria used for making regeneration decisions, Dr. C. D. Orchard, on behalf of the Forest Service made the following reply:

"Planting is an expensive proposition. It costs a lot of money to plant an acre of land. We can't see any
justification in spending the public's money in planting acres which we are reasonably certain will never pay us back that $40 per acre plus some little profit on it, over the course of the rotation. When we started to plant, it was a very simple matter to find the high sites on which we had no misgivings whatever it would pay to plant and we proceeded to plant those and progressively we have used up, planted those better sites."

If it is indeed true that the Forest Service makes an economic evaluation of each area before planting, then why do they not give the same choice to private forest operators? It is inefficient to force private individuals, in the name of sustained yield policy, to artificially regenerate, all areas, with a complete disregard for economic criteria, when the Forest Service itself is failing to regenerate many areas which would appear to be highly productive. It is certain, that much of the money invested by private companies in satisfying the regeneration requirements of their contracts, would yield a much higher rate of return if invested in rehabilitating N.S.R. and N.C.C. Crown lands on better than average sites.

If the British Columbia Forest Service does apply explicit economic criteria in making investment decisions, it has failed to make this clear in its reports. What, for example, is the rate of interest used for discounting future
yields and how are future values projected? It is more reasonable to assume that the Forest Service investment decisions are fairly arbitrary and that, although priority may be given to the regeneration of land of high productivity, there is no clearly defined cut-off point or standardized investment criteria.

On Crown forest land in British Columbia, regulated for sustained yield, regeneration costs are regarded as a necessary cost of logging and are treated as such in stumpage appraisals. Under such circumstances, it is argued, reforestation costs cannot be regarded as an investment and should not, therefore, carry the burden of interest charges. The question of whether reforestation costs should be regarded as an investment or an annual maintenance cost, in sustained yield forestry, was discussed by Streyffert (1960). Streyffert concluded that, if sustained yield forestry has to be practised by law, the cost of reforestation is a reinvestment and not a new investment, except to the extent that it would increase the sustained yield capacity of the forest.

On private forest land in British Columbia, which has been classified as Tree Farm Land, certain forestry costs may be deducted from the assessed value of the property for taxation purposes. These "allowable" costs include protection costs, operating costs, annual capital
maintenance charges, administration charges, stand improvement costs and reforestation costs. It is argued that, as Tree Farm Land has to be managed on a sustained yield basis, such costs are necessary in order to comply with law and should be tax deductible.

The fact that reforestation costs may be charged against stumpage on Crown land and forestry costs are tax deductible on Tree Farm Land may modify, considerably, the investment decisions of private forest operators. If a Tree Farm Licence holder can set reforestation charges against stumpage, he is quite justified in not regarding such charges as an investment. Likewise, the owner of a Certified Tree Farm may justifiably neglect carrying charges on forestry costs which are tax deductible. Under such circumstances forest investments, as far as the private forest operator is concerned, become far more attractive. Society, however, cannot, under any circumstances, neglect interest charges against forestry costs in making its investment decisions. By allowing forest operators to charge reforestation costs against stumpage, society is paying for reforestation indirectly through the stumpage charges foregone. Similarly, society is subsidizing forestry costs on Tree Farm land through reductions in tax revenues.

If efficiency in forest investment is to be
achieved in British Columbia funds must be directed into those areas yielding the highest economic returns. Investments must not be undertaken unless their expected yields, discounted to the present, exceed the initial investment cost. There are many questions to be answered concerning the nature of forest investment in British Columbia. For example, is it most profitable to reforest newly logged areas or concentrate on the reclamation of high quality N.S.R. and N.C.C. lands near the centres of population and manufacture? Would it not be better to spend money on spacing control in naturally regenerated stands than to carry out artificial regeneration on unstocked areas? At what point should reforestation at the extensive margin give way to investment in intensive forestry such as fertilization, thinning, pruning, etc.?

d) Rotation Policy for Second-Growth Stands

British Columbia's maximum sustained yield policy demands that second-growth stands be felled when their mean annual increment per acre, measured in terms of sound merchantable volume, is maximized. During the period of conversion to sustained yield, it may be necessary to leave second-growth stands beyond the age of maximum mean annual increment but, once sustained yield has been established, it is intended that all rotations will comply to this
criterion. The Forestry Handbook for British Columbia (1959) defined the "economic rotation" as:

"The rotation which coincides with the period of the culmination of the mean annual merchantable growth of the species concerned and results in the maximum average production of merchantable wood volume."

In discussing the rotations used in British Columbia the Handbook said:

"It (the rotation) should be long enough to produce the maximum average growth per acre per year.---- Generally the rotation is based on the culmination of mean annual increment expressed in the unit of measurement used for the principal products of the forest, as indicated by standard normal yield tables for the predominant species."

Economics of forest rotations were discussed in Chapter Five. It was shown that the major costs of holding standing timber are the opportunity cost of the capital, frozen in the forest crop, and the opportunity cost of the land occupied by the current forest crop. From an economic point of view, the optimum rotation is reached when the marginal cost of holding the standing timber, for an additional period, is just equal to the marginal revenue derived from the current crop during that period. The criteria used for determining forest rotations in British Columbia show a disregard for economic factors. The forest managers are not concerned with the value of the forest crop
but merely with the volume produced. No account is taken of the fact that unit timber values increase greatly with size, partly because large logs yield more valuable products than smaller logs and partly because larger trees can be logged, transported and milled at a lower cost per unit volume. The British Columbia Forest Service behaves as though the cost of capital in the British Columbia economy is zero and thus implies that there are no alternative uses for capital funds. Chief Justice Sloan appeared to be completely ignorant of the costs of holding standing timber. In discussing rotations in his 1956 report he emphasized his lack of concern for economic considerations, and his bias towards physical criteria for rotation length:

"The argument has been presented that the better sites produce their greatest mean annual increment at approximately fifty years, but it should be emphasized that this applies to the better sites only and that the fifty year rotation will produce a large number of small diameter (less than 12 inches d.b.h.) trees. In any event, the reduction in mean annual increment resulting from carrying stands an additional thirty to forty years is insignificant and will be offset by such advantages as improved quality increment, larger size trees, and less volume loss resulting from more frequent regeneration periods."

(Sloan, 1956)

Haley (1964) investigated the factors influencing the financial rotation of Douglas fir in Coastal British
Columbia and showed that financial rotations for managed stands of this species are generally much shorter than the rotations currently recommended by the British Columbia Forest Service. Using the British Columbia Forest Service inventory of Douglas fir in British Columbia, Haley found that the use of rotations, other than financial rotations, results in an economic loss to the province of about $7 million per annum, on this one species, and assuming a modest discount rate of 3 per cent per annum. (Smith and Haley, 1965).

e) Effect of Sustained Yield Management on the Economic Development of the Forest Industries

In Chapter Four, it was suggested that sustained yield forest management may retard economic development by setting an ultimate ceiling on the growth of the forest economy. This danger, it was pointed out, would be particularly serious in a country or region in which forestry plays a major role in the economy.

British Columbia's forest industries play an extremely important role in the economy. In 1964, the value added by manufacture in the forest industries was over 34 per cent of the value added by all manufacturing industries in the Province (Provincial Bureau of Economics and Statistics, 1965). Forestry, in terms of net value added annually, is more important than the agricultural, fisheries
and mining industries combined. In 1964, forest product exports from British Columbia had a gross value of over $909 million, that is 56 per cent of the total value of all products exported from the Province. Net investments in the forest industries of British Columbia in 1964 was $238 million, that is 15 per cent of total net investment in the Province. In addition, new investment in the forest industries stimulates investment in many secondary industries. For example, the current expansion in pulp capacity is stimulating investment in the chemical industries for the production of chlorine and sodium hydroxide.

Because of the importance of forestry, and forest based industries, to the economy of the Province, the effect of sustained yield policy on the development of the forest industries, particularly in the long run, cannot be ignored.

The British Columbia Forest Service, in defending sustained yield, generally takes the position that, in the past, forest production in British Columbia has been restricted by markets and not by the supply of raw material, and that this situation is likely to continue in the foreseeable future (Hughes, 1965). The forest industries, on the other hand, believe that raw material shortages will seriously curtail forest production in British Columbia in the near future, and the Province will be unable to take
full advantage of expanding world markets for forest products. Mahood (1965) said:

"The time is upon us where supply is a pressing limitation on the woods production."

and the Provincial Bureau of Economics and Statistics (1964 a) expressed the belief that lumber production in the Province is being seriously curtailed by the availability of sawlogs.

In order to examine the question of the effect of sustained yield on industrial development in British Columbia, several factors must be considered. Firstly, is there any evidence to show that the Forest Service's sustained yield estimates are inadequate to fulfill the needs of the forest industries? Secondly, has sustained yield seriously retarded the growth of the forest industries in the past? Thirdly, what is the potential of British Columbia forest products on world markets and will the forest industry be able to meet this potential within the framework of the existing sustained yield policy?

(1) Allowable Annual Cut Estimates of the British Columbia Forest Service

In 1957, the British Columbia Forest Service, on the basis of its latest inventory information, calculated allowable annual cut estimates for British Columbia by
Forest Region using the Hanzlik formula (see page 220). The current allowable annual cut on the Coast was given as 298 million cubic feet (1788 million f.b.m.)\(^{31}\) and in the Interior as 669 million cubic feet (3847 million f.b.m.), giving a total allowable annual cut for the whole Province of 967 million cubic feet (5635 million f.b.m.). These estimates were based on what the Forest Service then considered to be the currently exploitable forest resource (see page 223).

The Forest Service recognized that, as technology advanced and economic conditions changed, utilization standards would improve and more areas would become operable, thus increasing the allowable annual cut:

"Forestry practices, logging and utilization standards have steadily improved since the earliest days of the forest industry in British Columbia and it is quite clear that further improvements are to come. Hence, it is not realistic to assume that the current level of exploitation, previously defined, will continue indefinitely. As already stated, however, it cannot be expected to change during the next five to ten years, perhaps longer." (British Columbia Forest Service, 1957) (my emphasis)

The Forest Service advocated periodic recalculations

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\(^{31}\) The conversion from cubic feet to board feet has been made using conversion factors of: 1 cubic ft. = 6 f.b.m. on the Coast and 1 cubic ft. = 5.75 f.b.m. in the Interior.
of allowable cuts until, ultimately, the allowable annual cut of the Province would reach, what they called, "the full exploitation level". At this level, it was assumed that the sound-wood volume, at close standards of utilization, in all trees 10 inches d.b.h. and over, would be used from all accessible and potentially accessible forests. The estimated annual allowable cuts at "full exploitation level" were 995 million cubic feet (5970 million f.b.m.) on the Coast and 2033 million cubic feet (11,690 million f.b.m.) in the Interior giving a total Provincial allowable annual cut in the long run of 3,028 million cubic feet (17,660 million f.b.m.).

(ii) Actual Versus Allowable Annual Cut

In Figure 9 is shown the volume of timber cut in British Columbia, annually, between 1903 and 1964; the annual volumes of timber cut in the Interior region and in the Coastal region between 1917 and 1964; and the current and potential allowable annual cuts as calculated by the British Columbia Forest Service in 1957.

The actual annual cut in the Province has exceeded the allowable annual cut since 1954. In 1964, the volume of timber cut exceeded the current allowable cut by 65 per cent. In the Coastal region of British Columbia, the actual annual cut has exceeded the allowable annual cut almost every year.
Figure 9: Actual versus allowable cut in British Columbia, 1903 – 1964.

Current Annual Allowable Cuts
1. Coast – 1788 MM fb.m
2. Interior – 3847 MM fb.m
3. Province – 5635 MM fb.m

Full Potential Annual Allowable Cuts
4. Coast – 5970 MM fb.m
5. Interior – 11,690 MM fb.m
6. Province – 17,660 MM fb.m

Sources:
B.C. Forest Service Annual Reports.
since 1923. The only exceptions being in 1932 and 1933 at the depths of the Depression. In 1964, the volume of timber cut in the Coastal region exceeded the current allowable annual cut by almost 180 per cent. In the Interior region of the Province, the volume of timber cut annually was extremely small until the Second World War. Since 1945, the volume of timber cut annually in the Interior has risen sharply and, in 1964, the actual volume cut exceeded the allowable annual cut for the first time.

A large proportion of the timber cut annually in the Province is from areas which have not yet been committed to sustained yield management under approved working plans. In 1964, 38 per cent of the Provincial timber scale originated in unregulated areas. Although there is regional overcutting on Public Sustained Yield Units in the Vancouver Forest District and the southern Interior, the annual cut on regulated forest land, taking the Province as a whole, is usually within the limits set by the approved allowable cut. In Table 17 the actual cuts are compared to the allowable cuts on Tree Farm Licences and Public Sustained Yield Units, from 1952 to 1964. Only in 1962 and 1963 was overcutting in evidence on areas operated under approved allowable cuts.
Table 17. Comparison of Actual and Allowable Annual Cuts On Regulated Forest Land in British Columbia 1952 - 1964

<table>
<thead>
<tr>
<th>Year</th>
<th>Public Sustained Yield Units</th>
<th></th>
<th>Tree Farm Licences</th>
<th></th>
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<tbody>
<tr>
<td></td>
<td>Allowable Cut</td>
<td>Actual Cut</td>
<td>Actual Allowable</td>
<td>Allowable Cut</td>
</tr>
<tr>
<td></td>
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</tr>
<tr>
<td>1952</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>69.67</td>
</tr>
<tr>
<td>1953</td>
<td>-</td>
<td>89.73</td>
<td>-</td>
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</tr>
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<td>179.64</td>
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</tr>
<tr>
<td>1955</td>
<td>189.40</td>
<td>115.09</td>
<td>0.61</td>
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<tr>
<td>1956</td>
<td>-</td>
<td>188.46</td>
<td>-</td>
<td>170.53</td>
</tr>
<tr>
<td>1957</td>
<td>334.14</td>
<td>207.89</td>
<td>0.62</td>
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</tr>
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<td>1958</td>
<td>379.65</td>
<td>254.88</td>
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</tr>
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<td>1959</td>
<td>418.62</td>
<td>312.05</td>
<td>0.75</td>
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<td>1960</td>
<td>446.62</td>
<td>385.20</td>
<td>0.86</td>
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<td>514.99</td>
<td>454.03</td>
<td>0.88</td>
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<td>656.99</td>
<td>607.64</td>
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</table>

### Table 18. Forest Products Production in British Columbia 1947 - 1965

<table>
<thead>
<tr>
<th>Year</th>
<th>Lumber</th>
<th>Paper</th>
<th>Pulp</th>
<th>Plywood</th>
<th>Net Value all Products</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M M f.b.m.</td>
<td>M Tons</td>
<td>M Tons</td>
<td>M M Sq. Ft. (⅛-inch in basis)</td>
<td>Million $</td>
</tr>
<tr>
<td>1947</td>
<td>2707</td>
<td>413</td>
<td>593</td>
<td>268</td>
<td></td>
</tr>
<tr>
<td>1948</td>
<td>2938</td>
<td>425</td>
<td>688</td>
<td>373</td>
<td></td>
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<td>2951</td>
<td>472</td>
<td>667</td>
<td>359</td>
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</tr>
<tr>
<td>1950</td>
<td>3508</td>
<td>498</td>
<td>777</td>
<td>389</td>
<td></td>
</tr>
<tr>
<td>1951</td>
<td>3804</td>
<td>513</td>
<td>924</td>
<td>482</td>
<td></td>
</tr>
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<td>1965</td>
<td>6740</td>
<td>1538</td>
<td>3246</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source - Provincial Bureau of Economics and Statistics,  
*Summary of Business Activity in B.C. (1947 - 1965)*
Figure 10: Forest products production in British Columbia, 1947-1965.

Year
1945 1950 1955 1960 1965
Lumber (MM fbm)
Pulp (M tons)
Plywood (MM sq ft, 1/4-inch basis)

(iii) Development of Major Forest Industries Since the Initiation of Sustained Yield Policy

From the preceding section, it would appear that the current allowable cut of sawtimber in British Columbia is inadequate to meet the current demands on the forest resource. It would be reasonable to expect, therefore, that this apparent supply deficit would have discouraged investment in the forest based industries of the Province. Such is not the case, however. There is little evidence to indicate that the policy of sustained yield has retarded the overall development of the forest industries in British Columbia up to the present time. Investment in the forest industries has grown steadily since the introduction of sustained yield legislation. In 1965, net capital investment in the forest industries of British Columbia was $250 million, 15 per cent higher than in 1964 and 75 per cent higher than in 1963. There have been many changes in the pattern of forest investment over the last 20 years, however, as an examination of the forest industry, by sectors, will show.

The Lumber Industry

Table 18 and Figure 10 show the volume of lumber produced by British Columbia sawmills from 1947 to 1964. It can be seen that there has been a steep upward trend in lumber production throughout this period, indicating an
immense expansion in sawmill capacity. Most of this expansion has taken place in the Interior of the Province, however. Prior to the Second World War, practically all the lumber produced in British Columbia was manufactured in the Coastal region. In 1945, 80 per cent of all the lumber produced in the Province was cut on the coast and 20 per cent in the Interior. By 1954, the Interior's share of lumber production had risen to 39 per cent and, by 1964, to 55 per cent. There has been no major sawmill expansion on the Coast for several years and the industry is fast approaching full plant capacity. In the Interior there is a movement towards the consolidation of lumbering operations. Between 1956 and 1964 the number of operating sawmills declined from 2118 to 1235, while, during the same period, the 8 hour shift capacity of operating sawmills increased from 18,700,000 f.b.m. to 21,250,000 f.b.m. (Provincial Bureau of Economics and Statistics). It is difficult to say, to what extent the introduction of yield regulation on the Coast led to the lumber industries shift to the Interior. It is certain that, even in the absence of sustained yield, expansion of the sawmilling industry would have taken place in the Interior but the introduction of yield regulation on the Coast has almost certainly accelerated the process. The introduction of sustained yield has led to a severe
shortage of sawlogs on the south Coast which has been aggravated by the increased competition for logs from pulp-mills and plywood plants. It is doubtful whether sawmill capacity on the Coast can increase further, within the current framework of sustained yield regulation. In the Interior, particularly in the south, a situation similar to the Coast is likely to develop in the near future. In the Kamloops and Nelson Forest Districts the volume of timber cut annually greatly exceeds the allowable cut, as laid down by the British Columbia Forest Service, and there is increasing competition for stumpage from pulpmills.

Plywood Industry

Plywood production has grown steadily in British Columbia since the Second World War (Figure 10). In the past plywood production has been concentrated in the Coastal region but in recent years the diminishing supply of peeler logs has discouraged investment in Coastal plywood plants and current production is taxing existing plants to full capacity. New investment in plywood capacity is planned for the Interior and new plants have been, or are presently being, installed at Canoe, 100 Mile House and Golden. (Provincial Bureau of Economics and Statistics, 1964).

Pulp Industry

Pulp production in British Columbia grew steadily
between 1947 and 1962. Since 1962, however, there has been an unprecedented increase in pulpmill investment. In 1962, the first Pulpwood Harvesting Area was established, under section 17A of the Forest Act (see page 225), in the Prince George Forest District. This was followed, in 1963, by the establishment of the second Pulpwood Harvesting Unit in the Kamloops Forest District and by the third, in the Prince George Forest District in 1964.

In 1963, net capital investment in the pulp and paper industry was 117 million dollars, 54 per cent of the total net investment in all forest industries in the Province. In 1964, net investment in the pulp and paper industry rose to 131 million dollars, 10 per cent above the 1963 level. In 1964, planned investment in the pulp and paper industry amounted to 700 million dollars (Provincial Bureau of Economics and Statistics, 1964).

In 1964, the Provincial Bureau of Economics and Statistics estimated the pulp capacity of the Province to be approximately 345 million tons. Planned additional capacity, for the next 5-year period, is 3.3 million tons, or an average rate of increase of 660 thousand tons per annum. In 1964, British Columbia produced approximately 3.5 per cent of all the chemical pulp produced in the free world; by 1975 this share of pulp production should have increased to 6 per cent or even higher.
Unlike lumber mill and plywood plant expansion, pulpmill expansion is not confined to the Interior region of the Province. For example, in 1965, pulpmill development on the Coast included the completion of a $24 million expansion at Woodfibre, which doubled the mills pulp capacity; a $12.5 million kraft pulp expansion at Port Alberni; and smaller expansion projects at Port Mellon, Campbell River, Powell River, Prince Rupert, and Port Alice. Work commenced, during 1965, on a $100 million expansion programme at Powell River and the installation of new, 750 tons per day, kraft pulp mills at Gold River and Prince Rupert. Pulpmill development in the Interior, during 1965, included the completion of a new $17 million, 250 tons per day, kraft pulpmill at Kamloops; an $18.5 million expansion at Crofton; and the establishment of three kraft pulpmills at Prince George with a total combined capacity of 1975 tons per day. At the moment, 6 potential pulpmills, with secured timber supplies, are in the planning stages. These mills will be at Squamish and Kitimat on the Coast, and at Quesnel, Houston, and two north of Prince George, in the Interior. The Provincial Bureau of Economics and Statistics has estimated that approximately 1.7 million tons, or 51 per cent, of the proposed additions to pulpmill capacity, during the next 5 years, will be situated on the Coast.
Future Outlook for British Columbia Forest Industries

There is no evidence that, in the past, the sustained yield policy of British Columbia has seriously curtailed the overall growth of the forest industries in the Province but, whether this will be the case in the future, is open to question. The market outlook for all the major forest industries in British Columbia is good. The lumber industry, although it cannot expect any major gains in the domestic market, has the prospect of steady growth in the traditional United States and United Kingdom markets and an excellent chance of expanding trade in the Asia-Pacific area (Haley, 1964; Reed, 1965; Mitchell Press, 1965). The plywood industry can look forward to steady growth in all its major markets provided it can overcome the competition, both domestic and foreign, which is rapidly developing in this field (Haley, 1964; Reed, 1965). The pulp and paper industry has every reason to be optimistic about the future. Even if overcapacity develops in the short run, the long run prospects for this industry appear to be excellent (Nicholson, 1964; Mitchell Press, 1965). The forest industries will only be able to take advantage of the future market potential, however, if there is an adequate supply of raw material at their disposal.

It is doubtful whether, under current sustained yield policies, the full potential of British Columbia's
forest industries will be realized in the future. On the southern Coast, and in the southern Interior, sawlogs are already in short supply and stumpage prices are rapidly increasing; a situation which is certain to affect British Columbia's competitive position in world markets. Expansion of plywood and lumber capacity on the Coast has virtually ceased and no further growth in this region is envisaged under existing regulations. The lumber trade with the United Kingdom, the eastern United States and the Pacific region, however, is largely dependent on the production of Coastal mills. The Forest Service has encouraged the development of the pulp and paper industry by making available large volumes of "smallwood" at the relatively low price of 55 cents per cunit. It is upon the utilization, by the pulp and paper industry, of wood which is not suitable for the production of sawlogs, that the Forest Service intends to base its allowable cut revisions in the future. But, such increases are not going to aid the lumber and plywood industries. For example, the current allowable annual cut in the Coastal region is 298 million cubic feet, based upon trees 12 inches d.b.h. and over to rough utilization limits. By 1970, the coastal pulp industry will require approximately 250 million cubic feet of allowable annual cut (Mahood, 1965). This increase in allowable cut could be achieved by planning to utilize the sound wood
volume in trees 10 inches d.b.h. and over to close utilization limits (see Table 19, page 272). As the pulp industry should be able to use trees down to 9 inches d.b.h., or lower, the Forest Service would feel justified in making the necessary allowable cut adjustments, as described above. However, the increase in the allowable cut will be entirely committed to pulp production; the lumber and plywood industry will still be restricted to logging the same volume annually in trees 12 inches d.b.h. and over, and will only be able to increase production by competing with the pulp industry for smallwood supplies. That is, the increase in the allowable cut will not be spread over all size classes, at the discretion of the industry, but will be allotted to smallwood; the allowable cut of sawlogs remaining the same.

It is extremely likely that, in the future, the existing policy of sustained yield will severely retard the development of the forest industries in British Columbia, particularly those industries which are dependent on large-size sawlogs. The Government of the Province would be well advised to consider this aspect of their policies closely, in any future reappraisal of the forest management situation. In the past there has been a tendency to either disregard the question, or to dismiss it lightly as a predictable reaction, on the part of industry, to Governmental controls.
Sloan did not consider the effects of sustained yield on the long run development of the forest industries in either his 1945 or 1956 reports and the Government continues to disregard the repeated warnings of the forest industries on this matter. The Government will not increase the allowable sawlog cut but expects the sawmilling industry to make use of small diameter logs even though it may not be economically feasible to do so. The costs of logging and milling small material in British Columbia increase rapidly as log size decreases (Smith et al., 1961) and at the moment it is impossible for the sawmilling industry to compete successfully against the pulp industry for trees under 12 inches d.b.h. in most regions. Rees (1965) commented on this situation:

"A large part of the increase (in allowable cut) will be available in log sizes 7 to 11 inches in the Interior and 9 to 14 inches on the Coast. Prior to 1965, timber this small was considered uneconomical to recover in logging. It took the current pulpmill "explosion" to make sawmillers realize that smallwood can also be used for lumber recovery, supplemented by chip revenues. Exercising the smallwood option is the only way many of them can increase sawlog quotas."

Although it is true that many sawmills are beginning to make use of smaller sized logs, they are being
forced to do so at a high cost which can only be harmful to the competitive position of the industry. The fact that the pulp industry is expanding and can practise close utilization to 9 inches d.b.h., or lower, and has more than doubled the size of the economic resource base in British Columbia, should indicate to the Forest Service that their 1957 allowable cut estimates were extremely conservative and that drastic revisions are long overdue. These revisions should not differentiate between sawlogs and smallwood but should consider the forest resource base as a whole. For the Government to say that it is increasing allowable cuts, when it is merely adding the volume contained in small trees to the ultra-conservative cuts of sawlog material, is misleading. The complete disregard of the Forest Service for the economic factors governing wood utilization was emphasized by Rees (1965):

"The B. C. Forest Service now knows what the industry can utilize under the smallwood options for sawmills, and those who take up the increased quota may find themselves under fire and penalized by higher dues if they don't follow it through by doing a complete job of logging."

No one could deny that the British Columbia Government has done an excellent job in promoting the expansion of the pulp industry in the Province. By diversifying forest investment in this way, the forest economy has remained
buoyant even though the traditional sawlog industries are facing major raw material supply crises in many areas. The Government should recognize, however, that there is no room for complacency as far as the sawlog industries are concerned. In order to overcome the growing competition and win new markets, the lumber and plywood industries must be given access to sufficient supplies of the kind of raw material they are currently equipped to handle in the most economic manner. If old-growth stands are reserved at this time, the Province may find itself, in a few years time, with large reserves of sawlog timber but no markets in which to sell them. British Columbia, at the moment, is in the enviable position of having at its disposal large quantities of good quality timber, which can be logged and manufactured economically by an efficient and modern sawmilling industry. This timber must be used now to invade new markets and to improve British Columbia's trading position in traditional markets, thus providing a healthy economic atmosphere and a wide capital base for future economic growth. Any delay, particularly on the coast, might be too late and the great economic potential of the forest resource may be lost forever. The forest industries realize the gravity of the situation but it is up to the Government of the Province to take action:
"Without increases in the annual allowable cut of sawtimber, there will be no increase in B. C. lumber production available for sale to the Asia-Pacific or any other market. This limitation is underlined by the declining rate of increase in B. C. log production in the face of rising markets for all forest products, and by the rapidly increasing appetite for timber by the Province's pulp mill sector. And until the allowable cut is recalculated and brought up to date, the fear of Russian penetration in our Pacific lumber markets is academic." (Reed, 1965)

4. An Alternative Approach to Forest Management in British Columbia

The policy of sustained yield has been criticized as a rational objective for the Province of British Columbia. The question which now remains is: What alternative management policy should be employed? The forest management situation in British Columbia is, of course, very complex. Sweeping changes in policy objectives and management practices cannot be made immediately, but gradual changes could be made which would result, ultimately, in better and more realistic use of the forest resource.

a) Re-Assessment of the Allowable Annual Cut

One of the most urgent reforms necessary in British Columbia's forest management policy is the revision of the
basis for allowable annual cut calculations for sawtimber. Such a revision should ease the pressure on timber supplies, particularly on the Coast, until further changes in management policy become feasible. Even if further changes were neglected, a realistic approach to allowable cut calculations would be a great step forward.

Allowable cut calculations should anticipate rather than follow changes in utilization standards. This would appear to be fairly obvious but it is completely foreign to the current policy of the British Columbia Forest Service. If the Forest Service believed that future utilization standards were not going to improve, then, in the context of sustained yield policy, their criteria for calculating the allowable cut would be rational. The Forest Service has stated categorically, however, that it believes that standards of utilization will improve in the future (British Columbia Forest Service, 1958) and, therefore, their current allowable cut is completely unjustified.

Current allowable annual cuts in British Columbia, as calculated in 1957, are based on the sound wood volume in trees 12 inches d.b.h. and over; to rough standards of utilization; on operable, accessible sites of average or better productivity; deciduous species and lodgepole pine being excluded from the calculation.
Even in 1957, rough utilization standards were only practised, as a rule, on the most difficult sites in the Coastal region and, today, with the rapid development of the pulp industry, close utilization standards would be considered realistic in many areas. Although, for sawlogs, a 12 inch d.b.h. tree is close to the economic margin of logging feasibility, in most areas, the pulp industry is currently logging trees down to 9 inches d.b.h., or even lower. There is every reason to believe that the size of the zero marginal tree for sawlog purposes will fall considerably in the future as logging technology improves. In Sweden, British Columbia's most important rival in many of her major markets, the minimum tree size is about 5 inches d.b.h. and few trees exceed 12 inches d.b.h. (Smith, 1965).

The current allowable cut for sawtimber in British Columbia is calculated on the basis of only 22.7 million acres, of the 137 million acres of productive forest land in the Province, 67 million acres of which are regulated for sustained yield. It is a certainty that most of the areas which are currently considered inaccessible or inoperable will be used for wood production in the future.

The omission of lodgepole pine and deciduous species from allowable cut calculations is a very shortsighted approach to management planning. Lodgepole pine is rapidly becoming a major commercial species in the Interior
of the Province and deciduous species, although of minor importance in British Columbia, are being used to some extent by the pulp and sawmill industries.

In order to calculate the current allowable cut, the Forest Service made use of a rotation age of 100 years on the Coast and 120 years in the Interior, instead of the more desirable, and usually shorter, financial rotations. (see page 116)

Relatively small relaxations in the criteria used for the calculation of the allowable annual cut could lead to vast improvements in the current availability of timber. In Table 19 the Hanzlik formula has been used to calculate allowable annual cuts for different levels of forest utilization and varying rotation lengths. If, using current utilization standards, the operative rotation length was reduced to 80 years on the Coast and 100 years in the Interior, allowable cuts would be increased by approximately 7 per cent and 2 per cent on the Coast and in the Interior, respectively. Reduction of the marginal tree size from 12 inches to 10 inches d.b.h., and the use of close, instead of rough, utilization standards, would more than double the allowable cut on the Coast and in the Interior. The inclusion of all accessible and potentially accessible sites in the allowable annual cut calculations would increase the
Table 19. Allowable Cut Calculations for British Criteria For Allowable Cut Calculation

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<td>Sound wood volume to</td>
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<td>All species</td>
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<td>(Current)</td>
<td>rough utilization limits</td>
<td>Operable</td>
<td>Except</td>
</tr>
<tr>
<td></td>
<td>reduced for waste and</td>
<td>Accessible</td>
<td>Lodgepole</td>
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<tr>
<td></td>
<td>breakage</td>
<td>Sites of</td>
<td>Pine and</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Average or</td>
<td>Deciduous</td>
</tr>
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<td>Better</td>
<td>Species</td>
</tr>
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<td></td>
<td></td>
<td>productivity</td>
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</tr>
<tr>
<td>2</td>
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<td>As above</td>
<td>12 inches</td>
</tr>
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<td></td>
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</tr>
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<td>3</td>
<td>Sound wood volume to</td>
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</tr>
<tr>
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<td>close utilization limits</td>
<td>Operable</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Accessible</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sites of</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Average or</td>
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<td></td>
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<td>Better</td>
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<td>productivity</td>
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<td>All species</td>
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<td>4 inches</td>
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Columbia Using Various Criteria

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<th>Interior</th>
<th>Coast</th>
<th>Interior</th>
<th>Coast</th>
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<td>%</td>
<td>%</td>
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<td></td>
<td></td>
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<tr>
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<td></td>
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<td>103</td>
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<td>2588</td>
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<td>288</td>
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</table>
Coastal allowable annual cut by almost 270 per cent and the Interior allowable annual cut by almost 200 per cent. These allowable cut estimates are based upon current management and silvicultural practices. Allowable cuts could be further increased by improved protection against pests, by prompt reforestation, control of spacing, salvage of mortality by thinning, and improvement of site quality by draining and fertilization. In the long run, forest yields may also be increased substantially through tree selection and breeding programmes. Increasing allowable cuts by the intensification of forest management was discussed by Smith (1965).

b) Zoning Forest Land for Management Purposes

The second step, which should be taken in the reform of forest management in British Columbia, is the zoning of forest land by principal use. This would, of course, present many difficulties but would appear to be absolutely essential for the formulation of a rational forest management policy. The zoning need not be elaborate to be effective. Primarily, the forest land should be divided into two categories: areas in which timber production is the only objective; and areas in which other values such as recreation, watershed protection, agriculture, wild-life protection, or community stabilization have to be considered. Further subdivisions of the second
category of land should then be carried out according to principal land use. Particular attention should be given to defining those areas in which obvious clashes between land uses occur. Within each major land use category the forest area should be subdivided into smaller units for administration of specific management plans (the current system of Tree Farm Licences and Public Sustained Yield Units would form the basis of this subdivision). As far as possible, individual management units should be devoted to a single purpose but, of course, in some cases conflict between uses would be impossible to avoid.

c) Defining Management Objectives

(1) Timber Land

In those areas in which the only objective is the production of timber there is no apparent reason why the forest should not be managed in a way which is commensurate with the maximization of profits. Indeed, the pursuit of any other policy, in such areas, would prevent the maximization of the forests contribution to the welfare of society. How should government policy be designed in order to meet the profit maximizing objective?

In areas which are, by definition, of no social importance, there is no reason for government interference in the management of privately owned or controlled land, provided the tenure of such land is sufficiently secure.
There is a great deal of suspicion in British Columbia, of the actions of large forest companies left to their own devices. This suspicion springs from experience, prior to the amendment of the Forest Act of 1947, when utilization standards were low, high grading was the rule, regeneration was not encouraged following logging and the transient nature of the industry led to poor working conditions in the woods and instability of employment. The main cause of these phenomena, however, was that the forest operators did not have secure tenure over their forest lands and had no interest in maximizing the value of the forest in the long run. In addition, the best quality, most accessible, Coastal stands of old-growth timber were being rapidly depleted and the policy of most forest operators was to maximize their short run returns, for each timber sale, and move on to another area as quickly as possible. Sloan, in his 1945 report, recognized that the crux of the forest problem in British Columbia was insecurity of tenure when he remarked:

"Under our present system of temporary alienations of timber lands that revert to the Crown when logged, operators who cut these lands to secure raw material for their own conversion units are offered no encouragement to treat these lands as permanent tree farms producing continuous crops." (Sloan, 1945)
In order to overcome the tenure problem Sloan recommended the formation of privately controlled permanent management units and, upon this recommendation, the 1947 amendments to the Forest Act made provision for the formation of Forest Management Licences (Tree Farm Licences). The operators of Tree Farm Licences are mainly corporate firms with considerable investments in plant and equipment. There is every reason to believe that, if allowed to operate unrestrained, Tree Farm Licence holders will behave in a way which is designed to maximize the present worth of their enterprises, and, in so doing, will make a maximum contribution to the Provincial economy in terms of stumpage, logging taxes, corporate income taxes, employment and investment.

It might be argued that, even with security of tenure and no conflict between private and social values, profit maximization, on the part of the entrepreneurs in the forest industry, will not optimise the use of the resource, from the social point of view, if imperfections exist in either the factor or product markets. (See discussion on page 62).

In British Columbia competition within the forest industry is far from perfect. The product markets exhibit an oligopolistic structure. There is little product differentiation within the forest industries and the markets are dominated by a small number of very large firms which may
take the role of price leaders. The market for inputs is also imperfect and monopsony is not uncommon. It will be seen in the next section that competition for Crown stumpage in British Columbia is practically nonexistent.

It seems unlikely that market imperfections are sufficient cause for Government interference in the private forest industry of British Columbia. The presence of large oligopolistic firms may have beneficial effects which far outweigh the social costs of imperfect factor allocation, which may result from imperfect competition. Large firms, on the whole, are better informed than small firms about market opportunities and future market trends. They are, therefore, in a much better position to maximize the present worth of the resource. In the forest industry large firms achieve economies of scale in logging, manufacturing, and marketing which are beyond the means of smaller firms. The most important economies are probably achieved through the horizontal integration of product manufacturing processes. Economies in harvesting are becoming more important as the available forest stands become less accessible and more difficult to log. The prosperity of British Columbia, and

32 An exception to this generalization is the lumber industry of the Interior.
to a lesser extent, of Canada, depends on the competitive position of the British Columbia forest industries in world markets. The competitive ability of large firms is usually greater than that of smaller firms. Economies of scale in logging and manufacture allow large firms to maintain a competitive price, even when the quality and accessibility of the raw material is decreasing. They can afford to carry out research into harvesting techniques and manufacturing processes which will improve their competitive position and, usually, they have access to sufficient capital to be able to introduce innovations when they become available.

It would appear, therefore, that in areas which are free from conflict between private and social uses of the forest resource, the welfare of British Columbia would best be served if the government adopted a *laissez faire* attitude towards privately controlled forest areas. Tree Farm Licences should be subject to renewal every 21 years, as at present, thus assuring that any future changes in land use policy could be accommodated.

In areas which are to be solely managed for timber production, publicly controlled forest lands should be managed in a way which will maximize the net revenue accruing to the forest resource. This objective cannot be easily achieved and many problems will have to be faced. It is only by recognizing the problems
which exist and trying to overcome them, that a rational forest policy can be approached. Some of the problems surrounding the objective of management for maximum net revenue will be considered.

The Disposal of Crown Timber - One of the major difficulties which will have to be faced is the best method of disposing of Crown timber. Should the Government attempt to maximize the direct revenue accruing to the forest resource, in terms of stumpage, or are indirect revenues more important?

In British Columbia stumpage is paid on all timber cut from unalienated crown land. Stumpage is the price which a forest operator has to pay for the use of standing Crown timber. Stumpage appraisals are made by the British Columbia Forest Service, by species, and Crown Timber, within Tree Farm Licences, is sold at the appraised price. Crown timber on Public Sustained Yield Units, and on other unalienated Crown forest land, may be offered for sale at the appraised price by the Forest Service, or an interested party may locate, and make a formal application for the timber on a particular area. In the latter case, on approval of the application, the proposed sale is cruised

33 Detailed descriptions of the British Columbia Forest Service method of stumpage appraisal are given in Sloan (1956) and the Forestry Handbook of British Columbia (1959).
and appraised by the Forest Service and is advertised in the British Columbia Gazette and in the press. All Crown timber sales, whether offered by the Forest Service or solicited by a prospective buyer, are disposed of by public auction. Currently, bidding is usually carried out by sealed tender but open auctions do take place on occasion. The appraised stumpage price, as determined by the Forest Service, is a reserve price below which bids are not accepted. If there are no bids which equal the appraised stumpage price, the timber is reappraised and offered for sale again after a specified period of time has elapsed.

The successful bidder on a Timber Sale enters into a formal Timber Sale agreement with the Forest Service. In the Timber Sale contract the Forest Service stipulates conditions governing utilization standards, logging practices, the condition of the site after logging and the maximum time required for timber removal.

Although, under the Forest Act, all timber sales have to be advertised and put up for public auction, there is, in practice, little or no competitive bidding for most Crown timber which changes hands in British Columbia. In 1964, for example, 1896 timber sales took place of which 1723, or 91 per cent, were transacted at the appraised upset, or reserve, price (British Columbia Forest Service, Annual Report, 1964). The lack of competition for Crown
timber in British Columbia stems partly from tacit collusion between forest operators and partly from the "quota" system which has become an integral part of Forest Service procedure. The "quota" system operates as follows. In Public Sustained Yield Units the allowable annual cuts have been distributed among operators established within each Unit. The allowable cut, assigned to each operator, is known as his "quota". Only a "quota" holder may apply for a Timber Sale within the Sustained Yield Unit and the applicant has the right to meet, up to his "quota" limit, the highest bid made for stumpage, on the Timber Sale, when it is auctioned. Most of the Public Sustained Yield Units in the Province are fully committed to supplying existing "quota" holders and it is practically impossible for operators, without a "quota", to purchase any Crown timber. "Quotas" have become negotiable and, in order to gain a foothold in a Sustained Yield Unit, an operator must usually buy an existing "quota".

The "quota" system is open to a good deal of criticism on the grounds that it may, by virtually eradicating competition for Crown timber, prevent the most efficient use of the timber resource. If forest operators are assured of a timber supply, for which they do not have to compete, there is no guarantee that the timber will go into its highest use or be used by the most efficient
operators.

Under a system of free competitive bidding for a factor input, each entrepreneur will be willing to pay a unit price for the factor which is just equal to the factor's marginal contribution to the entrepreneur's total revenue (i.e. the value of the factor's marginal product). Thus, if an operator believes that 100 cubic feet of timber will add $5 to his total revenue, he will be willing to pay up to $5 per 100 cubic feet for the use of that timber. The value of a unit of raw material to the operator will depend on the efficiency of his operations and the value of his final product. If there is free competitive bidding for stumpage, timber will tend to move to the place where it is used most efficiently, to produce the manufactured product of the highest value. In a perfectly competitive stumpage market an optimum situation would be achieved when no unit of timber could be moved from one use to another without the total revenue, accruing to the forest resource, being reduced.

Obviously, the market for stumpage will always be far from perfect and optimum efficiency in timber utilization is, in practice, impossible to achieve. Nevertheless, open competitive bidding for the use of the forest resource will tend to direct timber into its most efficient use. The present "quota" system appears to be an effectual barrier to
maximum efficiency in timber utilization.

In most cases, open competition for Timber Sales results in stumpage prices far higher than the Forest Service appraised price. Apparently the Forest Service is not interested in maximizing the returns from the sale of stumpage. This view is corroborated by the fact that on at least one occasion in recent months, the bidding on pulpwood has been stopped because the price went too high. The Minister of Lands, Forests, and Water Resources has been criticized for these actions on the grounds that he is preventing the full potential realization of the forest resource. It seems probable, however, that the Government of British Columbia is willing to sacrifice high returns from stumpage sales for the advantages of, what they believe to be, a "healthy" forest industry. In British Columbia direct revenue from stumpage constitutes only a relatively small percentage of the total income from the forest resource. In 1964, for example, the revenue accruing to the Province of British Columbia from the forest resource was approximately $101 million. This included only $26 million in the form of stumpage, the rest being made up of: logging taxes $11 million; sales taxes $33 million; school, land and property taxes $5 million; the provincial share of corporate income taxes $12 million; and miscellaneous charges

It could be argued that low stumpage prices, in promoting a "healthy", relatively stable industry, will result in total forest revenues far higher than could be expected if free competition prevailed in the market for stumpage. It could also be argued that if British Columbia forest industries are allowed to obtain their raw material at a relatively low cost, they will be able to hold prices down and maintain their competitive position in the international forest products market. The British Columbia Forest Service also appears to hold the view that high stumpage prices prevent the practise of "good" forestry. By "good" forestry they mean a minimum of wastage in logging, the use of logging methods designed to promote regeneration, and the maintenance of site productivity. There is no guarantee, however, that these assertions are correct. The existing firms in the forest industries may be grossly inefficient compared to the would-be entrants and may only manage to stay in business by virtue of their cheap, and assured, supplies of raw material. It is quite conceivable that the encouragement of efficiency through free competition for stumpage, may increase both stumpage returns and indirect revenues and may promote more complete use of the
forest resource and an intensification of management practices. There is no evidence to suggest that any attempt has been made to study this problem in a systematic manner and the present policy appears to be based on arbitrary assumptions. From an economic point of view it would certainly be far better to encourage a competitive stumpage market and encourage forest industry, where necessary, by means of tax concessions.

The Projection of Stumpage Prices - The British Columbia Government is mainly concerned with the sale of stumpage. It was pointed out in the previous section that the only way to move towards the most efficient use of the forest resource is to allow competitive bidding for stumpage supplies and to assume that the maximization of stumpage revenues will also maximize the indirect revenues accruing to the forest resource. Consequently, the stumpage price is an extremely critical factor in determining the value of the forest resource to the people of British Columbia. It has been shown that, in order to make intelligent decisions concerning the rate of old-growth exploitation and the optimum rate of investment in second-growth stands, it is necessary to predict future trends in stumpage prices. The problems of price prediction for forest products, and for stumpage,
present a vast, almost untouched, field for econometric research. This field has been neglected in the past because emphasis has been placed on the physical, rather than the economic, control of the forest resource. The difficulties and uncertainties of price prediction should not preclude their use. Even under conditions of extreme uncertainty rational decisions can be made. Any attempt to understand the factors governing the value of the forest resource in British Columbia would be better than the present policy, which entirely avoids the problem.

The Operative Discount Rate - The factors affecting the discount rate to be used in forest management decision making were discussed in the appendix to Chapter Three. It was concluded that the operative discount rate should be at least equal to the firm's rate of return on its next best alternative capital investment.

It would be unrealistic and difficult for the Government of British Columbia to base the discount rate on the yield from the next best alternative investment. The Government is not subject to the budget constraints which beset private industry and a clear cut choice between projects does not usually exist. For example, the Government should not discount the returns from the forest resource at a rate of return it might expect from investments in a
hydroelectric power project. On the other hand, a private forest operator, with a clear cut choice between two alternative projects, would be quite justified in using the rate of return on the alternative project to discount the future returns for the existing project.

Instead of considering one or two individual projects the Government should base its discount rate on the average yield obtainable on capital in various sectors of the economy. The Statistical Summaries of the Royal Bank of Canada show that the average yield on Government of Canada bonds, during the last four years, was approximately 5 per cent. The average yield on industrial bonds between 1957 and 1965 was $5\frac{1}{2}$ per cent and the average dividend yield on common stocks during the last four years was approximately $3\frac{1}{2}$ per cent. Thus a discount rate of about 5 per cent would be fairly representative of the current opportunity cost of capital in British Columbia. Of course, this rate of discount will vary as economic conditions change and should be reviewed periodically.

ii) Multiple-Purpose Land

In those areas which are important for purposes other than the production of timber, forest managers should

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Reuber and Wonnacott (1961) recommended a discount rate of 5 per cent for public projects in Canada.
make use of some form of benefit-cost analysis (Chapter Six) to assess alternative management plans. It may be necessary, in such areas, to impose approved working plans on private owners and operators of forest land.

In British Columbia there are few forest areas where objectives, other than the production of timber, are exclusive. In most cases a compromise will have to be reached between timber production and the subsidiary uses of the forest. It is important that research be conducted into the nature of the production functions of such forest products as: recreation, wildlife, and water, for without such knowledge, satisfactory integration of forest uses is very difficult to achieve.

The most important area of conflict in British Columbia will be between management for revenue maximization and the need for stable, permanent communities, supported by a permanent forest industry. British Columbia is a vast Province, with many undeveloped regions and relatively poor communications. The benefits to be derived from the promotion of permanent communities in many areas of the Province are, obviously, very great. Apart from providing a better way of life for workers in the forest industry, the formation of permanent townships attracts other commercial enterprises and may lead, eventually, to the
economic development of a whole region. In such cases, the advantages of some form of sustained yield forestry may well outweigh other alternatives, and be the best plan to follow. It should not be assumed, however, that in such areas, a permanent forest operation is always better than a policy of planned forest liquidation. Each case must be judged on its own merits after all the relevant alternatives have been examined.

Even in areas where sustained yield is considered essential, management, within the constraints set by such a policy, should aim at maximizing the present worth of the enterprise. Economic criteria should replace physical management objectives; financial rotations should be practised and an economic balance should be achieved between old-growth and second-growth exploitation. The sustained yield plan should be flexible enough to accommodate cyclical changes in the demand for forest products and allowable cut calculations should anticipate secular changes in demand and price.
CONCLUSIONS

Sustained yield is one of the fundamental concepts of forest management. It originated in Europe between the 13th and 16th centuries in response to local timber shortages induced by political fragmentation and poor communications. It was systemized and put into serious operation on a national scale by the classical German and French foresters of the 19th century and was introduced to North America, by European foresters, at the end of the 19th century. Today, sustained yield is accepted as the principal goal of forest management by public forestry agencies throughout the United States and Canada.

It is difficult to define sustained yield policy concisely. It sometimes takes the form of a vague goal to which foresters aspire while at other times it is interpreted as a rigid prescription for forest management. Public forest agencies usually interpret sustained yield very rigidly as the management of a forest area in such a way that an equal, or near equal, volume of merchantable wood can be harvested annually, or periodically, in perpetuity. Closely associated with the policy of sustained yield, in many cases, is the concept of yield maximization and the joint policy of maximum sustained yield is often referred to.
Many advantages are claimed for sustained yield management including: the preservation of the forest resource for future generations; the amelioration of uncertainty in forest enterprises; the provision of regular incomes; the protection of social values; and the stabilization of communities. These factors do not provide sufficient reason for pursuing a policy of sustained yield forest management, indiscriminately. Many of the benefits claimed for sustained yield are not dependent on the production of equal annual, or periodic, harvests but are the result of continuous forest production. That is, the issue is not, usually, the rate of harvest but whether the forest land should remain productive. Certain social values may best be served by management for equal regular harvests but such cases are exceptional.

The application of rigid sustained yield policies can be severely criticized from an economic point of view. Except under very unusual circumstances management for equal annual, or periodic yields is incompatible with the maximization of the net present worth of the forest resource. Management for maximum sustained yield implicitly assumes that all input factors (i.e. labor, capital and land) are costless and, therefore, have no alternative use in the economy. Rigid sustained yield policies usually result in
an inelastic supply schedule for stumpage and, consequently, fluctuations in the demand for forest products lead to unstable stumpage prices and forest revenues. If the forest industries play a major role in the economy of a country or region, rigid sustained yield management may retard general economic growth and development. If forest land is dedicated, as it often is, to perpetual production, optimum efficiency in land use may be impossible to achieve.

It is evident that the pursuit of sustained yield may impose many real costs on society and on the individual entrepreneurs in the forest industries. The policy must be rejected, therefore, as a universal goal of forest management. It should be emphasized that there is nothing wrong with the concept of sustained yield, *per se*. The fault lies in its indiscriminate and rigid application.

The continuity of forest production can always be justified provided the necessary investment decisions are not arbitrary, but are governed by economic criteria. Such continuity of production provides society with many of the advantages claimed for sustained yield without the attendant disadvantages of regular annual or periodic harvests.

Sustained yield involving regular harvests may sometimes be perfectly acceptable if it is compatible with the policy objectives of the forest manager and is the
most efficient means of achieving these objectives. In order to choose the optimum harvest rate, however, a comparison must always be made between the relevant alternatives. Comparisons of management plans must take into account all the benefits and costs of each alternative and must deal with economic uncertainty in a systematic, consistent manner. Many aids to managerial decision-making exist; every effort should be made to adapt these techniques to the problems facing the forest manager.

Forest management in British Columbia provides an excellent example of the indiscriminate application of sustained yield principles. The policy of the British Columbia Forest Service, appears to be to manage every acre of forest land for maximum, sustained yield, in perpetuity. Great importance is attached to the maintenance of regular harvests on a regional basis. The variations allowed in rate of harvest seldom coincide with cyclical differences in demand for forest products. Allowable cuts are determined according to physical criteria with inadequate consideration for the economic value of the resource.

The Provincial Government justifies this system of management on the grounds that it is necessary for the protection of social values of the forest resource and will
lead to the establishment of permanent communities in the undeveloped regions of the Province. No attempt is ever made to investigate the effectiveness of the policy in achieving these aims, and the possibility that a more flexible system of management would be as good, if not better, is never admitted. Inflexible, sustained yield management is not confined to the area of social significance but is universal throughout the Province. The economic costs of sustained yield are never identified and management alternatives are seldom investigated. Sustained yield policy may actually be forcing 'premature' liquidation of timber held under temporary systems of alienation.

All the disadvantages of adherence to principles of inflexible sustained yield management, outlined above, are apparent in British Columbia. The most obvious and, perhaps, most serious consequences of this policy are that it may prevent expansion of manufacturing of lumber and plywood industries and reduce their ability to compete in world markets.

If the forest resource of British Columbia is to make a maximum contribution to the social welfare of the people of the Province, a new approach to forest management is required. Forest land should be zoned according to its principal use. The objects of management for each zone
should be clearly defined and a careful examination of management alternatives carried out. Those plans should be chosen which achieve the management objectives most efficiently. At all times full consideration should be given to the impact of forest management on the overall economic development of the forest industries.

It is hoped that the views expressed in this thesis will lead to an increased awareness of the economic disadvantage of rigid and uncompromising sustained yield forest management. Further investigations of this very important topic should test several management alternatives for each of the major forest regions of British Columbia.
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