Inventory of forest biomass left after logging

by

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This report was prepared under the forest energy program of the Canadian Forestry Service (ENFOR). Research and development activities were initiated a few years ago by ENFOR in order to acquire greater knowledge and to improve our technology, so that an important contribution to the country's energy needs will come from forest biomass. This program is part of a much larger program designed to promote the development and utilization of renewable sources of energy, in order to reduce our reliance on fossil fuels.

Under its agreement with the Government of Canada, the Forest Engineering Research Institute of Canada mandated "Le Fonds de recherches forestières de l'Université Laval" to do the studies required to produce this report.

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PREFACE

In connection with its program on Energy from the Forest (ENFOR), the Canadian Forestry Service asked the Forest Engineering Research Institute of Canada (FERIC) to make a study consisting of three projects. The main concern was to find ways of utilizing logging residue to produce energy.

Under the terms of its agreement with the Canadian Forestry Service, FERIC retained the services of "Le Fonds de recherches forestières de l'Université Laval" (FRUL) to design and implement the first project, namely, the inventory of the residual biomass left after various logging operations in the major forest types of Eastern Canada.

Close cooperation was maintained between FRUL and FERIC throughout the execution of the project. Periodic reports were prepared and presented at meetings held between FERIC and the Advisory Committee of the Canadian Forestry Service, on October 25 and December 18, 1979.

A B S T R A C T

The objective of this study was to quantify and qualify the forest biomass left after logging by current methods, such as tree-length, full-tree and shortwood. The study was carried out in four major forest types of Eastern Canada, namely, black spruce (Québec), jack pine (Ontario), sugar maple (Québec), and balsam fir (New Brunswick).

SUMMARY

In 1979, four major forest types were the subject of a study intended to make an assessment of the residual forest biomass resulting from the use of various logging methods.

Black spruce, jack pine, sugar maple and balsam fir types were selected for this study.

Logging operations were carried out according to one of the following methods: tree-length, full-tree or shortwood.

In Phase 1 of the project, sites were inventoried before logging using 0.04 ha sample plots.

In Phase 2 the sample plots used in Phase 1 were relocated after logging in order to quantify the residues made up of tops, branches, green stems and dead stems.

All residues found in the plot were weighed in their green condition and the moisture content of each category of residue was measured.

The overall oven-dry weight included the weight of stumps (above ground portion) as well as residual trees.

The following are the oven-dry weights (tonnes/hectare):

Tree-length:	black spruce stand	—	56.4
	jack pine stand	—	50.7
	sugar maple stand	—	77.2
	balsam fir stand	—	81.2
Full-tree:	black spruce stand	—	25.8
	jack pine stand	—	32.9
	balsam fir stand	—	72.4
Shortwood:	black spruce stand	—	75.3

COLLABORATORS

Messrs. Jacques Bélanger and Jean-Marie Dumont, both of the FRUL executive, were responsible for the project. The field work and writing of the report were done by:

Messrs.	Michel Laverdière	— Project Supervisor
	Gervais Bélanger	— Group Leader
	Georges Gaulin	— Group Leader
	Louis Laneville	— Research Collaborator
	Jacques Rousseau	— Assistant Research Collaborator

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INTRODUCTION

The purpose of this project was to determine the quantity and the category of cutover residue from common logging methods. The results were to be within a 80% precision level.

Large forest areas, widely distributed in Eastern Canada and logged by companies with the most common methods, offered suitable conditions for the study.

In all cases, the first choice was for the tree-length method, which is the most widely used in Canada. Special attention was also paid to full-tree logging, which might become the preferred method in the future.

Finally, one example of a shortwood operation was used for comparison with the other two methods.

Black spruce stands were surveyed at CIP Inc., La Tuque Division, Québec; jack pine stands at Reed Inc.[1)], Dryden, Ontario; sugar maple stands at Consolidated-Bathurst Inc., Portage-du-Fort, Québec; and balsam fir stands at Fraser Inc., Edmundston, New Brunswick (Figure 1).

A total of 105 sample plots (0.04 ha) were used in this study. Field work began at the end of June and was completed by the beginning of December 1979. Compilation and data analysis was completed in March 1980.

This report assesses the methodology used and describes the forest operations and the forest types studied. The emphasis is on the presentation of the results together with a brief outline of the new possibilities suggested by the findings.

P A R T I

EXPERIMENTAL DESIGN

1. GENERAL PROCEDURE

1.1. Sequence of operations

The same procedure was used with all the companies. First, there were preliminary discussions with the authorities of the company's woodlands division and forestry department. The cutting areas, the logging methods and the forest types to be studied were selected at that time. Forest inventory documents, maps, and other information required for subsequent work were also obtained.

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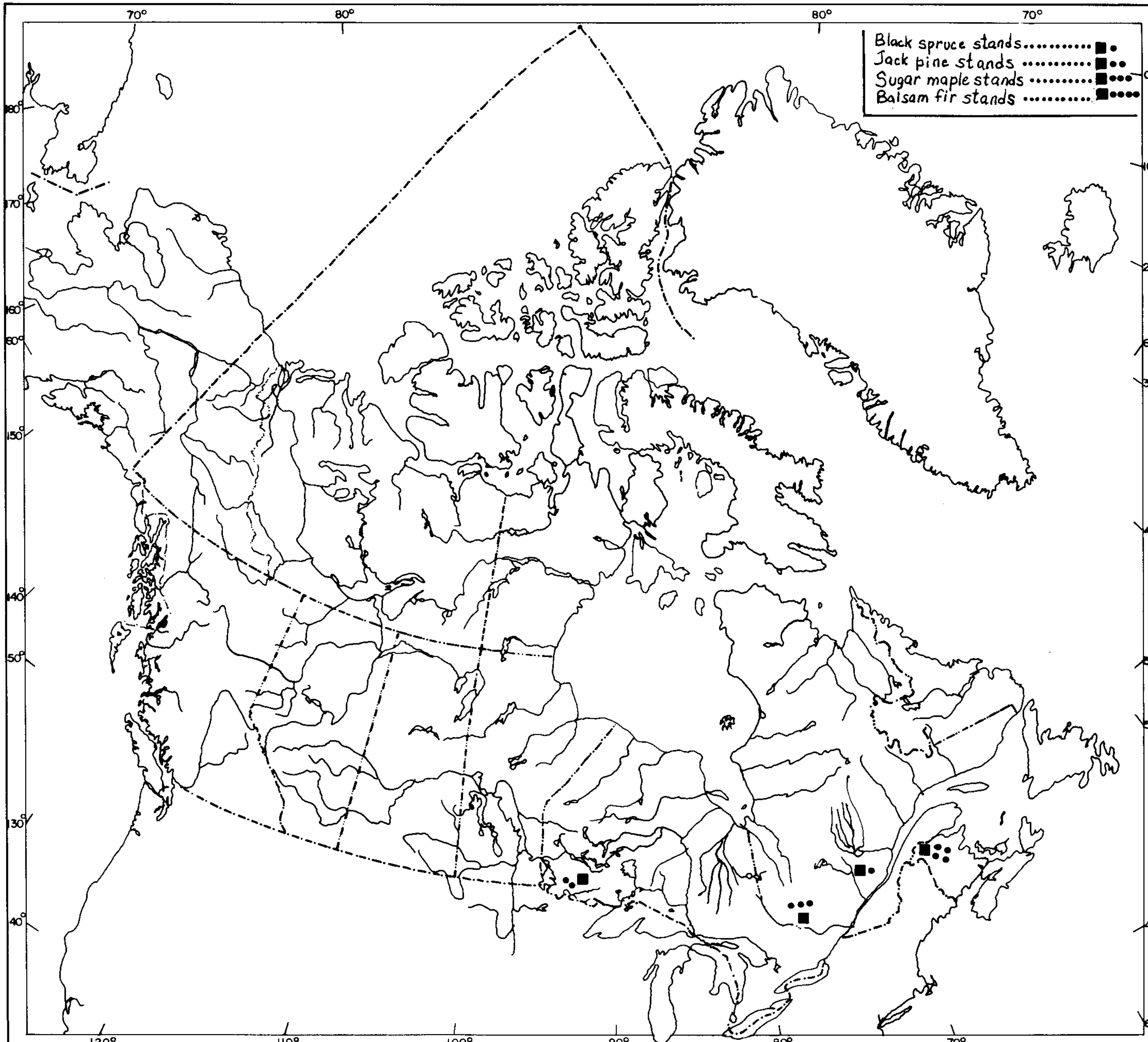
1) Has since become the property of Great Lakes Forest Products Limited.

Figure 1. Location of the study areas.



This first stage was under the direction of the project supervisor.

In the next stage, Crew no. 1 marked off the boundaries of the selected forest stands, located the sample plots, and conducted pre-logging inventories.

When the major portion of the stands had been logged, a second crew evaluated the residue left on the sample plots.

Samples were sent to the head-office to be oven-dried in order to calculate the moisture content of the material that had been weighed green in the field.

One engineer was responsible for compilation of data and also supervised the person in charge of drying the samples.

1.2. Personnel directly involved in the project

1.2.1. Organization chart

PROJECT SUPERVISOR

CREW NO. 1 Pre-cut inventory	CREW NO. 2 Post-cut inventory	SPECIAL STUDIES
1 group leader (senior forest technician)	1 group leader (forest engineer) in charge of inventory (7 junior forest engineers)	1 forest engineer in charge of samples (1 junior forest engineer)
1 junior forest engineer		
1 forestry student		

An average of 14 men worked in the field from June to December 1979 to complete the field work.

From December to March, three persons compiled and analysed the data, and wrote the report. The group was made-up of the project supervisor, the no. 2 group leader, and one junior engineer.

1.2.2. Job descriptions

a) Project supervisor: responsible for directing the project. He was required to make the preliminary contacts, organize and check the work of the crews, and control the budget.

b) Group leader, crew no. 1: responsible for locating the sample plots before logging and for the quality of the data collected. He also relocated the sample plots after logging.

c) Workers assigned to the collection of data, Crew no. 1: did all the work related to the pre-cut inventory.

d) Group leader, Crew no. 2: responsible for the post-cut inventory.

e) Member assigned to residue inventory, picking up, piling, transporting and weighing of the residue, assisting in sampling for moisture content, assisting in the measurement of stumps and residual trees.

f) Special studies member: study of methods of evaluating moisture content; study of the transect method, supervision, and conduct of the work involved in calculation of the moisture content and compilation of data.

g) Member assigned to weighing the samples: receiving the green samples, drying and weighing them in the laboratory; and compilation of moisture data and other related duties.

1.3. Measurement units

In order to prevent errors and to facilitate liaison with the companies that are not fully converted to the metric system, nearly all data were expressed in Imperial Units.

However, in accordance with current practice the results are presented in metric units. Conversion factors are given in Appendix 1.

2. METHODS OF PRE-CUT INVENTORY

Following the project supervisor's first tour of the selected company limits, a choice was made of certain cutting areas representative of the forest stand to be studied and soon to be logged. Pre-cut inventory consisted of establishing circular sample plots of 0.04 ha (0.1 acre) within the selected stands. Areas with easy access for post-cut inventory were preferred. To make certain that 15 sample plots would be measured, both before and after logging, a few extra plots were established to compensate for those that might not be measurable after logging.

The centre of the sample plot was marked by a tree which was barked and painted from the base to below its back cut level. A metal rod was also planted to further mark the plot centre. Reference points, visible after cutting, helped to relocate the plot centres.

Data were recorded on tally cards, as shown in Appendix 7. The counts of 2.54, 5.08 and 7.62 cm trees were recorded by 2.54 cm (1 inch) classes on an area of 0.004 ha (0.01 acre) around the centre of the plot. All trees of 10.16 cm + (4 inches) were also counted by 2.54 cm classes (1 inch). A caliper was used to measure the diameters. On five studies of dominant and codominant trees, notes were taken in each plot on species, vegetation layer, DBH over bark to the nearest 0.254 cm (0.1 inch), branching class (from 1 to 6), and age at stump level. Other information was noted on the forest stand observed (group of species, density, height and the stage of development), and on the site characteristics (slope, drainage, exposure). These data were estimated by the standards of the "Service de l'inventaire forestier du Ministère des Terres et forêts du Québec"[2], described in the "Cahier: Normes d'inventaire forestier 1975" published by the Québec Official Editor. The main herbaceous and moss strata were identified and an estimate of their abundance was recorded. A brief description of the logging methods used helped in the identification of the equipment and the time of logging.

In the sugar maple and balsam fir types sample plots of 0.08 ha (0.2 acre) were used. These plots were concentric with the 0.04 ha plot and were used for comparison with company results.

3. IMPORTANCE OF PRE-CUT INVENTORY

Various parameters were measured during the pre-cut inventory. It was necessary to collect mensurational data of the site where the residues were to be weighed as a future reference in estimating the relation between a forest type and the amount of residues to be expected after logging. The results obtained from one type of station can thus be applied more easily to other sites.

The purpose of this inventory was to permit comparison with company data. Repetition of the same survey proved to be valuable.

It may be concluded a priori that FRUL results would differ from the company's because the FRUL survey involved only a few 0.04-ha plots whereas the company averages were based on several tens of plots in a whole watershed or an entire stratum.

3.1. CIP, La Tuque (Windigo Camp)

3.1.1. Measured parameters and origin of basic data

Height, age and site class. Tables 1, 2 and 3 show the results obtained from FRUL's inventory. These values were compiled by logging method.

Heights and ages are averages of tree measurements. The site class was determined from the same observations. They were based on yield tables prepared by Vézina and Linteau (1968).

Basal area and merchantable volume. Inventory results from plots 1 to 30 and 40 to 45 were compared with the CIP results for the corresponding areas. All data shown in the FRUL tables represent all species taken together. In the case of CIP, the number of trees and the volume per acre were extracted directly from the company's records and basal area was determined from the number of trees per acre. The CIP volumes per acre were calculated from volume tables prepared by the company. The black spruce volume tables are very local since they vary between cutting areas.

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2) Now the "Ministère de l'Énergie et des Ressources".

TABLE 1

AVERAGE HEIGHT, AVERAGE AGE AND COMPARISON BETWEEN CERTAIN FRUL AND CIP DATA

TREE LENGTH METHOD

Sample Plot	Height (m)	Age (years)	Site Class	Basal Area (m^2/ha)		Gross Merchantable Volume (m^3/ha)		Average DBH (cm)	
	FRUL	FRUL	FRUL	FRUL	CIP	FRUL	CIP	FRUL	CIP
16	13.3	62	2	31	21	151	113	15.2	14.9
17	14.3	63	2	37	21	189	113	16.5	14.9
18	13.7	62	2	34	21	167	113	15.4	14.9
19	12.7	63	2	33	21	151	113	14.4	14.9
20	14.0	64	2	42	21	236	113	15.2	14.9
21	13.7	64	2	35	13	170	76	15.4	16.2
22	13.6	99	3	32	22	160	122	15.4	15.7
23	12.6	99	3	33	22	171	122	16.2	15.7
24	14.5	97	3	34	22	187	122	14.4	15.7
25	13.3	96	3	30	22	138	122	14.7	15.7
26	14.0	104	3	37	22	169	122	14.4	15.7
27	15.2	93	2	33	22	156	122	14.9	15.7
28	12.4	91	3	30	22	121	122	13.2	15.7
29	15.2	76	2	33	22	178	122	14.4	15.7
30	14.4	77	2	25	22	129	122	16.7	15.7
Average	13.8	81	2(2.4)	33	21	165	116	15.1	15.5

TABLE 2

AVERAGE HEIGHT, AVERAGE AGE AND COMPARISON BETWEEN CERTAIN FRUL AND CIP DATA

FULL TREE METHOD

Sample Plot	Height (m) FRUL	Age (years) FRUL	Site Class FRUL	Basal Area (m^2/ha) FRUL	Basal Area (m^2/ha) CIP	Gross Merchantable Volume (m^3/ha) FRUL	Gross Merchantable Volume (m^3/ha) CIP	Average DBH (cm) FRUL	Average DBH (cm) CIP
7	15.7	70	2	38	20	220	109	15.2	14.7
8	15.5	77	2	37	20	205	109	16.5	14.7
9	15.0	73	2	40	20	232	109	16.2	14.7
10	14.1	70	2	35	20	160	109	14.2	14.7
11	13.8	82	3	36	20	153	109	13.7	14.7
12	13.2	76	3	30	20	143	109	14.9	14.7
13	16.5	81	2	38	20	223	109	16.2	14.7
14	15.8	81	2	38	20	235	109	16.2	14.7
15	13.4	79	2	40	20	179	109	15.4	14.7
40	15.8	84	2	34	20	183	109	14.9	14.7
41	15.2	78	2	29	20	125	109	13.7	14.7
42	17.3	84	2	33	20	193	109	16.2	14.7
43	17.7	86	2	35	20	211	109	16.7	14.7
44	17.6	79	2	34	20	213	109	16.7	14.7
45	16.1	82	2	39	20	238	109	16.7	14.7
Average	15.5	79	2(2.1)	36	20	194	109	15.4	14.7

TABLE 3

AVERAGE HEIGHT, AVERAGE AGE AND COMPARISON BETWEEN CERTAIN FRUL AND CIP DATA

SHORTWOOD METHOD

Sample Plot	Height (m)	Age (years)	Site Class	Basal Area (m^2/ha)		Gross Merchantable Volume (m^3/ha)		Average DBH (cm)	
	FRUL	FRUL	FRUL	FRUL	CIP	FRUL	CIP	FRUL	CIP
1	17.9	81	2	35	22	207	122	16.0	15.7
2	15.8	77	2	36	22	217	122	16.7	15.7
3	17.3	69	1	42	19	257	119	17.0	17.0
4	16.8	80	2	41	19	244	119	16.7	17.0
5	18.6	78	1	38	22	253	122	18.7	15.7
6	17.3	68	1	34	22	228	122	18.7	15.7
31	15.7	88	2	41	29	245	149	16.5	14.7
32	14.3	80	2	31	29	170	149	15.4	14.7
33	15.3	77	2	37	29	237	149	17.7	14.7
34	15.8	73	2	36	29	223	149	17.5	14.7
35	14.8	78	2	40	13	224	81	18.2	16.2
36	15.2	77	2	35	18	183	102	17.0	15.7
37	16.0	77	2	32	18	185	102	16.2	15.7
38	16.9	81	2	36	18	207	102	16.5	15.7
39	16.7	77	2	36	18	207	102	15.7	15.7
Average	16.3	77	2(1.8)	37	22	219	121	17.0	15.6

Among the results obtained by FRUL, the number of trees per hectare and the basal area came from data measured in the field on 0.04 ha plots. The merchantable volume was derived from the Upper St-Maurice volume tables prepared by the "Service de l'inventaire forestier du Ministère des Terres et Forêts[3]. Average values for every logging method were obtained from 15 plots, often distributed in several stands.

Average DBH. The last two columns of the tables give the average tree diameter per plot. This parameter was calculated by the least squares method.

CIP calculated the average DBH from the average volume per tree and inserted that value into the equation used in making the volume table.

3.1.2. Analysis of results

Tables 1, 2 and 3 show clearly that the FRUL inventory results differ substantially from the CIP figures. At least part of that difference can be explained.

The two sets of data were obtained by fundamentally different sampling methods. The CIP data originated from random sampling whereas the FRUL results are from systematic sampling. The specific purposes of the inventories however justify the choice of sampling method in each case.

Most of the FRUL sample plots were established on high quality forest sites (black spruce-calliergon, calliergon-cornus, etc.). Plot location was based on such biological criteria as undergrowth species composition, crown density, and stand composition.

On the basis of the criteria used in plot location, it was expected that Site Class 2 would be predominant.

The results of using our method are reflected in the basal area and merchantable volume data where FRUL values are always greater than those of CIP.

In some instances CIP had selected forest types more suitable for shortwood logging with the Koehring harvester.

3.2. Reed Inc., Dryden

3.2.1. Measured parameters and origin of basic data

Tables 4 and 5 permit a comparison of the FRUL inventory results with those of Reed Inc. Values in Table 4 refer to Camp 34 which used the full-tree logging method; and in Table 5, to Camp 2 which used the tree-length logging method. Tables 6 and 7 provide additional information from the FRUL inventory.

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3) Now the "Ministère de l'Énergie et des Ressources".

TABLE 4

COMPARISON OF REED AND FRUL INVENTORY RESULTS

FULL TREE (CAMP 34)

Working Group	Sample Plot	Age (JP) (years)		Site (JP) Class (Plonski)		Height (JP) (m)		Stocking								Net Merchantable m^3/ha						Sample Plot
								FRUL				REED				FRUL			REED			
		FRUL	REED	FRUL	REED	FRUL	REED	JP	BS	Pop	WB	JP	BS	Pop	WB	SW	HW	Total	SW	HW	Total	
$JP_8Pop_1BF_1$																						
43	1	81	79	2	2	19,5	19,2	0,99	0,01	0,00	0,00	0,73	0,08	0,09	0,01	191	0	191	153	20	173	1
43	2	83	79	2	2	19,9	19,2	1,12	0,00	0,00	0,02	0,73	0,08	0,09	0,01	214	4	218	153	20	173	2
43	3	78	79	2	2	19,2	19,2	1,12	0,00	0,00	0,00	0,73	0,08	0,09	0,01	223	0	223	153	20	173	3
43	4	83	79	2	2	19,4	19,2	1,10	0,15	0,00	0,02	0,73	0,08	0,09	0,01	237	4	241	153	20	173	4
43	5	81	79	2	2	20,1	19,2	0,92	0,00	0,02	0,01	0,73	0,08	0,09	0,01	175	6	181	153	20	173	5
43	8	79	79	1	2	24,1	19,2	1,04	0,00	0,00	0,01	0,73	0,08	0,09	0,01	249	2	251	153	20	173	8
43	9	81	79	2	2	19,0	19,2	1,13	0,02	0,00	0,04	0,73	0,08	0,09	0,01	219	8	227	153	20	173	9
43	10	74	79	1	2	20,4	19,2	1,04	0,20	0,00	0,01	0,73	0,08	0,09	0,01	283	2	285	153	20	173	10
43	11	79	79	2	2	19,7	19,2	1,15	0,19	0,04	0,01	0,73	0,08	0,09	0,01	252	10	262	153	20	173	11
43	12	79	79	1	2	21,8	19,2	1,07	0,08	0,00	0,02	0,73	0,08	0,09	0,01	270	4	274	153	20	173	12
43	33	79	79	1	2	20,8	19,2	0,90	0,00	0,02	0,08	0,73	0,08	0,09	0,01	216	20	236	153	20	173	33
	$\bar{X}$	79,7	79	1,6	2	20,4	19,2	1,05	0,06	0,01	0,02	0,73	0,08	0,09	0,01	230	5	235	153	20	173	$\bar{X}$
JP_{10}																						
79	6	78	80	1	3	20,9	15,5	1,15	0,00	0,00	0,00	0,89	0,00	0,01	0,00	275	0	275	122	2	124	6
79	7	82	80	2	3	19,9	15,5	1,22	0,06	0,02	0,02	0,89	0,00	0,01	0,00	238	6	244	122	2	124	7
79	30	87	80	2	3	20,5	15,5	0,97	0,02	0,00	0,00	0,89	0,00	0,01	0,00	186	0	186	122	2	124	30
79	31	81	80	1	3	20,3	15,5	1,16	0,04	0,00	0,00	0,89	0,00	0,01	0,00	280	0	280	122	2	124	31
	$\bar{X}$	80,8	80	1,5	3	20,4	15,5	1,13	0,03	0,01	0,01	0,89	0,00	0,01	0,00	245	2	247	122	2	124	$\bar{X}$
Average		80,0	79,3	1,6	2,3	20,4	18,2	1,07	0,05	0,01	0,02	0,77	0,06	0,07	0,01	234	4	238	145	15	160	

TABLE 5

COMPARISON OF REED AND FRUL INVENTORY RESULTS

TREE LENGTH (CAMP 2)

Working Group	Sample Plot	Age (JP) (years)		Site (JP) Class (Plonski)		Height (JP) (m)		Stocking								Net Merchantable m^3/ha						Sample Plot
								FRUL				REED				FRUL			REED			
		FRUL	REED	FRUL	REED	FRUL	REED	JP	BS	Pop	WB	JP	BS	Pop	WB	SW	HW	Total	SW	HW	Total	
JP_8BF_2																						
53	13	79	82	2	2	19,0	20,1	1,50	0,19	0,03	0,00	0,68	0,23	0,02	0,00	317	9	326	170	6	176	13
53	14	77	82	2	2	19,5	20,1	1,12	0,27	0,00	0,00	0,68	0,23	0,02	0,00	257	0	257	170	6	176	14
53	15	79	82	1	2	21,5	20,1	1,15	0,29	0,00	0,00	0,68	0,23	0,02	0,00	326	0	326	170	6	176	15
53	16	77	82	1	2	21,6	20,1	1,04	0,25	0,00	0,07	0,68	0,23	0,02	0,00	292	9	301	170	6	176	16
53	17	79	82	1	2	20,7	20,1	1,00	0,32	0,01	0,00	0,68	0,23	0,02	0,00	295	3	298	170	6	176	17
53	18	82	82	1	2	21,5	20,1	0,84	0,22	0,00	0,00	0,68	0,23	0,02	0,00	239	0	239	170	6	176	18
53	19	79	82	1	2	21,2	20,1	1,05	0,21	0,00	0,00	0,68	0,23	0,02	0,00	288	0	288	170	6	176	19
53	20	81	82	1	2	22,3	20,1	1,23	0,27	0,00	0,00	0,68	0,23	0,02	0,00	342	0	342	170	6	176	20
53	22	82	82	3	2	17,0	20,1	1,31	0,32	0,00	0,00	0,68	0,23	0,02	0,00	237	0	237	170	6	176	22
53	23	82	82	2	2	18,7	20,1	1,20	0,20	0,00	0,00	0,68	0,23	0,02	0,00	264	0	264	170	6	176	23
53	24	81	82	2	2	19,0	20,1	1,09	0,27	0,00	0,00	0,68	0,23	0,02	0,00	255	0	255	170	6	176	24
53	25	81	82	1	2	20,6	20,1	1,13	0,14	0,03	0,00	0,68	0,23	0,02	0,00	295	9	304	170	6	176	25
53	26	84	82	2	2	19,3	20,1	1,11	0,26	0,00	0,00	0,68	0,23	0,02	0,00	257	0	257	170	6	176	26
	$\bar{X}$	80,2	82	1,5	2	20,1	20,1	1,14	0,25	0,01	0,01	0,68	0,23	0,02	0,00	282	2	284	170	6	176	$\bar{X}$
$JP_7BF_2Pop_1$																						
93	27	80	83	2	2	18,5	19,5	0,98	0,29	0,00	0,00	0,63	0,24	0,06	0,00	237	0	237	162	17	179	27
93	28	81	83	2	2	18,2	19,5	0,89	0,34	0,00	0,00	0,63	0,24	0,06	0,00	229	0	229	162	17	179	28
	$\bar{X}$	80,5	83	2	2	18,4	19,5	0,94	0,32	0,00	0,00	0,63	0,24	0,06	0,00	233	0	233	162	17	179	$\bar{X}$
Average		80,3	82,1	1,6	2	19,9	20,0	1,11	0,26	0,01	0,01	0,67	0,23	0,03	0,00	276	2	278	169	7	176	

TABLE 6

REED'S PRE-CUT INVENTORY

NUMBER OF TREES, BASAL AREA, NET MERCHANTABLE VOLUME,

AVERAGES AND AVERAGE DIAMETERS FOR EACH WORKING GROUP

TREE LENGTH METHOD

		Number of trees per hectare							Basal area (m^2/ha)							Merchantable Volume (m^3/ha)		
W-G	S.P.	JP	BS	Pop	WB	SW	HW	Total	JP	BS	Pop	WB	SW	HW	Total	SW	HW	Total
JP_8BF_2																		
53	13	1137	519	25	0	1656	25	1681	39	7	1	0	46	1	47	317	9	326
Camp	14	815	791	0	0	1606	0	1606	29	10	0	0	39	0	39	257	0	257
2	15	914	667	0	0	1581	0	1581	31	11	0	0	42	0	42	326	0	326
	16	741	568	0	49	1309	49	1358	28	9	0	2	37	2	39	292	9	301
	17	593	840	49	0	1433	49	1482	27	12	0	0	39	0	39	295	3	298
	18	469	445	0	0	914	0	914	23	8	0	0	31	0	31	239	0	239
	19	618	395	0	0	1013	0	1013	28	8	0	0	36	0	36	288	0	288
	20	692	544	0	0	1236	0	1236	34	10	0	0	44	0	44	342	0	342
	22	1557	1013	0	0	2570	0	2570	31	12	0	0	43	0	43	237	0	237
	23	1606	692	0	0	2298	0	2298	31	7	0	0	38	0	38	264	0	264
	24	939	741	0	0	1680	0	1680	28	10	0	0	38	0	38	255	0	255
	25	791	346	25	0	1137	25	1162	31	5	1	0	36	1	37	295	9	304
	26	717	494	0	0	1211	0	1211	29	9	0	0	38	0	38	257	0	257
Average		891	620	8	4	1511	12	1523	30	9	0	0	39	0	39	282	2	284
DBH Avg. (cm)		20,7	13,6	18,1	21,6	18,1	19,3	18,2										
$JP_7BF_2Pop_1$																		
93	27	840	692	0	0	1532	0	1532	25	11	0	0	36	0	36	237	0	237
Camp 2	28	667	741	0	0	1408	0	1408	23	12	0	0	35	0	35	229	0	229
Average		754	717	0	0	1471	0	1471	24	11	0	0	35	0	35	253	0	233
DBH Avg. (cm)		20,3	14,2	0	0	17,6	0	17,6										

TABLE 7

REED'S PRE-CUT INVENTORY

NUMBER OF TREES, BASAL AREA, NET MERCHANTABLE VOLUME,

AVERAGES AND AVERAGE DIAMETERS FOR EACH WORKING GROUP

FULL TREE METHOD

		Number of trees per hectare							Basal area (m^2/ha)							Merchantable Volume (m^3/ha)		
W-G	S.P.	JP	BS	Pop	WB	SW	HW	Total	JP	BS	Pop	WB	SW	HW	Total	SW	HW	Total
$JP_8Pop_1BF_1$																		
43	1	939	25	0	0	964	0	964	26	0	0	0	26	0	26	191	0	191
Camp	2	1063	0	0	25	1063	25	1088	29	0	0	0	29	0	29	214	4	218
34	3	1063	0	0	0	1063	0	1063	31	0	0	0	31	0	31	223	0	223
	4	791	272	0	25	1063	25	1088	28	6	0	0	34	0	34	237	4	241
	5	667	0	25	25	667	50	717	24	0	1	0	24	1	25	175	6	181
	8	741	0	0	25	741	25	766	28	0	0	0	28	0	28	249	2	251
	9	964	25	0	99	989	99	1088	29	1	0	1	30	1	31	219	8	227
	10	890	395	0	25	1285	25	1310	28	7	0	0	35	0	35	283	2	285
	11	766	321	25	25	1087	50	1137	30	7	1	0	37	1	38	252	10	262
	12	766	148	0	49	914	49	963	29	3	0	0	32	0	32	270	4	274
	33	692	0	25	124	692	149	841	25	0	0	2	25	2	27	216	20	236
Average		849	108	7	38	957	45	1002	28	2	0	1	30	1	31	230	5	235
DBH Avg. (cm)		20,4	16,1	20,7	13,3	20,0	14,6	19,8										
JP_{10}																		
79	6	741	0	0	0	741	0	741	31	0	0	0	31	0	31	275	0	275
Camp	7	642	49	25	25	691	50	741	32	2	1	0	34	1	35	238	6	244
34	30	618	25	0	0	643	0	643	25	1	0	0	26	0	26	186	0	186
	31	692	49	0	0	741	0	741	31	1	0	0	32	0	32	280	0	280
Average		673	31	6	6	704	12	716	30	1	0	0	31	0	31	245	2	247
DBH Avg. (cm)		23,8	19,1	17,8	15,2	23,7	16,6	23,6										

Tables 4 and 5. The first three columns give the ages, site classes and heights for every plot. Each column contains the FRUL data and the Reed logging inventory data. The three parameters given deal only with jack pine. FRUL values were determined from dominant and co-dominant trees (5 per plot) and the site class was taken from Plonski's tables (1960), using the jack pine age-height curve. The Reed data came from two different inventories, one for Camp 34 and one for Camp 2. The inventory of "working groups" 43 and 79 (Camp 34) was completed in 1975. In Table 4, the ages for jack pine taken from the Reed inventory were increased by 4 years to obtain the age for 1979. Because the inventories of "working groups" 53 and 93 were completed in 1978 the ages were increased by one year.

Reed inventory results also give site classes and heights for jack pine. These data are transcribed from the tables.

Basal area was calculated from tree counts and stocking and the merchantable volume of each plot was calculated.

Stocking was obtained by dividing the actual basal area (Tables 6 and 7) by the normal basal area proposed by Plonski. The age and site class parameters made it possible to use Plonski's tables. Since Plonski calculated the basal area by 5-year age classes most of the values used were interpolated from Plonski's values.

The net merchantable volume for each species then had to be calculated. A table prepared by Reed, similar to Plonski's table, gives the net merchantable volumes per acre by species for pure stands. As in Plonski's tables, age and site class enabled us to find a value in the table. That value multiplied by stocking gave the net merchantable volume of the species in the stand in question.

Reed obtained stocking values directly from the company's inventory records. Therefore, stocking corresponds to the year of inventory, that is, 1975 for working groups 43 and 79 and 1978 for working groups 53 and 93.

In order to obtain the net merchantable volume from the Reed data, the age, adjusted as described above, and site class values, as found during their inventory, were used. A corresponding volume for these values was determined from the Reed net merchantable volume tables, and was then multiplied by the stocking given in the Reed inventory.

3.2.2. Analysis of results

Tables 4 and 5 contain so much information that their analysis is difficult. It is, nevertheless, possible to draw a few general conclusions.

Full-tree logging (Camp 34). In working groups 43 and 93, FRUL age measures compare very well with Reed data. This is normal because the data were measured very accurately in both cases. It can be taken for granted that we are dealing with jack pine stands of approximately 80 years of age.

As mentioned previously, site classes were drawn from Plonski's age/height curves. Referring to the average site classes for working groups 43 and 79 in Table 4, the FRUL data show a better quality than Reed's. It is not customary to work out average site classes using decimals, but it permits a general appreciation of the results. For instance, site class 1.6, in Working Group 43, suggests that it could as well be a site 2 or site 1. But, if the site class is worked out from an average age of 80.2 years and an average height of 20.1 m, the coordinate obtained is situated exactly halfway between site 1 and site 2 on Plonski's curve. The same result is found for Working Group 79.

The difference between the average site classes obtained by FRUL and Reed are essentially related to height as is evident in the case of Working Group 79. Substantial discrepancies (as in Windigo) could result from our method of sampling in which stand density and composition were criteria for selecting the plots. In fact, the working group concept is not related to forest type.

A forest type is a plant association in the form of a distinct entity, from an ecological point of view, whereas the working group is an extensive forest area suitable for a particular treatment (Hudon, 1946). Therefore the forest type concept is ecological whereas the working group is related to management and logging. For instance, when a working group is said to have 80% jack pine and 20% poplar, it is very likely that poplar is scattered in small patches through the jack pine stand. Since one of the criteria for establishing a sample plot was to avoid the patches of poplar, chances are that we selected better growing conditions for jack pine than the average of the working group. This is also probably why stocking and net merchantable volume of jack pine differ substantially from Reed data.

Working Group 43 is described as having a volume of 10% poplar and 10% black spruce ($Jp_8Po_1Bs_1$). The FRUL inventory indicates more white birch than poplar and the total for both is under 10% of the total volume. Hardwood represents only 2% of the total volume. Black spruce gives about 5%. The jack pine stocking of 1.05 does not leave much room for the other species. In all, the results indicate clearly that FRUL sample plots were in a pure 80-year-old jack pine stand of high yield, given its site class between 1 and 2. The average jack pine DBH is well in line with these conclusions. According to the results, the average is 20.4 cm, whereas in Plonski's tables, the average DBH between sites 1 and 2 is 20.2 cm.

In Working Group 79, FRUL found higher jack pine stocking than Reed did but, here the stands are almost entirely jack pine with only a few traces of other species. This resembles what is called a working group (JP_{10}). Therefore, the sample plots were established in an 80-year old stand, with a very high stocking of jack pine of an excellent site class. The average DBH is 2 cm greater than could be expected in a site 1.

The differences between the results affect considerably the net merchantable volumes because of the combined effects of stocking and site class. In Working Group 79 that influence is very significant since the differences between FRUL and Reed site classes are very marked.

Tree-length logging (Camp 2). Several remarks dealing with Table 4 can also apply to Table 5, thus the description of Table 5 will be shorter.

In Working Group 53, the heights measured are on the average, identical to those of Reed for younger stands. Therefore, the FRUL site classes have a tendency to be better than the Reed classes.

In Working Group 93, ages and heights measured by FRUL are less than Reed values but site classes are the same.

In both working groups jack pine stocking is much higher than Reed stocking for reasons previously mentioned.

On the other hand the proportions of other species are comparable to Reed data, with the exception of Working Group 93, where no poplar was found in either survey.

The difference between the FRUL and Reed volume data is even greater than for the stockings in Working Group 53. This can be seen in Table 5 to be due to higher site classes. But, in Working Group 93, the volume and stocking differences are exactly the same since the site classes are the same in both inventories.

3.3. Consolidated-Bathurst, Portage-du-Fort (Camp Schyan)

Owing to the lack of company data on the sugar maple stand the pre-cut inventory was essential. FRUL figures were the only ones available. They were worked out from 13 sample plots (0.04 ha) and thus, were not necessarily representative of the entire stand. The wood was harvested by the tree-length method.

3.3.1. Measured parameters and origin of basic data

3.3.1.1. Height, age and site class

According to Table 8, the average height of dominant and codominant trees was 21.5 m. The stand was uneven-aged hardwood ranging from 101 to 170 years.

A theoretical site class was determined for this stand by dividing the average measured height into the normal height suggested by Lemieux (1963), for a sugar maple-hop hornbeam forest. The average ratio is 0.9.

3.3.1.2. Basal area and volume

The basal area and volume figures include all species. Sugar maple, hop-hornbeam and American beech were predominant. The company's local volume table, giving gross merchantable volume, was used for the measurements.

The average basal area was 24.6 m^2/ha and the volume was 189.7 m^3/ha.

TABLE 8

CONSOLIDATED-BATHURST, PORTAGE-DU-FORT

SUMMARY OF PRE-CUT INVENTORY RESULTS

SUGAR MAPLE

Plot no.	Site class	Avg. DBH (cm)	Dominants & codominants average height (m)	Dominants & codominants avg. age	Number of trees per hectare 0-9 cm	Number of trees per hectare 10 cm +	Basal area (m^2/ha) 10 cm +	Volume (m^3/ha) 10 cm +
1	0.8	20.6	18.5	113	0	593	19.9	150.8
2	0.9	22.2	19.8	112	988	717	27.8	206.6
3	0.7	21.5	17.1	165	0	544	19.7	148.6
5	0.9	22.7	19.0	101	741	593	23.9	189.3
6	0.9	23.4	19.7	121	494	741	31.9	259.2
9	0.9	23.8	22.3	170	1236	544	24.1	184.3
10	0.8	24.0	20.9	158	247	568	25.6	203.1
11	0.9	22.0	22.4	125	1977	568	21.6	164.6
12	0.9	23.6	24.0	161	247	642	28.0	211.4
13	1.0	24.8	23.6	122	1236	544	26.3	202.2
14	1.0	25.4	23.8	141	1483	469	23.8	175.1
16	0.9	28.8	20.6	129	1730	346	22.5	181.4
17	0.9	21.8	21.7	151	1977	667	24.9	189.8
Averages	0.9	23.3	21.5	136	949	578	24.6	189.7

3.3.1.3. Average DBH and number of trees per hectare

The average DBH was 23.3 cm for all the plots measured. The number of trees 10 cm or more was 578 per hectare, whereas the number of trees of 9cm or less was 949 per hectare.

3.4. Fraser, Edmundston, New Brunswick

The results of the pre-cut inventory are given in two different tables. Table 9 gives results for stands cut by the full-tree method and Table 10 results for stands cut by the tree-length method.

Site classes were taken from tables prepared by Vézina and Linteau (1968).

The difference between stand 171 and the others is quite apparent. It belonged to site classes 2 or 3, while the others were between classes 1 and 2. The number of trees per hectare was relatively low. In fact, this, and the average DBH, are the only variables that affect the volume, because the same volume tables were used for all forest types, disregarding site class. Fraser Inc. volume tables are based on average data for all site classes.

The volume of stand 30 was low. Although the number of trees per hectare was rather high, but the average diameter was low.

It is notable that in 4 stands out of 5 the measured values are much higher than the figures in the Fraser inventory. This could be explained by the same reasons given for the differences in the results obtained at Dryden and La Tuque. However, this difference was not apparent in the field.

4. METHODS OF POST-CUT INVENTORY

4.1. Relocation of sample plots

Sample plot centres were relocated from the reference points established before logging. Then, the perimeters of the 0.04 ha plots were marked on the ground very accurately with spray paint.

4.2. Collection of field data

4.2.1. Piling of logging residue

4.2.1.1. Residue crossing the plot perimeter

Once the perimeter of the plot was marked, all pieces crossing the line and having more than half of their surface outside the plot were removed. The balance of the residue was piled inside the plot.

TABLE 9

FRASER INC., EDMUNDSTON

PRE-CUT INVENTORY

FULL TREE

Stand	Sample plot	Dominants & codominants height (m) (FRUL)	Dominants & codominants age (FRUL)	Site class (FRUL)	Number of trees per hectare FRUL	Number of trees per hectare Fraser	Basal area (m^2/ha) FRUL	Basal area (m^2/ha) Fraser	Net volume (m^3/ha) FRUL	Net volume (m^3/ha) Fraser
168	22	13.7	42	1	1359	773	31.9	23.8	168.7	140.7
S	29	13.5	49	2	1631	773	40.3	23.8	220.9	140.7
6 I 5	30	15.5	52	1	1631	773	43.6	23.8	239.0	140.7
FS	31	16.3	48	1	1359	773	38.8	23.8	227.7	140.7
184/										
	Average	14.8	48	1.25	1495	773	38.7	23.8	214.1	140.7
171										
SH	28	16.9	78	2	568	591	22.5	21.1	137.1	119.8
6 I 4	32	13.2	70	3	1310	591	35.8	21.1	200.0	119.8
FS , TH										
62/										
	Average	15.1	74	2.5	939	591	29.2	21.1	168.6	119.8

TABLE 10

FRASER INC., EDMUNDSTON

PRE-CUT INVENTORY

TREE LENGTH

Stand	Sample plot	Dominants & codominants height (m) (FRUL)	Dominants & codominants age (FRUL)	Site class (FRUL)	Number of trees per hectare FRUL	Number of trees per hectare Fraser	Basal area (m^2/ha) FRUL	Basal area (m^2/ha) Fraser	Net volume (m^3/ha) FRUL	Net volume (m^3/ha) Fraser
30	1	15.6	57	1	1384	1021	34.4	23.2	184.4	124.6
S	2	15.0	56	1	2273	1021	41.6	23.2	192.8	124.6
4 II 4	3	16.4	59	1	1334	1021	36.0	23.2	198.5	124.6
FS	4	15.1	42	1	1705	1021	38.8	23.2	201.8	124.6
108/										
	Average	15.5	54	1	1674	1021	37.7	23.2	194.4	124.6
56	6	12.1	37	1	1606	1073	33.1	27.4	163.9	149.3
SH	7	13.4	63	2	1359	1073	29.8	27.4	151.9	149.3
6 I 5	8	14.6	52	1	1927	1073	41.9	27.4	215.4	149.3
FS , TH	9	14.5	60	2	1334	1073	38.8	27.4	222.3	149.3
54/	10	14.1	57	2	1310	1073	34.2	27.4	187.7	149.3
	Average	13.7	54	1.6	1507	1073	35.6	27.4	188.2	149.3
130	11	14.8	60	2	1532	1253	35.1	37.6	179.6	226.2
6 II 5	12	14.8	57	2	1310	1253	36.0	37.6	197.8	226.2
FS	13	15.4	59	1	1532	1253	32.3	37.6	159.5	226.2
41/	14	15.8	58	1	1656	1253	38.9	37.6	198.9	226.2
	Average	15.2	59	1.5	1508	1253	35.6	37.6	184.0	226.2

4.2.1.2. Categories of residue

Logging residues were classified into four distinct categories, as follows:

- tops
- branches
- green stems
- dead stems

All branches on green stems, either broken or complete, were cut, weighed and classified with branches. Moreover, stems cleared of branches were put in the green stems category.

Snags, and dead or diseased trees, either standing or fallen, were weighed and considered as dead stems.

4.2.1.3. Sampling of residue

Four samples for each category of residue were taken on each sample plot. Every sample was put in a sealed plastic bag and identified as follows:

- category of residue
- sample number
- plot number
- date of sampling

The location and the dimension of the samples varied depending on the category of residue.

Samples taken from branches were 15 cm long. However, since the moisture content in the branches varies with the length, the samples were taken in the following order:

1st sample: at 15 cm from the bigger end (or between 15 and 30 cm from the bigger end)
2nd sample: at 10% of the total length measured from the bigger end
3rd sample: at 20% of the total length measured from the bigger end

and so on, up to the 10th sample or 90% of the total length. The last sample was the last of the 15-cm pieces that could be cut from the sampled branch. Once the first series of cuts was completed, the same process was repeated, but starting from the smaller end.

Discs, 5 cm thick, were cut from tops and from green and dead stems. Sampling at regular intervals made it possible to determine the important moisture content variations along the stems. Sampling proceeded as follows:

1st sample: at 30 cm from the bigger end
2nd sample: at 10% of the length from the bigger end
3rd sample: at 20% of the length from the bigger end

and so on, up to the 10th sample or 90% of the length. The last sample of this series of cuts was taken at 30 cm from the smaller end. The same process was then repeated starting from the smaller end.

Branches attached to the sample discs were considered to be part of the sample.

4.2.1.4. Weighing of samples

Residues were put in metal boxes or on wooden racks. Each container had an identification number and was weighed empty beforehand.

Once the residues were piled in distinct bunches, the weighing operation began taking care to record every weight on Form 3 (Appendix 7) and in the appropriate column identifying the container used to carry the residue.

Once weighed, the residues were deposited outside the plot or on a section of the plot already measured.

4.2.2. Residual trees (standing)

In each plot the DBH and height of residual trees were measured. In the case of trees on the plot boundary, only those with more than half of their crown projection inside the line were included.

Trees not completely uprooted were classified as standing trees.

4.2.3. Stumps

Diameters and heights of stumps were recorded by species (Form 4, Appendix 7).

The measured diameter was the smallest diameter crossing the geometric centre of the cut surface and was measured under bark. The "Norme de mesurage volumétrique des bois non tronçonnés" of the Ministère des Terres et Forêts (1977 edition) was used for exceptional cases.

Stump height was measured in feet and tenths with the measurement taken from the highest root. When more than half of the stump's basal area was included inside the plot boundary, that stump was considered to be in the plot.

4.3. Sample analyses

4.3.1. Field analysis

In order to avoid any loss of moisture, samples were weighed as soon as possible to determine their green weight. The weight was recorded on the identification card placed inside the bag. A second identification card was tied to the fine metal wire used to close the bag firmly. The bag was then shipped to our laboratory in Québec.

4.3.2. Laboratory analysis

As soon as the samples arrived, the person in charge noted, on Form 5 (Appendix 7), the green weight of each sample as given on the identification card, as well as the sample number, the plot number, and the date of sampling. The sample was then placed in a drying oven at 105°C until its weight became constant. The oven-dry weight was then recorded on Form 5 (Appendix 7).

4.4. Calculation of moisture content

Once the oven-dry weight of the samples was known, a moisture content coefficient was found for each category of residue and logging method. This coefficient was applied to the green weights measured in the field.

The coefficient was calculated by dividing the sum of the oven-dry weights of the samples by the sum of green weights. The weights of all samples collected for a given method of logging were used in this calculation.

5. TESTS AND DEVELOPMENT

During the conduct of this project, some procedural problems had to be solved.

This section deals with improvements to the inventory procedure.

5.1. Tests on the use of the sawdust method to determine the moisture content of wood

5.1.1. Objectives

Under this forest biomass inventory project, FRUL took, each day, 16 solid samples of wood fibre in the form of discs. These were numbered and weighed green on the same day. They were then forwarded to Forêt Montmorency to be oven-dried at a temperature of 105°C for at least 16 hours. Determination of oven-dry weight makes possible the calculation of moisture content.

Another method for determination of moisture content is based on sawdust taken from woody materials to be tested. This method uses an OHAUS model 6010 Moisture Determining Balance, equipped with a built-in heat source. The weight is recorded when the green sample is first placed on the scale and is recorded again when the weight has stabilized (i.e. when "oven-dry" moisture content has been reached under the given conditions).

This experiment was done to assess the efficiency and speed of the sawdust method compared with the oven method.

5.1.2. Experimental process

Compared with other methods the oven-drying technique permits a very accurate evaluation of the moisture content in solid samples, such as discs or branch segments. In the experimental process, discs or small segments of branches are taken as samples to be oven-dried, and sawdust is extracted from these segments.

Forty-six samples of wood discs together with their 46 corresponding sawdust samples from residue (fir, spruce, white birch) in recent and old cutting areas at Forêt Montmorency were collected. The samples were subdivided into 5 categories as follows:

- tops
- branches
- green stems
- dead stems
- stumps

Because of the small amount of sawdust obtained from the branch segments the samples were taken from adjacent branches. This technique creates a safety hazard for the chain saw operator and it is impossible to prevent coarse and heterogeneous particles from getting into the sawdust.

The discs are weighed green and placed in the oven. Sawdust samples are placed one at a time on the Moisture Determining Balance. All of the steps in the procedure (from collection to weighing) are performed within 24 hours of sample collection. It should be noted that the relative humidity and barometric pressure varied during these trials and may have affected the results.

5.1.3. Use of the Moisture Determination Balance

Proper use of the Moisture Determination Balance requires certain precautions:

a) a sawdust sample weighing more than 5 grams takes a long time to dry and its dry weight will not stabilize easily;

b) an excessive source of heat (over 6 watts) will carbonize the sawdust at the top of the sample;

c) using a hot or even a warm container will lower the green weight of a new sample before the preliminary reading is taken.

Treating a sawdust sample takes approximately 5 to 6 minutes.

5.1.4. Results

The green weight moisture content (%) obtained by the oven and sawdust techniques are grouped in corresponding pairs of samples in Table 11 by residue categories. The linear regression formula and its statistical values were also compiled for each category as well as for all categories combined.

Figure 2 gives the relationship between the moisture contents obtained with the oven and sawdust methods for all samples combined, and all categories.

TABLE 11

RELATIONSHIP BETWEEN MOISTURE CONTENTS

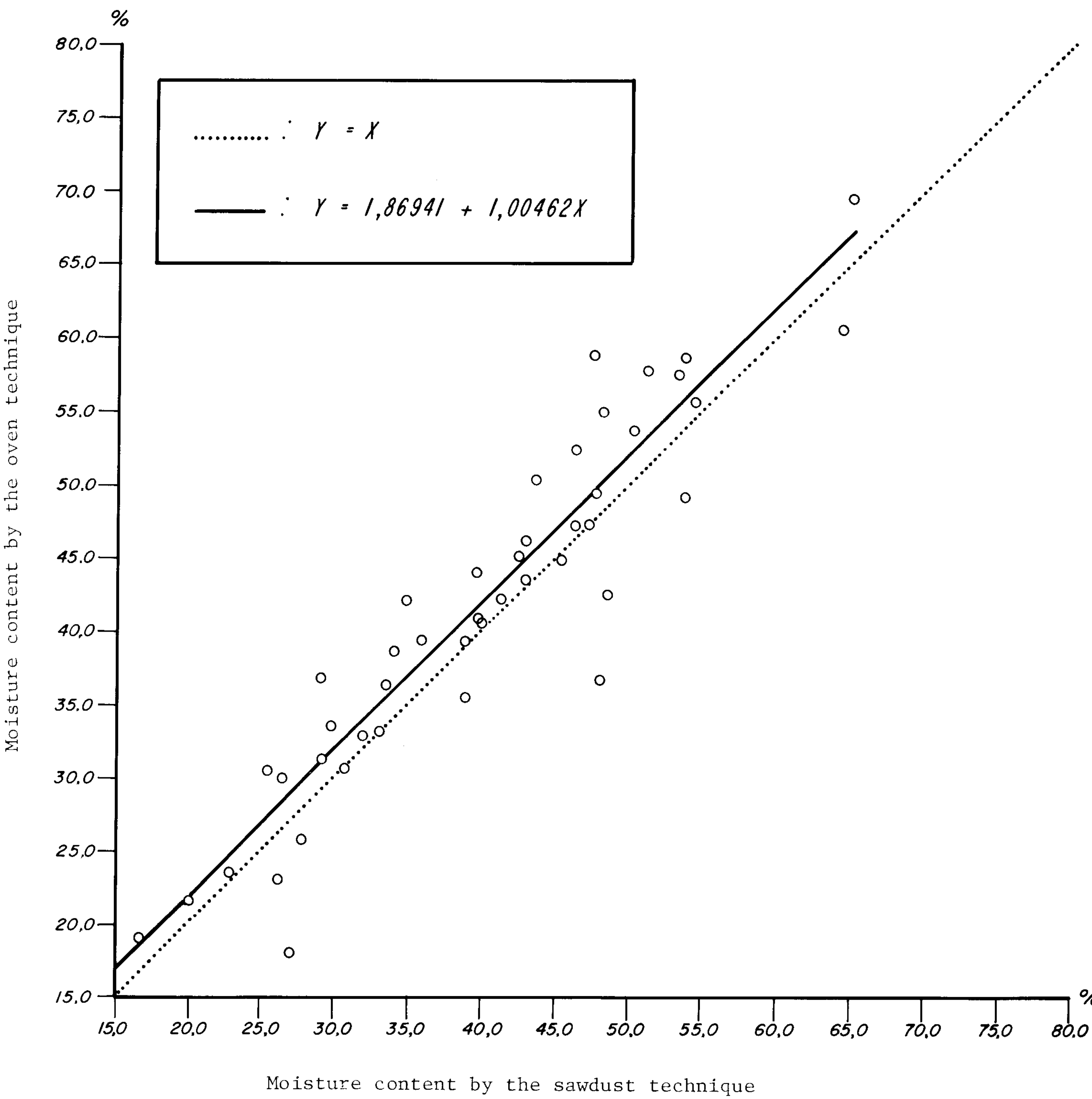
(WITH RESPECT TO GREEN WEIGHT)

OBTAINED BY THE OVEN AND THE SAWDUST TECHNIQUES

Category of residue	Moisture Contents (%) Y (oven)	X (sawdust)	Linear regression	Correlation coefficient (r)	R squared
Tops	50,4	43,5	Y = 9,34929 + 0,86639X	0,78549	0,61699
	58,9	47,4			
	57,5	53,4			
	58,7	53,6			
	53,7	50,2			
	44,8	45,4			
	38,7	33,9			
	36,8	48,0			
	36,9	29,0			
	36,4	33,4			
Branches	42,1	34,8	Y = -0,93565 + 1,11668X	0,89112	0,79410
	40,7	39,9			
	23,1	26,1			
	54,9	48,1			
	48,5	42,6			
	35,4	38,8			
	33,6	29,6			
	35,3	27,6			
	44,0	39,7			
	38,4	35,8			
Green stems	42,2	41,3	Y = -1,92470 + 1,10418X	0,97986	0,96012
	46,2	43,0			
	49,4	47,7			
	52,4	46,4			
	45,0	42,6			
	32,9	31,9			
	32,8	31,9			
	30,7	30,7			
	29,9	26,3			
	33,1	38,0			
Dead stems	49,1	53,9	Y = 0,98761 + 0,97300X	0,97319	0,94710
	23,6	22,9			
	19,2	16,5			
	60,6	64,3			
	30,5	25,5			
	18,1	27,0			
	69,5	64,9			
	40,9	39,9			
	55,7	54,5			
	21,7	20,0			
	31,3	29,2			
	25,9	27,7			
Stumps	47,3	47,3	Y = -15,23245 + 1,37467X	0,95595	0,91383
	57,8	51,3			
	39,4	38,7			
	47,2	46,3			
	43,5	42,9			
All categories	41,4	39,3	Y = 1,86941 + 1,00462X	0,93601	0,87611

Figure 2

Relationship between the moisture contents (% of green weight) obtained by the oven and sawdust techniques.



5.1.5. Discussion

Since the oven technique for measuring the moisture contents is rated as being very accurate, the sawdust technique generally tended to underestimate, with the exception of the dead stems category, where the results for all samples combined compared favourably. The difference between the moisture content determination methods is significant at a confidence level higher than 99%.

The weight of a sawdust sample dried on the Moisture Determination Balance does not fully stabilize. Once dried, the sample carbonizes and loses more weight. The operator must use judgement in timing the readings. This seems to apply more to the branch category, because that material is more heterogeneous.

The linear regression formulas mentioned above could be useful to assess the overall moisture contents of residue using only the sawdust technique. However, this technique is not satisfactory for tops and branches. Care must be taken not to extrapolate the formulas under conditions other than those of the present test, such as:

- treatment of the sawdust samples between 5 and 24 hours after sampling;
- decreasing relative atmospheric humidity during that period.

Therefore, if the change in relative humidity caused and underestimate owing to the drying of the samples, it would be advisable to make new comparative tests of these techniques under varying conditions of atmospheric humidity.

If the samples were treated quickly enough, or if they were put in cold storage, this would no doubt prevent their drying or moistening.

5.2. Carrying and weighing of residue

After the residues had been piled by category, they were carried in large aluminium boxes.

The field survey personnel soon realized that this method worked well with relatively small and less cumbersome pieces. After repeated trials, boxes came to be used exclusively for trunks cut into logs.

Wooden racks were built for carrying and weighing branches and tops. This resulted in more effective handling.

On the Consolidated-Bathurst limits another improvement was introduced in hardwood stands. A skidder was used to lift, carry and weigh the large pieces of wood (tops and trunks). A lever was installed under the hydraulic blade in front of the skidder. The scale was hooked on the end of the lever. The operator could then raise the piece of wood hanging under the scale to obtain weight readings.

This method saved time and also eliminated most of the manual labour of bucking and carrying the logs.

The same method did not work as well in Fraser's balsam fir stands. With a different model of skidder, the lever could not be fitted under the blade. Nevertheless a skidder was used to carry full length softwood trunks.

5.3. Relocation of the plots after cutting

Our first experiments demonstrated that it was nearly impossible to find all the plots in acceptable condition after the cut. Sometimes, an unforeseen secondary road would clear a large portion of the plot or a plot might be covered by log piles.

On two occasions changes in the logging method were made. In one the crew had to relocate plots to make sure of testing the desired logging method. In another area the inventory had to be simplified. This is why it was necessary to establish 17 to 18 plots before felling in order to recover at least 15 suitable for remeasurement.

P A R T I I

DESCRIPTION OF THE STATIONS SURVEYED AND EVALUATION OF THE RESIDUE LEFT AFTER LOGGING

1. GENERAL

1.1. Review of the principal logging methods in Canada

The three logging methods for which the survey of logging residue was carried out in 1979 are described in Appendix 4. Each method is characterized by variables depending on the degree of mechanization of the various stages of the harvesting operation.

1.2. Ecological information on forest types

The following sections (observations on forest types studied) give some information on the ecological nature of the sites investigated including geology, pedology, climatology and vegetation.

Meteorological data collected during the inventory are also of interest. The data were taken at the station nearest to the study site and show the meteorological conditions, mainly rainfall and temperature, prevailing a week before the beginning of the field work and up to the last day.

These data, especially rainfall over 6 mm[a], can be useful in the interpretation of certain variables affecting the moisture content of the residue. They are found in Appendix 5.

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a) Minimum quantity required to affect the moisture content of materials.

1.3. Details on the presentation of results

The presentation of results for each station offers more detailed information on each of the four forest types. This is followed by a synthesis of the most significant results to facilitate comparisons between logging methods and forest types.

2. BLACK SPRUCE; CIP INC., LA TUQUE, QUEBEC

2.1. Description of forest operations

This division of the company is responsible for logging operations taking place mainly in the Upper St-Maurice river watershed. The total production of the division is in the order of 1,300,000 m^3 annually. The pulpwood species are black spruce (75% of the volume), jack pine (13%) and balsam fir (12%).

Seventy-five percent of the wood is directed to the Trois-Rivières paper mill and 25% to the pulp mill at La Tuque. All the wood is driven on the St-Maurice River.

2.1.1. Location of the cutting areas studied

The Windigo camp, located at 160 km above La Tuque in the Upper St-Maurice, was used as headquarters for the field work. From this point, we had easy access to the main cutting areas selected on the basis of the logging method used: tree-length at Lac Daniel, shortwood at Lac Chien and full-tree logging at Lac aux Goelands.

2.1.2. Logging methods and production capacity

2.1.2.1. Tree-length method

The tree-length method, recommended by the company, is partly mechanized. Only skidding and bucking are done with machines. Forest workers on piece-work are grouped in three-man crews.

Two men do felling and delimbing, while the third man operates a cable wheeled skidder. Usually a Timberjack. Skidding distance averages 150 m.

The wood piled along the road is measured, loaded on trailer-trucks with a Tanguay or a Prentice knuckle boom loader, and hauled to a stationary Tanguay slasher located on the riverbank. Logs 2.45 m long are river driven to the mill.

At Camp Windigo, the annual cut in tree lengths is approximately 167,000 m^3. A total of 250 men live in the camp. This number includes all the men assigned to wood production as well as the camp personnel. The total annual cut for the camp is about 283,000 m^3.

2.1.2.2. Full-tree method

This logging method, as used by CIP, is fully mechanized, involving the two machines. The operators are paid on an hourly basis.

The machines are a Forano BJ-20 feller-buncher, and a Timberjack grapple wheeled skidder. Full trees are skidded an average distance of 180 m to the road.

Limbing and topping are done only at roadside by a Rocket delimber-topper, mounted on a JBC-808 frame.

The other operations, loading, hauling, and bucking, are performed by the method described previously for tree-length operations.

A volume of about 42,500 m^3 is cut annually at Camp Windigo by this method.

2.1.2.3. Shortwood method

This method which is widely used by CIP may require the use of one or several machines. Operators are paid on an hourly basis.

This operation is fully mechanized using a Koehring (KSH: Koehring Shortwood Harvester). This machine fells, delimbs, tops, bucks to 2.45 m lengths, forwards and piles. Forwarding distance is normally 230 m.

Wood is hauled to the river with ten-wheeled trucks and driven to the mill.

With this method about 73,600 m^3 are cut annually at Camp Windigo.

Table 12 summarizes the three logging methods used by CIP Inc.

2.2. Observations on the forest type

2.2.1. Location

B.1a — Laurentians-Onatchiway

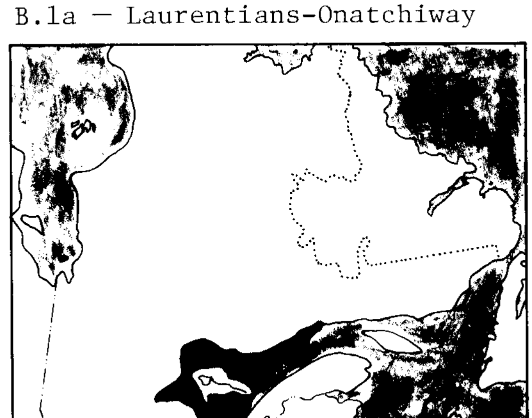


TABLE 12

SUMMARY OF CIP LOGGING OPERATIONS

	Felling	Limbing	Topping	Skidding	Forwarding	Piling	Loading	Slasher
Tree-length	Forest workers with chainsaws			Timberjack wheeled cable skidder 150 m	---	With skidder	Tanguay knuckle boom loader	Tanguay stationary slasher 2.45 m
Full-tree	Forano BJ-20 feller-buncher	JBC-808 delimber with rocket knives on frame		Timberjack wheeled grapple skidder 180 m	---	With skidder	Tanguay knuckle boom loader	Tanguay stationary slasher 2.45 m
Shortwood	Koehring KSH roundwood harvester			---	Koehring KSH 230 m	Koehring KSH	Self-loading truck	Koehring KSH 2.45 m

This region is located in the Laurentian uplands west of the section called Laurentians-Onatchiway (B.1a) by Rowe (1972). CIP's Camp Windigo is 150 km north-west of La Tuque.

2.2.2. Topography, geology and soils

Numerous glaciations have affected the regional topography. The land is undulating. The mountains have been rounded and have relatively low elevations. Sandy soils overlie Precambiran bedrock. Ferro-humic and humo-ferric podzols are the most common soil types in this area.

2.2.3. General climatic data

The average summer temperature (June, July, August) is 15.8°C and the total summer rainfall is 306 mm. The climate is continental, but rather humid and cold.

2.2.4. Forest vegetation

Shallow soil plateaux and poorly drained lands are covered with black spruce. This region has been largely invaded by the black spruce-hypnum association, an important climax of the Québec forest. These stands are usually established naturally or after fire, on acid soils with average to good drainage. The humus depth varies between 20 and 25 cm. Very few shrubs or herbaceous plants can grow under the black spruce canopy. Most of the forest floor is covered by a moss layer, mainly Calliergon schreberi. The black spruce-hypnum association belongs to site classes II and III with wood volumes ranging from 140 to 160 m^3 per hectare.

Balsam fir-Hylocomium-Oxalis, frequently originating from windfall, appears in more or less extensive patches. It is a transition forest of sites I and II, with a higher yield than the black spruce hypnum type (yield is approximately 225 m^3 per hectare). These types are found on deep soil slopes and on other cool and well drained sites.

The lower areas are colonized by black spruce - Ledum. These stands are less dense and belong to a lower site class than the preceeding types. A large population of Kalmia is a good indication of poor site quality. Sandy plateaux in river valleys may have been invaded after fire by jack pine and black spruce stands with a dense growth of calliergon and cornus. This transition forest is evolving towards a black spruce-calliergon type. Soils in general are so coarse that trembling aspen has little chance of developing.

2.2.5. Sampling area

Most of the sample plots are located in black spruce-hypnum type. Being widely exploited in Québec, this type was favored as sampling sites over the other types encountered. Kalmia and Ledum sites for instance, having a lower yield, were totally ignored.

2.3. Results

2.3.1. Weighing accuracy

Table 13 gives the statistical value of the results of weighed residue for the three logging methods. It shows the average weight, the range of weights, and the percentage of error with respect to the average at a 95% confidence level.

Table 13 is complemented by Figure 3, which shows the variation in the percentage of error with respect to the mean as a function of the measured plots. The maximum error permissible is 20%.

2.3.2. Oven-dry weight and moisture content

Talbe 14 gives the green and oven-dry weights and the moisture levels by category. This level is calculated on an oven-dry basis and shows much variation between the categories of residue, namely, from 45% to 72%.

2.3.3. Volume and weight of stumps and residual trees

Table 15 shows the green volumes and the oven-dry weights of residual trees and stumps, by species, for each logging method. Only the aerial portion of stumps was included in volumes.

The oven-dry weight was calculated from basic specific density coefficients.

2.3.4. Total oven-dry weight by logging method

Finally, Table 16 shows the oven-dry weight of residue, residual trees, and stumps, for each logging method. Tree-length leaves 56.4 t/ha; full-tree, 25.8 t/ha; and shortwood, 75.3 t/ha. The histogram (Figure 4) shows the relative importance of each category. It is following by Figure 5, a cumulative distribution of the preceeding categories, which shows clearly the contribution of each category to the total weight.

3. JACK PINE; REED INC., DRYDEN, ONTARIO

3.1. Description of forest operations

This company, owned by Reed Inc. at the time of the survey, was taken over by Great Lakes Forest Products Limited on December 16, 1979.

The study dealt with jack pine stands. The annual wood production is 1,300,000 m^3, half jack pine and half black spruce.

Approximately 880,000 m^3 are delivered by truck to the pulp mill and 250,000 m^3 to the company's sawmill.

TABLE 13

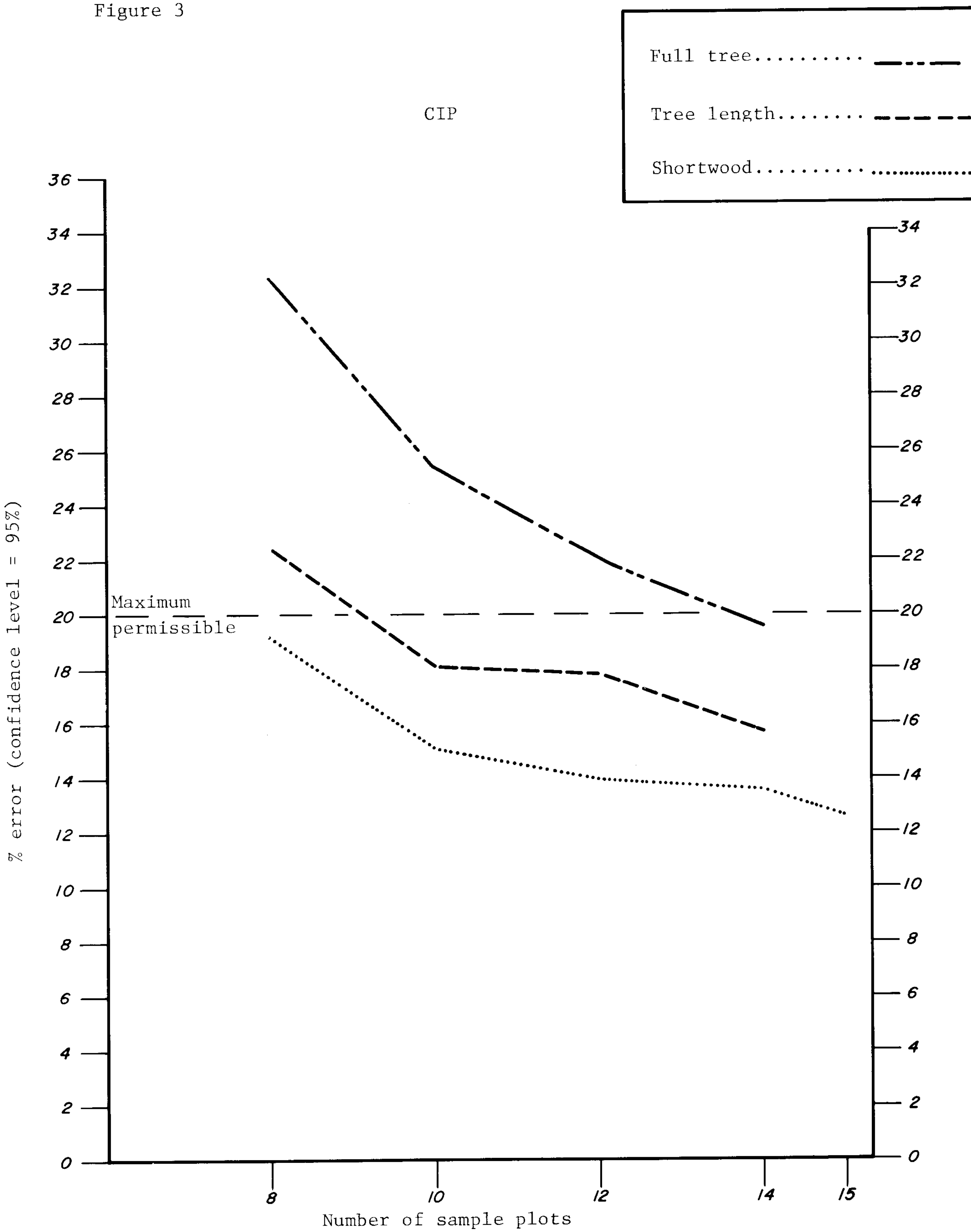
STATISTICAL VALUE OF THE WEIGHT OF GREEN RESIDUE FOR ALL SAMPLE PLOTS

BLACK SPRUCE

CIP, LA TUQUE

Logging method	Number of plots	Green weight of residue (t/ha)				% error from mean (95%)	Number of plots for confidence level	
		minimum	maximum	mean	standard deviation		95%	99%
Tree length	14	54.0	129.8	87.4	23.8	15.7	118	2957
Full tree	14	18.9	48.2	31.3	10.5	19.4	182	4539
Shortwood	15	71.2	165.6	114.5	26.2	12.7	84	2095

Figure 3



Evolution of error as a function of the number of sample plots — black spruce

TABLE 14

GREEN AND OVEN-DRY WEIGHTS OF RESIDUE (t/ha)
AND MOISTURE CONTENT (with reference to oven-dry weight)
BY CATEGORY
BLACK SPRUCE — CIP — LA TUQUE

Logging method		Category of residue: Tops	Branches	Green stems	Dead Stems	Total
Tree length	green weight	44.2	19.1	9.6	14.4	87.4
	dry weight	26.2	11.6	6.1	9.9	53.8
	% moisture	68	65	57	46	62*
Full tree	green weight	2.1	5.0	11.9	12.3	31.3
	dry weight	1.2	3.2	7.9	8.4	20.7
	% moisture	66	58	50	46	51*
Shortwood	green weight	18.6	37.8	35.2	22.9	114.5
	dry weight	11.1	22.0	21.8	15.8	70.7
	% moisture	67	72	61	45	62*

* % weighed moisture

TABLE 15

GREEN VOLUME AND OVEN-DRY WEIGHT
OF RESIDUAL TREES AND STUMPS BY SPECIES,
FOR THE VARIOUS LOGGING METHODS
BLACK SPRUCE — CIP — LA TUQUE

	Tree-length						Full-tree					Shortwood				
	BS	JP	BF	WB	Pop	Total	BS	BF	WB	Pop	Total	BS	WB	BF	JP	Total
Residual trees																
Green volume m^3/ha	0.9	0.1	0.0*	1.2	0.9	3.1	1.5	0.1	3.8	2.4	7.8	2.8	0.8	0.0*	---	3.7
Oven-dry weight t/ha	0.3	0.0*	0.0*	0.6	0.3	1.3	0.6	0.0*	2.0	0.9	3.5	1.1	0.4	0.0*	---	1.6
Stumps																
Green volume m^3/ha	3.0	0.0*	0.0*	0.1	---	3.1	3.3	0.0*	0.5	---	3.8	6.1	0.8	0.3	0.2	7.4
Oven-dry weight t/ha	1.2	0.0*	0.0*	0.0*	---	1.3	1.3	0.0*	0.2	---	1.6	2.4	0.4	0.1	0.1	3.0

* figures between 0.01 and 0.05

--- absent species

TABLE 16

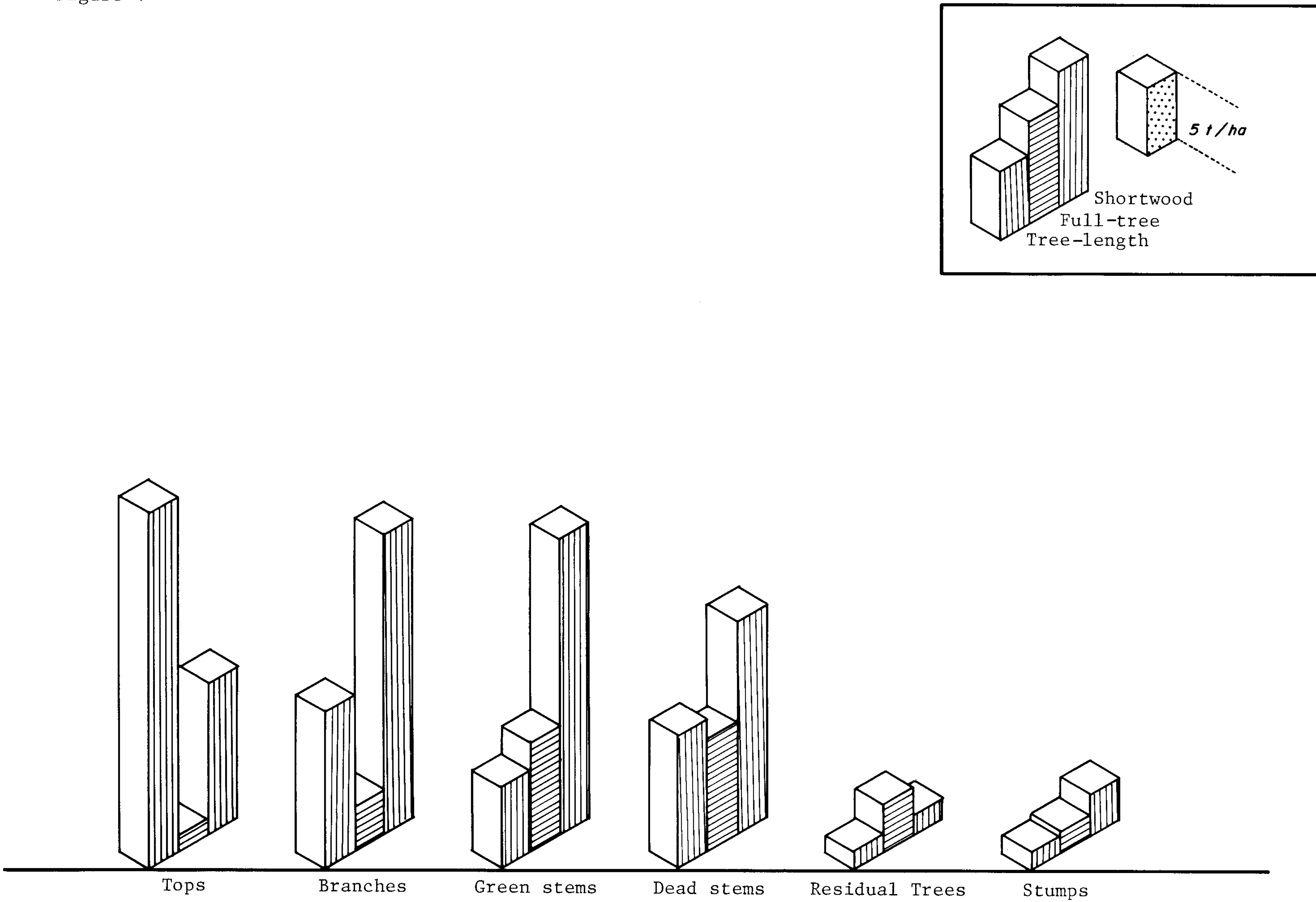
OVEN-DRY WEIGHT OF RESIDUE

RESIDUAL TREES AND STUMPS (t/ha)

BLACK SPRUCE — CIP — LA TUQUE

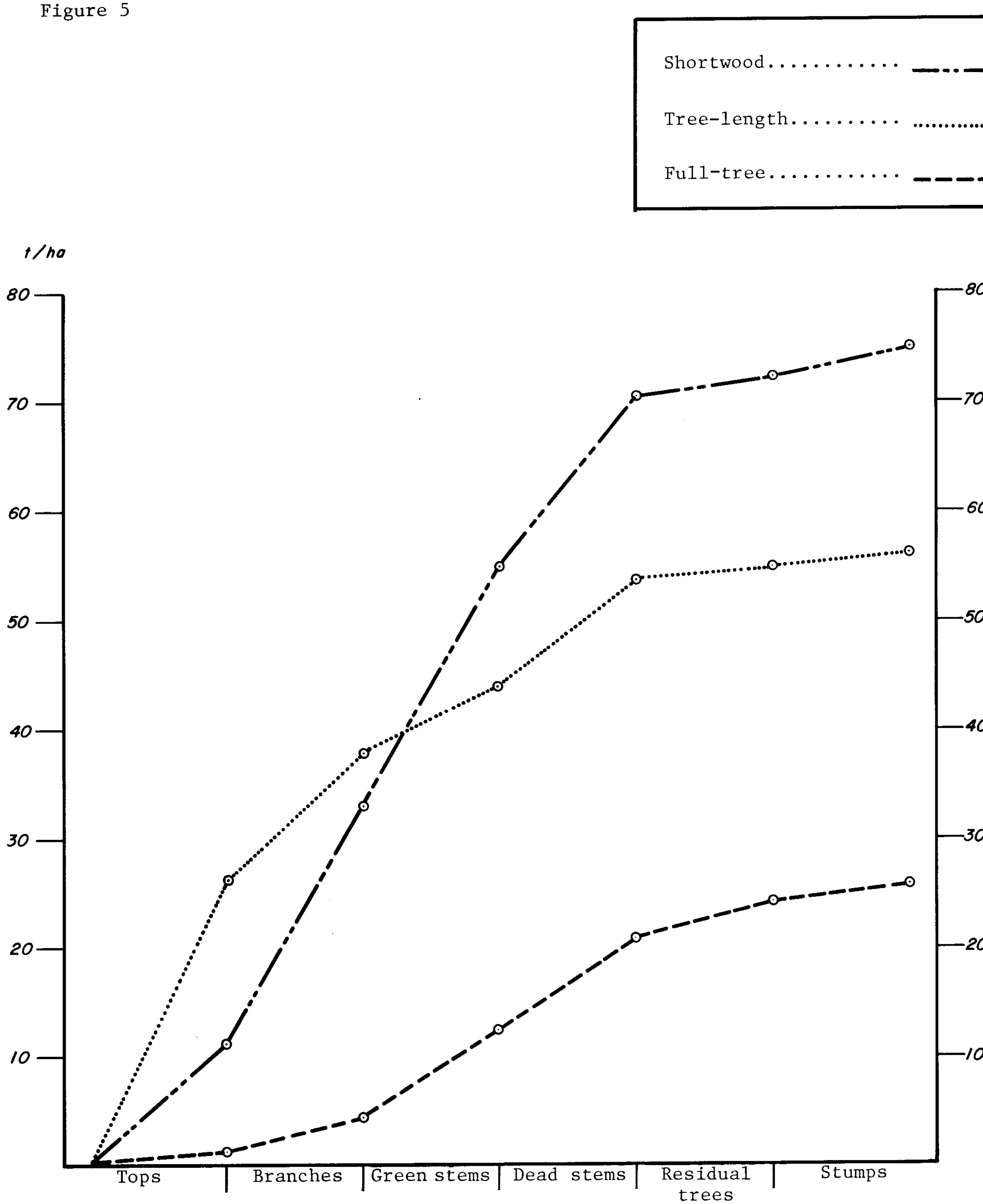
Logging Method	Categories									
	Tops	Branches	Green stems	Sub-total	Dead stems	Total residues	Residual trees	Sub-total	Stumps	Total
Tree-length	26.2	11.6	6.1	43.9	9.9	53.8	1.3	55.1	1.3	56.4
Full-tree	1.2	3.2	7.9	12.3	8.4	20.7	3.5	24.2	1.6	25.8
Shortwood	11.1	22.0	21.8	54.9	15.8	70.7	1.6	72.3	3.0	75.3

Figure 4



Distribution of the oven-dry weight of residue by category and by logging method — black spruce

Figure 5



Cumulative distribution of the oven-dry weight of residue by category and by logging method — black spruce

3.1.1. Location of the surveyed cutting areas

The headquarters for this second survey were at Dryden, a small locality about 350 km from Thunder Bay in northern Ontario. From that point we had access to camps 2 and 34, which used tree-length and full-tree logging methods, respectively. Camp 2 is about 40 km north of Dryden and Camp 34 is 30 km from Ignace, which is 100 km east of Dryden.

3.1.2. Logging methods and production capacity

3.1.2.1. Tree-length method

Forest workers, grouped in three-man crews, are paid by the hour. They are driven to work by bus every morning and are back home at night. In fact there are no camps in the woods, except for a few trailers for the foreman, the garage, and the parts warehouse. All the equipment, including chain saws, is owned by the company.

The working crew is made up of 3 men. Two men fell, delimb and top and the third operates a Tree Farmer wheeled cable skidder. The skidding distance averages about 120 m. The skidder also piles the trees on the dumps. (Table 17)

At Camp 2 a crew of 25 to 30 men produced an annual cut of approximately 90,600 m^3.

3.1.2.2. Full-tree method

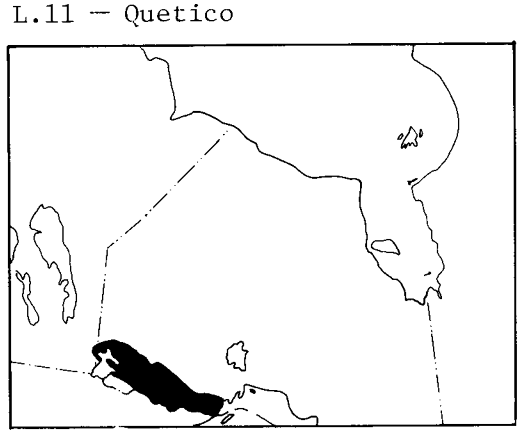
All operations by this method are fully mechanized. Forest workers are classified as machine operators and paid on an hourly basis.

For this type of operation the company uses a Koehring KFF. Felling, forwarding, and piling are done by the machine. The wood is forwarded over an approximate distance of 245 m. (Table 17)

A delimber-slasher ÖSA 705 at the landing cuts trees into 4.9 m lengths. The operation has an approximate annual production of 113,300 m^3 with 20 men.

3.2. Observations on forest types

L.11 — Quetico



B.11 — Upper English River

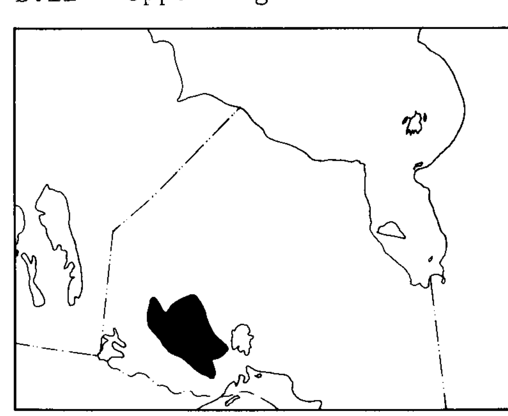


TABLE 17

SUMMARY OF REED FOREST OPERATIONS

	Felling	Limbing	Topping	Skidding	Forwarding	Piling	Loading	Slasher
Tree-length	Forest workers with chainsaws			Tree farmer wheeled cable skidder 120 m	---	With skidder	In lengths	?
Full-tree	Koehring KFF feller-forwarder	ÖSA 705 delimber bucker		---	Koehring KFF 245 m	Koehring	Drott	ÖSA 705 4,9 m

3.2.1. Location

Two locations were chosen for logging surveys in the Ontario jack pine forest. First, at Camp 34 on Reed's woodlands a full-tree operation is located 40 km south-west of Ignace. This locality is on the Trans-Canada Highway (No. 17) approximately 100 km south-east of Dryden. According to Rowe (1972), this area is in the north-centre limit of the Quetico section (L.11). It is also at the northern boundary of the Great Lakes - St-Lawrence region. Second, a tree-length operation at Reed's Camp 2, about 40 km north-east of Dryden. This section has been named by Rowe "Upper English River" (B.11). It is a transition zone between the boreal forest to the north and the Greal Lakes - St-Lawrence forest to the south.

According to the Ontario Ministry of Natural Recources' classification (Hills, 1952), both of these sections are grouped within one site region based on the specific capacity of a site to maintain a biological potential. Hills calls this region Lake Wabigoon (4S). It is part of the sub-humid section of western Ontario.

3.2.2. Topography, geology and soils

Region 4S is part of the Precambrian Shield. Thin coarse-textured soils result from glaciation. It has been subdivided by Hills (1959) into several districts. Camp 34 is in Manitou district and Camp 2 is in the Sunstrum district. The average altitude is 396 m.

According to Zoltai (1965), the topography in the Camp 34 (full-tree) area is characterized by round hills, with a few steep slopes. Generally, differences between elevations are less than 60 m. Superficial stony silty sands lie on deposits of rounded rocks. Predominant parent material is granite with intrusions of crystalline sedimentary and volcanic rocks. Deep sands are found near lakes.

The Camp 2 (tree-length) area has a topography similar to Camp 34, but it is often less hilly. Slopes under 5% and elevations below 15.6 m are common. Shallow silty sands cover moderately broken rock deposits. In the plain soils are mainly of the gravelly and sandy types. The parent material is granite and there are practically no indications of clay in the whole region.

3.2.3. Climatic data

The climate is continental, cool and sub-humid. The average annual temperature is between 0.5°C and 2.2°C. The total annual rainfall varies from 52 to 80 cm, of which nearly two-thirds fall during the growing season. The summer rainfall (June, July and August) around Camp 34 reaches 283 mm and, at Camp 2, 251 mm. There are 103 frost free days. Frequent dry speels result in extensive forest fires.

3.2.4. Forest vegetation

Nearly all the forests of the region originated from fire. According to Zoltai (1965) the establishment of pioneer conifer stands was greatly favoured by fire and seed availability. Pioneer hardwood (aspen) stands are scarce. In addition transition and climax forest types are very rare. The sub-humid climate does not favour species generally found on dry sites. But instead a proportional distribution of boreal species controlled by soil moisture conditions. The ability of jack pine to invade recent burns and its tolerance of drought has permitted its establishment in the area.

When seeds were available after a fire pioneer jack pine stands colonized the dry to humid sites of the region while black spruce occupied fresh to damp sites. As soon as the forest reaches its climax jack pine disappears. Except for a few remaining jack pines the area will be occupied by hardwood and fir. Black spruce is well represented in climax forests on fresh or damp sites. White spruce is well represented in the climax forest, except on dry sites. After logging chances are that the area will be naturally reforested by poplar and fir, rather than by jack pine. Dry sites with silty sandy soils occupied by jack pine stands belong to site class 2 whereas a cool or moist site with similar characteristics is in class 1. These sites are occupied by dense shrub and herbaceous vegetation. "*Aster macrophyllus*" is typical of these stations.

3.2.5. Sampling areas

Some of the stands sampled were pure jack pine. In most cases there was a proportion of 10 to 20% black spruce as well as trembling aspen, scattered in small pockets.

At Camp 34, a few plots were established in a pure jack pine stand on a high quality dry site.

On the other hand, black spruce and trembling aspen were always present on moist sites.

On both sites black spruce , wherever present, grew as a jack pine under-storey, with a difference in height of about 4.5 m.

In general, regeneration consisted of fir, aspen, and black spruce.

White birch was present everywhere in the Camp 34 area, but was almost completely absent from the stand tested at Camp 2.

3.3. Results

3.3.1. Weighing accuracy

Table 18 gives the statistical importance of weights from both logging methods. The main figures are the means for the 15 plots, the extreme weight values, and the percentage of error at the 95% confidence level.

Figure 6 shows the percentage of error and analyses its variation as a function of the number of plots measured.

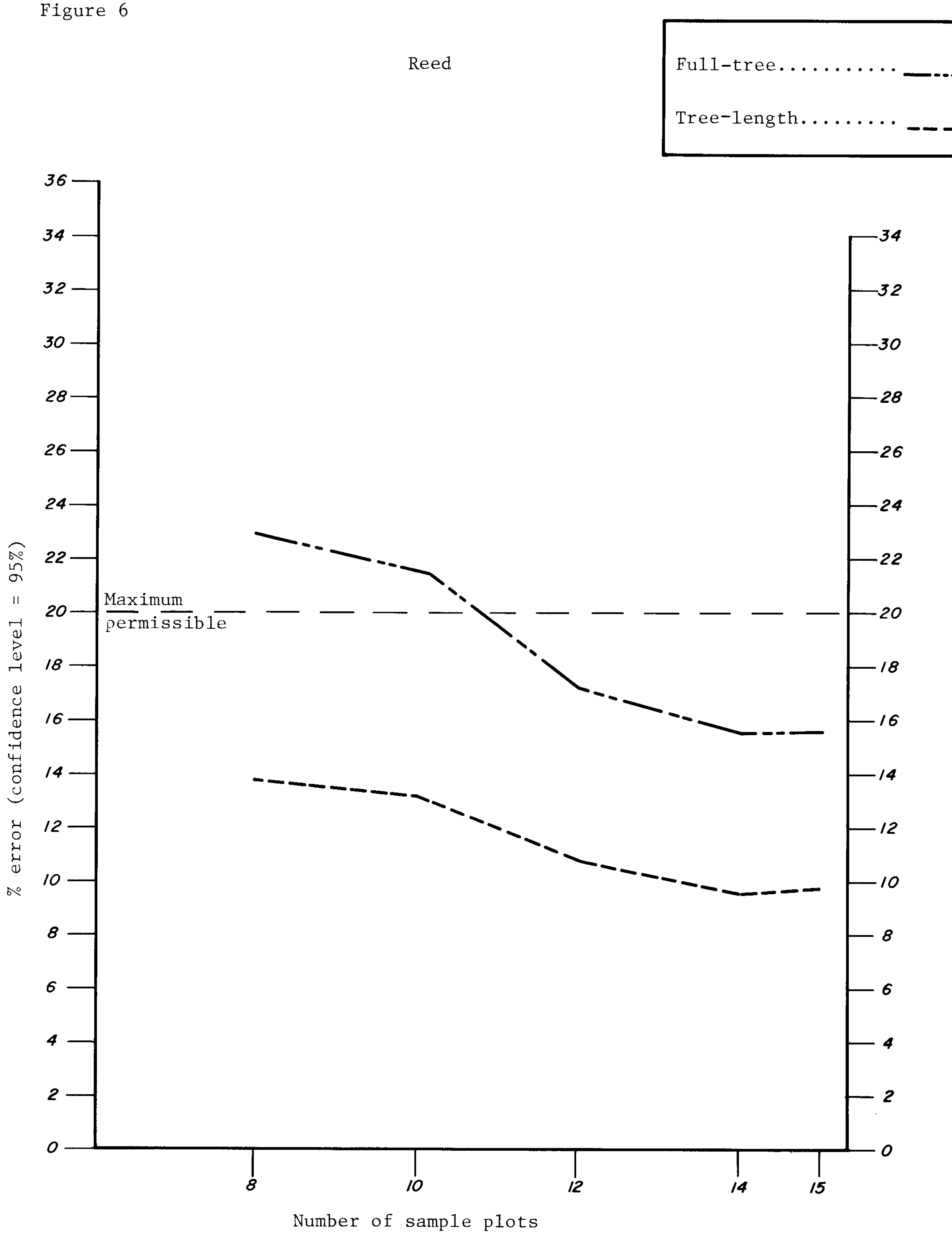
TABLE 18

STATISTICAL VALUE OF THE WEIGHT OF GREEN RESIDUE FOR ALL SAMPLE PLOTS

JACK PINE, REED INC., DRYDEN

Logging method	Number of plots	Green weight of residue (t/ha)				% error from mean (95%)	Number of plots for confidence level	
		minimum	maximum	mean	standard deviation		95%	99%
Tree-length	15	54,7	108,1	80,4	14,0	9,6	49	1214
Full-tree	15	24,7	73,6	47,1	13,3	15,6	127	3177

Figure 6



Evolution of error as a function of the number of sample plots — jack pine

3.3.2. Oven-dry weight and moisture content

Table 19 gives green and oven-dry weights as well as the moisture content of residue. The moisture content, calculated in terms of oven-dry weight, varies from 44% to 82%, depending on category.

3.3.3. Volume and weight of stumps and residual trees

Table 20 gives the green and oven-dry weights of residual trees and stumps by species and logging methods. The stump column includes only the above-ground portion. The volume is converted into weight by means of a specific basal density factor taken from tables.

3.3.4. Total oven-dry weight by logging method

The total oven-dry weight of residue, residual trees and stumps for each logging method may be found in Table 21.

It is notable, that the tree-length method left 50.7 t/ha as compared with 32.9 t/ha for the full-tree method.

The relative importance of the categories of residue is illustrated by Figure 7. Figure 8 presents the same data in the form of a cumulative curve which shows clearly the influence of each class on the total weight.

4. SUGAR MAPLE; CONSOLIDATED-BATHURST INC., PORTAGE-DU-FORT, QUEBEC

4.1. Description of forest operations

A stand of sugar maple-hop hornbeam, in the Ottawa woodlands division of Consolidated-Bathurst Inc., was selected for the study of a hardwood stand.

The annual cut of the division is 360,000 m^3. The company exploits a very large number of species (over twenty) that are in demand for a large variety of uses.

At the study site sugar maple, American beech, yellow birch and white pine were the main species being cut.

Depending on species and quality, the wood may be directed to five different places: the Portage-du-Fort pulp mill, veneer mills of Mont-Laurier and Lac Mégantic, the Fortin sawmill at Fort-Coulonge for hardwoods and the Consolidated-Bathurst sawmill at Braeside for softwoods.

Most of the transportation to the mill is by truck, but the softwood sawlogs are dumped in the Ottawa River at Cheneaux, near Portage-du-Fort.

4.1.1. Location of the surveyed cutting areas

Headquarters were at the Schyan Depot, near the river of the same name, about 170 km north-west of Hull.

TABLE 19

GREEN AND OVEN-DRY WEIGHTS OF RESIDUE (t/ha)
AND MOISTURE CONTENT (with reference to oven-dry weight)
BY CATEGORY
JACK PINE, REED INC., DRYDEN

Logging Method		Category of residue				
		Tops	Branches	Green Stems	Dead Stems	Total
Tree-length	green weight	29.0	23.6	8.9	18.9	80.4
	dry weight	15.9	14.9	5.4	13.1	49.3
	% humidity	82	58	66	44	63*
Full-tree	green weight	3.4	3.8	10.5	29.4	47.1
	dry weight	2.1	2.4	6.6	19.9	31.0
	% humidity	63	56	59	47	51*

* % weighed moisture

TABLE 20

GREEN VOLUME AND OVEN-DRY WEIGHT
OF RESIDUAL TREES AND STUMPS BY SPECIES,
FOR THE VARIOUS LOGGING METHODS
JACK PINE, REED INC., DRYDEN

	Tree-length						Full-tree						
	JP	Pop	BS	WB	BF	Total	JP	WB	SM	BS	Pop	BF	Total
Residual trees													
Green volume m^3/ha	---	---	0.0*	0.0*	0.0*	0.0*	---	0.1	0.2	0.0*	0.4	---	0.7
Oven-dry weight t/ha	---	---	0.0*	0.0*	0.0*	0.0*	---	0.1	0.1	0.0*	0.1	---	0.3
Stumps													
Green volume m^3/ha	2.6	0.0*	0.6	0.1	---	3.3	3.4	0.3	0.1	0.1	0.0*	0.0*	3.8
Oven-dry weight t/ha	1.1	0.0*	0.2	0.0*	---	1.4	1.4	0.1	0.0*	0.0*	0.0*	0.0*	1.6

* figures between 0.01 and 0.05

--- absent species

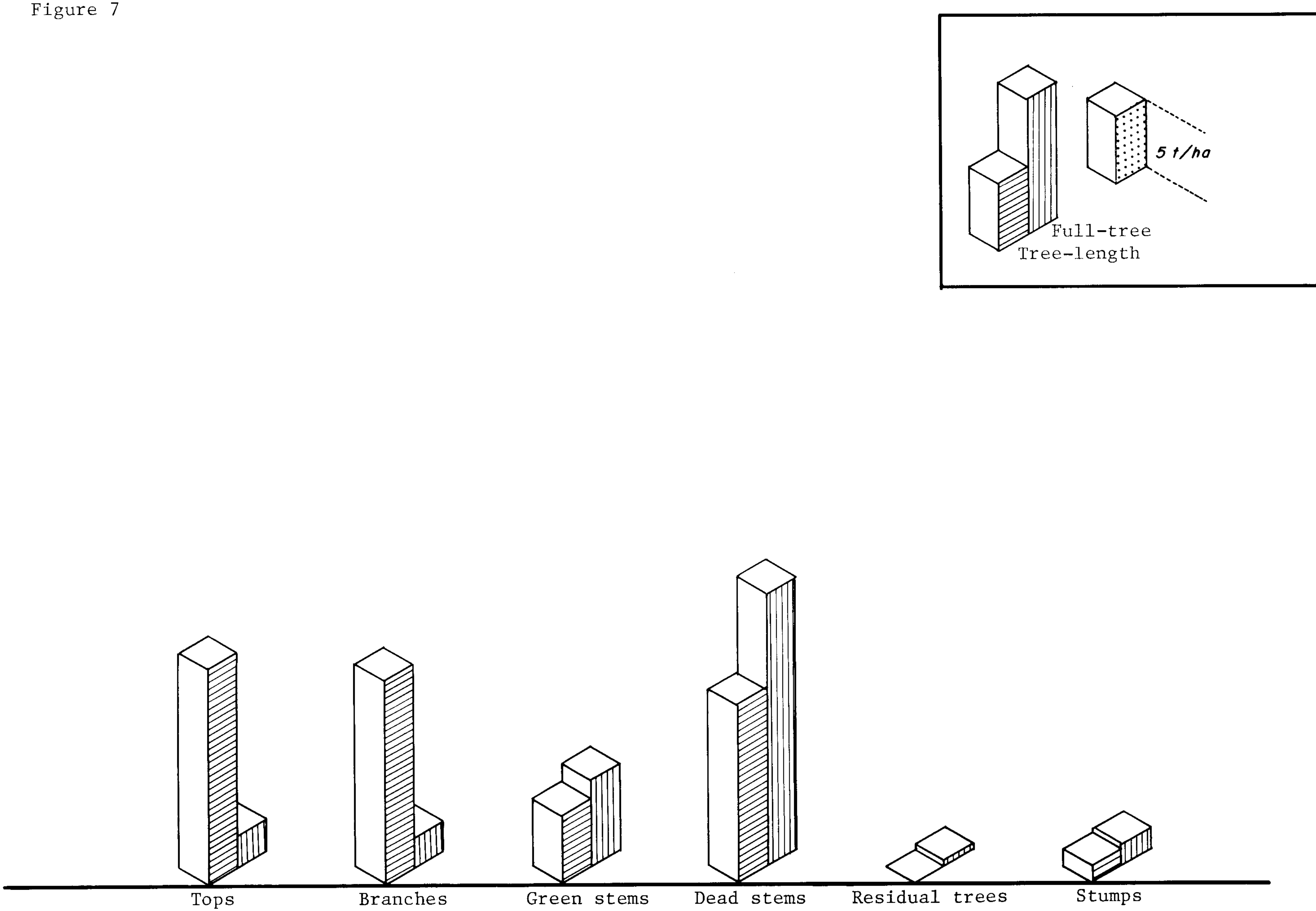
TABLE 21

OVEN-DRY WEIGHT OF RESIDUE
RESIDUAL TREES AND STUMPS (t/ha)

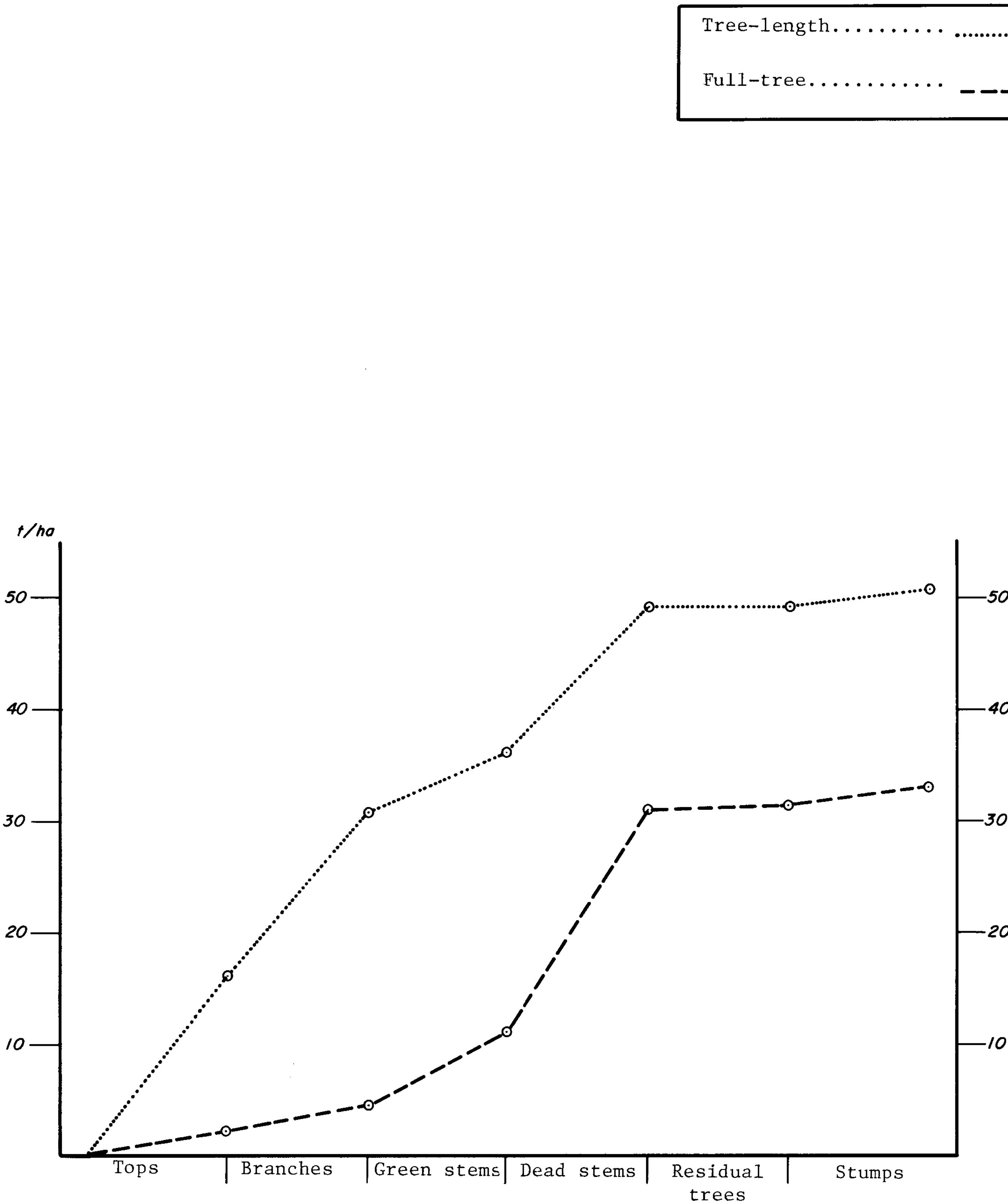
JACK PINE, REED INC., DRYDEN

Logging method	Categories									
	Tops	Branches	Green stems	Sub-total	Dead stems	Total residues	Residual trees	Sub-total	Stumps	Total
Tree-length	15.9	14.9	5.4	36.2	13.1	49.3	0.0	49.3	1.4	50.7
Full-tree	2.1	2.4	6.6	11.1	19.9	31.0	0.3	31.3	1.6	32.9

Figure 7



Distribution of the oven-dry weight of residue by category and by logging method — jack pine



Cumulative distribution of the oven-dry weight of residues by category and by logging method — jack pine

4.1.2. Logging method and production capacity

4.1.2.1. Tree-length logging

Forest workers on piece work operate in pairs — a woodcutter and a skidder operator. That machine may be a Timberjack or more often a Tree Farmer wheeled cable skidder. Skidding distances may reach 1,200 m.

At the Schyan cutting area no trees were piled in the woods. All wood cut was forwarded to a large landing, measured at the back of the skidder, piled and bucked on the spot by a Tanguay slasher. Trucks were loaded by a Drott Knuckle boom loader.

The camp housed 100 men who produce 72,000 m^3 annually.

An unusual aspect of the operation was that it was carried out in degraded stands.

Diameter limit logging was done in the survey area between 1956 and 1962. Yellow birch was cut to a minimum diameter of 40 cm, the other hardwoods 30 cm and softwoods to 25 cm. Therefore, only trees of veneer and sawlog quality were salvaged.

In the present cut the diameter limit was 15 cm. Sizeable and well graded logs were directed to sawmills or veneer mills and the rest was used as pulpwood. However, low grade oak and basswood, as well as non-commercial hop hornbeam and cedar, were left standing

Table 22 describes the Logging operations briefly.

4.2. Observations on the forest stand

4.2.1. General data on the region

L.4c — Middle Ottawa

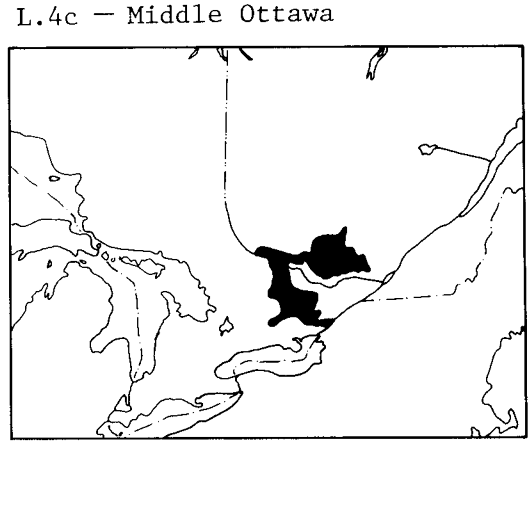


TABLE 22

SUMMARY OF CONSOLIDATED-BATHURST'S FOREST OPERATIONS

	Felling	Limbing	Topping	Skidding	Forwarding	Piling	Loading	Slasher
Tree-length	Forest workers with chainsaws			Timberjack Tree Farmer wheeled cable skidder max. 1200 m	---	With skidder	Drott knuckle-boom loader	Tanguay stationary slasher

According to Rowe (1972) the survey area is located in forest section L.4c, and is part of the Great Lakes - St-Lawrence region.

As described by Rowe, "the area is roughly U-shaped, comprising in the main hardrock upland which encloses the Palaeozoic lowlands of the upper St. Lawrence on all but the eastern side...The usual constituents of the upland forests are sugar maple, beech, yellow birch, red maple, and eastern hemlock, almost always accompanied by eastern white pine and red pine. The last two species also characterize dry ridges and sand flats in association with jack pine. Varying amounts of white spruce, balsam fir, trembling aspen, white birch, red oak and basswood are present throughout.

The topography is irregular, varying from lowland flats to a strongly rolling type of upland terrain. Dystric brunisols and humo-ferric podzols are usual".

4.2.2. Geology

The approximate location of the survey area is shown by a circle at the bottom of Figure 9. It is on the precambrian massif of the Canadian Shield, not far from the depressed zone of nearly horizontal layers. This depressed zone is a paleozoic formation, forming a sort of groove between the Shield and the Appalachians where the St. Lawrence River runs (Grandtner, 1966).

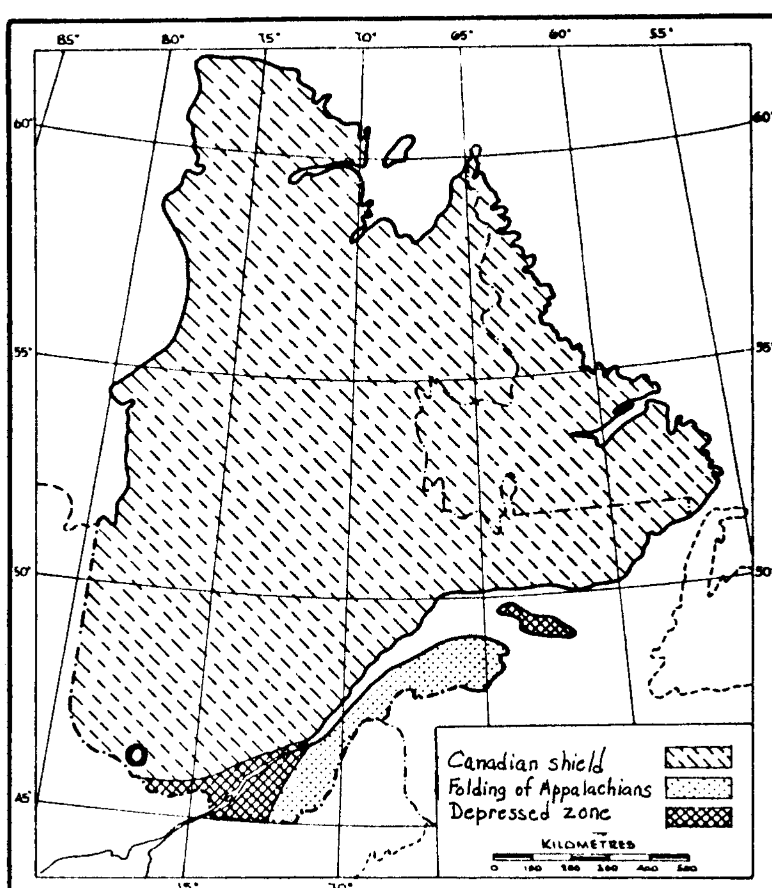


Figure 9. Major structural units of the Province of Québec

4.2.3. Topography

Every structural geological unit corresponds to a topographic entity. The lowest and latest shelf, the Québec shelf, is a surface resulting from erosion having an average altitude of 100 m, whose western boundary corresponds with the area of this study (Grandtner, 1966). (Figure 10)

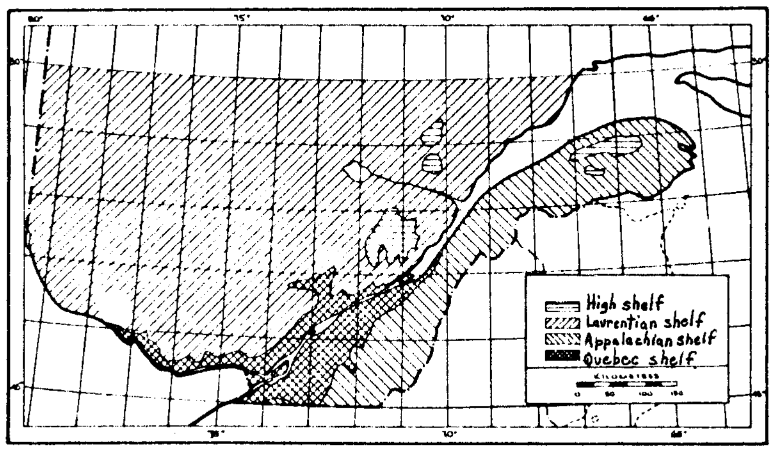


Figure 10. Major topographic sectors of southern Québec

The Laurentian shelf, adjacent to the Québec shelf, has an altitude varying between 300 and 500 m. This range corresponds with the elevations measured at the field study area. The topography is hilly all along the Ottawa River as far as Mattawa. The same topography is found along the Rouge, Lièvre and Gatineau Rivers as the Ottawa River is approached. The topography flattens towards the north.

Between Pointe-aux-Chênes and Île-aux-Allumettes, along the Ottawa River, we find the Ottawa River alluvial plain with the Champlain sea deposits. These deposits extend as far as north of Maniwaki in the Gatineau basin, and up to Ferme-Neuve, along the Lièvre River. This entire region has been cleared of its forest and colonized (Lafond and Ladouceur, 1968), as noted by Rowe in his study of region L.4c.

4.2.4. Climatic data

The 21°C (70°F) isotherm characterizes the July temperature of the Ottawa valley, from Pointe-aux-Chênes to Fort coulonge. Temperature falls quickly north of Fort Coulonge and Rapide-des-Joachims. A second isotherm, of 19.4°C (67°F), passes slightly to the north of the survey area. According to Lafond and Ladouceur (1968), that July isotherm coincides with a forest climax area, the sugar maple-yellow birch forest. Further south, along the 21°C isotherm, the Laurentian maple forest is predominant.

Rainfall shows a more irregular pattern than temperature. The data published by the Bureau of Meteorology of the "Ministère des Richesses Naturelles du Québec" indicate that the less rainy regions (under 800 mm) are in two distinct areas (Figure 11): one east of Lake Temiscamingue, between the town of Temiscamingue and Lake Kipawa; and the other, from the Schyan and Noire Rivers region, running eastward as far as the southern section of the Coulonge River watershed (Lafond and Ladouceur, 1968). There is a definite connection between low precipitation and the importance of pine forests. Blanchard's (1960) rainfall map shows very similar information about those two regions (Figure 12).

4.2.5. Forest vegetation

In the Ottawa River watershed, there are four large climax regions. From south to north, we find in turn the Laurentian maple forest, the sugar maple-yellow birch forest, the yellow birch-fir-red spruce forest, and the white birch-fir-white spruce forest (Lafond and Ladouceur, 1968).

Our field word area is in the maple-yellow birch climax association. Its northern boundary runs approximately along latitude 46°40' and along the Ottawa river. Its boundary is situated at the beginning of the clay belt formed by Champlain sea deposits. The Laurentian maple forest begins near Waltham, about 50 km south-east of the study area.

In this sector we find grey-brown and brown forest soils, whereas the maple-yellow birch forest is associated with brunisolic soils (Lafond and Ladouceur, 1968).

The normal sere of the sugar maple-yellow birch forest climax area includes the following associations in their order of development: Ledum and Chamaedaphne bog, black ash forest, cedar-Rhamnus forest, fir-thuya forest, fir-Dryopteris-Oxalis forest, yellow birch-fir-red spruce forest of the Viburnum-Oxalis type, sugar maple-yellow birch forest of the Viburnum type, maple-beech forest, white pine forest with some red pines, and red oak forest. This description was taken from a report by Lafond and Ladouceur (1968).

4.2.6. Sampling areas

The sample plots were measured at Lake Indien about 25 km from the Ottawa River. Average altitude is around 300 m. The topography is rather hilly. The area is at the boundary of the precambrian massif, near the depressed zone, as described by Grandtner (1966). This is just out of the Champlain deposits that cover part of the region (from Pointe-aux-Chênes up to Île-aux-Allumettes).

According to climatic data the sector is in the centre of a low precipitation zone, i.e., below the regional average. This dry climate favours the development of red pine-white pine forest, which have been heavily logged. Therefore these pine stands may be found in large numbers only in the Schyan River watershed, where access is difficult and the stands are younder than those in the surrounding areas. (Lafond and Ladouceur, 1968)

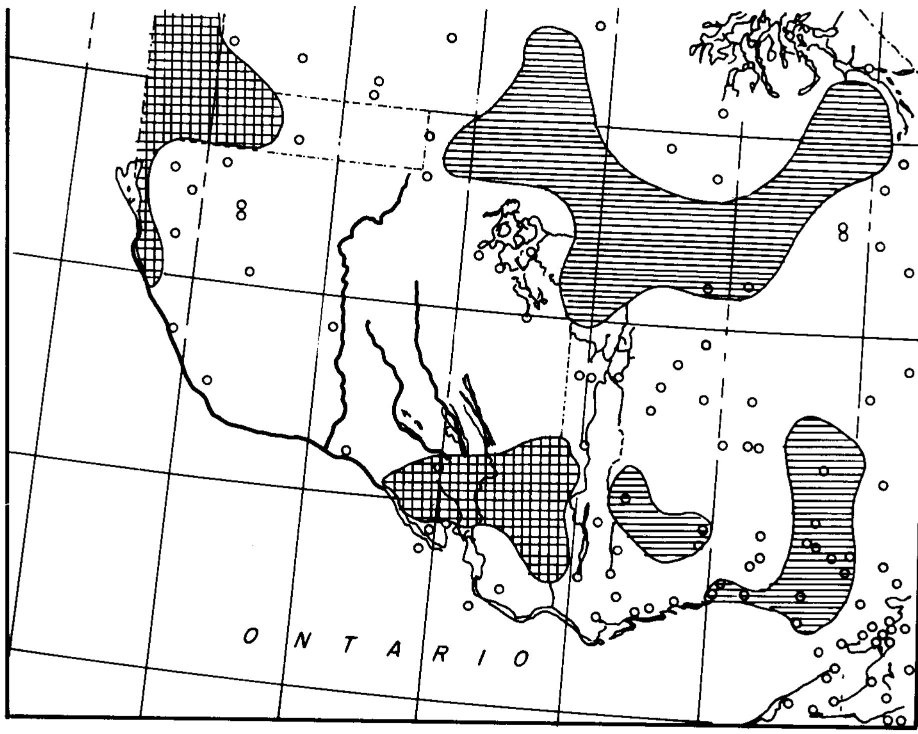


Figure 11. Distribution of isohyet in the Ottawa River drainage basin. (in.) (Lafond & Ladouceur, 1968)

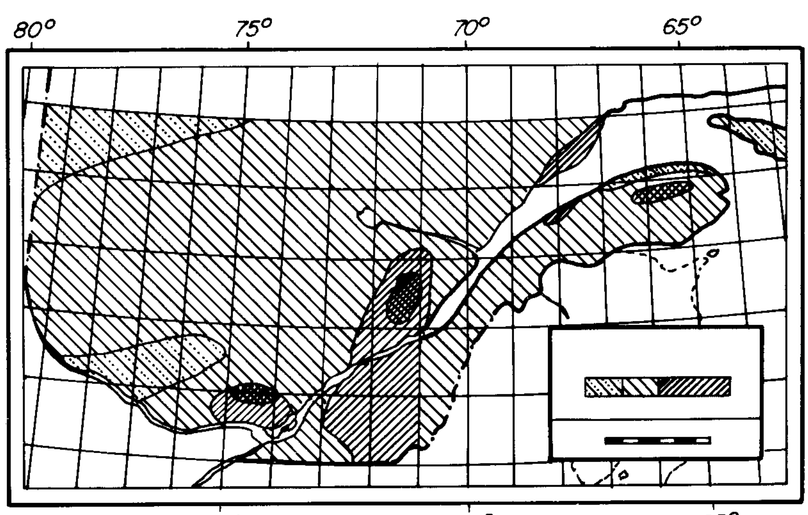


Figure 12. Average annual precipitation in southern Québec. (mm) (Blanchard, 1960)

Plots were established on a hilltop and on upper slopes. Sampled stands consisted of three main species; sugar maple, hop hornbeam and American beech. In general, hop hornbeam was as plentiful as beech and, in some plots, it was the only tree species along with maple — an association found mainly on the top of the hill, whereas downhill, hop hornbeam decreased and was replaced by beech and yellow birch.

On the hilltop, a few large red oaks were found. In fact the plot was located near the boundary of the distribution area of sugar maple-oak forest and red oak forest.

White pine, grey birch, white birch, and striped maple may be found on slopes, where the variety of species is greater.

The maple-hop hornbeam forest (Lemieux, 1963) is at the top of the hills. It is likely to be a sub-association with beech (Brown, 1974), since beech was the only species found often in large numbers.

Lafond and Ladouceur (1968) did not mention the maple-hop hornbeam forest in their study of the Ottawa River watershed, because of the size of their project. According to Lafond (private conversation, 1980), that association was judged to be a variant of the maple-beech forest, since it is very similar ecologically and occupies the same habitat.

The climax association, the maple-yellow birch forest, is found on mesic slopes. Yellow birch is not as plentiful as beech. We are dealing with a forest greatly modified by logging operations that took place for the last time around 1960. Nevertheless, it could be a beech sub-association of maple-yellow birch forest or simply a maple-beech forest. These two ecological associations are described by Lemieux (1963).

4.3. Results

4.3.1. Weighing accuracy

Table 23 shows the main statistical sampling data: standard deviation, mean and extreme values and percentage of error with reference to the mean. This last value is shown in more detail by Figure 13. It gives the error variation as a function of the number of plots.

4.3.2. Oven-dry weight and moisture content

In Table 24 we find the green and oven-dry weights and the moisture content (calculated with reference to the oven-dry weight) for the four categories of residue. The moisture content varied from 60% to 76% between categories.

4.3.3. Volume and weight of stumps and residual trees

Table 25 shows green and oven-dry weights of stumps and residual trees by species and logging method.

Stumps were measured above the ground only. There were many residual trees because of cutting specifications (see chapter 4.1). Oven-dry weight was calculated from specific density factors.

TABLE 23

STATISTICAL VALUE OF THE WEIGHT OF GREEN RESIDUE

FOR ALL SAMPLE PLOTS

SUGAR MAPLE

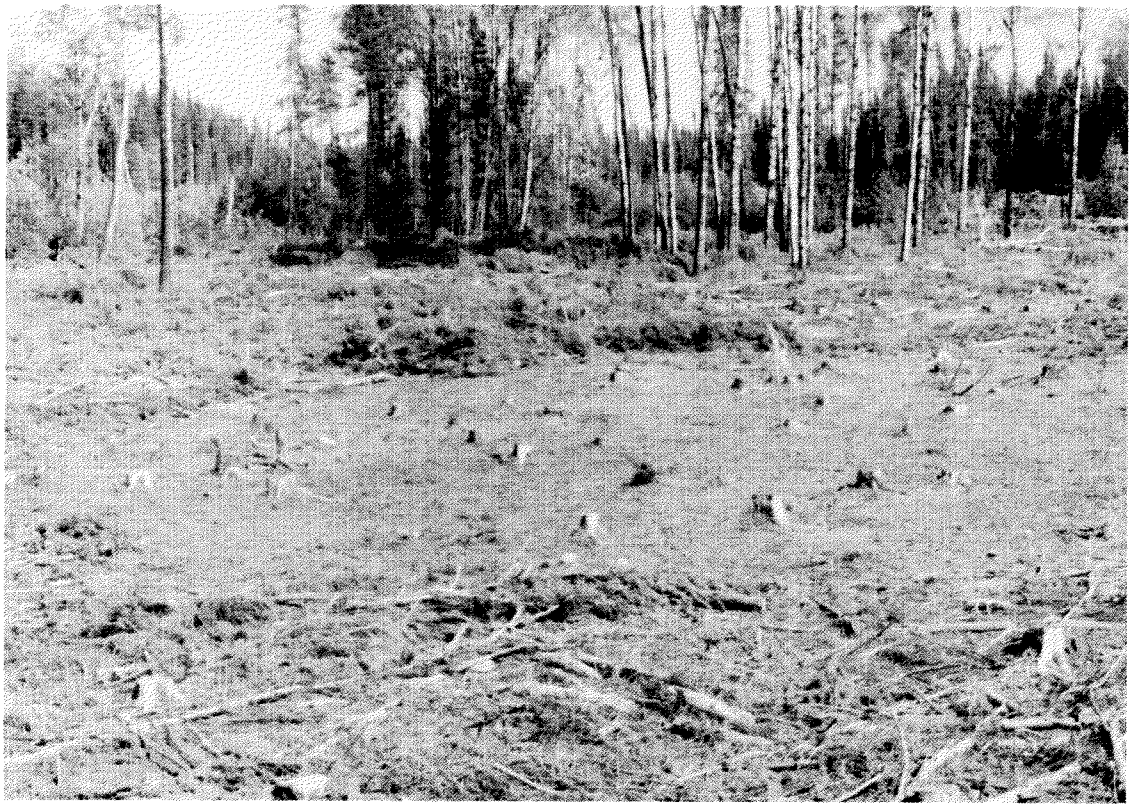
CONSOLIDATED-BATHURST, PORTAGE-DU-FORT

Logging method	Number of plots	Green weight of residue				% error from mean (95%)	Number of plots for confidence level	
		minimum	maximum	mean	standard deviation		95%	99%
Tree-length	13	79.1	163.5	114.7	25.2	13.1	77	1929

Photo no. 1: Tree-length black spruce, CIP. In the foreground, we can see a sample plot with residue piled by categories. The continuous distribution of residue can be seen in the background.

Photo no. 2: Full-tree black spruce, CIP. The first step is to outline the plot circumference with spray paint on the ground. Residue is then piled.

Photo no. 3: Shortwood black spruce, CIP. This is the balance frame and the containers used to weigh the residue. Note the difference between the plot cleared of all residue and the remainder outside the plot.



Phote no. 4: Tree-length jack pine, Reed Inc. The appearance of a sample plot after weighing. Only stumps are left to be measured.

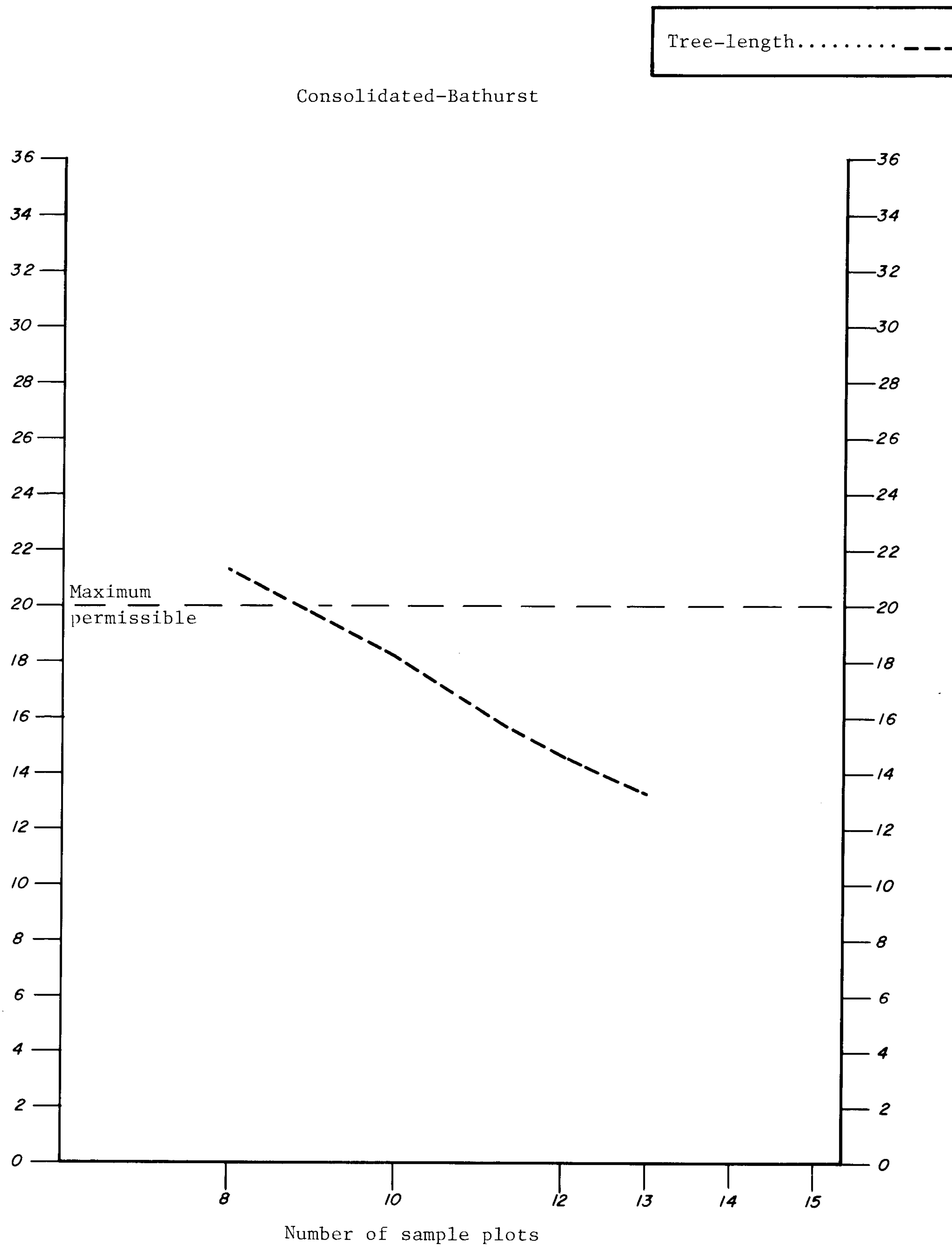
Photo no. 5: Full-tree jack pine, Reed Inc. The first operation after cutting is to relocate the sample plots measured before cutting. The centre of the plot is then marked by a red ribbon.

Photo no. 6: Tree-length sugar maple, Consolidated-Bathurst. Because of the logging method, the stand condition and the size of residue, a skidder was a great help in picking up tangled residue, weighing and clearing the plot.

Photo no. 7: Tree-length balsam fir, Fraser. This plot makes a trench in the residue cover.

Photo no. 8: Full-tree balsam fir, Fraser. Much residue may be seen lying on the ground. Dead stems account for a high percentage of the total. Unfavourable climatic conditions during that period are evident.

Figure 13



Evolution of error as a function of the number of sample plots — sugar maple

TABLE 24

GREEN AND OVEN-DRY WEIGHT OF RESIDUE (t/ha)

and MOISTURE CONTENT (with reference to oven-dry weight)

BY CATEGORY

SUGAR MAPLE, CONSOLIDATED-BATHURST, PORTAGE-DU-FORT

Logging method		Category of residue				
		Tops	Branches	Green stems	Dead Stems	Total
Tree-length	green weight	71.5	5.9	16.3	21.0	114.7
	oven-dry weight	44.1	3.5	10.2	11.9	69.7
	% moisture	62	71	60	76	65*

* % weighed humidity

TABLE 25

GREEN VOLUME AND OVEN-DRY WEIGHT
OF RESIDUAL TREES AND STUMPS BY SPECIES,
FOR THE VARIOUS LOGGING METHODS
SUGAR MAPLE, CONSOLIDATED-BATHURST, PORTAGE-DU-FORT

	Tree-length								
	SM	HH	BE	RO	WS	YB	WB	WP	Total
Residual trees									
Green volume m^3/ha	8.3	2.7	2.7	---	0.0*	0.6	---	---	14.5
Oven-dry weight t/ha	5.0	1.8	1.6	---	0.0*	0.4	---	---	8.8
Stumps									
Green volume m^3/ha	3.3	0.2	0.3	0.6	---	0.1	0.1	0.0*	4.5
Oven-dry weight t/ha	2.0	0.1	0.2	0.3	---	0.1	0.0*	0.0*	2.7

* figures between 0.01 and 0.05

--- absent species

4.3.4. Total oven-dry weight

Where the tree-length method was used, the total residue of stumps and residual trees was 81.2 t/ha (Table 26). Figure 14 illustrates the relative importance of each category whereas Figure 15 shows cumulative values of the same data.

5. BALSAM FIR; FRASER INC., EDMUNDSTON, NEW BRUNSWICK

5.1. Description of forest operations

This company's woodlands were selected for the study in balsam fir stands.

The field work was done in the districts of Edmundston and Kedgwick where 700,000 m^3 are cut annually. Balsam fir is the main species with red and black spruce and some white spruce. Sub-jobbers harvest residual white pine and white birch.

The wood cut by Fraser is delivered to the Kedgwick sawmill (440,000 m^3), the Edmundston cardboard and pulp mill (180,000 m^3) and to small local wood users (80,000 m^3).

5.1.1. Location of the surveyed cutting areas

Tree-length operations were studied at Camp 28 and full-tree at Camp 69. These camps are 50 km apart. Camp 69 is approximately 100 km from Edmundston.

5.1.2. Logging methods and production capacity

5.1.2.1. Tree-length method

Felling, limbing and topping operations are done by piece workers in three-man crews: two wood cutters and one skidder operator.

Skidding is done over a distance of about 150 m with a John Deere or a Clark Ranger wheeled cable skidder and trees are piled along the roads.

Trucks are loaded with a Tanguay knuckle boom loader. The wood is hauled in tree lengths, or in 4.9 m logs, after being bucked by a stationary Tanguay slasher.

This camp houses about 40 men and the annual production capacity is about 110,000 m^3.

5.1.2.2. Full-tree method

Trees are felled with a Drott-40 feller-buncher and skidded along the roads with a John Deere, wheeled grapple skidder. Maximum skidding distances are about 305 m. Limbing and topping are done at the landing with a Logma delimber on tracks. Loading is done with a Tanguay knuckle boom loader. Logs are cut with a Tanguay or Nesco stationary slasher.

TABLE 26

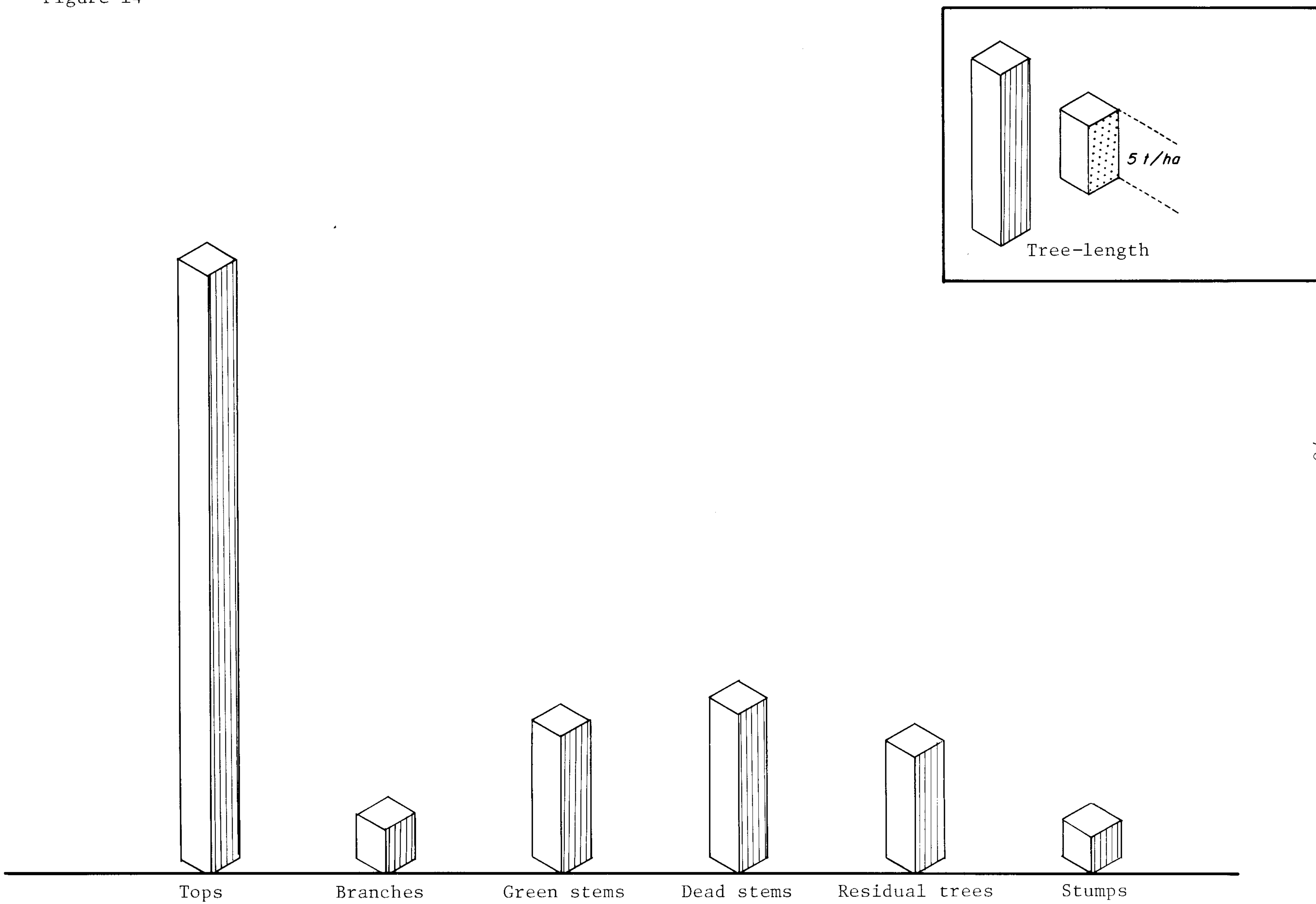
OVEN-DRY WEIGHT OF RESIDUE,

RESIDUAL TREES AND STUMPS (t/ha)

SUGAR MAPLE, CONSOLIDATED-BATHURST, PORTAGE-DU-FORT

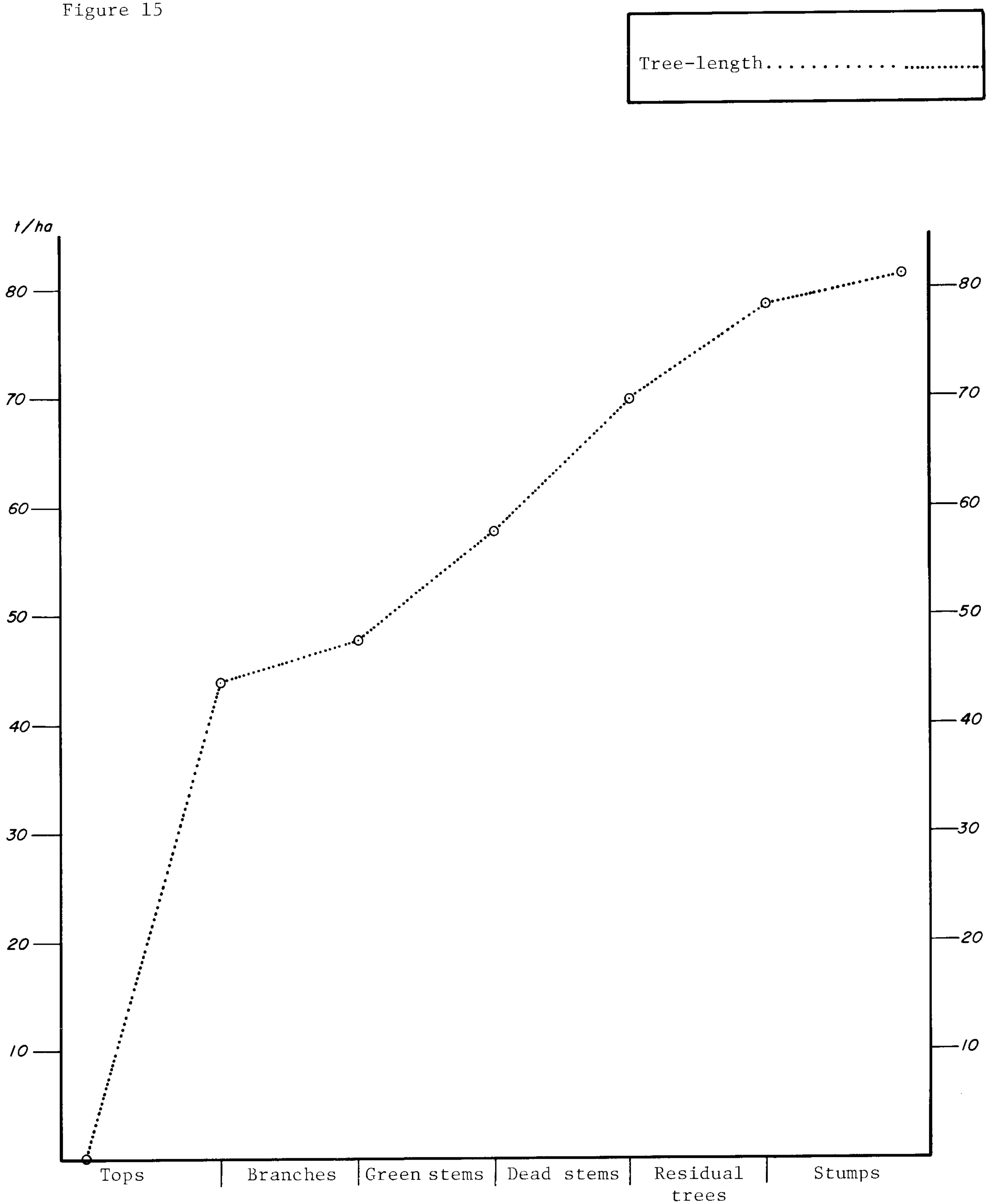
Logging method	Categories									
	Tops	Branches	Green stems	Sub-total	Dead stems	Total residues	Residual trees	Sub-total	Stumps	Total
Tree-length	44.1	3.5	10.2	57.8	11.9	69.7	8.8	78.5	2.7	81.2

Figure 14



Distribution of the oven-dry weight of residue by category — sugar maple

Figure 15



Cumulative distribution of oven-dry weight of residue by category -- sugar maple

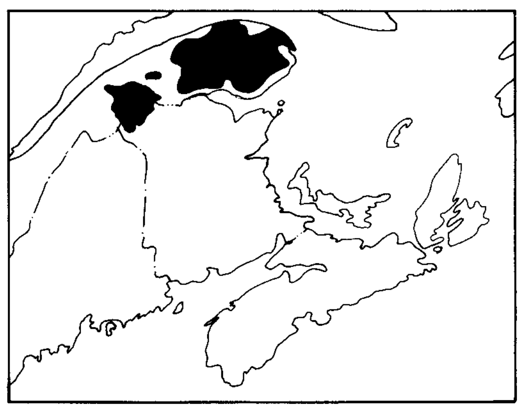
Woodcutters are classified as machine operators and are paid on an hourly basis. The camp holds 45 men producing 85,000 m^3 annually.

Table 27 summarizes the two types of operations.

5.2. Observations on forest stand

5.2.1. Location

B.2 — Gaspé



This study was carried out in the New Brunswick Highlands Ecoregion, more precisely in the district of the Kedgewick River. According to Rowe (1972), this district is located at the south-east end of the boreal forest classified as forest section B.2, "Gaspé". The surveyed area is also at the end of the section, very close to the Great Lakes — St-Lawrence region, section L.6 named Temiscouata-Restigouche.

5.2.2. Topography, geology and soils

The topography of the region is hilly. Soils on steep hills are stony, sandy loam originating from a slaty schist, of "Argillite", and sandstone. Because of the crumbly nature of the parent rock and the sharp incline of its cleavage, soils are deep and well-structured. They are relatively fine-textured humo-ferric podzols and very acid at the surface. Drainage is usually average to good.

5.2.3. Climatic data

The climate is continental and rather cold, with great seasonal and daily variations in the temperature, but rainfall is more constant. The summer average temperature (June, July, August) is 15.6°C. In general, it is rather humid with a total summer rainfall of 306 mm.

5.2.4. Forest vegetation

The climax of birch-balsam fir forest characterizes this district. It is an association of natural origin and relatively stable. Because of past disruptions or logging operations, the present forest is in a transition stage. This is evidenced by its intermediate age and its storied

TABLE 27

SUMMARY OF FRASER'S FOREST OPERATIONS

	Felling	Limbing	Topping	Skidding	Forwarding	Piling	Loading	Slasher
Tree-length	Forest workers with chainsaws			John Deere, Clark Ranger cable wheeled skidder 150 m	---	With skidders	Tanguay or Drott-40 knuckle boom loader	Tanguay stationary slasher 4,9 m
Full-tree	Drott-40 feller-buncher	Logma delimber-topper on tracks		John Deere grapple wheeled skidder max.: 305 m	---	With skidders	Tanguay knuckle boom loader	Tanguay stationary slasher 4,9 m or Nesco

appearance or tendency to be uneven-aged. Balsam fir is predominant while white birch and black and red spruces are common secondary species. White pine is scattered throughout the territory, except on sites of fire origin. These tall and isolated trees are highly visible. Loucks (1968) is of the opinion that black spruce, rather than red spruce, has a distribution similar to that of white birch and white spruce. He considers that red spruce is more concentrated on high elevations while yellow birch prefers lower slopes.

The white birch population is relatively small, having been greatly reduced by birch dieback; a disease that affected white and yellow birches between 1940 and 1950 in all of northeastern America. A very large number of white birch snags still persists. Fires as well as logging operations, have stimulated balsam fir reproduction. Apparently, these stands, originating from old birch forests, belong to the Cornus-Oxalis type and site class. According to Lafond (1969), these stands have a very high fibre yield. The under storey consists of shurbs, including mountain maple, while mosses, especially Hypnum Schreberi, are patchy. The purer balsam fir stands of the region belong to the Hylocomium-Oxalis type. According to Lafond these fir stands usually originate from intensive windfalls and constitute a transition forest of site classes I or II becoming very dense in their nature stage. There is no shrub stratum.

The above mentioned stands represent the two main forest types of the region. Owing to their high site class, rapid growth in volume results in a shortened rotation.

The maple-yellow birch forest begins at the south of the area, near the St-John River watershed.

5.2.5. Sampling areas

The four sampling areas selected in that region corresponded well with the above ecological description. They were in a balsam fir forest of a good site class. Nearly all of these areas had already been cut over. The first area had a southern aspect and had many irregular and uneven-aged stands with veterans of 90 years of age and more. A large number of trees were blown down. On the other hand, many plots within these stands had a quite regular and predominant storey of fir averaging 50 years of age. Two other selected areas were adjacent with north or north-east exposures. The western-most area was on an upper hillside, whereas the other was on a lower slope. The stand found here was at a regular stage of development, and between 50 and 60 years old. The last place selected was occupied by 60-year-old stands, had a southern exposure, and a good standing volume.

5.3. Results

5.3.1. Accuracy of weighing

Table 28 shows the statistical values for residue weights obtained from both logging methods. It gives the mean weight for all plots, the standard deviation, the error with reference to the mean at a 95% confidence level. Figure 16 shows the amount of decreasing error as a function of the number of plots. However, because of bad weather, only 6 plots were sampled for the full-tree method.

5.3.2. Oven-dry weight and moisture content

Table 29 gives the green and oven-dry weights and the moisture content of residue. This last value was calculated on an oven-dry basis and varies between 76% and 113%.

Values are high because fir has a higher moisture content than other woods and the measurements were taken immediately after cutting. Moreover sampling in the winter resulted in residue often being covered with ice or snow. This was taken into account when sampling for the calculation of moisture content. These values should not be taken as average balsam moisture contents.

5.3.3. Volume and weight of stumps and residual trees

Table 30 shows the green volumes and the oven-dry weights of residual trees and stumps, by species and logging method. Stumps were measured above the ground. Oven-dry weights were obtained by adjusting green volumes by means of specific density factors.

5.3.4. Total oven-dry weight by logging method

Table 31 shows the total oven-dry weight of residue, residual trees and stumps for each logging method. The result is 77.2 t/ha for the tree-length method and 72.5 t/ha for the full-tree method.

The full-tree value may be surprising, but there was a very large volume of dead wood (3814 t/ha) in partial windfalls. Furthermore, since this was a winter operation, branches broke during skidding, leaving a greater than usual volume on the ground. Figure 17 illustrates the importance of each class of residue, Figure 18 shows cumulative curves, illustrating the influence of each class on the total weight.

6. SYNTHESIS OF THE RESULTS FOR ALL STATIONS

6.1. Warning

It was felt that a representation of the results of all stations grouped together would be useful. This permits the comparison of values obtained between logging methods, species and categories of material. However the various forest types in the comparison have a structure and a dynamism of their own. This will induce a high degree of variability. Moreover, forest operations also have a variable character since they involve machine operators and machines, with different skills and speeds, even on similar logging methods. In spite of this it is possible to detect trends and correlations between methods for certain categories of residue.

6.2. Results

6.2.1. Total weight for all stations

Table 32 gives the oven-dry weights of residue for each study area. In Table 33, the results are shown by logging method.

TABLE 28

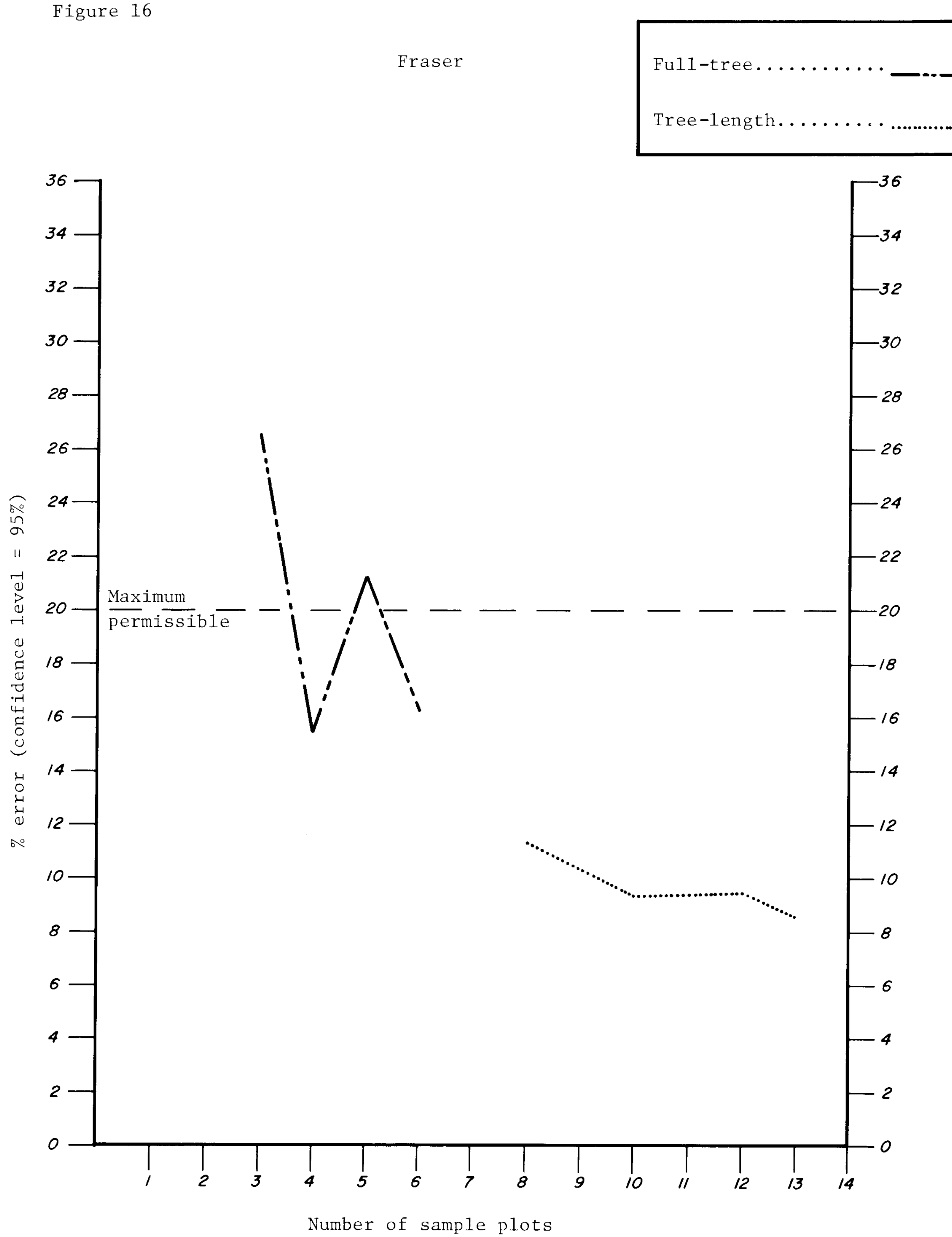
STATISTICAL VALUES OF THE WEIGHT OF GREEN RESIDUES

FOR ALL SAMPLE PLOTS

BALSAM FIR, FRASER INC., EDMUNDSTON

Logging method	Number of plots	Green weight of residue				% error from mean (95%)	Number of plots for confidence level	
		minimum	maximum	mean	standard deviation		95%	99%
Tree-length	13	110.3	180.0	143.4	20.4	8.6	32	811
Full tree	6	105.8	159.6	124.7	19.3	16.3	38	959

Figure 16



Evolution of error as a function of the number of sample plots — balsam fir

TABLE 29

GREEN AND OVEN-DRY WEIGHT OF RESIDUE (t/ha)

AND MOISTURE CONTENT (with reference to oven-dry weight)

BY CATEGORY

BALSAM FIR, FRASER INC., EDMUNDSTON

Logging method		Category of residue				
		Tops	Branches	Green stems	Dead stems	Total
Tree-length	green weight	49.1	34.3	22.2	37.7	143.4
	oven-dry weight	23.1	16.3	11.4	21.1	71.9
	% moisture	113	111	94	79	99*
Full-tree	green weight	12.5	18.4	26.1	67.7	124.7
	oven-dry weight	6.6	9.3	12.4	38.4	66.7
	% moisture	90	99	109	76	87*

* % weighed moisture

TABLE 30

GREEN VOLUME AND OVEN-DRY WEIGHT
OF RESIDUAL TREES AND STUMPS BY SPECIES,
FOR THE VARIOUS LOGGING METHODS
BALSAM FIR, FRASER INC., EDMUNDSTON

	Tree-length						Full-tree					
	BF	RM	WB	YB	RS	Total	BF	RM	WB	YB	RS	Total
Residual trees												
Green volume m^3/ha	0.2	2.2	0.6	3.1	0.1	6.2	0.7	0.0*	3.3	1.6	0.0*	5.7
Oven-dry weight t/ha	0.1	1.2	0.3	1.8	0.0*	3.3	0.2	0.0*	1.7	0.9	0.0*	2.9
Stumps												
Green volume m^3/ha	3.2	0.3	0.2	1.0	0.1	4.8	4.7	0.3	0.5	1.3	---	6.8
Oven-dry weight t/ha	1.1	0.1	0.1	0.6	0.1	2.0	1.6	0.2	0.3	0.7	---	2.8

* figures between 0.01 and 0.05

--- absent species

TABLE 31

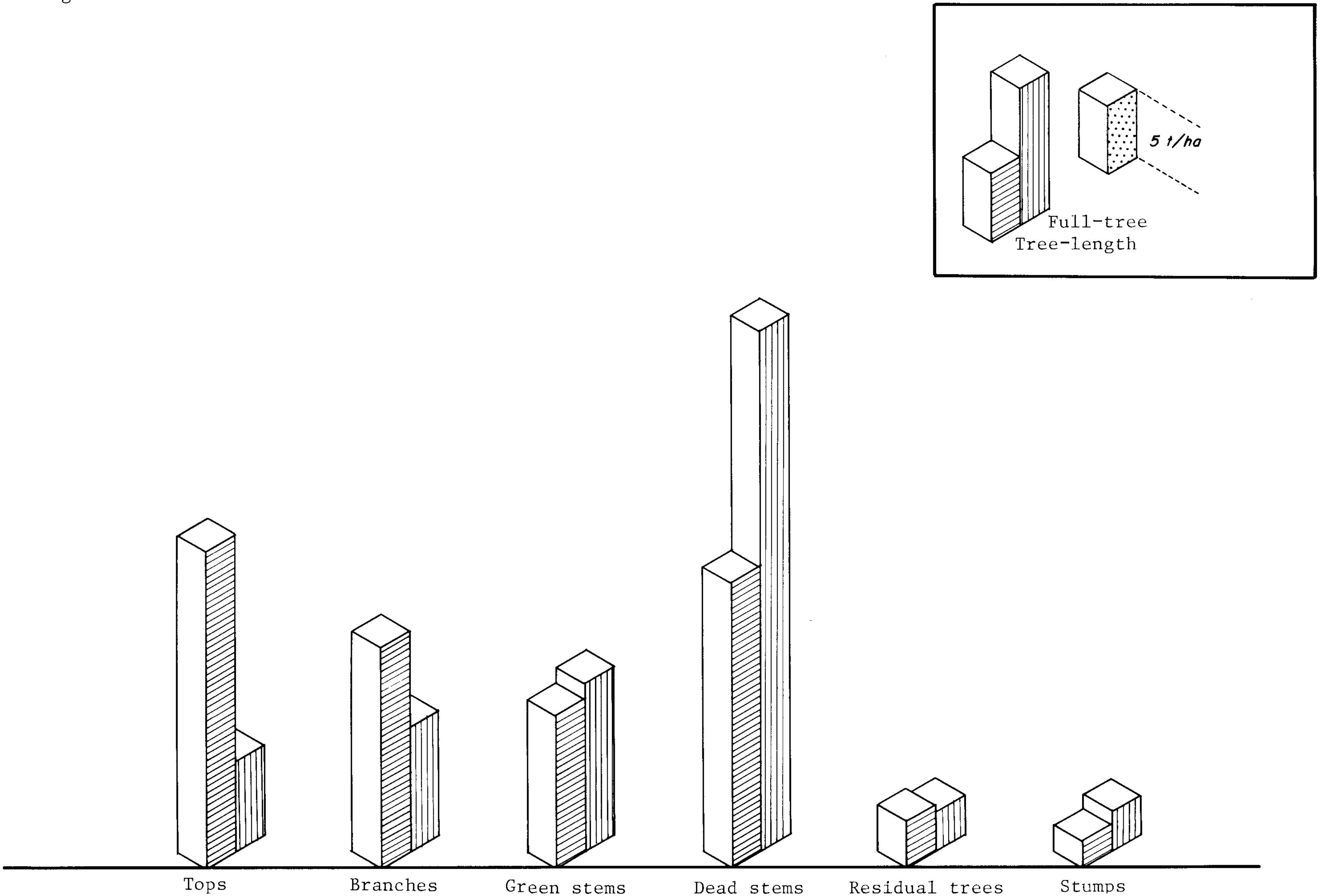
OVEN-DRY WEIGHT OF RESIDUE,

RESIDUAL TREES AND STUMPS (t/ha)

BALSAM FIR, FRASER INC., EDMUNDSTON

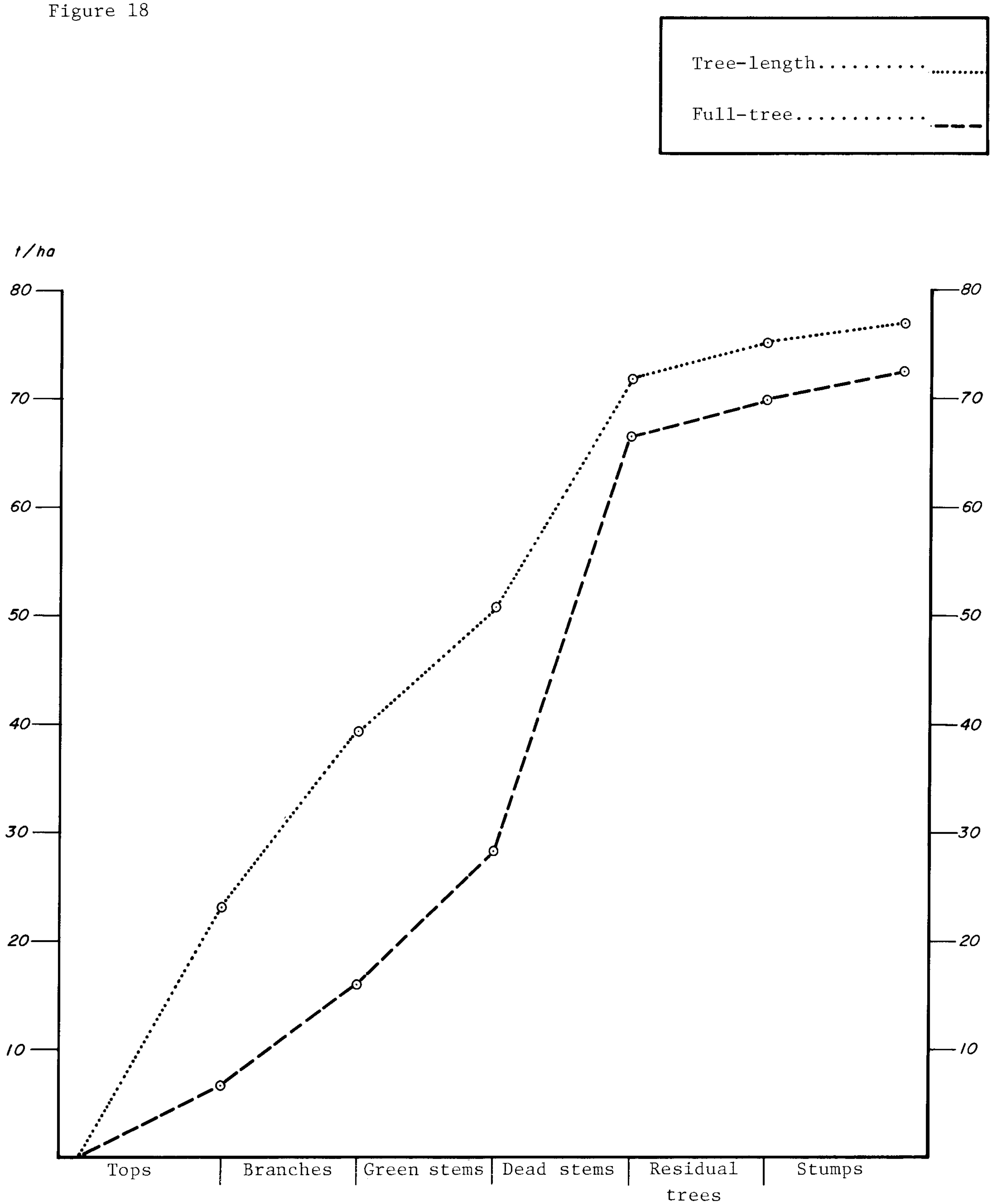
Logging method	Categories									
	Tops	Branches	Green stems	Sub-total	Dead stems	Total residues	Residual trees	Sub-Total	Stumps	Total
Tree-length	23.1	16.3	11.4	50.8	21.1	71.9	3.3	75.2	2.0	77.2
Full-tree	6.6	9.3	12.4	28.3	38.4	66.7	2.9	69.6	2.8	72.4

Figure 17



Distribution of the dry weight of residue by category and by logging method — balsam fir

Figure 18



Cumulative distribution of the oven-dry weight of residue by category and by logging method — balsam fir

TABLE 32

OVEN-DRY WEIGHT OF RESIDUE,
RESIDUAL TREES AND STUMPS
(t/ha) FOR THE 4 STATIONS

Station	Number of plots	Logging method	Categories						
			Tops	Branches	Green stems	Dead stems	Residual trees	Stumps	Total
Black spruce	14	tree-length	26.2	11.6	6.1	9.9	1.3	1.3	56.4
CIP — La Tuque	14	full-tree	1.2	3.2	7.9	8.4	3.5	1.6	25.8
	15	shortwood	11.1	22.0	21.8	15.8	1.6	3.0	75.3
Jack pine	15	tree-length	15.9	14.9	5.4	13.1	0.0	1.4	50.7
Reed — Dryden	15	full-tree	2.1	2.4	6.6	19.9	0.3	1.6	32.9
Maple forest Consolidated-Bathurst Portage-du-Fort	13	tree-length	44.1	3.5	10.2	11.9	8.8	2.7	81.2
Balsam fir	13	tree-length	23.1	16.3	11.4	21.1	3.3	2.0	77.2
Fraser — Edmundston	06	full-tree	6.6	9.3	12.4	38.4	2.9	2.8	72.4

TABLE 33

OVEN-DRY WEIGHT OF RESIDUE,
RESIDUAL TREES AND STUMPS
(t/ha)
COMPARISON BY LOGGING METHOD

Logging method	Stations	Tops	Branches	Green stems	Sub-total	Dead stems	Total residues	Residual trees	Sub-total	Stumps	Total
Tree-length	BS	26.2	11.6	6.1	43.9	9.9	53.8	1.3	55.1	1.3	56.4
	JP	15.9	14.9	5.4	36.2	13.1	49.3	0.0	49.3	1.4	50.7
	BF	23.1	16.3	11.4	50.8	21.1	71.9	3.3	75.2	2.0	77.2
	SM	44.1	3.5	10.2	57.8	11.9	69.7	8.8	78.5	2.7	81.2
Full-tree	BS	1.2	3.2	7.9	12.3	8.4	20.7	3.5	24.2	1.6	25.8
	JP	2.1	2.4	6.6	11.1	19.9	31.0	0.3	31.3	1.6	32.9
	BF	6.6	9.3	12.4	28.3	38.4	66.7	2.9	69.6	2.8	72.4
Shortwood	BS	11.1	22.0	21.8	54.9	15.8	70.7	1.6	72.3	3.0	75.3

In tree-length operations, the residue amounts to 56.4 t/ha in black spruce type, 50.7 t/ha in jack pine, 77.2 t/ha in balsam fir and 81.2 t/ha in sugar maple.

In full-tree operations, spruce type yields 25.8 t/ha, jack pine 32.9 t/ha and balsam fir 72.4 t/ha.

In shortwood operations, black spruce type yields 75.3 t/ha of residue.

Figures 19, 20 and 21 show the values for each class of residue and all logging methods. These values are cumulated in figures 22, 23 and 24, showing the contribution of each category of residue to total weight.

6.2.2. Moisture content

Table 34 gives the moisture content for each study area and by category of residue. There is much variation in the moisture contents between categories and between species (from 44% to 113%).

It must be noted that black spruce and jack pine were weighed in the summer (August, September) whereas sugar maple and balsam fir were weighed in the fall (October and November). In the latter group, snow and ice clinging to the material increased the moisture content.

6.3. Comments on the results

It was felt that expressing the values in % of total weight for each logging method would be useful (Table 35).

In general, the first three categories of residue (tops, branches, and green stems) are mainly caused by the logging operations.

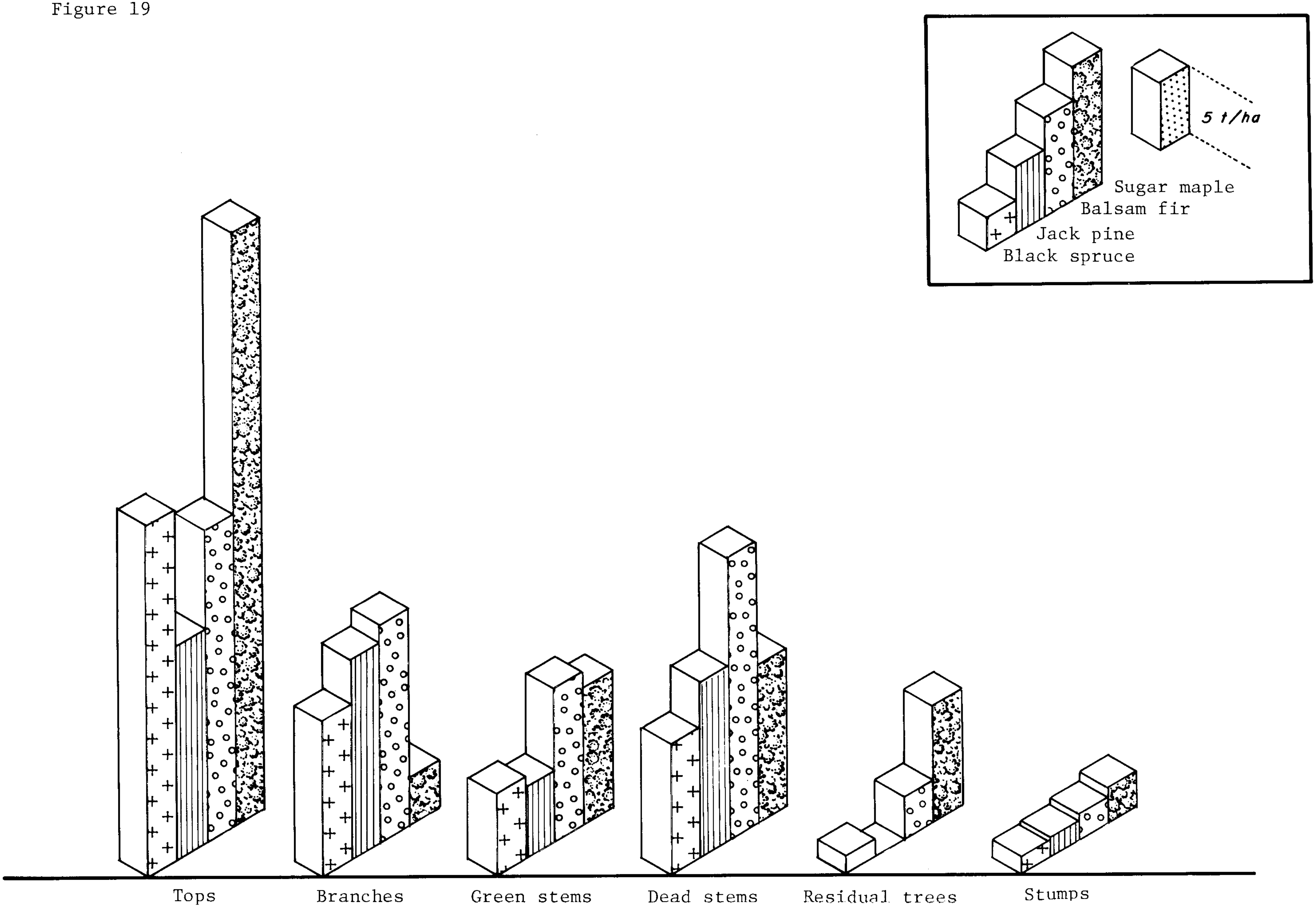
The presence of dead stems is most probably due to ecological factors such as insect infestations, windfalls, over-maturity or, in certain cases, the partial influence of old cuts. The latter factor was observed in the sugar maple stand cut selectively 25 years ago.

In three-length, as well as in shortwood logging, tops, branches and dead stems add up to 70% of the total weight (from 66% to 78%) compared with less than 50% (33 to 48% in full-tree operations).

Moreover, the total weight of the four categories of residue left on the ground represents 90% of the total weight of all residue. Stumps (aerial portion) account for only 3% to 4%, while the amount of residual trees is variable.

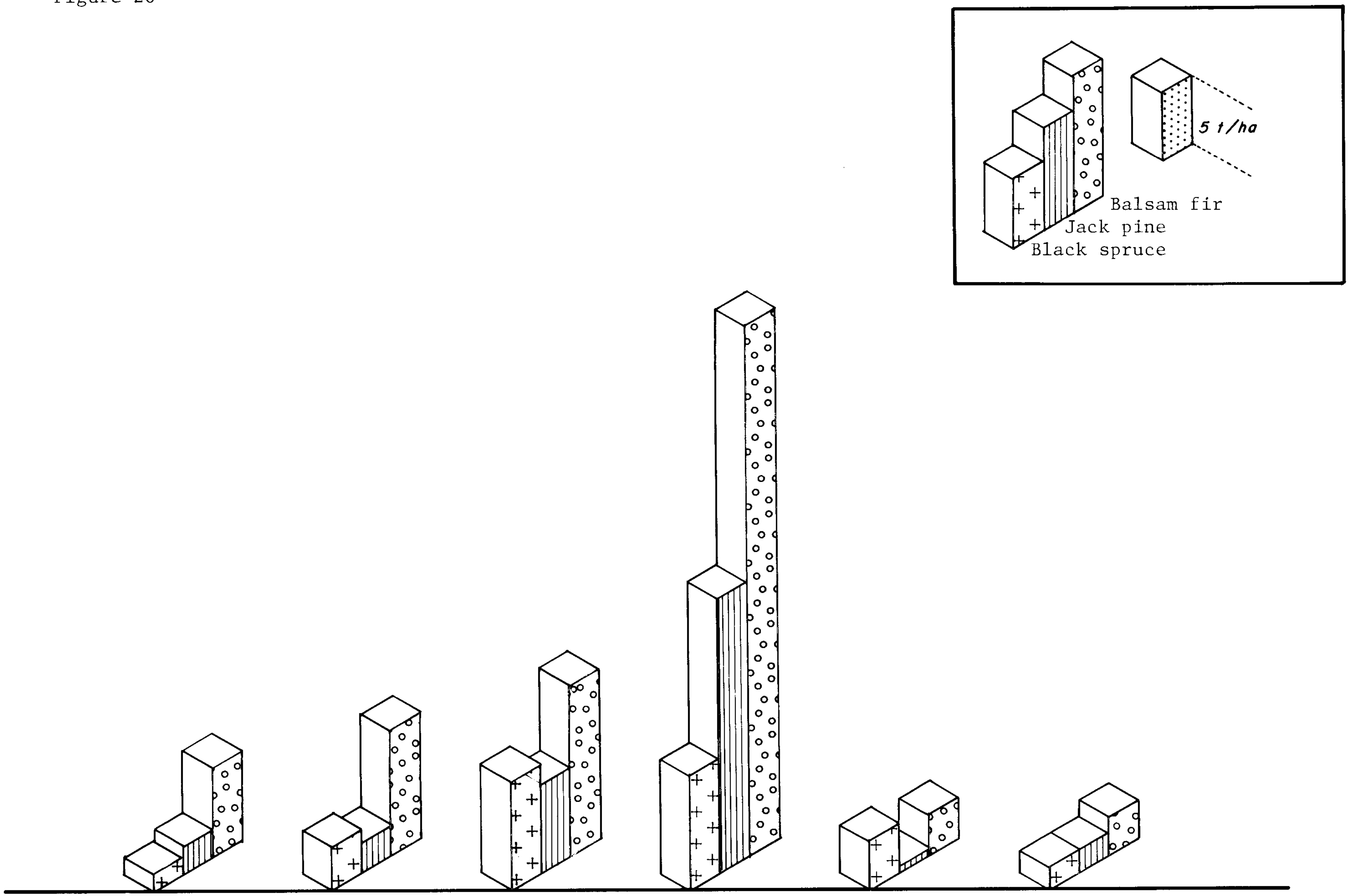
Residual trees were mostly non-commercial hardwoods (white birch, poplar in softwood stands. Since we were dealing with very pure softwood stands, residual trees represented a very small proportion of the total weight. Nevertheless, there were two exceptions to tis; black spruce stands cut by the full-tree method with a certain quantity of white birch, and the sugar maple stand where cutting prescriptions required leaving trees of various species uncut.

Figure 19



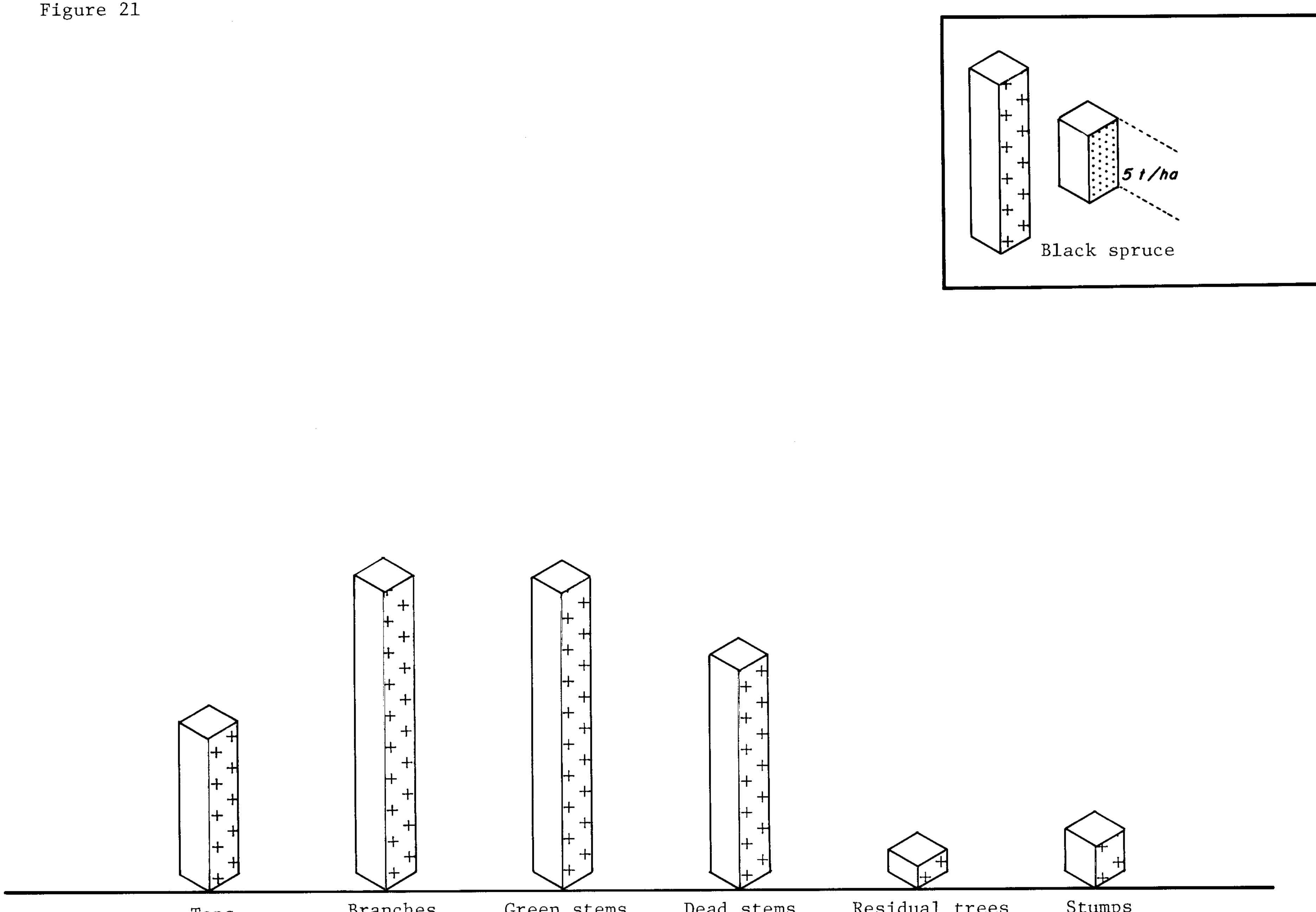
Distribution of residue by category for all stations — tree-length logging

Figure 20



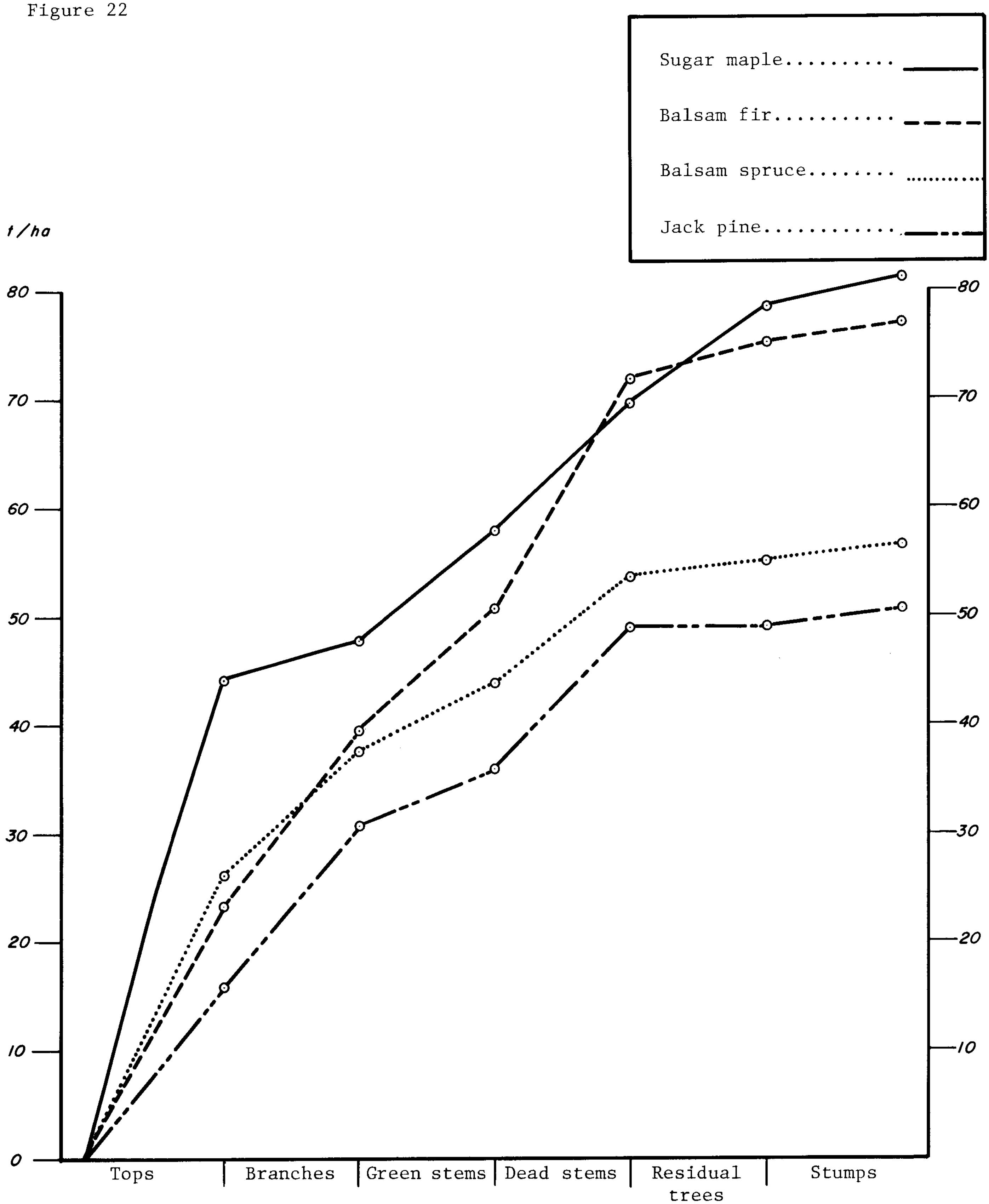
Distribution of residue by category for all stations — full-tree logging

Figure 21



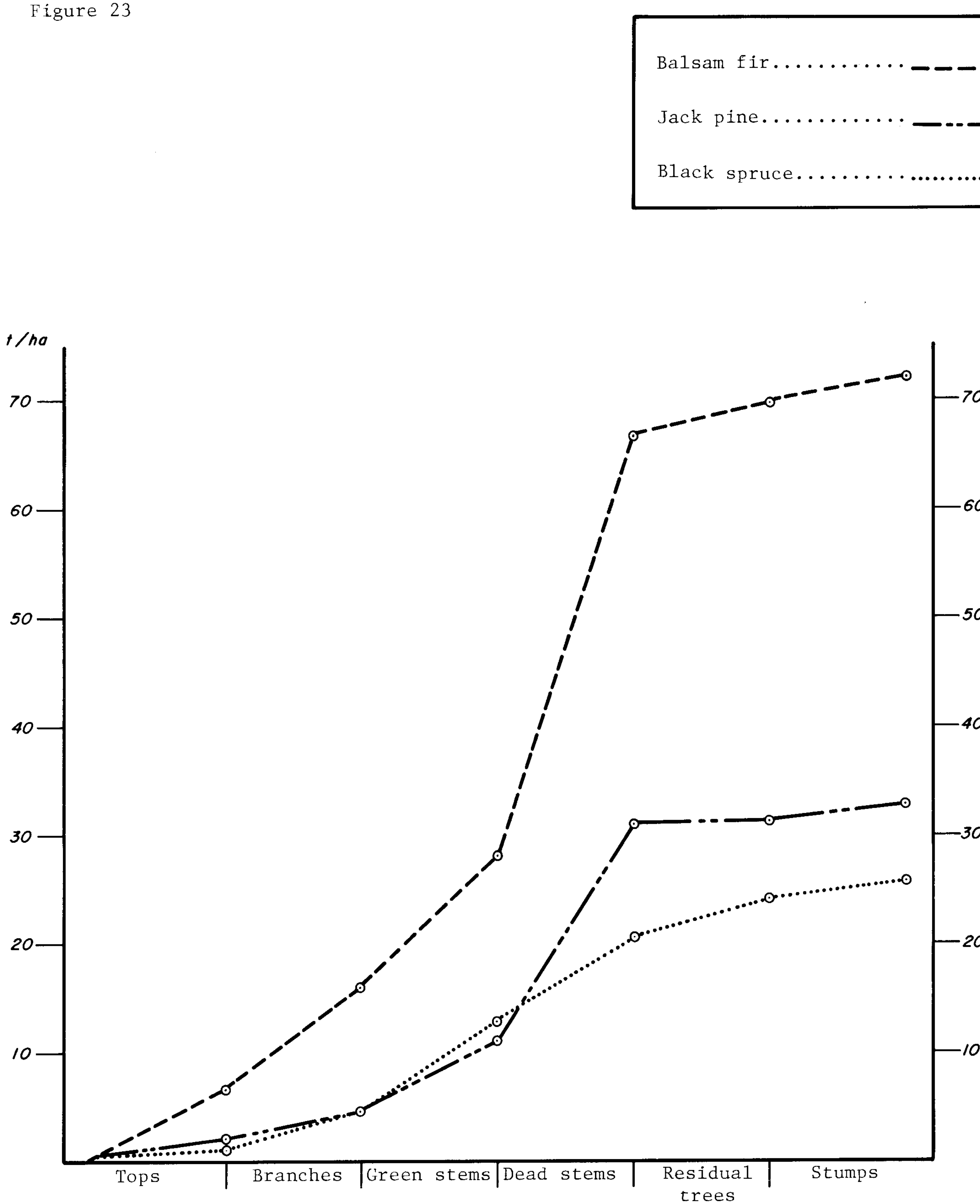
Distribution of residue by category — shortwood logging

Figure 22



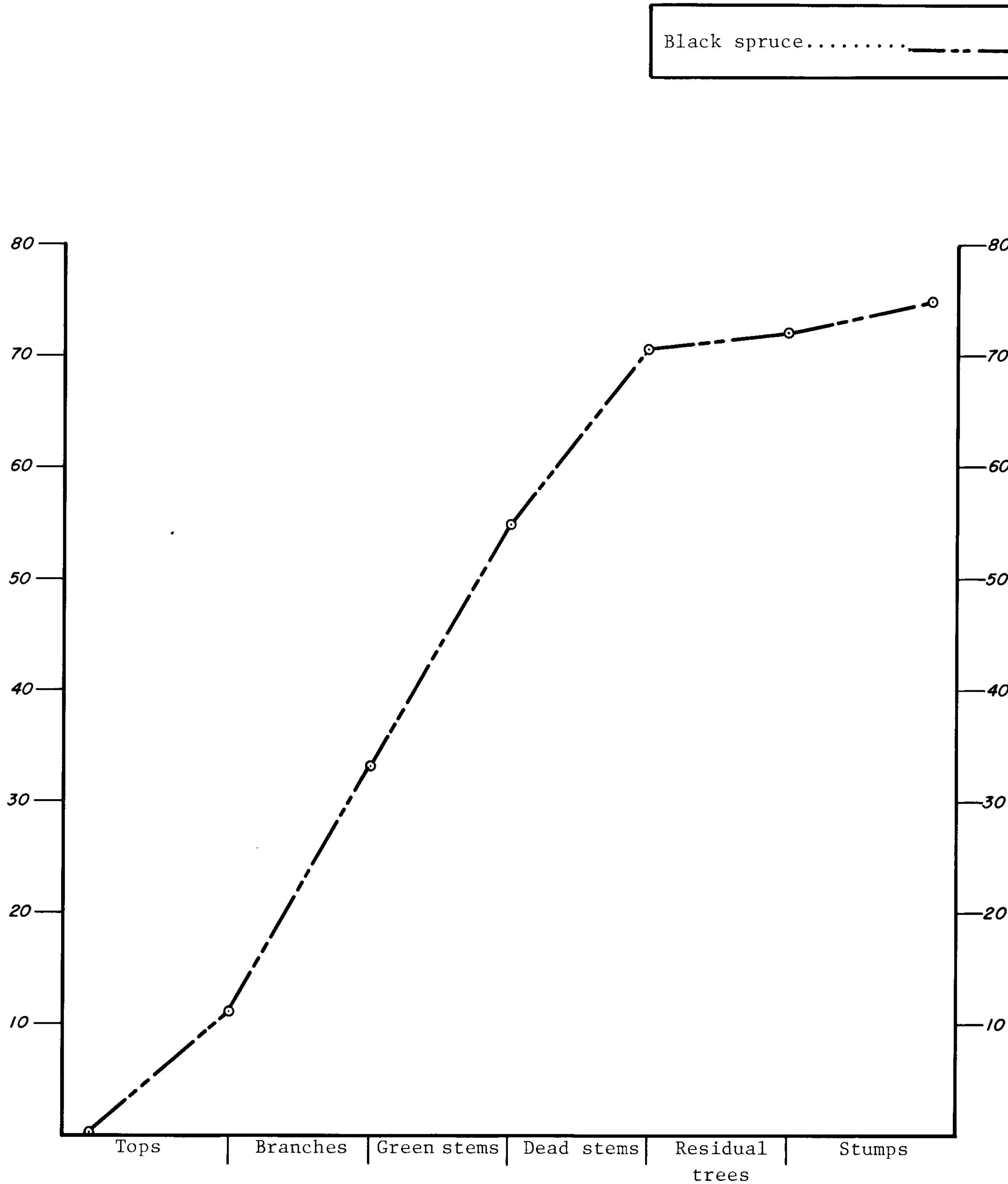
Cumulative distribution of oven-dry weight by category of residue for all stations — tree-length logging

Figure 23



Cumulative distribution of oven-dry weight by category of residue for all stations — full-tree logging

Figure 24



Cumulative distribution of oven-dry weight by category of residue for all stations – shortwood logging

TABLE 34

MOISTURE CONTENT OF SAMPLES
FOR ALL STATIONS
(with reference to oven-dry weight)

Station	Logging method	Categories of resisue				All categories weighted average
		Tops	Branches	Green stems	Dead stems	
Black spruce	tree-length	68	65	57	46	61
CIP — La Tuque	full-tree	66	58	50	46	52
	shortwood	67	72	61	45	61
Jack pine	tree-length	82	58	66	44	64
Reed — Dryden	full-tree	63	56	59	47	52
Sugar maple Consolidated-Bathurst Portage-du-Fort	tree-length	62	71	60	76	64
Balsam fir	tree-length	113	111	94	79	100
Fraser — Edmundston	full-tree	90	99	109	76	85

TABLE 35

PERCENTAGE OF CATEGORIES OF RESIDUE

WITH REFERENCE TO TOTAL OVEN-DRY WEIGHT FOR ALL STATIONS

Logging method	Stations	Categories									
		Tops	Branches	Green stems	Sub-total	Dead stems	Total residues	Residual trees	Sub-total	Stumps	Total
Tree-length	BS	46	21	11	78	18	96	2	98	2	100
	JP	31	29	11	71	26	97	0	97	3	100
	BF	30	21	15	66	27	93	4	97	3	100
	SM	54	4	13	71	15	86	11	97	3	100
Full-tree	BS	5	12	31	48	32	80	14	94	6	100
	JP	6	7	20	33	61	94	1	95	5	100
	BF	9	13	17	39	53	92	4	96	4	100
Shortwood	BS	15	29	29	73	21	94	2	96	4	100

7. RELATION BETWEEN VOLUME BEFORE CUTTING AND WEIGHT AFTER CUTTING

Correlation tests were done on the plot measurements to establish a mathematical relationship between the volume and the weight of residue after logging.

With a maximum of 15 plots in each case, it would be risky to extrapolate the results directly to all stands. On the other hand these values may be considered as fair indications with the proposed confidence intervals.

7.1. Observations on the tests and the selected parameters

A linear relation between the merchantable volume before logging and the oven-dry weight of residue after logging was first attempted. Statistical analysis clearly indicates that there is little or no linear correlation (Table 36).

TABLE 36

VALUES OF CORRELATION COEFFICIENT R

(BLACK SPRUCE)

Analysed Parameters	Tree-Length	Full-Tree	Shortwood
1) Total oven-dry weight vs merchantable volume	0.200000	-0.09538	-0.33186
2. Total dry weight except dead vs merchantable volume	0.29417	-0.15950	-0.07403
3) Total oven-dry weight vs total volume	0.12843	-0.04005	-0.26399
4) Total dry weight except dead vs total volume	0.25277	-0.06418	-0.03241

Curvilinear correlation attempts were made for the same data. In some cases they produced results that were superior to linear correlation. In the case of the sugar maple stands at Portage-du-Fort a comparison of the weights found in the plots measured before cutting (0.08 ha) with the weights from the post-cut measurement (0.04 ha), gave a correlation coefficient value of 0.6. This is an indication that significant correlation for certain forest types could be obtained, given a sufficiently large number of sample plots for each method.

After rejecting the study of linear or curvilinear correlations, the ratio sampling method was tried and it produced more significant results.

However, one must be careful when making a definite interpretation of these ratios. In fact, the quotient deal with two easily quantifiable factors.

For a better picture the influence of machine operators should be measured, because working technique and performance are viable. So also is the company (or government) policy with regard to the quantity of commercial wood that may be left on the ground.

Variations in residue may also occur within one logging method. For instance, a full-tree operation with skidding done by a Timberjack should leave more branches and stems than an operation with forwarding done by a Koehring KFF. The trend was evident between black spruce and jack pine study areas. The difference was even greater in balsam fir winter operations, when the wood was easily broken.

7.2. Correlation expressed as a ratio

Table 37 shows the relationship between merchantable volume before cutting and oven-dry weight after cutting, for all stations. This ratio, shown in the 4th column of the table, gives the relationship between weight (t/ha) and volume (m^3/ha). The 6th column gives the extreme deviations of the ratio, for a 95% confidence level.

For the same data, Table 38 shows a comparison of the merchantable volume and the total oven-dry weight not counting the dead stems, since these are not logging residue.

Tables 39 and 40, give a comparison of the merchantable volumes of living and standing dead trees. The test was done on two stations, to assess the influence of standing dead trees on the weight after cutting.

7.3. Analysis of the results

7.3.1. Use of ratio

Results derived from the use of the ratio sampling method are a good indication of the influence of the logging method on the residue accumulation.

Hence, to calculate the oven-dry weight of residue (dead stems excepted) of a black spruce stand on storey in site class 2, with a merchantable volume of 2,000 m^3, and depending on the logging method (Table 38) we would use this formula, (merchantable volume) x (ratio ± conficence interval) = oven-dry weight, and find:

m^3	R	(kg/m^3)	(kg)

a) Tree-Length

2,000 m^3 (279,760 ± 44,462 kg/m^3) = 559,520 ± 88,924 kg

TABLE 37

TABLE OF RATIOS

OVEN-DRY WEIGHTS OF RESIDUE VS MERCHANTABLE GREEN VOLUME BEFORE CUTTING

STATION	LOGGING METHOD	SUM OF PLOTS WEIGHT (kg)	SUM OF PLOTS VOLUME (m^3)	RATIO (kg/m^3)	STANDARD DEVIATION (kg/m^3)	CONFIDENCE INTERVAL (95%) (kg/m^3) Lower limit	CONFIDENCE INTERVAL (95%) (kg/m^3) Upper limit	ERROR (95%) (%)
Black spruce	Tree-length	781,499.35	2,295.867	340.394	24.567	291.261	389.528	14.15
	Full-tree	362,166.78	2,708.356	133.722	14.652	104.418	163.026	21.48
	Shortwood	1,155,147.4	3,288.498	351.269	19.523	312.222	390.316	10.89
Jack pine	Tree-length	765,094.430	4,160.145	183.911	9.773	164.364	203.457	10.42
	Full-tree	494,950.630	3,569.088	138.677	10.856	116.965	160.389	15.34
Sugar maple	Tree-length	1,046,733.900	2,466.321	424.411	26.252	371.907	476.915	12.12
Balsam fir	Tree-length	1,013,930.100	2,454.426	413.103	25.669	361.765	464.441	12.18
	Full-tree	439,709.863	1.193.381	368.457	48.216	272.042	464.889	25.65

TABLE 38

TABLE OF RATIOS

OVEN-DRY WEIGHT OF RESIDUE (dead stems excluded) VS GREEN MERCHANTABLE VOLUME

STATION	LOGGING METHOD	SUM OF PLOTS WEIGHT (kg)	SUM OF PLOTS VOLUME (m^3)	RATIO (kg/m^3)	STANDARD DEVIATION (kg/m^3)	CONFIDENCE INTERVAL (95%) (kg/m^3) Lower limit	CONFIDENCE INTERVAL (95%) (kg/m^3) Upper limit	ERROR (95%) (%)
Black spruce	Tree-length	642,750.93	2,295.867	279.760	22.231	235.498	324.422	15.56
	Full-tree	245,913.31	2,708.356	90.798	11.282	68.235	113.361	24.35
	Shortwood	917,895.420	3,288.498	279.123	14.968	249.187	309.060	10.51
Jack pine	Tree-length	563,117.260	4,160.145	135.360	8.840	117.679	153.041	12.80
	Full-tree	194,955.070	3,569.088	54.623	6.498	41.626	67.620	23.32
Sugar maple	Tree-length	809,036.610	2,466.321	361.282	23.513	314.255	408.308	12.76
Balsam fir	Tree-length	729,648.860	2,454.426	297.279	24.108	249.062	345.495	15.89
	Full-tree	204,217.423	1,193.381	171.125	21.449	128.228	214.023	24.57

TABLE 39

TABLE OF RATIOS

TOTAL DRY WEIGHT OF RESIDUE VS GREEN AND DEAD VOLUME

STATION	LOGGING METHOD	SUM OF PLOTS WEIGHT (kg)	SUM OF PLOTS VOLUME (m^3)	RATIO (kg/m^3)	STANDARD DEVIATION (kg/m^3)	CONFIDENCE INTERVAL (95%) (kg/m^3) Lower limit	CONFIDENCE INTERVAL (95%) (kg/m^3) Upper limit	ERROR (95%) (%)
Sugar maple	Tree-length	1,046,734.000	2,507.605	417.424	25.355	366.713	468.135	11.91
Balsam fir	Tree-length	1,013,929.700	2,594.510	390.798	28.122	334.555	447.042	14.10
	Full-tree	439,725.806	1,231.656	357.020	43.202	270.600	443.424	23.72

TABLE 40

TABLE OF RATIOS

OVEN-DRY WEIGHT OF RESIDUE (dead stems excluded) VS VOLUME GREEN AND DEAD

STATION	LOGGING METHOD	SUM OF PLOTS WEIGHT (kg)	SUM OF PLOTS VOLUME (m^3)	RATIO (kg/m^3)	STANDARD DEVIATION (kg/m^3)	CONFIDENCE INTERVAL (95%) (kg/m^3) Lower limit	CONFIDENCE INTERVAL (95%) (kg/m^3) Upper limit	(95%) (%)
Sugar maple	Tree-length	891,036.740	2,507.605	355.334	23.158	309.018	401.649	12.77
Balsam fir	Tree-length	729,648.620	2,594.510	281.228	25.044	231.140	331.136	17.45
	Full-tree	204,217.177	1,231.656	165.807	20.536	124.736	206.879	24.28

b) Full-Tree

2,000 m^3 (90,978 ± 22,564 kg/m^3) = 181,596 ± 45,128 kg

c) Shortwood

2,000 m^3 (279,123 ± 29,936 kg/m^3) = 558,246 ± 59,872 kg

The same reasoning applies to other stations.

However, caution is necessary when extrapolating these values to forest types that differ significantly from those tested here.

7.3.2. Comparison between logging methods and between stations

Ratio sampling applied to black spruce shows little or no difference in residue accumulation from either tree-length or shortwood logging. Since this was the only study area where both methods were in parallel, it would be interesting to find out what the trend would be at other stations.

In tree-length and full-tree operations, residue accumulation is quite variable between species. However, when the dead stems (Table 38) are excluded the results are similar for black spruce and balsam fir in tree-length logging.

In the total oven-dry weight (Table 37), the values for black spruce and jack pine, in full-tree operation are similar. Finally, there is no significant influence on the value of the ratio when the standing dead trees are added to the merchantable volume before cutting. (Tables 39 and 40)

7.3.3. Discussion on the choice of correlated parameters

When information generally available from forest companies is considered merchantable volume by storey should be used as the volume before cutting.

As for the oven-dry weight after cutting, a ratio giving the total weight of residue excluding the dead stems should be used because the amounts of dead wood vary greatly between forest types.

CONCLUSION

In spite of a late start, about the end of June, it was possible to inventory 4 stations by the beginning of December.

In general the work was carried out as planned. The costs remained within the budget estimates, although some costs were not easy to estimate because they were unprecedented.

Adjustments and modifications of the methods were made throughout the field work. Should this kind of work be continued, an attempt should be made to mechanize the weighing of residue.

This method of inventorying the residue is accurate and suitable for basic studies that might be required for many other forest types in Canada. Nevertheless, the results of this study concern four widely distributed forest types and well-known logging methods.

Our results might be extensively applicable but for more specific results, it would be necessary to proceed according to the following criteria:

- establish the relationship between the forest types analyzed snd larger forest groups;
- consider the inherent va-iations of forest site, stage of development, and age of forest stands;
- present the results with their statistical variations (confidence level).

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APPENDICES

APPENDIX 1

CONVERSION FACTORS

BETWEEN THE INTERNATIONAL

AND IMPERIAL SYSTEMS

1 cm	=	0.39 in	1 in	=	2.54 cm
1 m	=	3.28 ft	1 ft	=	0.30 m
1 m^2	=	10.76 ft	1 ft^2	=	0.0929 m^2
1 ha	=	2.47 ac	1 ac	=	0.404 ha
1 m^2/ha	=	4.355 ft^2/ac	1 ft^2/ac	=	0.229 m^2/ha
1 m^3	=	35.31 ft^3 = 0.35 cunit	1 ft^3	=	0.0283 m^3
1 m^3/ha	=	14.29 ft^3/ac = 0.14 cunit/ac	1 ft^3/ac	=	0.0699 m^3/ha
1 (t mét) t	=	1.102 (Long t) tn	1 tn	=	0.907 t
1 t/ha	=	0.446 tn/acc	1 tn/ac	=	2.242 t/ha
1 t/m^3	=	1 g/cm^3 = 62.42 lbs./ft^3	1 lb/ft^3	=	0.016 g/cm^3 = 0.0166 t/m^3

APPENDIX 2

DENSITY OF THE IMPORTANT SPECIES OBSERVED

SPECIES	SYMBOL	DENSITY (t/m^3)
White spruce	WS	0.35
Black spruce	BS	0.40
Red spruce	RS	0.38
White pine	WP	0.32
Jack pine	JP	0.40
Balsam fir	BF	0.33
White birch	WB	0.51
Yellow birch	YB	0.56
Red oak	RO	0.58
Red maple	RM	0.52
Sugar maple	SM	0.60
Beech	BE	0.53
Hop hornbeam	HH	0.65
Trembling aspen	POP	0.37

APPENDIX 3

LIST OF TREE SPECIES ENCOUNTERED

ENGLISH NAME	SCIENTIFIC NAME	ABBREVIATION
Downy serviceberry	*Amelanchier* med.	SB
Sitka alder	*Alnus crispa* B. Ehrn.	SA
Speckled alder	*Alnus rugosa* B. Ehrh.	SPA
Grey birch	*Betula populifolia* Marsh.	GB
White birch	*Betula papyrifera* Marsh.	WB
Yellow birch	*Betula alleghaniensis* Britton	YB
Pin cherry	*Prunus pensylvanica* L.f.	PC
Red oak	*Quercus rubra* L.	RO
Mountain ash	*Sorbus americana* Marsh.	MA
White spruce	*Picea glauca* (Moench) Voss	WS
Black spruce	*Picea mariana* (Mill.) B.S.P.	BS
Red spruce	*Picea rubens* Sarg.	RS
Mountain maple	*Acer spicatum* Lam.	MM
Sugar maple	*Acer saccharum* Marsh.	SM
Striped maple	*Acer pensylvanicum* L.	STM
Red maple	*Acer rubrum* L.	RM
American beech	*Fagus grandifolia* Ehrh.	BE
Hazelnut	*Corylus cornuta* L.	HAZ
Hop hornbeam	*Ostrya virginiana* (Mill.) K. Koch	HH
Trembling aspen	*Populus tremuloides* Michx.	POP
White pine	*Pinus strobus* L.	WP
Jack pine	*Pinus banksiana* Lamb.	JP
Balsam fir	*Abies balsamea* (L.) Mill.	BF
Black willow	*Salix* L.	BW
Red elder	*Sambucus pubens* Michx.	REL
White cedar	*Thuja occidentalis* L.	WC

APPENDIX 4

COMMON LOGGING METHODS IN CANADA

1.11 SHORTWOOD

This logging method may be classified in three different types of operations: manual, partly mechanized and mechanized.

1.111 Manual operation

Felling, limbing, bucking and bunching or piling are done manually by forest workers. Forwarding is the only mechanical operation. In Canada, the average and maximum forwarding distances are 180 m and 370 m respectively.

1.112 Partly mechanized operation

In this type of operation, there are only two partly mechanized phases; bucking and piling.

Forwarding to the road is done over average and maximum distances of 245 m and 490 m respectively.

1.113 Mechanized operation

All harvesting and processing operations are mechanized. Trunks are cut into 2,45 m lengths. The only variable of the system is in the number of machines used. In fact, one machine may go through the entire process or there may be one machine for each operation. In the latter case, forwarding distances are longer. They may go from 470 m to 945 m as compared with 135 m and 260 m.

TABLE 1

SUMMARY OF THE VARIOUS OPERATIONS

OF SHORTWOOD LOGGING

TYPE OF OPERATION	MANUAL OPERATION	MECHANIZED OPERATION
MANUAL	felling limbing bucking bunching or piling	forwarding
PARTLY MECHANIZED	bucking piling	felling limbing forwarding
MECHANIZED		felling limbing bucking piling forwarding

1.12 TREE-LENGTH OPERATION

This is the most commonly used logging system in Canada. In 1978, more than half of the wood was cut by this method. As with short-wood there are three distinct operations: manual, partly mechanized and mechanized.

1.121 Manual operation

Felling and limbing are done by a forest worker. Trees are then skidded with a cable skidder to roadside where a worker takes care of bucking with a chain saw. He will cut the tree in 1.22 m or 2.45 m lengths or in sawlogs. Piling may be mechanized or not.

Average and maximum skidding distances are 165 m to 330, respectively.

1.1221 Manual felling

Felling and limbing are done manually. The average and maximum skidding distances are 160 m and 330 m, respectively.

1.1222 Mechanized felling

In this operation, a feller-buncher is used. Limbing is the only manual operation. Cable skidders work to distances varying from 170 m to 290 m.

1.1223 Bucking

Bucking is also a mechanized operation. Generally, in Canada, this operation is done at roadside, with the exception of Québec, where it is mostly done at the riverside where piling is not necessary. Roadside piling is mechanized.

1.123 Mechanized operation

Limbing may be done in two different ways, either simultaneously with the felling operations or later at the landing by a delimber.

1.1231 Felling-limbing

This operation is done with a feller-delimber. Trees are then skidded or forwarded to the landing over distances of 160 m and 380 m respectively.

1.1232 Limbing

This second method makes use of a feller-buncher. Mechanized limbing subsequently follows at the landing. Skidding or forwarding is done over average and maximum distances of 130 m and 390 m respectively.

1.124 Bucking

Bucking is done with machines, generally, at roadside, riverside, at the railroad or in a mill yard.

1.13 FULL TREE

This is a relatively recent logging system. It may be partly or fully mechanized.

1.131 Partly mechanized operation

Felling is done manually, followed by skidding over average and maximum distances of 140 m and 245 m.

1.132 Mechanized operation

All operations are performed by machines, but the number of machines may vary.

1.1321 One machine

The same machine fells and skids or forwards over distances of 160 m and 395 m respectively.

1.1322 Two machines or more

To accomplish the same work, at least two machines are used for felling and moving the wood to the loading site. Average and maximum distances are 200 m and 490 m.

1.133 Processing

Limbing, topping, bucking, chipping and piling are also mechanized. The site for these operations may vary depending on equipment available for hauling, type of roads, and distances to the point of delivery. These operations are carried out at the slasher site in tree-length operations. In some cases, certain operations may use different sites.

TABLE 2

SUMMARY OF THE VARIOUS OPERATIONS

OF TREE-LENGTH LOGGING

TYPE OF OPERATION	MANUAL OPERATIONS	MECHANICAL OPERATIONS
MANUAL	felling limbing bucking piling	skidding piling
PARTLY MECHANIZED	felling limbing	skidding bucking piling
	limbing	felling-bunching skidding bucking piling
MECHANIZED		felling-bunching limbing skidding or forwarding bucking piling
		felling-limbing skidding or forwarding bucking piling

TABLE 3

SUMMARY OF THE VARIOUS OPERATIONS OF FULL-TREE LOGGING

TYPE OF OPERATION	MANUAL OPERATIONS	MECHANIZED OPERATIONS
PARTLY MECHANIZED	felling	limbing skidding bucking piling
MECHANIZED		felling skidding or forwarding limbing bucking piling

Reference: Canadian Pulp and Paper Association, 1979

Summary of forest operations reports, 1978 or 1978-79.

Woods and Forests Division. Logging Group.

APPENDIX 5

METEOROLOGICAL DATA

a) Black spruce. CIP, La Tuque

Meteorological data for the period from July 13th. to August 20th, 1979.

- Meteorological station No. 332 (Lac Martel) of the Society of Conservation for the region of Québec-Maurice; altitude of the station: 335 m.

- Approximate location of plots with respect to the meteorological station:

Camp Windigo

Sample plot	22-23-24-25 26-27-28-29 30	1-2-3-4 5-6	31-32-33-34 35-36-37-38	16-17-18 19-20-21	40-41-42 43-44-45	7-8-9-1 11-12-1 14-15
Direction	45^{o} NO	52^{o} NO	29^{o} NO	52^{o} NO	49^{o} NO	51^{o} NO
Distance	27 km	31 km	43 km	25 km	43 km	43 km

Data in the next table are from observations made at 12:50 hours, standard time.

OBSERVATIONS AT 12:50 PM

DATE	TEMPERATURE (°C) AT 12:50 PM	RAINFALL (mm)	WIND VELOCITY (km/h)	RELATIVE HUMIDITY (%)
13 JULY	25	0.0	12	48
14	29	0.0	24	48
15	30	0.0	19	54
16	22	36.1	19	58
17	20	0.0	19	40
18	24	0.0	10	39
19	25	0.0	32	43
20	22	0.1	24	54
21	27	0.0	26	37
22	19	1.0	18	95
23	20	0.0	16	41
24	30	0.0	32	46
25	29	0.0	16	57
26	18	57.4	6	85
27	22	0.0	10	54
28	24	0.0	10	53
29	25	15.0	14	54
30	27	0.0	22	49
31	24	0.0	35	67
1 AUGUST	24	0.8	24	41
2	19	0.8	5	95
3	26	5.1	36	51
4	20	0.0	10	90
5	20	5.1	15	72
6	19	12.0	30	72
7	17	0.0	24	57
8	16	5.1	24	65
9	15	0.5	30	53
10	15	0.0	14	64
11	14	1.5	29	53
12	18	0.0	13	38
13	19	0.0	13	47
14	15	15.2	15	84
15	13	4.8	10	77
16	15	0.5	10	74
17	16	0.0	8	65
18	15	0.0	10	64
19	13	6.4	5	95
20	17	0.0	8	75
21	19	2.3	13	67
22	21	0.0	13	35
23	23	0.0	10	44
24	19	4.3	6	95
25	24	5.3	30	71
26	19	0.0	10	51
27	23	0.0	16	59
28	18	0.8	10	71
29	28	5.1	10	95
30	16	5.1	25	84
31	16	2.3	15	51

192.6 mm of rain fell during the study period. Showers exceeded 6 mm on 6 occasions.

b) Jack pine. Reed Paper, Dryden

Meteorological data for the period from September 9th. to 28th, 1979.

- Meteorological station of Ignace; "Ministry of Natural Resources, Ontario".

- Altitude of the station: 450 m

- Altitude and approximate location of all plots with reference to the station.

Camp 34

Location: 33 km - 51° SW

- The data in the following table originate from observations made at 08:00 hours or at 13:00 hours, standard time.

  Maximum and minimum temperatures were taken within a 24 hour period beginning at 08:00 hours.

- Meteorological station of Dryden Airport; "Ministry of Natural Resources, Ontario".

- Altitude of the station: 412 m

- Altitude and approximate location of working area with reference to the station.

Camp 2

Location: 26 km - 37° NE

- The data in the following table are from observations made at 08:00 hours or at 1300 hours, standard time.

- Maximum and minimum temperatures were taken within a 24 hour period beginning at 08:00 hours.

IGNACE STATION

OBSERVATIONS 13:00 HOURS

DATE	TEMPERATURE (°C) 24 hrs min.	4 hrs max.	at 18:00 H	RAINFALL (mm)	WIND VELOCITY	RELATIVE HUMIDITY (%)
9 September	5.0	19.0	16.0	0.0	8	81
10	4.0	15.0	11.5	0.0	6	68
11	4.0	12.0	9.5	2.6	6	94
12	5.0	19.0	17.0	0.8	10	77
13	5.0	13.0	11.0	0.4	16	83
14	5.0	9.0	9.0	5.2	9	71
15	5.0	20.0	16.0	0.6	6	72
16	7.0	27.0	23.0	0.0	19	49
17	14.0	23.0	20.5	0.0	14	68
18	4.0	12.0	7.0	0.4	12	63
19	-2.0	15.0	11.5	0.0	12	68
20	1.0	12.0	10.0	1.5	9	94
21	-1.0	14.0	11.5	5.8	10	63
22	-3.0	12.0	12.5	0.0	4	60
23	-2.0	20.0	15.0	0.0	13	71
24	1.0	18.0	15.0	0.0	15	63
25	3.0	19.0	18.0	0.0	17	46
26	-1.0	21.0	18.0	0.0	12	43
27	1.0	19.0	18.5	8.4	10	78
28	3.0	--	6.0	1.7	10	100

DRYDEN AIRPORT

OBSERVATIONS 13:00 HRS

DATE	TEMPERATURE (°C)			RAINFALL (mm)	WIND VELOCITY	RELATIVE HUMIDITY (%)
	24 hrs min.	24 hrs max.	at 18:00 H			
9 September	6.5	17.5	16.0	0.0	7	74
10	8.5	17.7	10.5	0.0	10	67
11	4.0	13.8	9.0	1.6	11	98
12	6.8	12.0	14.3	0.5	11	80
13	6.1	13.6	10.0	2.5	15	86
14	6.1	13.6	9.0	10.5	12	65
15	3.0	13.0	16.2	0.0	12	69
16	7.0	18.2	24.5	0.0	23	36
17	9.5	29.0	22.0	0.0	21	54
18	4.0	8.0	6.4	2.0	17	62
19	0.5	15.0	11.8	0.8	15	63
20	0.3	17.0	9.5	2.2	11	95
21	4.0	15.1	11.5	2.8	17	49
22	1.0	13.0	12.0	0.0	7	55
23	1.0	16.0	16.5	0.0	12	56
24	3.1	19.0	15.5	0.0	25	51
25	10.0	18.0	17.5	0.0	31	39

For that period, the total rainfall at Dryden Airport added to 22.4 mm, and there was only one shower of more than 6 mm.

The Ignace Station had total precipitation of 27.4 mm, and one shower exceeded 6 mm.

c) Sugar maple. Consolidated-Bathurst, Portage-du-Fort

Meteorological data for the period from October 14th. to 30th, 1979.

- Meteorological station of Rapide-des-Joachims; Ministère des Richesses Naturelles du Québec.

- Altitude of the station: 122 m

- Camp Schyan

- Altitude and approximate location of plots with reference to the station.

- Altitude: 366 m

- Location: 23 km - 82° SE

- The data in the following table is from observations made at 1800 hrs, standard time or, in case of rain, adding both observations made at 0800 hrs and 1800 hrs.

  Maximum and minimum temperatures are taken within a 24 hour period beginning at 1800 hrs.

  Relative humidity was found in tables showing readings from wet and dry thermometers; the tables originate from "Indice forêt-meteo", Canadian method"; Forestry Technical report, February 25th, 1978; Environment Canada."

CONSOLIDATED-BATHURST, PORTAGE-DU-FORT

OBSERVATIONS 1800 HRS

DATE	TEMPERATURE (°)			RAINFALL (mm)	WIND VELOCITY	RELATIVE HUMIDITY (%)
	24 hrs min.	24 hrs max.	at 1800 H			
14 October	1.5	5.0	2.0	0.0	5	84
15	- .5	7.0	5.5	1.4	15	53
16	-3.0	8.5	4.0	3.2	C**	71
17	1.0	7.0	6.0	0.0	C	86
18	-2.0	11.5	5.5	0.0	C	73
19	-2.5	7.5	7.0	2.6	5	100
20	7.0	21.5	16.0	9.2	15	100
21	15.0	23.0	20.5	10.0	10	79
22	16.0	27.5	20.5	1.2	C	79
23	13.0	20.5	13.0	8.0	C	89
24	2.5	13.0	3.0	3.6	15	77
25	0.0	12.0	10.0	0.0	15	88
26	-1.5	2.0	0.0	0.0	10	100
27	-1.0	4.0	2.0	0.0	5	84
28	-1.0	3.5	0.0	30.0*	3	91
29	0.0	4.0	3.0	0.0	3	92
30	1.0	5.0	1.0	0.0	C	100

* Snow

** "C" means "calm"

A total of 39.2 mm of rain and 30 mm of snow fell during the period. On three occasions, showers exceeded 6 mm.

d) <u>Balsam fir. Fraser, Edmundston</u>

Meteorological data for the period from November 11th. to December 2nd, 1979.

- Meteorological station: "Rapids Depot" (camp 27); Environment Atmosphérique (Environment Canada)

- Altitutde of the station: 167 m

- Altitude and approximate location of plots with reference to the meteorological station:

Camp 28

Plots:	11-12-13-14	1-2-3-4-6 7-8-9-10
Altitude:	Between 250 and 300 m	
Direction:	59^{o}NO	84^{o}NO
Distance:	10 km	12 km

The data in the next table are from observations made at 0830 hrs and 1630 hrs, or adding both in case of rain.

Data concerning wind velocity and relative humidity are not in these meteorological reports.

FRASER-EDMUNDSTON

Camp 27 (for field work at Camp 28)

DATE	TEMPERATURE (^oC) min.	max.	at 1600 h	RAINFALL (mm)	SNOW (mm)
11 November	0.0	4.0	1.0		
12	- 2.5	2.5	1.0		
13	3.0	4.0	2.0		
14	- 1.0	1.5	1.0		T*
15	- 4.0	-1.5	-4.0		6.0
16	- 7.0	0.0	-1.0		T
17	-10.0	0.0	0.0		T
18	-10.0	-1.0	-8.0		
19	-11.5	-0.5	-3.0		
20	-10.0	-3.0	-3.0		
21	- 3.5	4.0	1.0		2.0
22	- 3.0	1.0	0.0		1.0
23	0.0	1.5	1.0	0.3	
24	0.0	2.0	2.0		
25	0.0	7.0	2.0		
26	- 2.0	6.0	2.0	4.0	
27	2.0	5.0	4.0	23.6	
28	- 1.5	5.0	4.0	0.3	
29	- 1.0	1.5	-1.0	2.0	
30	- 4.0	-2.0	-3.0	0.3	
1 December	-10.0	-1.0	-7.0		
2	-17.0	-3.5	-5.0		

* T means "trace"

- Meteorological station: "Nine Mile BRK" (camp 68); Environment Canada.
- Altitude and approximate location of plots with reference to the meteorological station.

Camp 69

Altitude: Between 250 and 300 m

Direction: 84^{o} NE

Distance: 8 km

The data in the following table are from observations made at 0830 hrs and 1630 hrs or adding both in case of rain.

Data on wind velocity and relative humidity do not appear in the meteorological reports.

FRASER-EDMUNDSTON

Camp 68 (for field work at camp 69)

DATE	TEMPERATURE (°C) min.	max.	at 1600 h	RAINFALL (mm)	SNOW (mm)
11 November	- 2.0	-12.0	2.0		
12	- 5.0	2.0	0.5		
13	- 2.5	1.5	0.5		
14	- 5.0	0.0	-0.5		2.0
15	- 6.0	- 3.0	-4.0		32.0
16	-10.0	5.0	5.0		
17	-10.0	4.0	4.0		
18	-14.0	-4.0	-4.0		
19	-11.0	-3.0	-4.5		
20	-11.0	-4.5	-4.5		
21	- 7.0	0.0	0.0		10.0
22	- 3.0	-0.5	-0.5	2.0	10.0
23	- 3.0	3.0	3.0		
24	- 3.0	5.0	5.0	10.0	
25	- 2.0	5.0	5.0		
26	- 7.0	3.0	3.0	30.0	
27	- 2.0	4.0	4.0		
28	- 1.0	5.0	3.0		
29	-12.0	3.0	-4.0		
30	-12.0	6.0	0.0		
1 December	- 6.0	0.0	-3.0		
2	-11.0	-8.0	-8.0		

During the period from November 11th. to December 2nd, total rainfall was 30.5 mm, and only snowfall was 9 mm at camp 27 station. Rain exceeded 6 mm on one day.

At camp 68 station, there was 42 mm of rain and 54 mm of snow.

APPENDIX 6 (a)

Number of Stumps

For all Stations

Logging Method	Station	Number of Plots	Number/ha minimum	Number/ha maximum	Number/ha mean	Average Diameter (cm)	Average Volume (m^3)	%<9 cm
Tree-length	BS	14	2669	5066	3712	13.37	0.84	42.61
Full-tree	BS	14	1557	4794	3196	14.25	1.19	35.01
Shortwood	BS	15	1680	5486	3318	14.64	2.24	37.74
Tree-length	JP	15	1754	5214	3090	14.45	1.07	35.29
Full-tree	JP	15	1063	3707	2354	15.30	1.63	42.06
Tree-length	SM	13	766	1804	1289	16.50	3.52	57.37
Tree-length	BF	13	2693	5239	3547	15.48	1.36	43.94
Full-tree	BF	6	2866	6104	3892	15.15	1.76	56.93

APPENDIX 6 (b)

Number of Residual Trees

For all Stations

Logging Method	Station	Number of Plots	Number/ha minimum	Number/ha maximum	Number/ha mean	Average Diameter(cm)	Average Volume (m^3)	%<9 cm
Tree-length	BS	14	0	445	118	7.92	26.16	68.66
Full-tree	BS	14	0	815	293	8.46	26.71	68.67
Shortwood	BS	15	0	618	69	9.60	53.53	61.90
Tree-length	JP	15	0	74	7	2.54	0.30	100.00
Full-tree	JP	15	0	222	59	4.90	11.48	91.67
Tree-length	SM	13	49	890	300	9.79	48.19	63.92
Tree-length	BF	13	0	346	57	14.98	109.30	46.67
Full-tree	BF	6	0	297	82	12.48	69.09	60.00

APPENDIX 7

FORMS

FOR RECORDING DATA

BIOMASS PROJECT

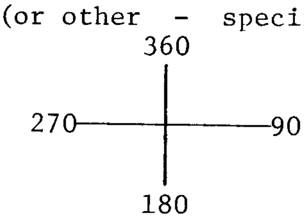
PRE-CUT INVENTORY

Forest Zone	Logging Method	Plot No.
____________	____________	____________

1. Location of Sample Plot:

Sketch of starting point and location of the plot

Reference Trees (or other - specify)



2. Mapped stratum: ____________________
reference:

3. Observed stratum:
Species association: ____________________
Density: ____________________ Height: ____________
Stage of Development: ____________________
Branching class: ____________________

4. Characteristics of the station:
Slope: __________ Drainage: ____________ Exposure: ______
Main species of the herbaceous stratum:

Main species in moss stratum:

Site class:

5. Logging details:

	Equipment used		
	At the stump		At the landing
Felling			
Limbing			
Bucking (length)			
Topping			
Forwarding			

Estimated date of logging:

Useful references: write on the back of this sheet names, functions, and phone numbers of reference - persons.

FORM 2

Plot: | | |

Tree Count

Spp / DBH cm	01	02	03	TOTAL 1-2-3	04	05	06	07	08	09	10	11	12	13									TOTAL 4 +
BS																							
BF																							
JP																							

Spp / DBH cm	01	02	03	TOTAL 1-2-3	04	05	06	07	08	09	10	11	12	13									TOTAL 4 +
WB																							
POP																							
SM																							

Tree Studies

Remarks:

Date:

Crew:

FORM 3

SAMPLE PLOT

WEIGHING OF RESIDUES

Plot No: ____________

Date: ______/______/______

Weight of Residues \ Type of Residues		Tree Tops	Branches	Broken Stems	Trees: Dead Diseased
Box	1				
Box	2				
Samples	1				
	2				
	3				
	4				
	5				
	6				

SAMPLE PLOT

Stumps ☐ Residual Trees ☐

Plot No.: ____________ Date: ____/____/____

DIAMETER-HEIGHT

Species															
D	H	D	H	D	H	D	H	D	H	D	H	D	H	D	H

FORM 5

SAMPLING OF RESIDUE

MOISTURE ANALYSIS

Type of residue or slash: ______________________________

DATE (1)	SAMPLE NO. (2)	PLOT NO. (3)	GREEN WEIGHT (air) (grams) (4)	OVEN-DRY WEIGHT (air) (grams) (5)	REMARKS