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The Yukon forest reconnaissance inventory 1985

G.M. Bonnor and E.T. Oswald

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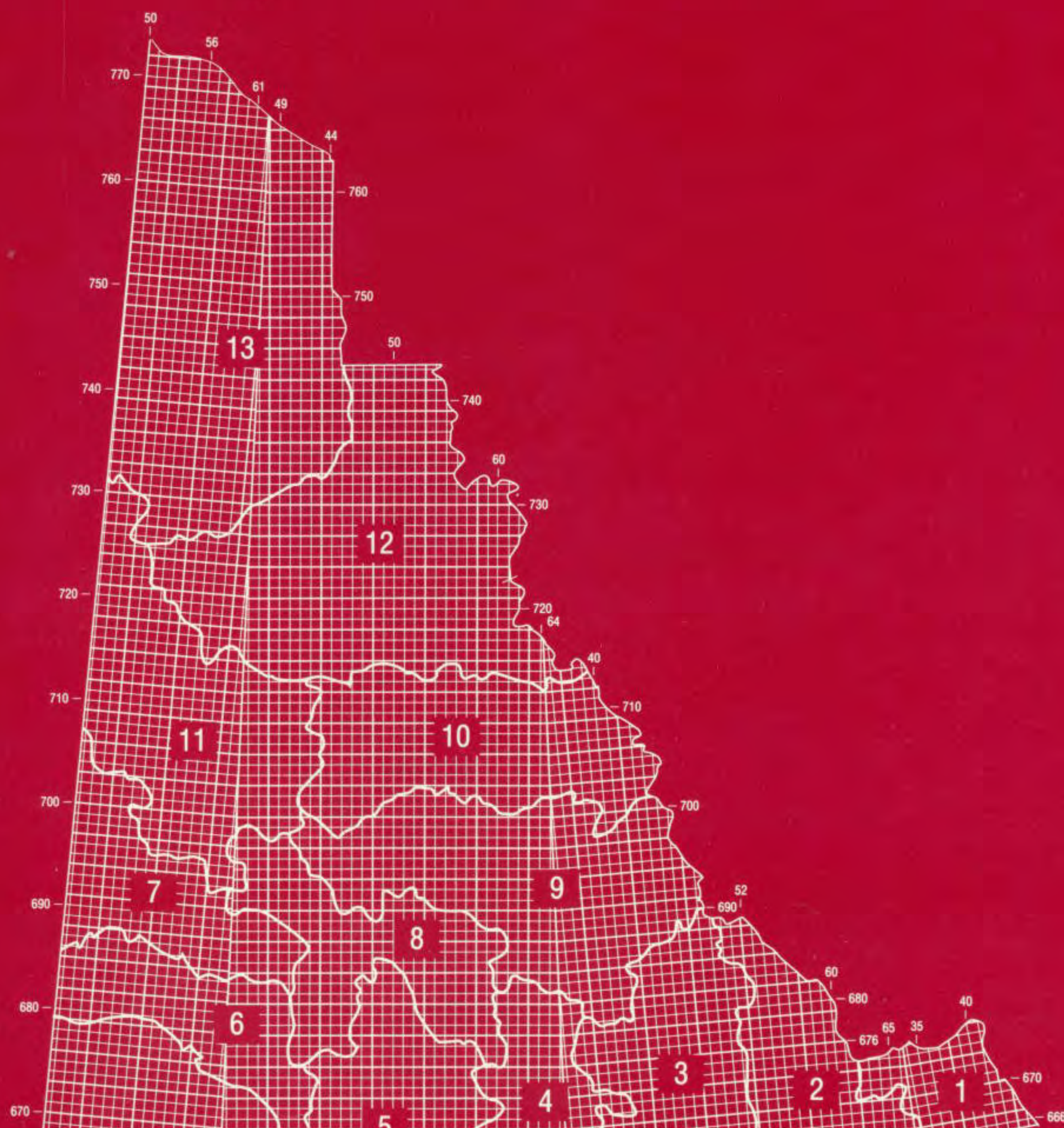

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Abstract

This reconnaissance inventory of the Yukon Territory is an extensive inventory for broad planning purposes. It provides estimates of areas, wood volumes and forest biomass by major forest types, ecoregions, and forest management units. Volume and biomass estimates by species are also provided, as well as biomass estimates by tree and stand components. More detailed estimates can be derived but the accuracy of such estimates is low. The use of existing aerial photography and sample plots has kept costs low, but low accuracy is the result.

The inventory shows that 27 million ha, or 57% of the Yukon, is forest land. Of this, 5.4 million ha is stocked productive forest land, which supports a growing stock of 459 million m^3 or 317 million tonnes of biomass. Most of the growing stock belongs to the softwood forest type (76%), the immature height-age class (66%), and the medium (lowest) site class (88%). Average volume is 86 m^3/ha. These values are all considerably higher than those obtained in a previous inventory.

The data are summarized on computer by 10x10 km UTM (Universal Transverse Mercator) referenced grid cells, which provide a ready summary and mapping capability.

Résumé

Le présent inventaire de reconnaissance du Yukon est un vaste inventaire forestier á des fins de planification. Il fournit des estimations des superficies, des volumes de matière ligneuse et de la biomasse forestière par principaux types forestiers, écorégions et unités d'aménagement forestier. Il présente également des estimations de volume et de biomasse par essence ainsi que de la biomasse des composantes de l'arbre et du peuplement. On peut obtenir des estimations plus détaillées, mais leur degré de précision est faible. Le recours aux photographies aériennes existantes et à des places-échantillons a permis de garder les coûts à un niveau raisonnable, mais s'est traduit par un faible degré de précision.

L'inventaire montre que les terrains forestiers du Yukon couvrent 27 millions d'hectares, soit 57 % du territoire. De ce chiffre, 5,4 millions d'hectares sont des terrains forestiers boisés productifs où le matériel sur pied est évalué à 459 millions de m^3 ou 317 millions de tonnes de biomasse. Ce sont surtout des forêts de résineux (76 %) jeunes (classes d'âge et de hauteur) (66 %) occupant des stations de qualité moyenne (inférieure) (88 %). Leur volume moyen est de 96 m^3/ha. Ces chiffres sont tous beaucoup plus élevés que ceux obtenus lors d'un inventaire précédent.

Ces données ont été récapitulées et informatisées par quadrilatères de 10 km x 10 km à projection U.T.M. (Mercator transverse universal) qui permettent de dresser rapidement des sommaires et des cartes.

Introduction

Background

In the early 1950's the Northern Administration Branch and the Forestry Branch, both of the Department of Northern Affairs and National Resources, initiated a forest inventory in the Yukon and Northwest Territories to provide forest maps and volumetric data for the planning and control of forest industrial activity. By 1969, 137 000 km^2 had been mapped for general planning purposes of which 58 275 km^2 was in the Yukon Territory. The total area of the Yukon Territory is 482 515 km^2.

Additional surveys were conducted in 1968 and 1969 by consultants under contract to the Department and were centered in the Teslin and Watson Lake areas. These surveys updated earlier estimates and provided the basic information necessary to plan and control logging operations.

As part of a project to assess the economic potential for growth and development of Yukon's resources, a forestry study (Gairns 1968) was completed and provided the first overview forest inventory of the Territory south of 66° North Latitude. It was based on previous government reports and an aerial examination of the forest that included 4800 km of reconnaissance flying to check accuracy and to update the data where changes occurred. These area and volume figures were used in reporting the Territory's resources in the reports on Canada's forest inventory for 1976 and 1981.

The area and volume estimates of the Yukon's forest resources are 15 to 30 years old. Attempts have been made to adjust these data for fire occurrence, but an update of the inventory is required.

Scope and Objective

The reconnaissance inventory of the Yukon Territory is an extensive forest inventory for broad planning purposes at the territorial level. Land classes and major forest types are mapped and estimates of area, volume, and biomass are developed for forest land. It is not intended to provide enough detail or be sufficiently accurate to make decisions for specific sites.

The objective of the inventory is to provide broad, cost-effective estimates of area, volume and biomass of the forest resources in the Yukon, for the purpose of:

(1) developing plans and policies for use of the resources;

(2) assisting in the selection of areas requiring more intensive inventories, and providing the basic data for that purpose;

(3) reporting forest information to the national forest inventory; and

(4) developing research programs.

Description of Area

Location and Physiography

The forested portion of the Yukon lies mostly between 60° and 65° N. Lat. and stretches from the Alaska-Yukon border (141° W. Long.) east to the boundary with the Northwest Territories (height of land along the Rocky Mountains). Within this area there are three prominent mountain ranges lying in a northwest-southeast direction that strongly influence the climate. The St. Elias (containing the highest peak in Canada), Kluane, and Coast ranges combine to form an initial barrier to weather patterns from the Pacific Ocean. The Pelly and Cassiar ranges form another ridge near the middle of the area, and the Rocky Mountains form a third ridge at the border between the Yukon and the Northwest Territories. The Ogilvie, Wernecke and Selwyn mountains form the northern boundary of the area. These mountains channel storm tracts resulting in drier conditions on the northerly or lee side than on the windward side. The northerly sides, particularly of the St. Elias group, are colder than the southerly sides, especially during winter as a result of arctic storms.

One minor and two major drainage systems operate in the area. Most of the area is drained through the Yukon River system, which flows northwest in the Yukon and turns west to flow through Alaska to the Bering Sea. The southeast part is drained through the southeasterly flowing Liard River system which eventually turns north to the Mackenzie River and on to the Beaufort Sea. A small part of the southwest is drained by the Alsek River system to the Gulf of Alaska.

Geology

The dominant geological material of the area is of metamorphic origin, with lesser amounts of intrusive, sedimentary and volcanic materials (Douglas and MacLean 1963; Templeman-Kluit 1974). These materials were variously scoured or modified by several alpine or continental glaciations, except in the northwest part of the area (Hughes 1972; Bostock 1966; Prest *et al.* 1967) which escaped glaciation. Volcanic activity in the southwest corner resulted in varying thicknesses of ash being deposited over much of the area (Hughes *et al.* 1972). The valley material is largely glacio-fluvial and lacustrine material modified by wind and water.

Morainal and colluvial materials are common on mid to upper slope positions, respectively.

Climate

The climate of the area ranges from a cold maritime regime in the southern Yukon River valley to a cold arctic regime on the lee side of the St. Elias Mountains and a cold alpine regime at upper elevations. The major part of the lower elevation terrain endures a cold continental climate modified by physiography. Mean annual temperatures vary from -1°C at Carcross, Teslin and Whitehorse to -7°C at Ross River and Beaver Creek. Permafrost is widespread, particularly on west and north aspects and in finer textured soils (Brown 1973). Annual precipitation ranges from 226 mm at Carcross to 605 mm at Tuchita and Tungsten. The precipitation is reasonably well distributed throughout the year, but moisture deficits usually occur during the late spring and early summer. The windward side of the mountain ranges receive more precipitation and are generally colder than lower elevations, but temperature inversions are common.

Vegetation

The vegetation is primarily controlled by climate and secondarily by the interaction of climate, topography, and soils. The lower elevations are forested with mixed or pure stands of deciduous and evergreen species, grading into sub-alpine and alpine communities at higher elevations. The southeast part of the area has the best climate for forest production. Here, white spruce (*Picea glauca* (Moench) Voss), black spruce (*Picea mariana* (Mill.) B.S.P.), lodgepole pine (*Pinus contorta* Dougl.), alpine fir (*Abies lasiocarpa* (Hook.) Nutt), tamarack (*Larix laricina* (Du Roi) K. Koch), aspen (*Populus tremuloides* Michx.), balsam poplar (*Populus balsamifera* L.), and white birch (*Betula* spp.) are present. Going northwestward, first tamarack disappears, then alpine fir, and then lodgepole pine. White spruce is the most productive species in most late seral and climax stands. Balsam poplar is a fast invader of alluvial sites. Lodgepole pine and aspen owe their existence for the most part to the occurrence of fire where they are initial invaders. Black spruce (and tamarack in the southeast) tends to occupy wetter and colder sites at mid to lower elevations, while alpine fir can extend well into subalpine environments. White birch is found mostly on cooler sites.

The coarse textured soils originating from glacial outwash or subsequent wind-worked dunes tend to be dry, making them susceptible to wildfire. White spruce is virtually absent from many of these sites due to the frequency of fire. On the other hand, lodgepole pine can be very abundant and become stagnant within 25 years following fire. Aspen is often abundant on lacustrine material and calcareous soils, but many early seral stages can have both aspen and lodgepole pine. White spruce may become established with the early seral species or come in later, but is slower growing and may not be evident for decades after a fire. Given time, it will replace lodgepole pine and aspen on all forestable sites, being associated with black spruce on wetter and colder sites and subalpine fir at higher elevations. The rate of white spruce dominance is much faster on moist, well drained, nutrient-rich soils than on dry soils. With the development of forest vegetation and concurrent accumulation of organic matter in the absence of fire, the soils become colder and permafrost near the surface becomes more prevalent, especially on moist to wetter sites. This condition favors black spruce and it will largely replace white spruce, or be the major secondary tree species in many situations. Thus, climax forests will consist of black spruce on the wettest and coldest sites, black spruce and white spruce on wet to moist sites, white spruce on drier sites, and subalpine fir at higher elevations. The deciduous species will take opportunistic roles in temporary clearings, but will not become dominant. However, the climax conditions will not develop unless fire is eliminated for periods in excess of 300 years.

Forest Succession

Forest fires are the principal cause of forest succession. Aside from the climate and physiography, fires have the most significant role in vegetation development. Nearly all land below the alpine zone has been burnt in the last 300 years; much of it has burned several times during this period. The interval between burns is of importance because some species require several years to develop and reproduce themselves. If the interval between burns is too short, the species can be eliminated; reproductive material is then required from an outside source to reintroduce the species. White spruce is the most significant species affected by short intervals between fires because it is a highly desirable commercial species, it requires at least 25 years to produce viable seed, and longer periods are required to produce seed in sufficient quantities to permit reestablishment. Thus, there are many areas where white spruce is sparse or virtually absent. It also lacks the semi-serotinous cones and the ability to reproduce by layering inherent in black spruce.

Lodgepole pine and aspen usually owe their presence to fires. Lodgepole pine possesses serotinous cones which release lots of seed when opened by fire. One of the problems when old-growth pine stands burn is the over production of seedlings which results in over-crowded or "dog-hair" stands that become stagnated in about 20 years. The pine seedlings grow relatively fast during the first few decades, which generally keeps them ahead of other species that may be in competition. Another attribute of lodgepole pine is that it can start producing cones with viable seeds in less than 10 years, and by 20 years of age can have enough seed to reestablish the species if another fire occurs.

Most sites on which lodgepole pine grows are relatively coarse textured, moderately well to excessively drained, and have a moisture deficit during the summer. This restricts shrub and forb species that can be abundant on other sites. Consequently, the understory vegetation could be dominated by lichens (*Cladonia* spp.) on the driest sites, kinnikinnick (*Arctostaphylos uva-ursi* (L.) Spreng.) and grass on mesic sites, and alder (*Alnus crispa* (Ait.) Pursh), soapberry (*Shepherdia canadensis* (L.) Nutt), shrub birch, or willow (Salix spp.) on the moist sites. Most of these shrub species have root systems that can survive fire; consequently, they appear soon after a fire. Some perennial forbs can survive in a similar manner, but others become established from latent seed or seed blown in from surrounding areas. White spruce, or sometimes black spruce on colder sites and alpine fir at higher elevations, may become established at the same time as lodgepole pine on moist to mesic sites, but the species grows much slower initially and requires several decades to become prominent. Depending on site conditions, white spruce, black spruce, and alpine fir, singularly or in combination, replace lodgepole pine after the first generation. On the very dry sites, lodgepole pine usually forms an open stand allowing new pine seedlings to develop in openings; white spruce invasion on such sites is slow, so that more than one generation of pine may occur.

Trembling aspen reproduces after fire largely by suckering, especially on finer textured, moist, or somewhat alkaline sites. In fact, there is evidence that fires promote suckering where aspen root systems are well developed prior to the fire. Aspen can thus survive fires even when the interval between fires is quite short. It appears that the densest young aspen stands are those that have burnt more than once within a 100-year period. Though some young stands are initially quite dense, they are self-thinning. The most vigorous shoots soon form a closed canopy over subordinate shoots and other vegetation, and this situation persists through the life of the stand.

Aspen tends to occupy the finer textured and usually more moist sites but can also occur on exposed south-facing slopes that are very warm and dry. The understory vegetation may consist of kinnikinnick and grass on the drier sites, and lush forbs and mixed shrubs with increasing moisture. Willows are perhaps the most common competing species on mesic to moist sites, and under certain conditions willows can dominate the vegetation. White spruce, and occasionally black spruce, can originate very soon after a fire, but aspen can easily over-top these seedlings for several decades. Balsam poplar may occur with the aspen on some upland sites, particularly around Haines Junction, but for the most part it stays on the richer alluvial sites. Where it does occur on upland sites, it acts very much like aspen and tends to develop with it, sometimes at a faster rate so it grows taller than the aspen.

On colder and often more moist north aspects with or without permafrost, the revegetation following fire is somewhat different. These sites would have little or no lodgepole pine or aspen on them before the burn; the stands consist mainly of black spruce and alpine fir, usually with some white spruce, and an understory of shrub birch, willow, Labrador tea, and moss. Because of the coldness of these sites, the organic matter on the soil surface is often quite thick from moss and debris accumulations and the slow decomposition rate. With the increase in moisture, the depth of burn in the organic matter is minimal. Consequently, there is an abundance of seed in the organic material, and the root systems of most shrub species survive. Thus, following the fire, the vegetation that comes back consists largely of species already there. Black spruce is the primary tree species; sometimes it can be very dense, but it may be accompanied by varying amounts of alpine fir and white spruce. White birch is often present in small amounts on these sites, and sometimes becomes more plentiful following a fire. On the rare occasions that it gains control to dominate a site, it may last for one generation. At higher elevations, subalpine fir often develops from latent seed, but must compete with shrub birch and willow originating largely from root stalks.

Ecoregions

During 1975, a broad-based geophysical survey of the Yukon Territory was conducted. Information on landform, vegetation, soil and site parameters and climate was obtained and used to delineate 22 ecoregions (Oswald 1976; Oswald and Senyk 1977). A map of ecoregions in the Yukon Territory is shown in Appendix 1, which also describes their characteristics. The land capability for forestry was mapped by Senyk *et al.* (1988).

Methods

The methods used in this inventory followed standard Canadian procedures with the following two exceptions.

(a) To reduce costs, existing information was used almost exclusively: mapping was completed without the acquisition of new air photos, and field sampling relied primarily on existing sample plot data.

(b) While traditional forest type maps were produced, the data were summarized not by stands within map sheets but by 5x5 and 10x10 km geographically referenced 'cells'; this simplified computer-assisted mapping and data handling.

Mapping

Paper and mylar (stable base) copies of National Topographic Series (NTS) maps at a scale of 1:250 000 were obtained. The maps – of which 43 were required to cover the Yukon – were overprinted with the Universal Transverse Mercator (UTM) 1-km grid.

Existing air photography was also obtained. Photo scales ranged from 1:50 000 to 1:70 000, and dates of photography ranged from 1965 to 1984 (Appendix 2). Where no suitable photos were available (mostly in northern, unproductive forest areas) Landsat imagery was used instead.

Air photo interpretation consisted of delineating and labelling each forest and land type using a forest and land classification system (Appendix 3). In essence, forest land was separated from non-forest land and water, and the forests classified as productive were further interpreted with respect to forest cover type, height-age, crown closure and site quality.

The information interpreted from photos was then transferred from the photos to the base maps. Ownership boundaries were likewise transferred to the base maps from legal records and maps.

Area Compilation

The forest type maps resulting from photo interpretation were digitized: within each 5x5 km UTM grid cell the mapped polygons were digitized and their areas were calculated. The characteristics of each polygon were also recorded. The resulting data, comprising forest and land areas within 5x5 km cells, were stored in the computer as records of a file. To this file was added ecoregion (Appendix 1) and forest management unit (Figure 1) boundaries derived from other maps. This was done by determining to which ecoregion or management unit each cell belonged, and recording the appropriate number in the file. Thus, all area records of a cell belong to the same region and unit.

The resulting area file was used not only to produce tabular summaries and maps of area data, it also served as a basis for stratification of volume and biomass estimates. These estimates were limited to areas of productive forest land which were classified by forest cover type (softwood, mixedwood or hardwood), height-age (regeneration, immature or mature), crown closure (open, moderate or dense), site (very good, good or medium). Details of the forest and land classification system are provided in Appendix 3.

With three classes per classifier, a total of 81 combinations or strata are possible. However, since no volume or biomass estimates were required for the first height-age class (regeneration), the number of strata for which volume and biomass estimates were required was reduced to 54.

Field Sampling

Detailed tree and stand data were obtained mostly from existing sample plots. Much time and effort was spent in editing and validating the approximately 2500 plots, and converting to metric units those which were found to be usable. This set of base data was augmented by plots established during the 1983 to 1985 field seasons in strata otherwise devoid of plots. The number of such additional plots was limited by resource availability and was not based on statistical considerations. A total of 1580 plots were selected for use. They are tabulated by stratum and year in Appendix 4.

Volume and Biomass Compilations

Summaries were required for two volume utilization classes and for biomass:

(1) merchantable volume of pulpwood size trees, i.e. larger than 9 cm in diameter at breast height (dbh). Merchantable volume excludes stump and top wood of the bole;

(2) merchantable volume of sawlog size trees i.e. larger than 25 cm dbh; and

(3) forest biomass, which includes the wood and bark of all parts of the tree and all tree sizes. It is measured in oven-dry tonnes or kilograms.

The basic procedure was to use plot values to construct, as a first step, stand volume or stand biomass tables. Species percentages were then derived and applied to the table values. For biomass, two additional steps were required: tree component percentages were derived and applied to each species, and biomass of

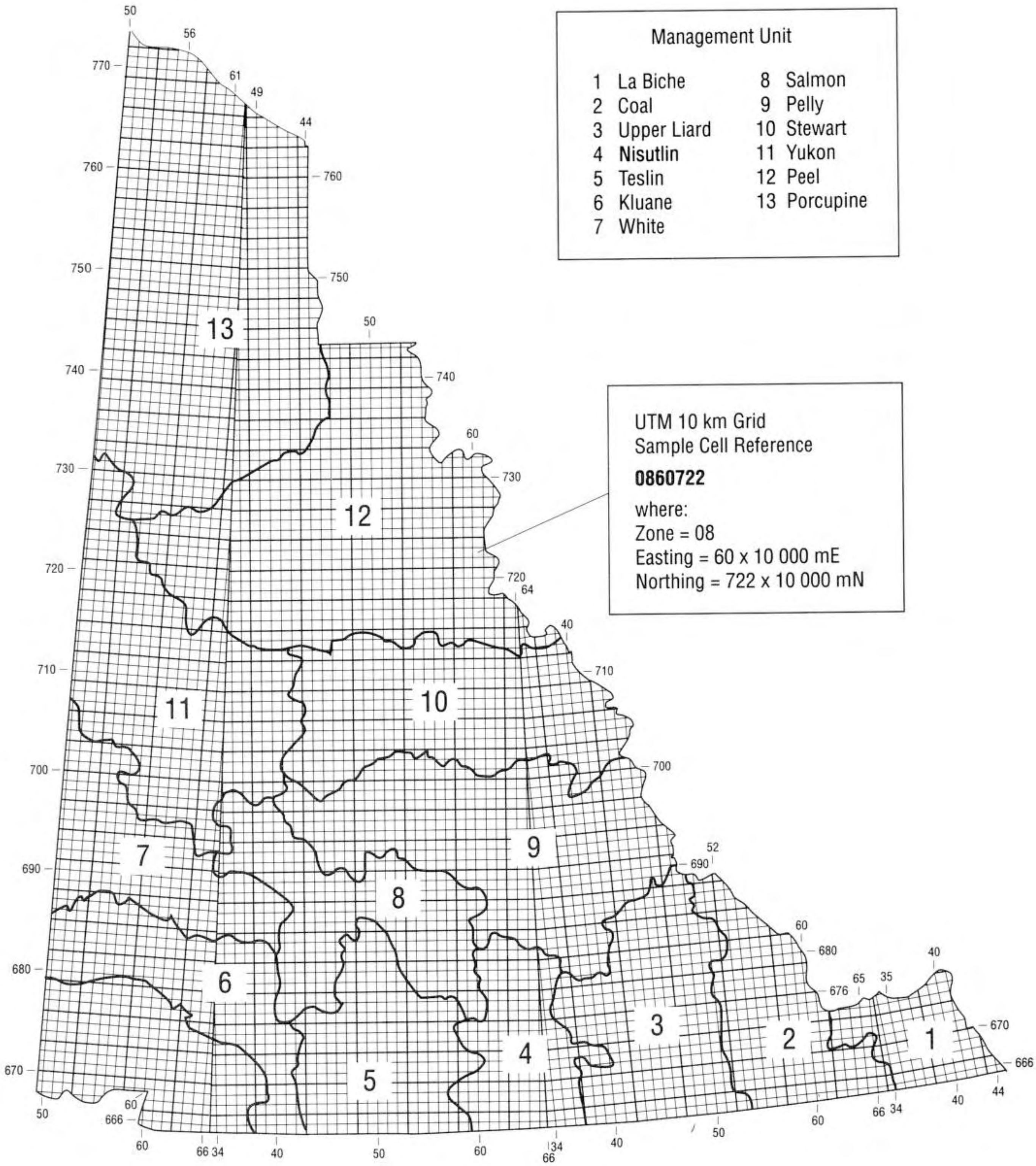


Figure 1. Forest management units and the UTM grid system.

small trees, i.e., of trees less than 9 cm in dbh, were obtained. Details of these steps are given below.

1) Constructing stand volume and stand biomass tables

Height-diameter equations, as well as tree volume and biomass equations from Honer (1984), were obtained (Appendix 5) and applied to the basic tree data within plots to calculate individual tree volumes and biomass values, which were summarized by diameter classes within species. In addition to the above mentioned data, plot location, stand information (including any evidence of disturbances) and soil characteristics were recorded.

A stand volume table for the first volume summary (pulpwood size trees) was constructed as follows:

(a) The merchantable volume of each plot (in m³/ha, all species and dbh classes) was selected;

(b) these volumes were listed by stratum and an average stratum volume calculated;

(c) using a statistical package available on the computer (SAS Procedure: Generalized Linear Models), a stand volume table was derived using the model

$$V = m + FT_i + HA_j + DE_k + SI_l$$

where V = stand volume;
m = population mean;
FT_i = forest cover type class i,
HA_j = height-age class j;
DE_k = crown closure (stocking) class k; and
SI_l = site class l

To ensure that stratum input values obtained from few sample plots did not carry undue weight, the analysis was done using as weights the number of plots per stratum, up to a maximum of four.

In a similar manner, a volume table for trees of sawlog size (dbh >25 cm) was derived. Finally, a biomass table was constructed using this procedure applied to total plot biomass (Appendix 6).

2) Species Composition

Species composition (SC) was calculated for each of the two volume utilization classes, and for biomass. Separate values were derived for the three forest cover types (softwood, mixedwood, and hardwood) using stratum areas as weights, as follows:

$$V_{ij} = \frac{A_j}{n_j} \sum V_{ijk}$$

where V_{ij} = volume of species i, stratum j (in m³);
A_j = area of stratum j (in ha);
n_j = no. of plots in stratum j; and
v_{ijk} = volume of plot k, stratum j, species i (in m³/ha).

Also, V_{iS} = sum of V_{ij} of strata with softwood forest type
= volume of species i, softwood forest type;
V_{iM} = volume of species i, mixedwood forest type; and
V_{iH} = volume of species i, hardwood forest type

Further, $SC_{iS} = 100\, V_{iS} / V_S$

where SC_{iS} = percentage of species i in softwood forest type
and V_S = volume of softwood forest type;

Similarly,

$SC_{iM} = 100\, V_{iM} / V_M$ and

$SC_{iH} = 100\, V_{iH} / V_H$

The resulting tables of species composition are shown in Appendix 7.

3) Biomass Components

These components include seven tree components for trees with dbh more than 9 cm (Appendix 8) and one consisting of small-tree biomass.

The tree biomass components were calculated for each tree using the tree biomass equations, and summarized by plot. These data were separated by height-age class and by forest cover types and used to compile, for the major species, a set of values expressing the component biomass as a percentage of total tree mass (Appendix 8). These percentages were applied to the per-hectare biomass values for each species which were previously derived.

The biomass of small trees was obtained as follows:

(a) each of the supplementary sample plots (measured in 1983-1985) included a sub-plot of 28 m² in which small trees (dbh ≤ 9.0 cm) were measured;

(b) the above tree data were used to compile per-hectare estimates of biomass, by height-age class and forest cover type (Appendix 6).

Data Bases

The volume data base was created by adding the volume data to the area file: the species composition percentages were applied to the total stand volumes to obtain individual species volumes. These were attached to the appropriate records of the area file. This process was undertaken for each of the two utilization classes.

The biomass data base was constructed in a similar manner. However, instead of having just two volumes per species, the data base included biomass by seven tree components per species as well as biomass of submerchantable trees.

Results

A copy of the volume and biomass data base was recompiled to 10x10 km UTM referenced cells. It was sent to the Petawawa National Forestry Institute which summarized the data. Results of the inventory are available in three forms:

(1) Area, volume or biomass data for individual cells or groups of cells. Information can be extracted through an interactive data retrieval system.

(2) Fixed format tabular summaries for the whole data base. Some of the more significant summaries are given in this report.

(3) Choropleth maps which display selected attributes.

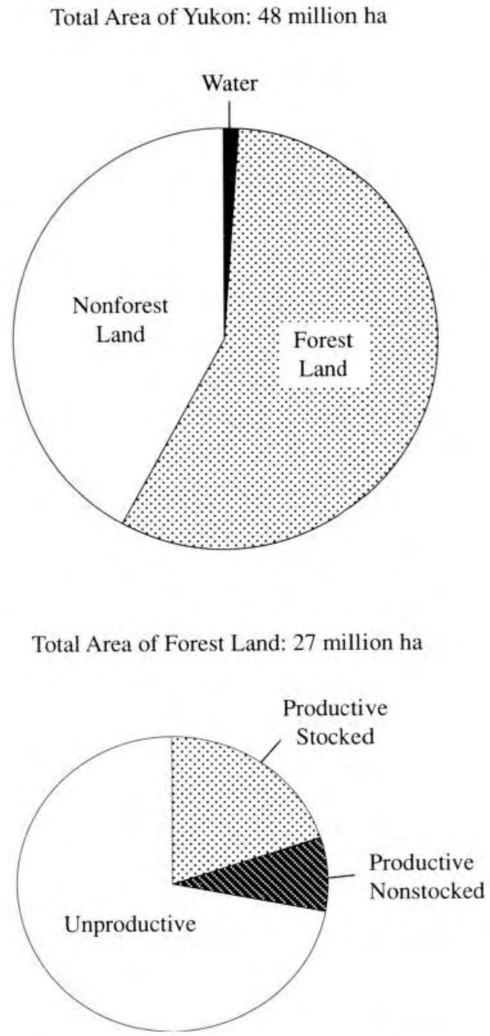


Figure 2. Area distribution of the Yukon Territory

Basic Area, Volume, and Biomass Summaries

Of the 48 million ha which comprise the Yukon Territory, 57% or 27 million ha is forest land. Only 1% is water. Of the forest land, 72% is unproductive, 8% is non-stocked productive, and 20% (5.4 million ha) is stocked productive forest lands. These statistics are illustrated in Figure 2.

The stocked productive forest land supports a growing stock of 459 million m^3 (Table 1) if all pulpwood size (dbh >9.0 cm) merchantable trees are included. If only trees of sawlog size (dbh >25.0 cm) are counted, the growing stock is reduced to 165 million m^3, or about one-third. White spruce is the predominant species, accounting for 306 of the 459 million m^3, or 67%.

In terms of forest biomass, the growing stock is comprised of 179 million oven dry tonnes of merchantable stem wood and 138 million tonnes of non-merchantable material, for a total of 317 million tonnes (Table 1). The merchantable stem wood is the same tree component for which volumes are given in the preceding column: if an average wood density of 0.39 is assumed, its multiplication by the volume yields the biomass value: $0.39 \times 459 = 179$. The non-merchantable material includes non-merchantable components of merchantable-sized trees, as well as small trees (dbh $\leq$ 9.0 cm). A breakdown of these on a per-hectare basis is given in Appendices 6 and 8.

The non-stocked productive forest land of 2.2 million ha includes 1.6 million ha of "unproven" stocking: it may be stocked in the silvicultural sense but supports little or no vegetation of commercially significant species. Of the remaining 0.6 million ha that is positively identified as being non-stocked, forest fires caused 99% of the depletion.

Table 1. Wood volume and biomass by species group

Species group	Volume (million m^3) (dbh > 9.0 cm)	Biomass (million t) Merchantable Stem Wood	Non-merchantable Material	Total
Black spruce	25	11	10	21
White spruce	306	112	91	203
Lodgepole pine	75	35	18	53
Other Conifers	14	5	5	10
Sub-Total	420	163	124	287
Aspen	27	10	9	19
Poplar	11	5	3	8
Birch	1	1	2	3
Sub-total	39	16	14	30
Total	459	179	138	317

Table 2. Forest area, volume and biomass by cover type

Cover	Area	Volume*		Biomass**	
Type	(million ha)	(million m^3)	(m^3/ha)	(million t)	(t/ha)
Softwood	3.85	347	90	237	62
Mixedwood	1.30	94	72	67	52
Hardwood	0.21	18	86	13	62
Total	5.36	459	86	317	59

* Pulpwood utilization class (dbh > 9.0 cm)
** All tree and stand components

Summaries for Stocked Productive Forest Land

A breakdown by forest cover type (Table 2) shows that 72% of the area and 76% of the growing stock belong to the softwood cover type. This type also supports the highest average growing stock values: 90 m^3/ha or 62 t/ha.

The summary by height-age (Table 3) shows that the immature class is the largest, at 4.04 million ha. It also supports two-thirds of the growing stock: 305 million m^3 and 212 million t. However, as expected, the mature class has the highest averages, at 117 m^3/ha and 80 t/ha. The regeneration class is very small (0.005 million ha), and no growing stock is ascribed to it.

It must be noted that the height-age classes are interpreted from air photos and Landsat images. In many cases, the features used for interpretation can be seen only imperfectly. Thus, interpretation errors are common. It is quite likely that the area of regeneration is an underestimate; it should include some of the "unproven stocking" areas. Also, some of the immature forest may include some mature forest of low site quality.

As expected, the separation of stocked, productive forest land by site classes (Table 4) shows that, as site quality decreases, area increases. The extent of the increase in area is significant: 91% of the area and 88% of the volume is in the lowest (medium) productivity class. By comparison, the next lower class (unproductive), which is not shown in the table, is even larger, at 19.7 million ha. The highest class (very good) has only 0.069 million ha.

Conversely, as site quality decreases, per hectare values of growing stock also decrease; the very good class has almost twice the volume of the medium class, 160 versus 83 m^3/ha.

Table 3. Forest area, volume and biomass by height-age class

Height-age class	Area (million ha)	Volume* (million m^3)	Volume* (m^3/ha)	Biomass** (million t)	Biomass** (t/ha)
Regeneration	0.005	-	-	-	-
Immature	4.04	305	76	212	52
Mature	1.32	154	117	105	80
Total	5.36	459	86	317	59

* Pulpwood utilization class (dbh > 9.0 cm)
** All tree and stand components

Table 4. Forest area, volume and biomass by site class

Site Class	Area (million ha)	Volume* (million m^3)	Volume* (m^3/ha)	Biomass** (million t)	Biomass** (t/ha)
Medium	4.874	405	83	279	57
Good	0.413	43	104	31	75
Very Good	0.069	11	160	7	102
Total	5.356	459	86	317	59

* Pulpwood utilization class (dbh > 9.0 cm)
** All tree and stand components

Choropleth Maps

The maps were produced by summarizing for each cell an attribute (e.g., area of productive forest land), expressing it as a percentage of total cell area, assigning the value to a class and plotting it. Since most cells are the same size (100 km^2), the percentages also reflect total values. The individual cell values are not reliable, hence the maps should be examined for patterns only.

The area of productive forest land (Figure 3) is concentrated in the southeast and south central areas of the Yukon Territory. This pattern is repeated in the following maps (Figures 4 and 5), which also show higher average volume for coniferous species than for deciduous ones.

Summaries by Ecoregions and Management Units

The summary of forest area, volume, and biomass by ecoregions (Table 5) should be examined in conjunction with Appendix 1, which includes a map of the ecoregions. The percentage of forest land is generally high in the southeast corner of the Territory (up to 93%), while in the southwest corner (ecoregion 7) and in the north it is low due to altitude and latitude, respectively.

The area of non-stocked productive forest land (which includes the "unproven" stocking class) varies considerably among ecoregions, both in total hectares and as a percentage of productive forest land. In one case (ecoregion 12), there is more non-stocked area than stocked area. In the north (ecoregions 14-22), the area of productive forest land is very low compared to the rest of the Territory.

Total quantities of volume and biomass follow a similar trend; with the exception of ecoregion 7 (in mountainous Kluane National Park), growing stock is significantly larger in ecoregions 1-13 (southern) than in ecoregions 14-22 (northern). Average volume and biomass are high in the first five ecoregions, but low in the western and northern ecoregions. The reason for the high volume and biomass in ecoregions 20-22 is not clear; the values are likely in error, and the error was likely caused by a combination of small area values and lack of sensitivity of the inventory design.

The summary of forest area, volume, and biomass by forest management units (Table 6) should be examined in conjunction with Figure 1, which is a map of forest management units. A similar pattern to that of the ecoregions is apparent: the highest proportions of stocked productive forest land, and the highest per hectare growing stock values are found in the southeast corner. The two northern units (12 and 13) contain the least productive forest land. The average growing stock values are unexpectedly high, but of dubious accuracy.

Discussion

A reconnaissance inventory is defined as "An exploratory, extensive forest inventory with no detailed estimates obtained [in which] a formal sampling design is generally not used, and no precision estimates are obtained" (Bonnor 1978). This inventory fits the definition reasonably well; it is extensive in that it covers a large area, no formal sampling design was used, and no precision estimates are made. On the other hand, the inventory resembles the next higher level of inventory (the regional inventory) in that it is not exploratory, previous inventories and compilations have been made, and some detailed estimates are obtained. Thus, the inventory provides overall estimates of good accuracy, and detailed estimates of poor accuracy. The detailed estimates have been obtained through use of detailed data (air photos and sample plots). The poor accuracy results from the use of existing air photos and sample plots: the air photography used for stand delineation and interpretation is often old, of small scale, and of incomplete coverage. Also, the field sample plots are very subjectively and unevenly located, and are up to 30 years old. The effect on volume and biomass tables of these errors is one of averaging: the volumes at the high end of the range (e.g., 202 m^3/ha in Table 1(a) of Appendix 6) should probably be higher (closer to 300 m^3/ha), while the low volumes (e.g., 57 m^3/ha) should be lower (closer to 40 m^3/ha). These aspects have been known and accepted at the outset as trade-offs between cost and accuracy of the inventory.

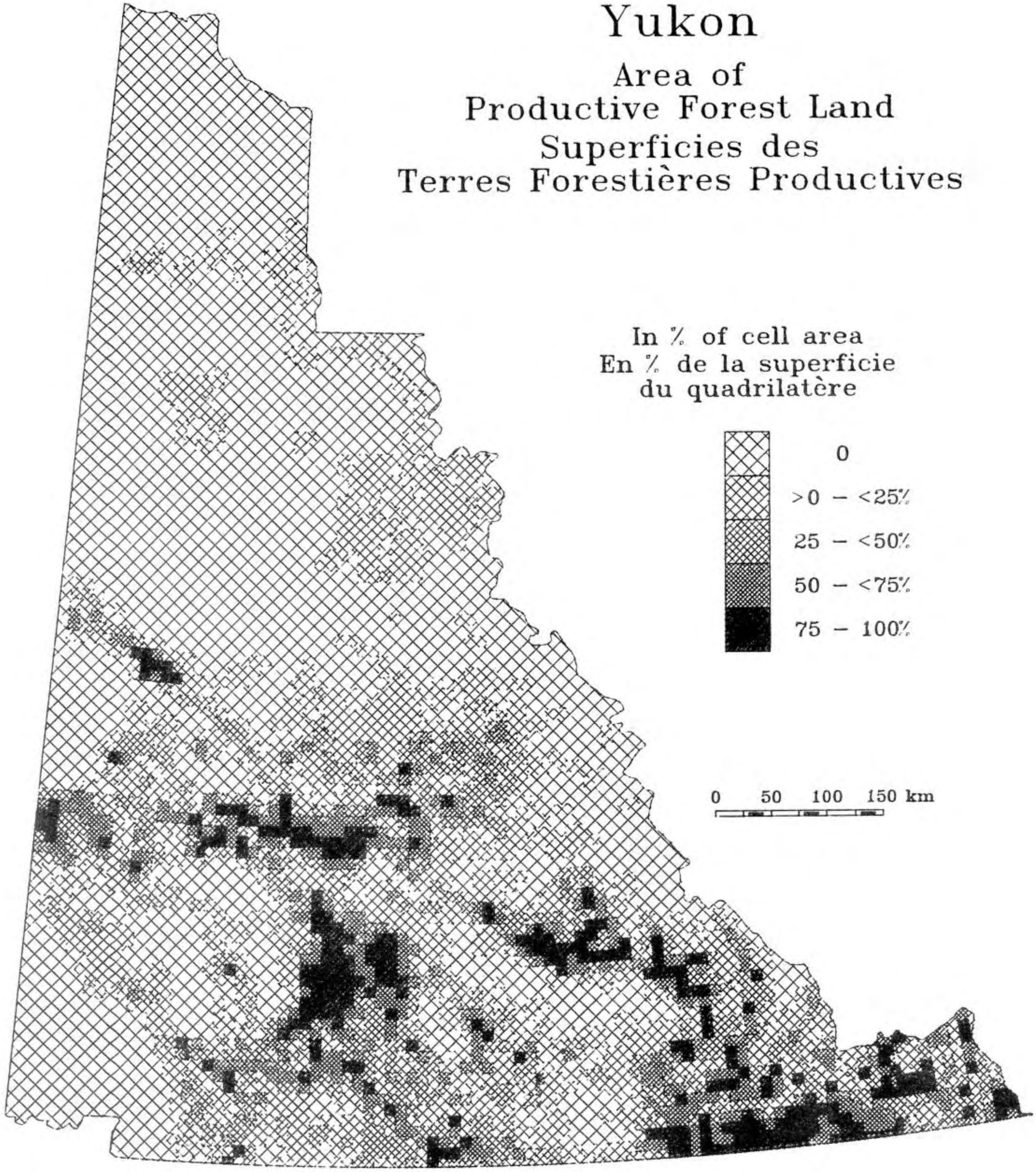
While the inventory design does not permit the calculation of statistically defensible errors of estimates, such errors can be approximated. As an informed guess, the errors of estimates of primary attributes (area by forest and land classes, volume and mass by all species and components) will not exceed:

15% for Territory-wide estimates;

30% for estimates by ecoregions and management units; and

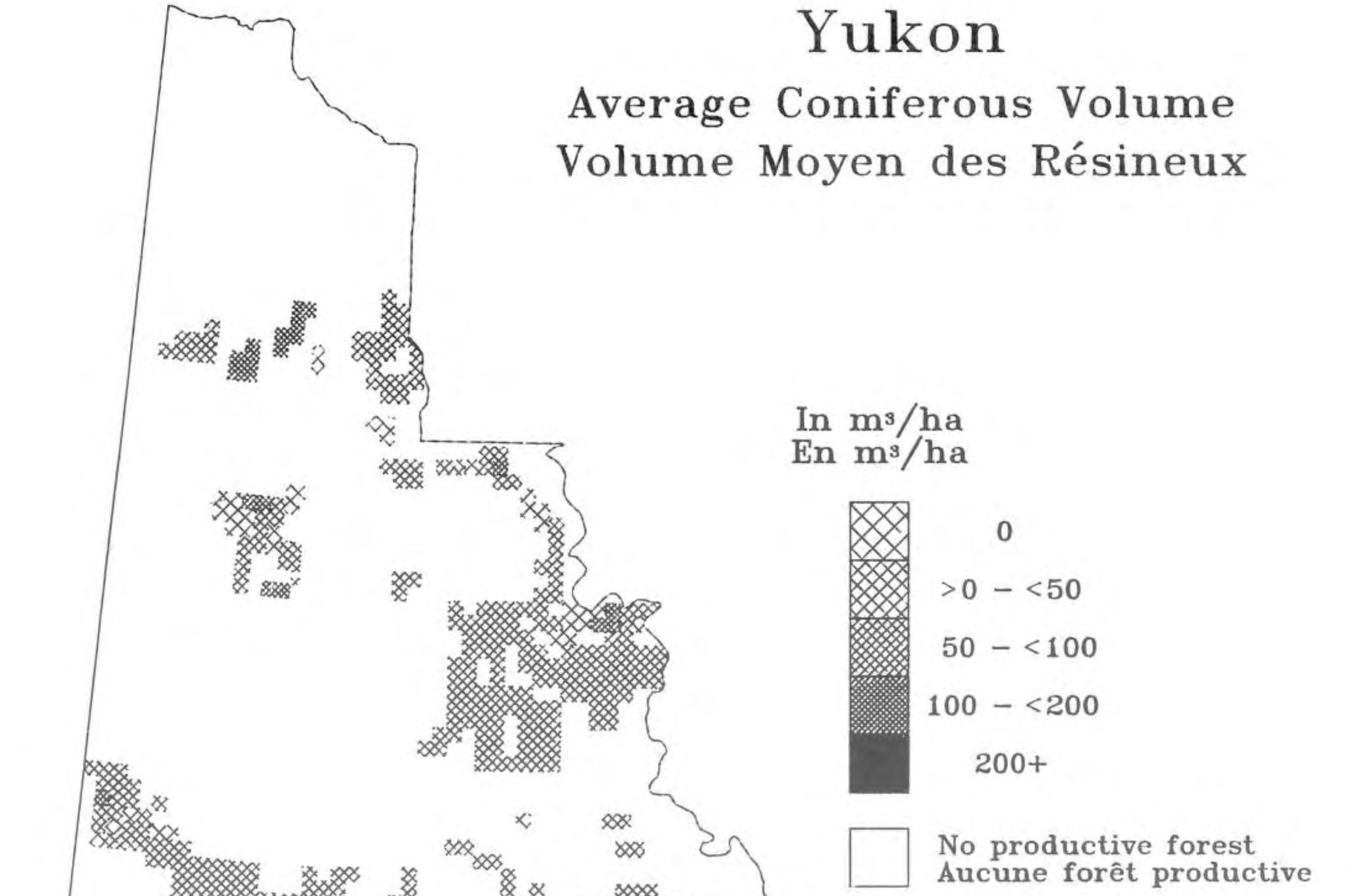
60% for estimates by forest types (strata).

Volume and biomass estimates for specific species will have larger errors. Such estimates should not be made for any class or geographical subdivisions of the Territory other than utilization classes and cover types (Appendix 7). Similarly, biomass estimates by tree components should not be made for any classes or geographical subdivisions of the Territory other than height-age classes and cover types (Appendix 8).



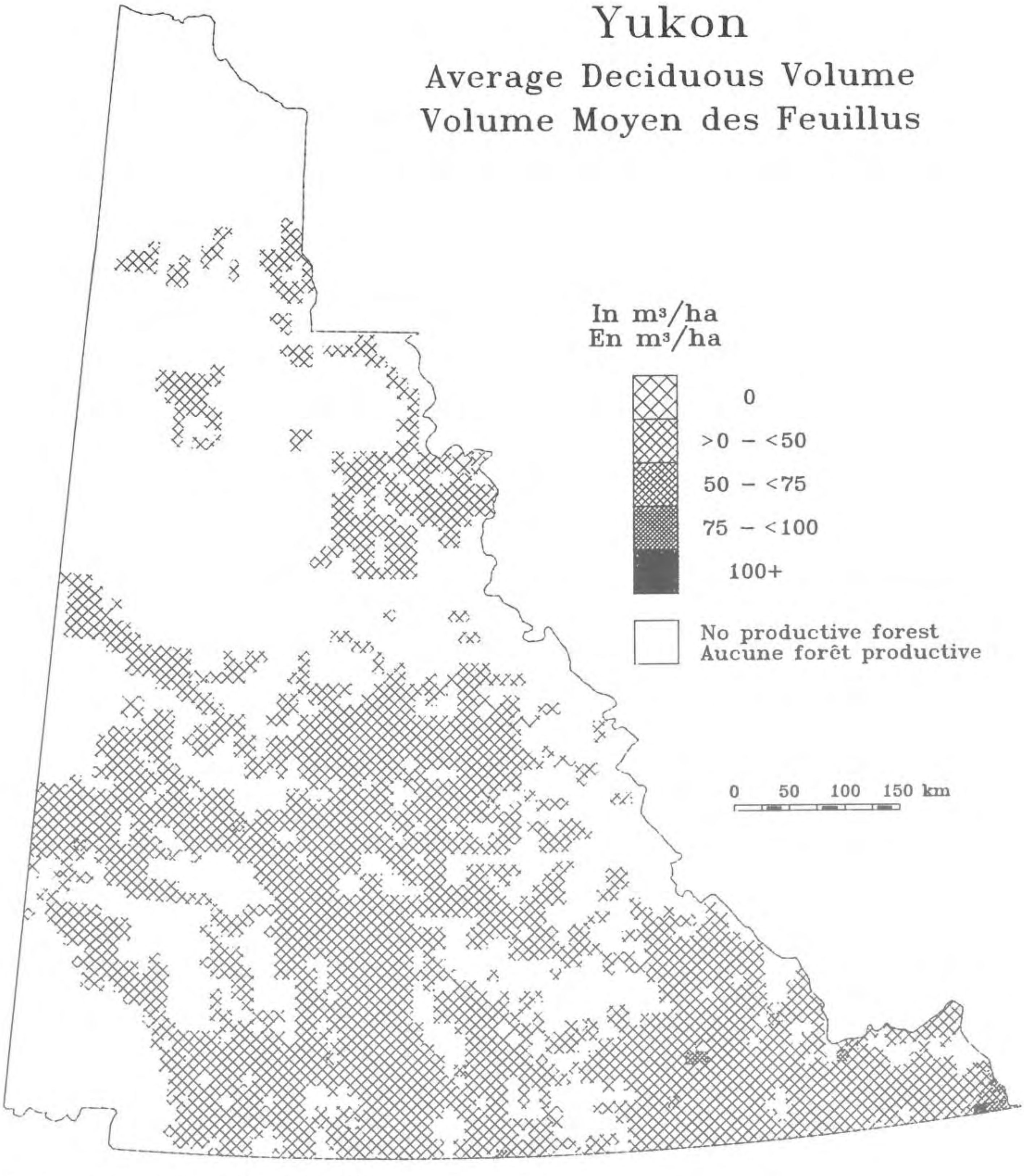
Source: Canada's Forest Inventory 1986.
Source: Inventaire des forêts du Canada 1986.
Produced by the Petawawa National Forestry Institute, Canadian Forestry Service, 1988.
Préparé par l'Institut forestier national de Petawawa, Service canadien des forêts, 1988.

Figure 3. Choropleth map: Area of productive forest land.



Source: Canada's Forest Inventory 1986.
Source: Inventaire des forêts du Canada 1986.
Produced by the Petawawa National Forestry Institute, Canadian Forestry Service, 1988.
Préparé par l'Institut forestier national de Petawawa, Service canadien des forêts, 1988.

Figure 4. Choropleth map: Average coniferous volume.



Source: Canada's Forest Inventory 1986.
Source: Inventaire des forêts du Canada 1986.
Produced by the Petawawa National Forestry Institute, Canadian Forestry Service, 1988.
Préparé par l'Institut forestier national de Petawawa, Service canadien des forêts, 1988.

Figure 5. Choropleth map: Average deciduous volume.

Table 5. Area, volume and biomass by ecoregion

	Area (1000 ha)				Volume*		Biomass**	
		Forest	Productive Forest Land					
Ecoregion	Total	Land	Non-stocked	Stocked	(1000 m^3)	(m^3/ha)	(1000 t)	(t/ha)
1. Beaver River	1528	1352	193	434	40 601	94	27 951	64
2. Liard River	2018	1883	275	895	93 528	104	63 923	71
3. Logan Mountains	1262	531	47	236	21 962	93	14 919	63
4. Pelly Mountains	3133	1398	55	208	19 566	94	13 441	65
5. Lake Laberge	3364	2806	458	972	86 804	89	59 839	62
6. Coast Mountains	1299	316	7	218	16 421	75	11 419	52
7. St. Elias Mountains	1782	34	0	22	1654	75	1186	54
8. Ruby Range	2120	943	25	267	19 436	73	13 567	51
9. Wellesley Lake	820	657	2	229	16 213	71	11 499	50
10. Dawson Range	2453	1558	141	282	21 054	75	14 518	51
11. Klondike River	2599	1800	58	290	20 251	70	14 089	48
12. Pelly River	3545	3151	656	563	43 537	77	30 166	54
13. Mayo Lake Ross River	4051	3127	213	345	26 299	76	17 877	52
14. Itsi Range	1350	678	10	9	697	77	473	52
15. Wernecke Mountains	2469	482	1	36	2691	75	1823	51
16. South Ogilvie Mountains	1190	263	0	9	702	78	474	53
17. North Ogilvie Mountains	4320	1768	0	22	1744	79	1197	54
18. Eagle Plain	1662	1186	0	25	1779	71	1263	50
19. Peel River	1911	1707	10	70	5142	73	3524	50
20. Berry Creek	464	185	0	8	701	88	476	60
21. Old Crow Basin	1737	511	0	18	1696	94	1164	65
22. Northern Mountains and Coastal Plain	1775	204	0	11	919	84	640	58
Other+	1423	876	17	182	16 011	88	11 366	62
All	48 275	27 416	2168	5351	459 408	86	316 794	59

* Pulpwood utilization class (dbh > 9.0 cm)
** All components
\+ Areas not classified by ecoregion

Table 6. Area, volume and biomass by forest management unit

Management	Area (1000 ha)				Volume*		Biomass**	
		Forest	Productive Forest Land					
Unit	Total	Land	Non-stocked	Stocked	(1000 m^3)	(m^3/ha)	(1000 t)	(t/ha)
1. La Biche	768	664	98	256	24 671	96	16 992	66
2. Coal	2113	1491	235	606	60 439	100	41 398	68
3. Upper Liard	2939	2068	195	712	74 140	104	50 502	71
4. Nisutlin	1666	1134	112	216	21 941	102	15 073	70
5. Teslin	2435	1480	251	675	60 727	90	41 916	62
6. Kluane	4565	1053	23	427	30 789	72	21 507	50
7. White	2244	1667	2	340	24 296	71	17 109	50
8. Salmon	2736	1849	304	527	41 555	79	28 650	54
9. Pelly	4957	3841	726	478	37 586	79	25 890	54
10. Stewart	3927	2570	59	339	25 619	76	17 521	52
11. Yukon	4612	3264	77	423	29 551	70	20 512	48
12. Peel	6700	3235	10	108	7 965	74	5 438	50
13. Porcupine	7997	2598	0	70	5 762	82	4 010	57
Other+	616	497	76	174	14 367	83	10 276	59
All	48 275	27 416	2168	5351	459 408	86	316 794	59

* Pulpwood utilization class (dbh > 9.0 cm)
** All components
\+ Areas not classified by ecoregion

The question of accuracy, i.e., reliability of the estimates, becomes important when results of the present inventory are compared with those of previous inventories. Three of these exist: the compilation by Gairns (1968), the data contained in Yukon RRAMS (Lee *et al.* 1978), and the national inventory of 1981 (Bonnor 1982). However, the last two are updates of the first one and are not considered further.

The comparison (Table 7) shows that estimates of areas, but particularly of volumes, are higher in 1985 than in 1968. In the case of areas, the differences can be explained by differences in classifications and definitions, as well as by the exclusion in 1968 of the northern Yukon from the inventory. Also, better fire protection may have helped to increase the areas of forest land. In the case of volumes, some of the differences can be explained by the exclusion in 1968 of some forest types from volume estimation. To a lesser extent, the difference in volume may also be explained by the exclusion of northern Yukon and better fire protection, as well as by growth during the past 17 years. However, the 81% increase in total volume and 62% increase in volume per hectare cannot be totally explained by these factors; errors have been made, and most of them are ascribed to the 1968 inventory.

Provisional estimates from the present inventory are included in the 1986 national forest inventory (Forestry Canada 1988). Subsequent improvements to the provisional data base have resulted in differences between summaries of areas and volumes.

Conclusions

This reconnaissance inventory provides extensive data on the forest resources of the Yukon Territory, i.e., the quantity and quality of forest land, and the growing stock it supports in terms of volume and biomass. Data are also available by species and, for biomass, by components. These latter data are important if the wood is to be used for energy production, or for a combination of energy and fibre production. Referencing and summarizing the data by grid cells also provides location-specific estimates from which choropleth maps can be derived.

Existing sources of information (air photos, satellite imagery, field sample plots) have been used as much as possible. This has resulted in a large quantity of detailed information obtained at a reasonable cost. At the same time, this reliance on existing information has reduced the accuracy of the estimates. The user is cautioned that estimates for areas smaller than ecoregions and management units are unreliable. Thus, the maps using cell-level data should be considered indicators of patterns and concentrations rather than absolute values.

Table 7. Comparison of past and present inventory results

Source	Area of forest land (million ha)		Volume	
	All	Stocked, productive	(million m^3)	(m^3/ha)
Gairns (1968)	20	4.8	253	53
Present inventory (1985)	27	5.4	459	86

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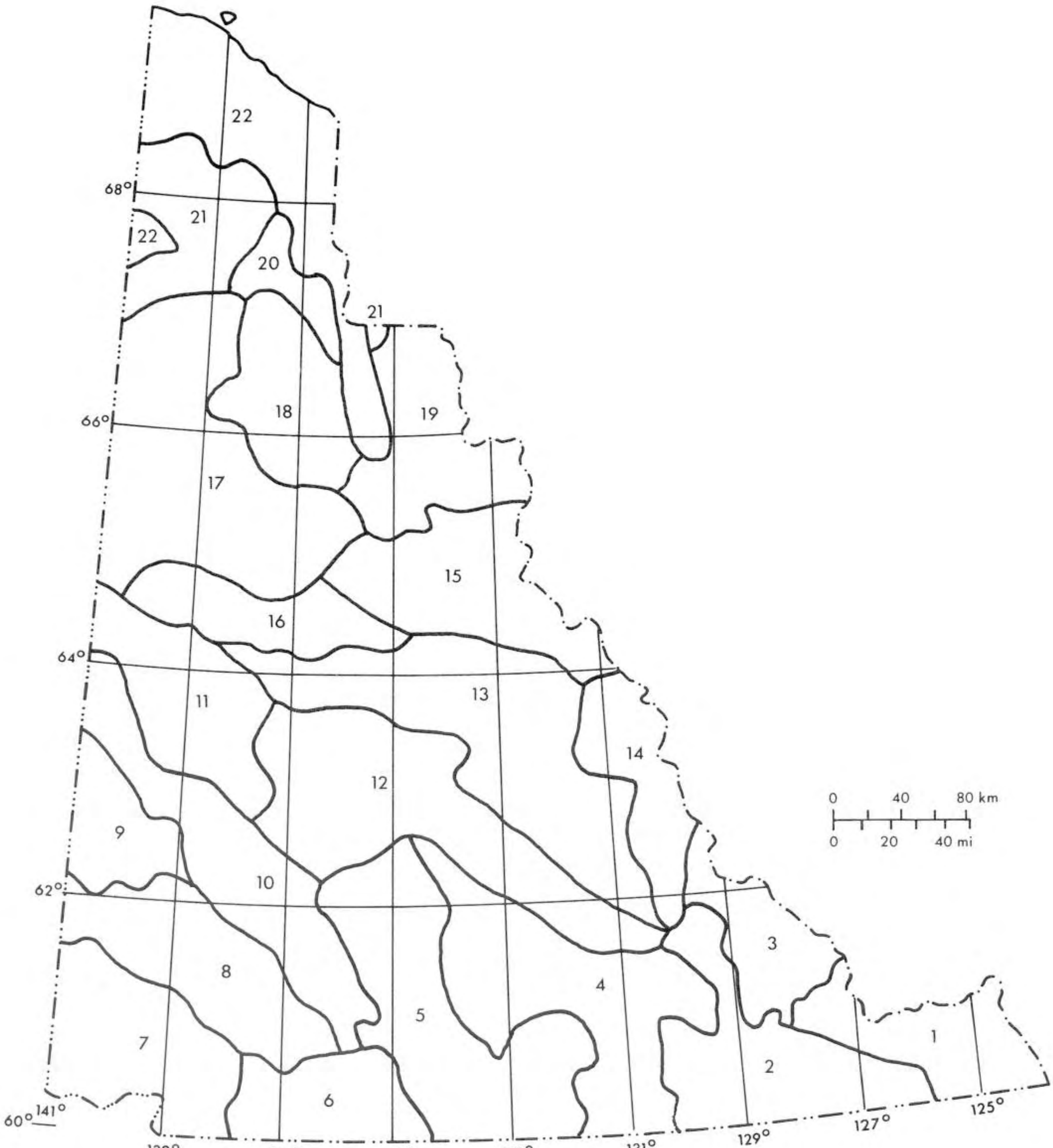
22
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127°
125°

Appendix 1

Ecoregions of the Yukon Territory

1. Beaver River: 3% of Yukon - 16 350 km^2. Mostly forested with open black and white spruce and lodgepole pine; lichens prominent on well-drained sites, moss on wet sites; black spruce and larch in bogs, alpine fir and shrub birch-willow-lichen near tree line; treeline at 1200-1350 m; precipitation and temperature moderate.

2. Liard River: 5% of Yukon - 24 670 km^2. Forested, with closed and nearly closed stands of black and white spruce and lodgepole pine; understory mostly moss with or without shrubs and forbs; black spruce and larch in bogs, aspen on dry sites, white spruce and balsam poplar on flood plains, alpine fir in subalpine; treeline at 1500 m; precipitation and temperature moderate.

3. Logan Mountains: 2% of Yukon - 13 190 km^2. Mostly alpine treeless tundra of shrub birch-willow-sedge, open black and white spruce-lichen in valleys and lower slopes, aspen and lodgepole pine on warmer sites, alpine fir and shrub birch-willow in subalpine; treeline at 1350-1500 m; precipitation high, temperature moderate.

4. Pelly Mountains: 7% of Yukon - 36 140 km^2. High elevation treeless tundra common, white and black spruce-moss at lower elevations, white spruce and lodgepole pine on warmer sites, alpine fir and shrub birch-willow in subalpine, sedge tussock in alpine wetlands; treeline at 1350-1500 m; precipitation moderately high, temperature moderate.

5. Lake Laberge: 7% of Yukon - 37 860 km^2. Open white spruce and lodgepole pine with moss understory common, black and white spruce on cool sites, aspen or sagebrush-grassland on drier sites, alpine fir present, larch absent; treeline at 1200-1350 m; precipitation low, temperature moderately warm.

6. Coast Mountains: 3% of Yukon - 15 200 km^2. Alpine tundra prominent, white spruce-soapberry-moss at lower elevations, shrub birch-willow at higher elevations, white spruce-aspen or lodgepole pine on warmer sites, alpine fir and black spruce scarce; treeline at 1050-1200 m; precipitation high, temperature moderate.

7. St. Elias Mountains: 4% of Yukon - 22 370 km^2. High elevation ice and snow fields, white spruce-moss at lower elevations, black spruce bog and shrub birch-willows on cooler sites, aspen and white spruce on warmer sites; treeline at 1050 m; precipitation high, temperature cold.

8. Ruby Range: 5% of Yukon - 24 670 km^2. Open white and black spruce-moss common, black spruce bogs or white birch-alder on cooler sites, white spruce-aspen-moss-forb on warmer sites, balsam poplar on upland sites, lodgepole pine rare; treeline at 1200 m; precipitation low, temperature moderately cold.

9. Wellesley Lake: 2% of Yukon - 10 900 km^2. Low elevation open bog, black spruce-*Sphagnum* common, black spruce bog and bog-fen complex on cool moist sites, white spruce-white birch-aspen-moss-alder on warm dry sites, treeline at 1050 m; precipitation low, temperature moderately cold.

10. Dawson Range: 6% of Yukon - 29 540 km^2. Mostly treeless, shrub birch-willow common, white spruce on warm dry sites, very open white and black spruce-willow-shrub birch at lower elevations, sedge tussock (black spruce) on cool moist sites; treeline at 1200 m; precipitation moderately low, temperature moderately cold.

11. Klondike River: 4% of Yukon - 21 510 km^2. Black spruce and white birch-*Ledum-Sphagnum* is common, aspen and white spruce on drier sites with balsam poplar on flood plains, lodgepole pine scarce; treeline at 1050 m; precipitation moderate, temperature moderately cold.

12. Pelly River: 7% of Yukon - 45 150 km^2. White and black spruce-shrub-moss is common, black spruce bog in moist cool lowlands, aspen (white spruce) or sagebrush-grassland on warm, dry sites, lodgepole pine common, alpine fir sparse; treeline at 1350-1500 m; precipitation low, temperature moderately cold.

13. Mayo Lake Ross River: 9% of Yukon - 45 600 km^2. Open black spruce-moss (lichen) common, white spruce on warm dry sites, black spruce bog-fen in lowlands, aspen, white birch and lodgepole pine sparse, larch absent, alpine fir in subalpine; treeline at 1350-1500 m; precipitation moderate, temperature moderately cold.

14. Itsi Range: 3% of Yukon - 15 200 km^2. High elevation tundra, open black and white spruce-lichen on lower slopes, shrub birch-willow common, bog-fen in valleys, alpine fir in subalpine but sparse; treeline at 1350-1500 m; precipitation high, temperature moderately cold.

15. Wernecke Mountains: 5% of Yukon - 28 390 km^2. High elevation tundra, black and white spruce-moss (lichen) on protected warmer sites, shrub birch-willow is common, bog-fen complexes, sedge tussock, in wetland; treeline at 1200 m; precipitation high, temperature moderately cold.

16. South Ogilvie Mountains: 3% of Yukon - 13 900 km^2. High elevation treeless tundra, sedge tussock bogs in valleys, and shrub birch-willow on slopes, open black and white spruce on protected warm sites; treeline at 1050 m; precipitation moderate, temperature moderately cold.

17. North Ogilvie Mountains: 9% of Yukon - 47 040 km^2. Moderate elevation treeless tundra with sedge tussock or shrub birch-willow, white spruce on protected sites, scattered black spruce on low elevation bogs; treeline at 900 m; precipitation moderate, temperature cold.

18. Eagle Plain: 3% of Yukon - 17 500 km^2. Very open black spruce-larch-sedge tussock common, white spruce and white birch on well-drained sites, bog-fen common in lowlands; treeline at 750 m; precipitation low, temperature cold.

19. Peel River: 4% of Yukon - 20 940 km^2. Black spruce-lichen common, black spruce-larch-sedge tussock on wetter sites, white spruce-white birch on well drained sites; treeline at 600-750 m; precipitation low, temperature moderately cold.

20. Berry Creek: 1% of Yukon - 5 450 km^2. Black spruce-sedge tussock is common, black spruce-lichen and shrub-lichen on cool dry sites, white spruce on warm sites, larch scarce; treeline at 450 m; precipitation low, temperature cold.

21. Old Crow Basin: 3% of Yukon - 16 630 km^2. Open white and black spruce-lichen (moss) common, black spruce-lichen or *Sphagnum* on cooler sites, white spruce-lichen (alder) on warmer sites, larch sparse; treeline at 300-450 m; precipitation low, temperature cold.

22. Northern Mountains and Coastal Plain: 6% of Yukon - 33 340 km^2. Mostly treeless tussock tundra, scattered black and white spruce on protected sites, shrub heath on many warmer sites; treeline at 0-300 m; precipitation low, temperature cold.

Appendix 2

Air photo and Landsat imagery coverage

Forest management unit	Air Photo Coverage			Landsat
	% of area	scale	date	coverage (%)
1. LaBiche	100	1:70 000	1973-77	-
2. Coal	100	1:70 000	1973-82	-
3. Upper Liard	100	1:50 000	1968-77	-
4. Nisutlin	95	1:50 000	1970	5
5. Teslin	100	1:70 000	1965-79	-
6. Kluane	100	1:70 000	1977-79	-
7. White	-	-	-	100
8. Salmon	90	1:50 000	1965-79	10
9. Pelly	75	1:50 000	1968	25
10. Stewart	55	1:50 000	1968-84	45
11. Yukon	5	1:50 000	1973-77	95
12. Peel	60	1:50 000	1968-77	40
13. Porcupine	95	1:50 000	1970-77	5

Appendix 3

Forest and land classification system

1. Ownership and Status.
   All areas are classified as to Ownership (= Federal) and Status (= Reserved or Non-reserved).

2. Basic Types
   All areas are classified as to area type (= Land or Water). Land is further classified as to Forest or Non-forest.

3. Forest Productivity
   Forest Land is classified as to productivity or site quality:
   Productive Forest Land: (see site classes below)
   Unproductive Forest Land: Dry, Wet

4. Classification of Productive Forest Land

Cover Type

Softwood	76 - 100% of canopy is coniferous
Mixedwood	26 - 75% of canopy is coniferous
Hardwood	0 - 25% of canopy is coniferous

Height-Age Class

Regeneration	0.1 - 7.5 m in height
Immature	7.6 - 17.5 m in height
Mature	17.6+ m in height

Crown Closure (Stocking)

Open	10 - 34.9% canopy density (sparsely stocked)
Moderate	35 - 54.9% canopy density (moderately stocked)
Dense	55%+ canopy density (well stocked)
Nonstocked	$10\%^{-}$ canopy density. This class is further classified by cause: burn, cut, pest, other

Site Class

Very good	Recent alluvium, good drainage and fertility, no permafrost
Good	Slopes, soil texture and fertility are moderate, no permafrost
Medium	Moderately steep slopes, coarse textured soils, imperfect drainage and/or fertility deficiency
Unproductive	Steep slopes, eroded banks and ridges, excessive drainage or low fertility, average stand height at 100 years will be less than 10 m
Unproductive	Excessive soil moisture, exposure, alkalinity or shallowness to bedrock or permafrost. Average stand height at 100 years will be less than 10 m

Appendix 4

Number of sample plots* by stratum

Stratum	Year 1953	1954	1959	1966	1983	1984	1985	Total
Softwood								
Immature								
Sparsely stocked								
very good site	-	-	-	-	1	-	-	1
good site	4	7	7	-	-	1	1	20
medium site	8	8	24	-	14	24	-	78
moderately stocked								
good site	14	14	4	-	4	4	-	40
medium site	93	8	3	-	9	7	1	121
well stocked								
good site	12	30	15	-	5	-	-	62
Mature								
Sparsely stocked								
very good site	-	-	-	2	-	-	-	2
good site	6	15	1	3	1	-	-	26
medium site	6	-	-	-	7	-	-	13
moderately stocked								
very good site	-	8	-	-	2	8	1	19
good site	12	26	17	-	10	-	1	66
medium site	38	-	-	-	3	-	1	42
well stocked								
very good site	-	16	46	-	-	-	-	62
good site	6	43	81	-	5	-	-	135
Mixed Wood								
Immature								
Sparsely stocked								
good site	-	17	-	-	-	-	-	17
medium site	14	-	-	-	4	3	2	23
moderately stocked								
very good site	3	4	-	-	-	-	-	7
good site	8	4	-	-	-	-	-	12
medium site	9	11	3	-	6	-	1	30

* Excludes plots in the regeneration height-age class, which is assumed to have no volume.

Appendix 4 (Cont'd)

Stratum	Year 1953	1954	1959	1966	1983	1984	1985	Total
well stocked								
very good site	-	-	-	-	-	-	1	1
good site	3	4	-	-	-	-	-	7
medium site	-	-	2	-	1	-	-	3
Mature								
Sparsely stocked								
good site	6	58	-	-	-	-	-	64
medium site	7	-	-	-	7	5	1	20
moderately stocked								
very good site	-	140	417	5	-	-	-	562
good site	20	1	-	-	-	-	-	21
medium site	10	-	-	-	3	2	1	16
well stocked								
very good site	-	10	6	-	-	-	-	16
good site	38	9	6	-	1	-	-	54
mediumsite	5	7	6	-	-	-	-	18
Hardwood								
Immature								
Sparsely stocked								
medium site	3	-	-	-	-	3	-	3
moderately stocked								
very good site	-	-	-	-	-	1	-	1
medium site	-	-	-	-	-	6	-	6
well stocked								
good site	-	-	-	-	-	-	1	1
Mature								
Sparsely stocked								
good site	-	-	-	-	1	-	-	1
moderately stocked								
very good site	-	-	-	-	-	-	1	1
good site	-	-	-	-	3	-	-	3
medium site	-	-	-	-	-	1	-	1
well stocked								
good site	-	-	-	-	2	-	-	2
Total	325	440	638	10	89	65	13	1580

Appendix 5

Equations

1. Height - diameter equations

(a) models

Lodgepole pine

$H = aD + bD^2$

Where H = tree height (m)

D = stem diameter at breast height (cm)

a,b = coefficients

All other species

$H = a\,D^b$

(b) coefficients

Ecoregion	Lodgepole pine		White spruce		Other conifers		Hardwoods	
	a	*b*	*a*	*b*	*a*	*b*	*a*	*b*
1,3	1.1659	-0.0135	2.2387	0.7039	1.3955	0.8148	2.3379	0.6487
1,3	1.1659	-0.0135	2.2387	0.7039	1.3955	0.8148	2.3379	0.6487
2	1.1659	-0.0135	1.1341	0.9135	1.3955	0.8148	2.3379	0.6487
4	0.9566	-0.0124	1.2345	0.8208	1.2650	0.7268	1.5243	0.7732
5	0.9754	-0.0087	1.4135	0.8033	1.5649	0.7675	3.6961	0.4758
6-8	0.9754	-0.0087	1.2067	0.8242	1.3570	0.7709	2.0908	0.5866
9	0.9754	-0.0087	1.8708	0.7561	1.1562	0.8408	2.7878	0.5598
10	0.9754	-0.0087	1.2702	0.8834	1.2855	0.8329	2.7479	0.5878
11	0.9088	-0.0092	1.2702	0.8834	1.2855	0.8329	2.7479	0.5878
12-22	0.9088	-0.0092	1.2722	0.8803	1.3003	0.8396	2.4793	0.5893

Species group spans the Lodgepole pine through Hardwoods columns.

2. Tree volume equations

(a) Total volume

Model: $TV = aD^b H^c$

where TV = Total stem volume (m^3)

D = stem diameter at breast height (cm)

H = tree height (m)

a,b,c = coefficients

Coefficients:

Species group	Ecoregions	a	b	c
Lodgepole pine	4, 12	0.0000470	2.00235	0.90398
	Others	0.0000515	1.95239	0.91923
White spruce	4,5,8,15-22	.0000419	1.77630	1.11743
	Others	.0000433	1.77531	1.10980
Other conifers	4,8,9, 15-22	0.0000452	1.876679	0.99520
	Others	0.0000429	1.82290	1.07309
Hardwoods	All	0.0000392	1.88989	1.04839

(b) Merchantable volume

Model: $MV = TV\ (r_1 + r_2 X + r_3 X^2)$

where MV = merchantable volume (m^3)

$X = t^2 D^{-2} (1\text{-}0.04365b)^{-2} (1 + S/H)$
with t = top diameter inside bark = 8 cm
S = stump height = 0.3 m
b = coefficient
r = coefficients

Coefficients:

Species group	r_1	r_2	r_3	b
Lodgepole pine	0.9568	-0.1278	-0.8108	0.118
White spruce	0.9611	-0.2456	-0.6801	0.176
Other conifers	0.9526	-0.1027	-0.8199	0.164
Hardwoods	0.9057	-0.0708	-0.8375	0.145

3. Tree biomass equations: merchantable trees (D > 9.0 cm)

(a) Models
Primary components:

$$M_p = a + b\,D^2H$$

where M_p = tree component biomass (kg)
D = stem diameter at breast height (cm)
H = tree height (m)
a,b = coefficients

Secondary components:

$$M_s = M_m \, (c + d/D^3)$$

where M_s = tree component biomass (kg)
M_m = biomass of stem (wood and bark) components
c,d = coefficients

(b) Coefficients

Species group	Primary components			Secondary components		
	Name	*a*	*b*	Name	*c*	*d*
Lodgepole pine	Total tree	4.0587	0.02021	Merchantable stem wood	0.90908	-249.78
	Stem wood	2.5632	0.01504	Merchantable stem bark	0.09091	3.637
	Stem bark	0.9666	0.00140	Stump wood	0.04062	14.217
	Branches	-0.7921	0.00284	Stump bark	0.00406	3.3532
	Foliage	1.32100	0.000927	Top (wood and bark)	-	246.14
White spruce	Total tree	18.915	0.01433	Merchantable stem wood	0.86778	-304.39
	Stem wood	5.0735	0.01138	Merchantable stem bark	0.13222	-1.91056
	Stem bark	3.3980	0.00134	Stump wood	0.03857	34.698
	Branches	4.7114	0.00109	Stump bark	0.0061	9.0083
	Foliage	5.7860	0.000518	Top (wood and bark)	-	306.30
Other conifers	Total tree	8.9002	0.01848	Merchantable stem wood	0.84949	-310.39
	Stem wood	3.0719	0.01373	Merchantable stem bark	0.15051	-11.052
	Stem bark	1.2823	0.00233	Stump wood	0.04837	35.796
	Branches	1.8989	0.00167	Stump bark	0.00827	12.556
	Foliage	2.6977	0.000771	Top (wood and bark)	-	321.44
Hardwoods	Total tree	0.70631	0.01867	Merchantable stem wood	0.80622	-257.83
	Stem wood	1.4926	0.01158	Merchantable stem bark	0.19377	-65.278
	Stem bark	0.83798	0.00272	Stump wood	0.04242	14.222
	Branches	-2.2299	0.00413	Stump bark	0.01058	3.1332
	Foliage	0.61294	0.00024	Top (wood and bark)	-	323.11

4. Tree biomass equations: small trees ($D \leq 9.0$ cm)

(a) $0 < D \leq 9.0$ cm

Model: $M = a D^3$
where M = tree biomass, in kg

Coefficients:

Lodgepole pine:	$a =$	0.0274131
White spruce:		0.0284185
Other conifers:		0.0301704
Hardwoods:		0.0219859

(b) $0 < H \leq 1.3$ m

Model: $M = aH$

Coefficients:

Lodgepole pine:	$a =$	0.1275
Other conifers:		0.2514
Hardwoods:		0.2077

Appendix 6

Stand volume and biomass tables

1. Volume tables

(a) Pulpwood utilization (dbh >9.0 cm), m³/ha

Cover type / Height-age	Crown closure*								
	Open			Moderate			Dense		
	Site*			Site*			Site*		
	Very good	Good	Medium	Very good	Good	Medium	Very good	Good	Medium
Softwood									
Immature	132	81	74	145	94	87	170	119	112
Mature	164	114	107	177	127	120	202	152	145
Mixedwood									
Immature	115	65	57	128	78	71	153	103	96
Mature	147	97	90	161	110	103	186	135	128
Hardwood									
Immature	122	71	64	135	85	78	160	110	103
Mature	154	104	97	168	117	110	193	142	135

(b) Sawlog utilization (dbh > 25.0 cm), in m³/ha

Softwood									
Immature	83	33	20	82	37	25	98	48	36
Mature	107	56	44	111	61	48	122	72	59
Mixedwood									
Immature	77	26	14	81	30	18	92	41	29
Mature	101	50	38	105	54	42	116	65	53
Hardwood									
Immature	93	43	31	97	47	35	108	58	46
Mature	117	67	54	121	71	58	132	82	69

* Defined in Appendix 3.

2. Biomass table. Biomass in oven dry tonnes per hectare (t/ha), all components

Cover type Height-age	Crown closure* Open			Moderate and Dense			Small trees
	Site*			Site*			
	Very good	Good	Medium	Very good	Good	Medium	(dbh ≤ 9.0 cm)
Softwood							11
Immature	81	55	50	92	70	62	8
Mature	103	77	72	117	92	85	3
Mixedwood							18
Immature	72	46	41	83	59	53	6
Mature	93	67	62	104	83	74	4
Hardwood							12
Immature	81	54	49	91	66	61	10
Mature	102	76	71	120	93	81	5

* Defined in Appendix 3.

Appendix 7

Species composition for volume and biomass estimates

Utilization class	Cover type	Species group						
		Black spruce	White spruce	Lodgepole pine	Other conifers	Trembling aspen	Balsam poplar	Birch
dbh > 9.0 cm	Softwood	5	69	18	4	3	1	-
	Mixedwood	8	65	13	-	11	2	1
	Hardwood	1	30	1	-	34	33	1
dbh > 25.0 cm	Softwood	1	88	5	3	1	2	-
	Mixedwood	1	80	7	-	8	4	-
	Hardwood	0	40	1	0	28	28	3
Biomass	Softwood	6	66	19	4	3	1	1
	Mixedwood	10	63	12	1	11	2	1
	Hardwood	1	27	1	0	34	36	1

Appendix 8

Biomass of tree components for major species (%)

Species group	Merchantable stem wood	Stump wood	Bark of merchantable stem	Stump bark	Top (wood plus bark)	Branches	Foliage and fruits
Immature softwood and mixedwood stands							
Black spruce; white spruce	50	5	10	1	12	12	10
Lodgeole pine	64	4	7	-	8	11	7
Trembling aspen; balsam poplar	52	4	12	1	12	16	3
Birch	50	4	12	1	15	15	3
Immature hardwood stands							
Black spruce; white spruce	61	5	10	1	11	12	10
Lodgeole pine	63	4	7	-	8	11	7
Trembling aspen; balsam poplar	55	4	13	1	7	18	2
Birch	48	4	12	1	18	14	3
Mature stands							
Black spruce; white spruce	60	4	11	1	6	10	8
Lodgeole pine	69	3	7	1	1	14	5
Trembling aspen; balsam poplar	56	4	13	1	4	20	2
Birch	55	4	13	1	6	19	2