The impact of whole-tree and conventional harvesting on white birch sites in central Newfoundland: an ENFOR establishment report

B.A. Roberts and B.D. Titus

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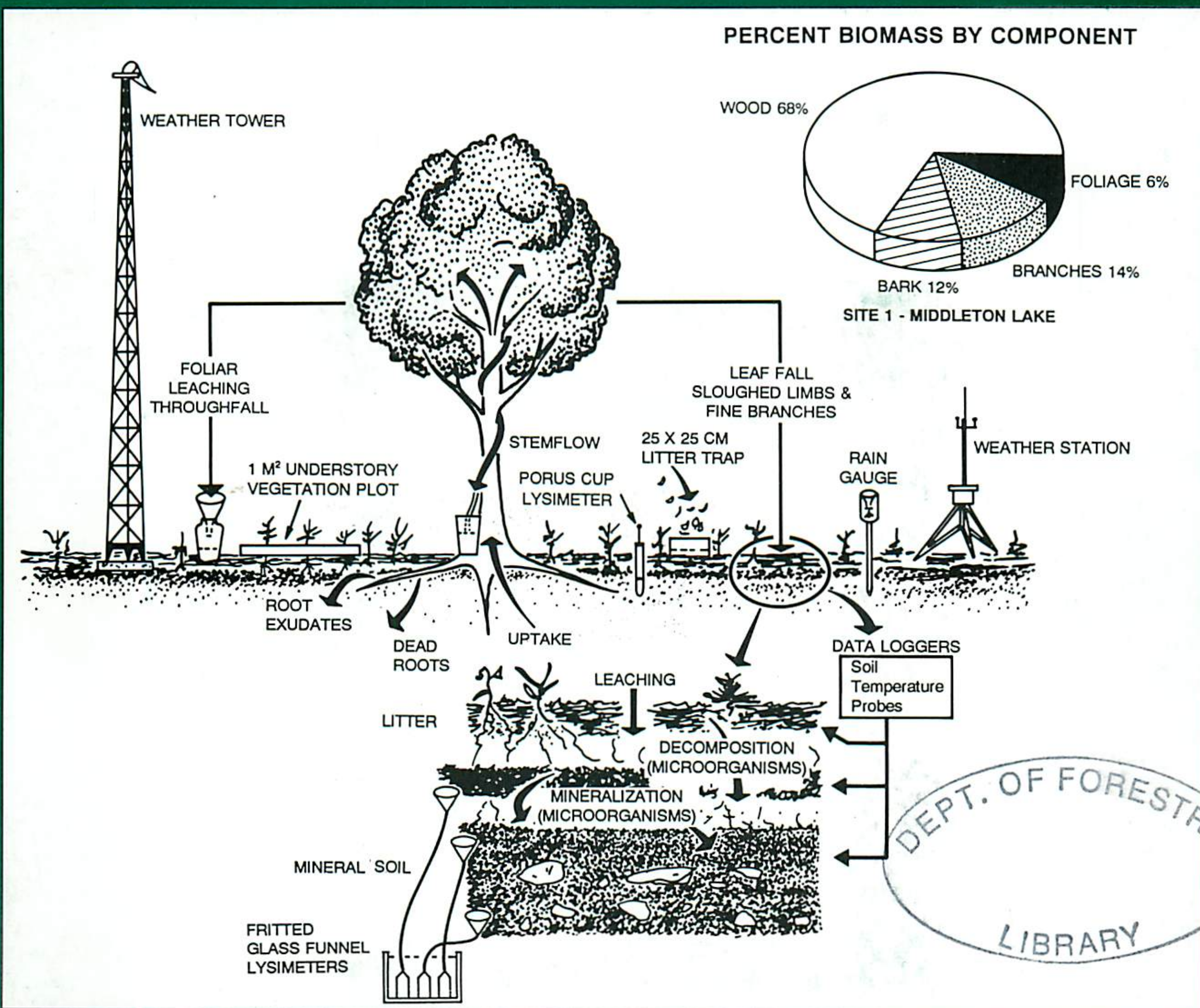

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Cover Caption: ENFOR white birch harvesting experimental instrumentation scheme, central Newfoundland.

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THE IMPACT OF WHOLE-TREE AND CONVENTIONAL HARVESTING ON WHITE BIRCH SITES IN CENTRAL NEWFOUNDLAND: AN ENFOR ESTABLISHMENT REPORT

by

B.A. Roberts and B.D. Titus

NATURAL RESOURCES CANADA
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ABSTRACT

White birch (*Betula papyrifera* Marsh.) makes up about 12% of the total tree volume in insular Newfoundland and is the preferred industrial and domestic fuel wood. It is a major component in all balsam fir (*Abies balsamea* (L.) Mill.) stands on the island and forms pure stands after cutting and wildfire. Little is known regarding the environmental impact of harvesting this species, which often grows on imperfectly drained but high capability sites. This report outlines the objectives and describes the establishment of five major field studies being conducted to assess the impact of whole-tree and conventional harvesting of white birch on future site productivity in central Newfoundland. The five major studies include:

(i) Site selection, experimental layout and biomass inventory;
(ii) Determination of the impact of harvesting on nutrient leaching rates using porous cup, fritted glass plate and zero-tension lysimeters;
(iii) Inventory of understory vegetation and description of disturbance plots and soils;
(iv) Determination of litter and slash decomposition rates;
(v) Quantification of litter production in white birch stands.

Three harvesting treatment plots (whole-tree harvest, conventional harvest, control stand) were established across the slopes in each of three stands of 5 hectares in area or greater in areas in central Newfoundland. Each of the treatment plots were 1 ha in area (100 m x 100 m) and were subdivided into 25 sub-plots (20 m x 20 m). A total of thirty-six 1 m x 1 m quadrats were placed in the lower right-hand corner of each 20 m x 20 m sub-plot, plus along two outside edges of every treatment plot for monitoring vegetation cover and abundance.

Biomass in each treatment plot was estimated before harvesting took place. Wood, branches, bark and foliage made up approximately 66, 14, 12 and 7% of the total biomass, respectively, in all three stands. Total biomass on the three sites was greater than 100 tonnes per hectare. Stem densities ranged from 594 to 2131 stems per hectare, and heights ranged from 10 to 20 m at ages 55 to 60 years.

Nutrients (NH_4-N, NO_3-N, P, K, Ca, Mg, and pH) were measured in rainfall, throughfall and stemflow. Soil solution was sampled using porous cup, fritted glass and zero-tension lysimeters. Litterfall, litter decomposition and slash decomposition were also monitored. Weather stations were established on all 3 treatment plots on one site (Middleton Lake) to develop a hydrological model for later determination of soil nutrient fluxes.

RÉSUMÉ

Le bouleau blanc (*Betula papyrifera* Marsh.) représente environ 12% du cubage total du bois sur pied de l'île de Terre-Neuve; pour l'industrie et le particulier, it est la source préférée de bois de chauffage. Le bouleau forme des peuplements purs après les coupes et les feux de friche, en plus d'occuper une place importante dans les peuplements de sapin baumier (*Abies balsamea* (L.) Mill.) de l'île. On en sait fort peu sur les incidences environnementales de la récolte du bouleau, une essence qui pousse souvent sur les sols mal drainés mais d'un haut niveau de productivité forestière. Le présent rapport décrit les objectifs et la mise en oeuvre de cinq grandes études sur le terrain visant à évaluer les répercussions de la récolte traditionnelle et de la récolte d'arbres entiers en ce qui concerne le bouleau blanc dans le centre de Terra-Neuve:

(i) Sélection, description et inventaire de la biomasse du site expérimental.
(ii) Mesure des incidences de la récolte sur les taux de lessivage des substances nutritives au moyen d'un tensiomètre, d'un entonnoir de verre fritté et de lysimètres san tension.
(iii) Inventaire de l'étage dominé, lopins protégés et échantillonnage des sols.
(iv) Détermination des taux de décompostion de la litière et des rémanents.
(v) Production de litière dans les peuplements de bouleau blanc.

Trois lopins de récolte (récolte d'arbres entiers, récolte traditionnelle, lopin-témoin) ont été créés en travers des versants de chacun des trios peuplements de moins de cinq hectares sélectionnés dans la région centrale de Terre-Neuve. Chacun de ces lopins d'un hectare (100 m x 100 m) a été subdivisé en 25 sous-lopins (20 m x 20 m). Le couvert et l'abondance de la végétation ont été mesurés dans trente-six quadrats de 1m de côté aménagés dans le coin inférieur droit de chaque sous-lopin, ainsi que le long de deux bords extérieurs de chaque lopin.

La biomasse de chaque lopin a été évaluée avant la récolte. Le bois, les branches, l'écorce et le feuillage constituaient respectivement environ 66%, 14%, 12% et 7% de la biomasse totale de chacun des trios peuplements. La biomasse totale des trois sites dépassait les 100 tonnes par hectare. La densité des tiges allait de 594 à 2 131 tiges par hectare et les hauteurs variaient de 10 à 20 mètres pour des arbres de 55 à 60 ans.

Le contenu en substances nutritives (NH_4-N, NO_3-N, P, K, Ca et Mg) et le pH de l'eau de pluie, de l'eau de pénétration par les frondaisons et de l'eau d'écoulement sur l'écorce ont été mesurés. Des solutions du sol ont été échantillonnées avec un tensionmètre, un verre fritté et des lysimétres san tension. Les dépôts de litière, la décomposition de la litière et la décomposition des rémanents ont aussi été évalués. Des stations météo ont été installées sur les trois lopins de traitement d'un emplacement (au lac Middleton), aux fins de l'élaboration d'un modèle hydrologique qui permette le calcul ultérier des échanges de substances nutritives dans le sol.

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ACKNOWLEDGEMENTS

The authors would like to thank Abitibi-Price Inc. and their staff in Grand Falls-Windsor for help with the initiation and harvesting phases of the study, especially R. McKelvie, H. Taylor, F. Rowsell, R. Dwyer, J. Evans and C. Young.

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THE IMPACT OF WHOLE-TREE AND CONVENTIONAL HARVESTING ON WHITE BIRCH SITES IN CENTRAL NEWFOUNDLAND: AN ENFOR ESTABLISHMENT REPORT

by

B.A. Roberts and B.D. Titus

INTRODUCTION

White birch (*Betula papyrifera* Marsh.) is a common component in balsam fir forest types (Meades and Moores 1989), which are the most common forest types in Newfoundland. White birch also forms pure stands after harvesting and wildfire on medium to high quality sites, and in total accounts for some 12% (24 million m^3) of the total tree volume within insular Newfoundland (Dept. of Forestry and Agriculture 1989). White birch has a higher B.T.U. rating than softwoods and stands of this species have been harvested since 1978 for hog fuel for steam generation of electricity at the Abitibi-Price, Inc. mill in Grand Falls-Windsor, central Newfoundland. White birch is also the preferred domestic fuel wood in Newfoundland, and central Newfoundland supplies much of the large demand for the Avalon Peninsula, which in 1983 was estimated to be 34 892 solid m^3 (Northland Associates Limited 1984). The more productive stands of white birch often grow on imperfectly drained sites of low traffic ability but of high capability (Canada Land Inventory Class 3-4). Little is currently known regarding the environmental impact of harvesting birch stands on these sites.

Important aspects of nutrient removal, leaching rates and changes in detrital decomposition rates as a result of harvesting may be obtained by conducting a controlled cutting experiment in which pre- and post-treatment monitoring of nutrient pools and flows are carried out. This information is required if boreal forest stands are to be managed in a sustainable manner. A study was therefore initiated in central Newfoundland in three white birch ecosystems of different site quality to determine the environmental impact of two different harvesting methods (whole-tree and conventional) on future site productivity by quantifying nutrient removals in biomass, by monitoring nutrient leaching and humus decomposition rates, and by determining vegetation successional patterns. The main objectives were: *(i)* to quantify the mensurational characteristics of pre-harvested stands, and the biomass and nutrient contents of vegetation on all three treatment plots per site; *(ii)* to quantify flows of nutrient inputs and outputs in mature stands and adjacent harvested treatment plots; *(iii)* to quantify the effects of harvesting on understory vegetation and soil physical characteristics. Five major studies are outlined and described in this report: *(i)* Site selection, experimental layout and biomass inventory; *(ii)* Determination of the impact of harvesting on nutrient leaching rates using porous cup, fritted glass plate and zero-tension lysimeters; *(iii)* Inventory of understory vegetation and description of disturbance plots and soils; *(iv)* Determination of litter and slash decomposition rates; *(v)* Quantification of litter production in white birch stands. An overall schematic diagram of the instrumentation on the treatment plots and site measurements taken in these five studies is given in Figure 1.

SITE DESCRIPTIONS

In November 1989 three study sites (Middleton Lake, Badger West and Moose Pond) were selected in mature pure white birch stands of approximately 5 hectares in size each near Badger in central Newfoundland (Figures 2 to 5). All three of the white birch stands are typical of the medium to high quality white birch stands found in central Newfoundland. After preliminary analysis of vegetation (Study III below) the sites were classified as being *Dryopteris*-white birch or *Dryopteris-Clintonia*-white birch types, although an element of white birch-aspen was evident at Moose Pond (Table 1). Soils were orthic humo-ferric podsols and orthic gleysols. Seepage occurs over an underlying fragipan on some parts of the Moose Pond site, which is on a moderate (≥ 20%) slope, and on all parts of the Middleton Lake site (< 5% slope). The Badger West site is well drained and on a 10-15% slope. The Middleton Lake site is of the highest site quality, followed by the Moose Pond site and then the Badger West site. This is reflected in the white birch heights and mensurational characteristics (Table 2). All three sites originated from fern rich balsam fir forests after wild fire (Table 3). The Badger area is typical of central Newfoundland and the growing season averages 81 days and 1225.5 degree days ≥ 5.0°C. Average total precipitation is 943.5 mm, with 163.2 mm of that falling as snow (Table 4).

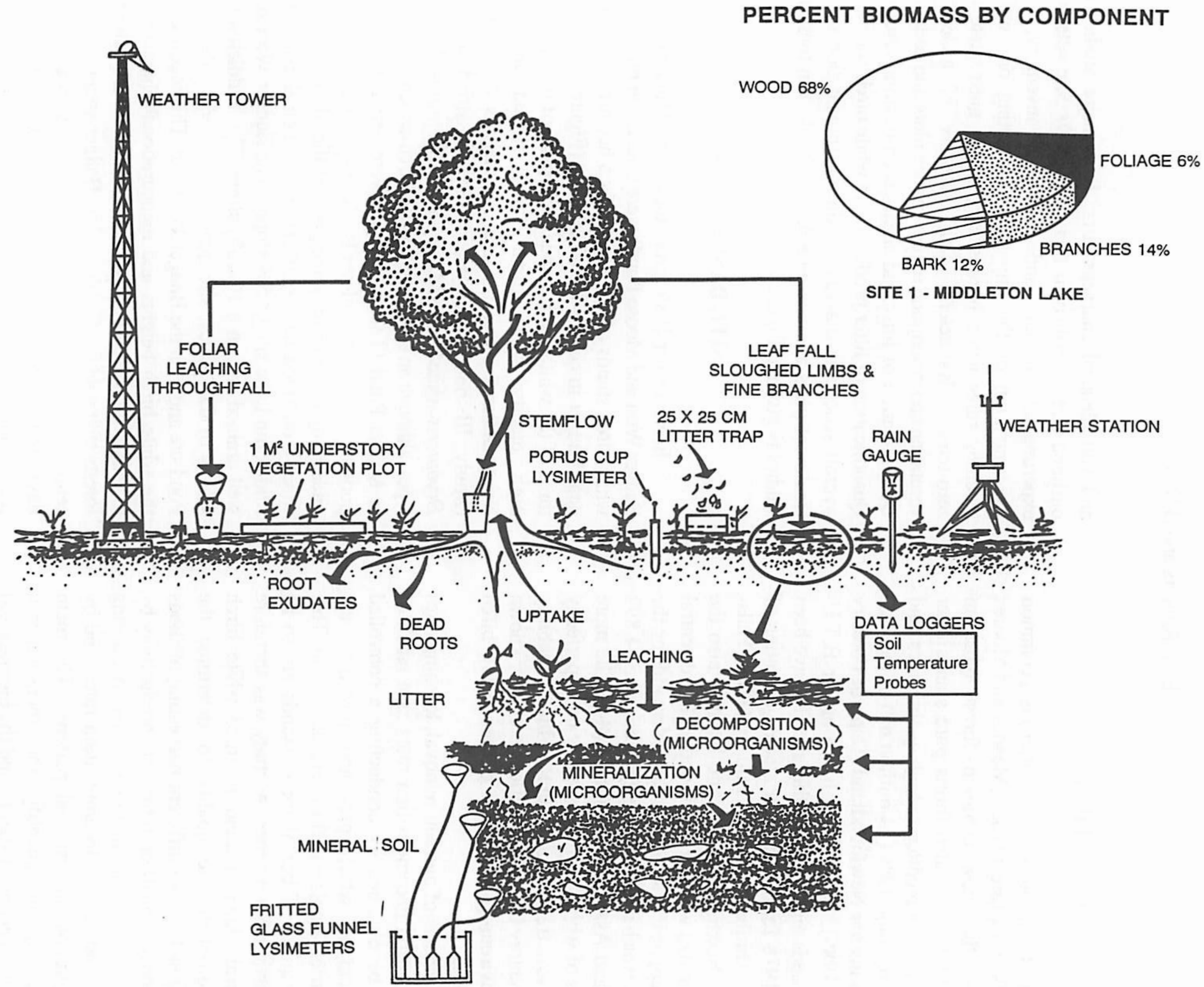

Figure 1. Instrumentation of EnFor white birch harvesting sites, central Newfoundland.

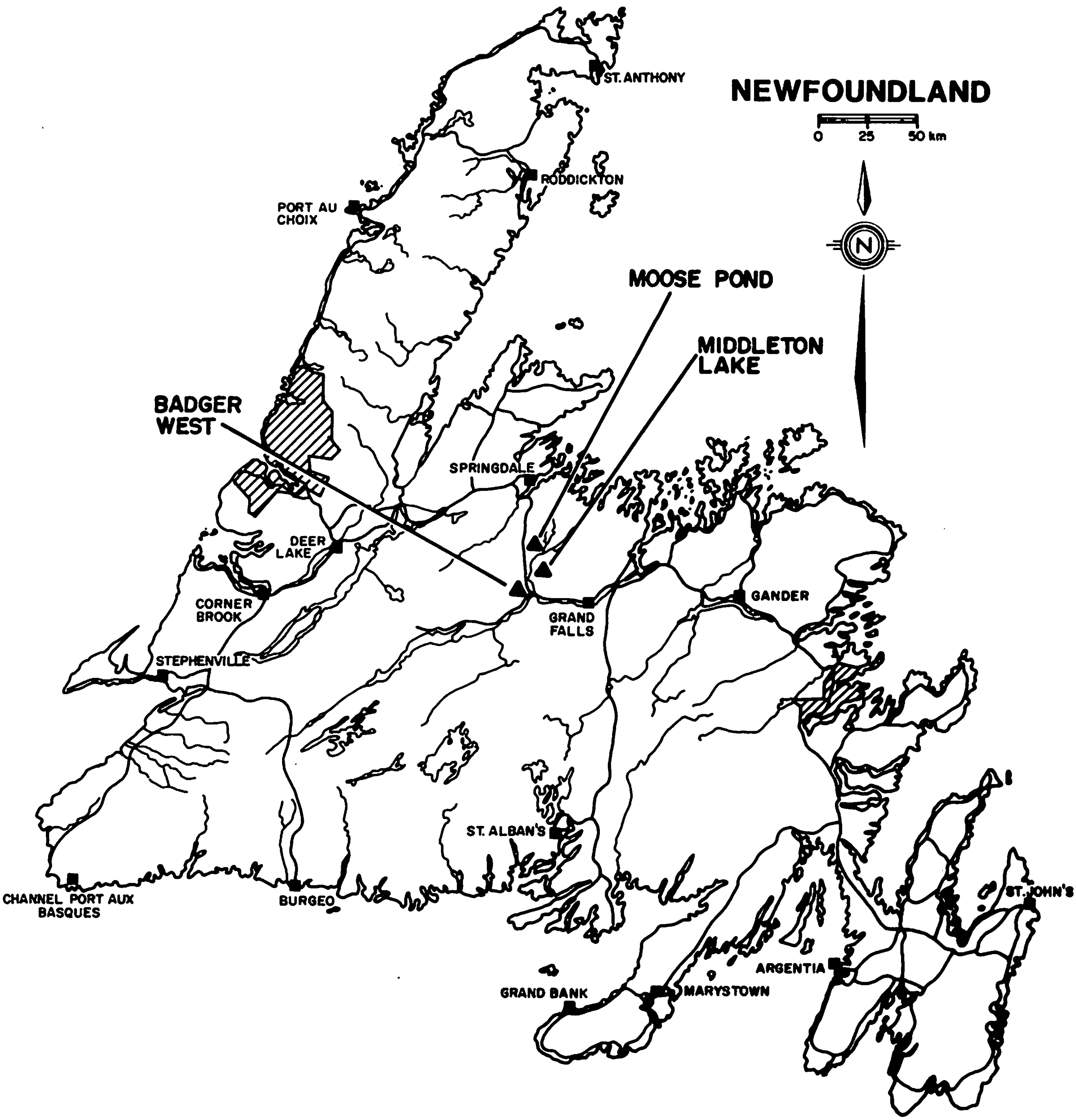

Figure 2. Location of three study sites near Badger, central Newfoundland.

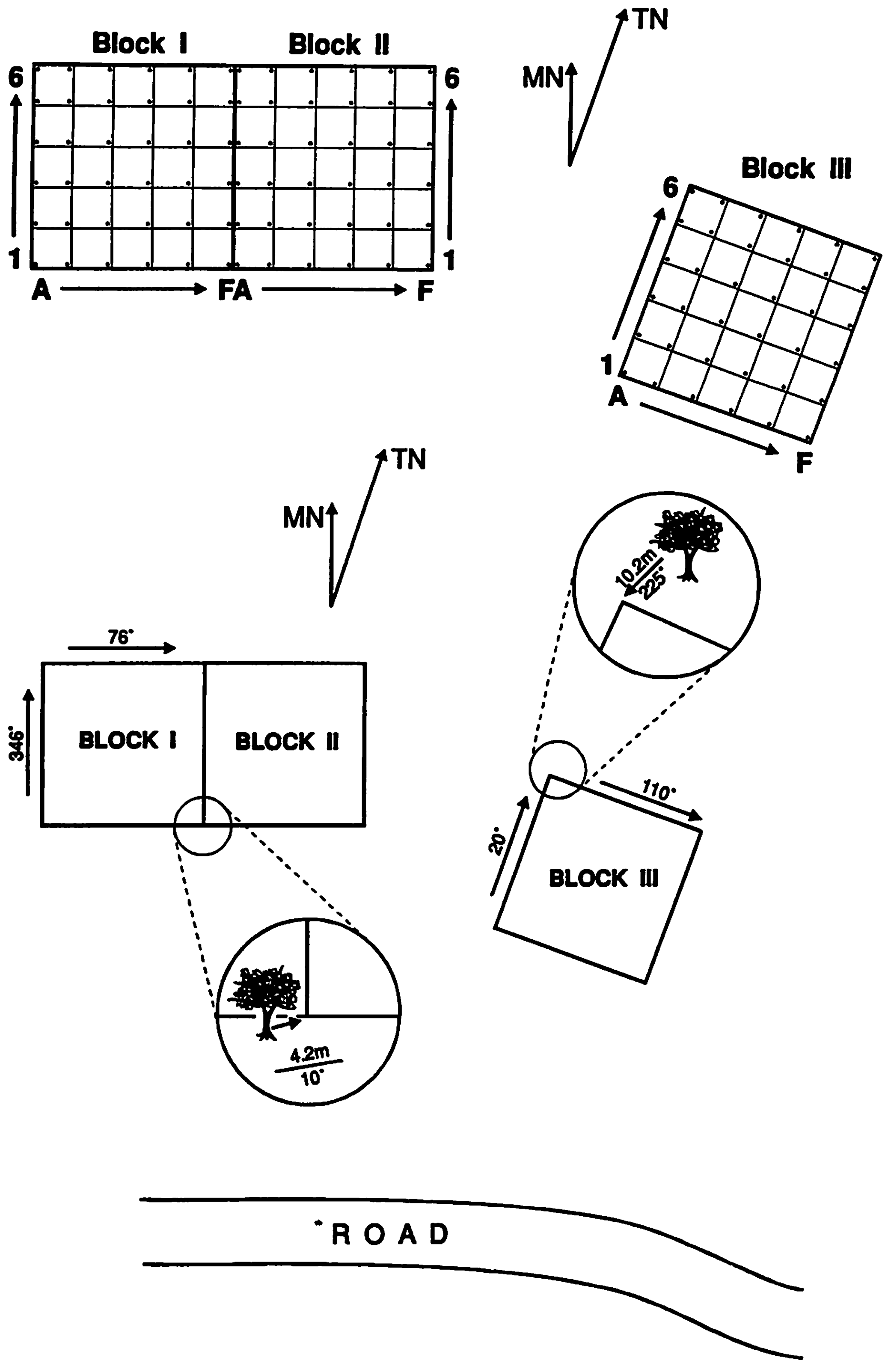

Figure 3. Middleton Lake site map and treatment plot layout.

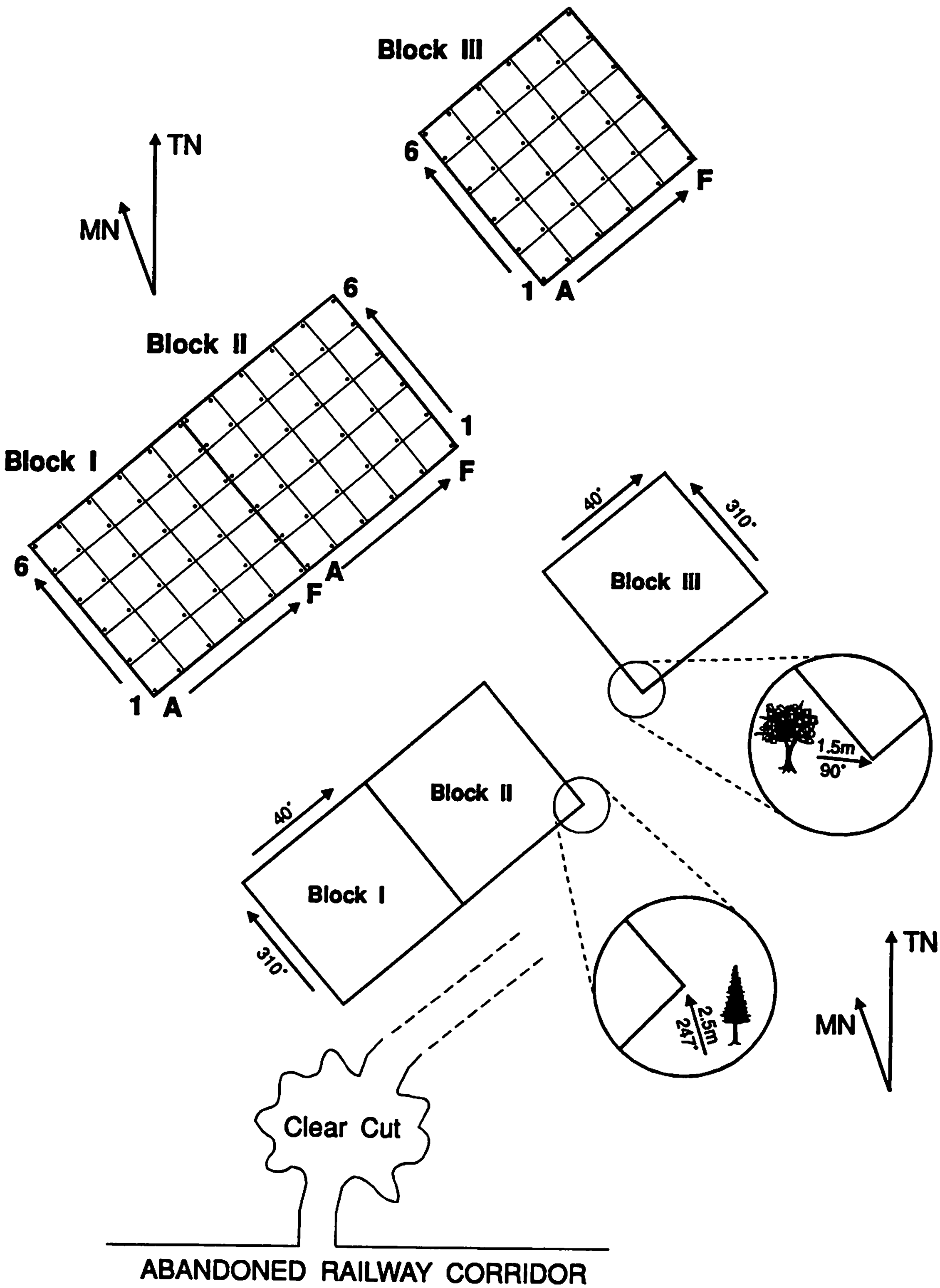

Figure 4. Badger West site map and treatment plot layout.

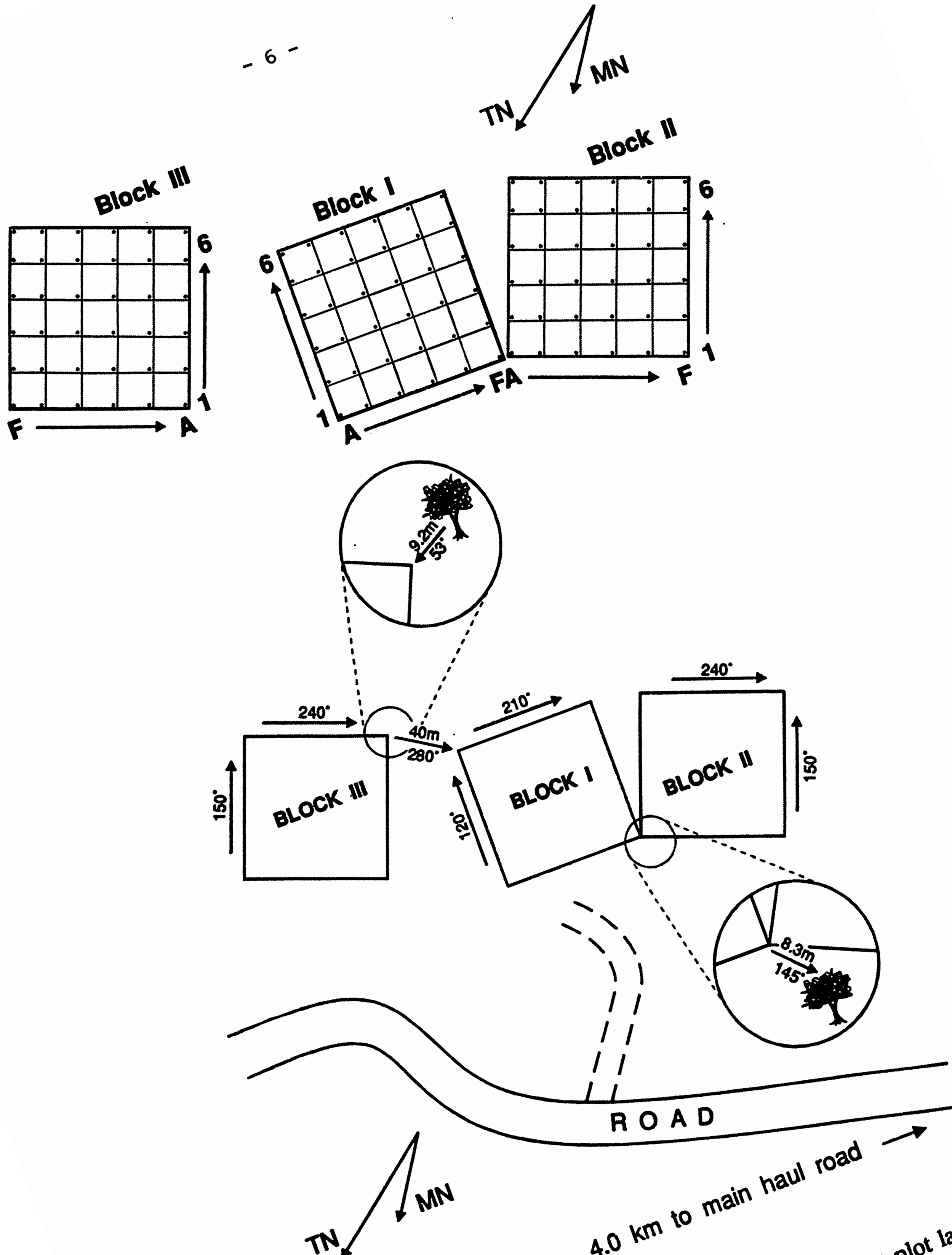

Figure 5. Moose Pond site map and treatment plot layout.

Table 1. Classification of white birch forests in central Newfoundland (*after* Roberts and Bajzak 1984, Meades and Moores 1989).

forest type	forest[a] capability	soil parent materials and landforms	soil[b] drainage	soil subgroup
1. White Birch Forest on unstable soils (Bu)	6 - 7E	Talus and Scree slopes, BC - boulder colluvium	2	Orthic Regosol on unstable boulder colluvium
2. *Rubus* - Birch (Br)	4M	Cx - Colluvium and till. Mp - Morainal Plain, till deposit, gently sloping	4	Gleyed Dystric Brunisol, Orthic Gleysol with seepage
3. *Dryopteris - Clintonia* - Birch (Bdc)	3M - 4M	Mp, Cx, At - Alluvial terrace	2 - 3	Orthic Humo-Ferric Podzol, Gleyed Humo-Ferric Podzol with seepage
4. *Dryopteris* - Birch (Bd)	3M - 2C	Mp, At	3 - 2	Orthic Humo-Ferric Podzol, Gleyed Dystric Brunisol
5. *Kalmia* - Birch (Bk)	5 - GMF	At, Gt - Glacio - fluvial terrace	2	Orthic Ferro-Humic Podzol, with Mor ± weak ortstein
6. Birch - Aspen (Bta)	3M - 4M	Mp, At, Mh - Hummocky moraine, strongly rolling	3	Orthic and Gleyed Ferro-Humic Podzols ± Fragipan

[a] see Meades and Moores (1989)
[b] Canada Soil Survey Committee (1978)

Table 2. Mensurational characteristics of three treatment plots (conventional harvest, whole-tree harvest and control stands) on three white birch sites in central Newfoundland.

site	height[a] (m)	d.b.h.[a] (cm)	stump age[a] (years)	number[b] of trees ha^{-1}		
				minimum	maximum	mean
Middleton Lake						
conventional	15.6 ± 2.3	24.4 ± 6.0	60 ± 5.3	325	1200	688
WTH	15.5 ± 5.1	22.6 ± 4.8	64 ± 6.1	235	1075	681
control	13.6 ± 2.7	22.2 ± 6.1	62 ± 5.0	225	925	594
Badger West						
conventional	12.7 ± 2.7	14.1 ± 4.4	55 ± 6.0	1550	2200	1786
WTH	12.4 ± 1.8	13.6 ± 3.5	51 ± 5.5	625	2575	1794
control	12.4 ± 2.0	13.5 ± 4.0	55 ± 7.0	1725	2675	2131
Moose Pond						
conventional	14.4 ± 2.5	21.2 ± 6.7	54 ± 8.7	600	1200	769
WTH	13.9 ± 2.8	17.9 ± 4.9	54 ± 9.3	500	1500	964
control	15.8 ± 3.2	20.0 ± 5.0	55 ± 8.4	525	975	716

[a] n = 90 (10 trees per 9 (20 m x 20 m) sub-plots per treatment plot)
[b] based on number of trees in 9 sub-plots (20 m x 20 m) per treatment plot

Table 3. Secondary succession of balsam fir forest types in Newfoundland (modified *after* Damman 1964, 1967 *in* Wells *et al.* 1972).

forest type	disturbance	successional type
Rubus-Balsam Fir[a]	Fire	*Rubus*-Birch
Rubus-Balsam Fir	Logging, Windthrow	No Change
Rubus-Balsam Fir (+Mountain Maple)	Fire	(*Galium*-Mountain Maple)[b]
Rubus-Balsam Fir (Mountain Maple)	Logging, Windthrow	*Galium*-Mountain Maple
Dryopteris-Balsam Fir	Fire	*Dryopteris*-Birch
Dryopteris-Balsam Fir	Fire, Logging, Windthrow	(*Galium* Mountain Maple)
Dryopteris-Rhytidia Delphus-Balsam Fir	Fire, Logging, Windthrow	No Change
Dryopteris-Hylocomium-Balsam Fir	Fire	*Dryopteris-Clintonia*-Birch
Dryopteris-Hylocomium-Balsam Fir	Fire	(Black Spruce-Moss)
Dryopteris-Hylocomium-Balsam Fir	Logging, Windthrow	No Change

[a] includes the typical *Rubus*-Balsam Fir and the wet *Rubus*-Balsam Fir types.
[b] brackets indicate possible succession.

Table 4. Climatic features of Badger, central Newfoundland, recorded over a 30-year period from 1951-1980 (Environment Canada 1982).

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
mean monthly temperature (°C)	-7.5	-7.9	-4.2	1.3	6.8	12.5	16.7	15.9	10.9	6.1	1.5	-4.8	3.9
degree-days (≥ 5°C)	0.2	0.1	2.4	9.8	72.7	222.3	354.4	317.1	171.3	60.8	12.4	2.0	1225.5
total precipitation (mm)	67.7	54.3	70.0	48.3	71.4	80.3	91.4	102.1	83.0	105.0	103.2	66.8	943.5
total rainfall (mm)	31.2	17.3	36.4	45.6	65.0	78.8	91.4	103.7	83.2	99.5	93.3	45.1	790.5
total snowfall (cm)	32.3	40.0	37.5	8.6	9.1	1.4	0.0	0.0	0.0	2.5	11.3	20.5	163.2

frost-free days: June 13 to Sept 3 = 81 days

last spring frost: earliest - June 5; latest - June 21

first fall frost: earliest - July 29; latest - Sept 22

EXPERIMENTAL DESIGN

The null hypothesis for the experiment is that harvesting, regardless of method, does not affect nutrient cycling and successional processes. The three treatment plots were laid out in a randomized complete block design with multiple observations per experimental unit:

$$Y_{ijl} = \mu + \tau_j + \beta_i + \omega_{ij\cdot\cdot} + \epsilon_{(ij)l}$$

where Y_{ijl} = response observation
μ = fixed constant
τ_j = treatment effect
β_i = block effect
ω_{ij} = experimental error
$\epsilon_{(ij)l}$ = sampling error
i = 1,..., n where n = number of blocks (3)
j = 1,..., k where k = number of treatments (3)
l = 1,..., m where m = number of observations per experimental unit

and the resultant ANOVA table takes the form:

source of variation	degrees of freedom
treatment	k-1
block	n-1
experimental error	(n-1)(k-1)
sampling error	nk(m-1)
total	nkm-1

DESCRIPTION OF STUDIES

Study I. Site selection, experimental layout and biomass inventory

Objective: To establish three treatment plots on each of the three sites, and to determine the pre-harvest biomass within each treatment plot.

The following field procedures were used to lay out treatment plots on each site:

1. Each of the nine 100 m x 100 m (1 ha) treatment plots were sub-divided into 25 sub-plots of 20 m x 20 m (0.04 ha) (Figure 6).

2. Each sub-plot corner was marked with a numbered stake for easier locating after harvesting (36 stakes per treatment plot).

The following pre-harvest vegetation field data were collected in nine 20 m x 20 m sub-plots forming a cross (+) in the centre of each treatment plot (Figure 6):

1. All trees ≥ 5 cm dbh (diameter at 1.3 m outside bark) were tallied by species and 2 cm diameter classes. Only trees with stumps within the plot boundary were recorded. Living and sound dead stems were separated, and all standing and downed trees not sound enough for skidding were marked with a blaze at breast height but were not tallied.

2. Ten trees of each major species (*i.e.* species which comprised ≥ 25% of the total basal area) were selected to cover the range of diameters (≥ 5 cm dbh) found in the plot. Total height (to the nearest 0.3 m) and dbh (to the nearest 0.1 cm) of each sample tree were recorded.

3. A maximum of five trees of each minor species (*i.e.* species which comprised < 25% of the total basal area) were selected and heights and diameter obtained as above.

On each 5 m x 5 m (0.0025 ha) quadrat nested within each sub-plot (Figure 6) more detailed vegetation data was obtained:

1. All woody vegetation < 5 cm dbh and ≥ 1.3 m in height was tallied.

2. Three stems of each species were randomly selected, and heights and diameters were measured.

The total biomass per hectare was computed for stemwood, stem bark, branches and foliage by species and 2 cm dbh classes for each treatment plot using conventional methods and biomass equations developed in Newfoundland for white birch (Lavigne 1982).

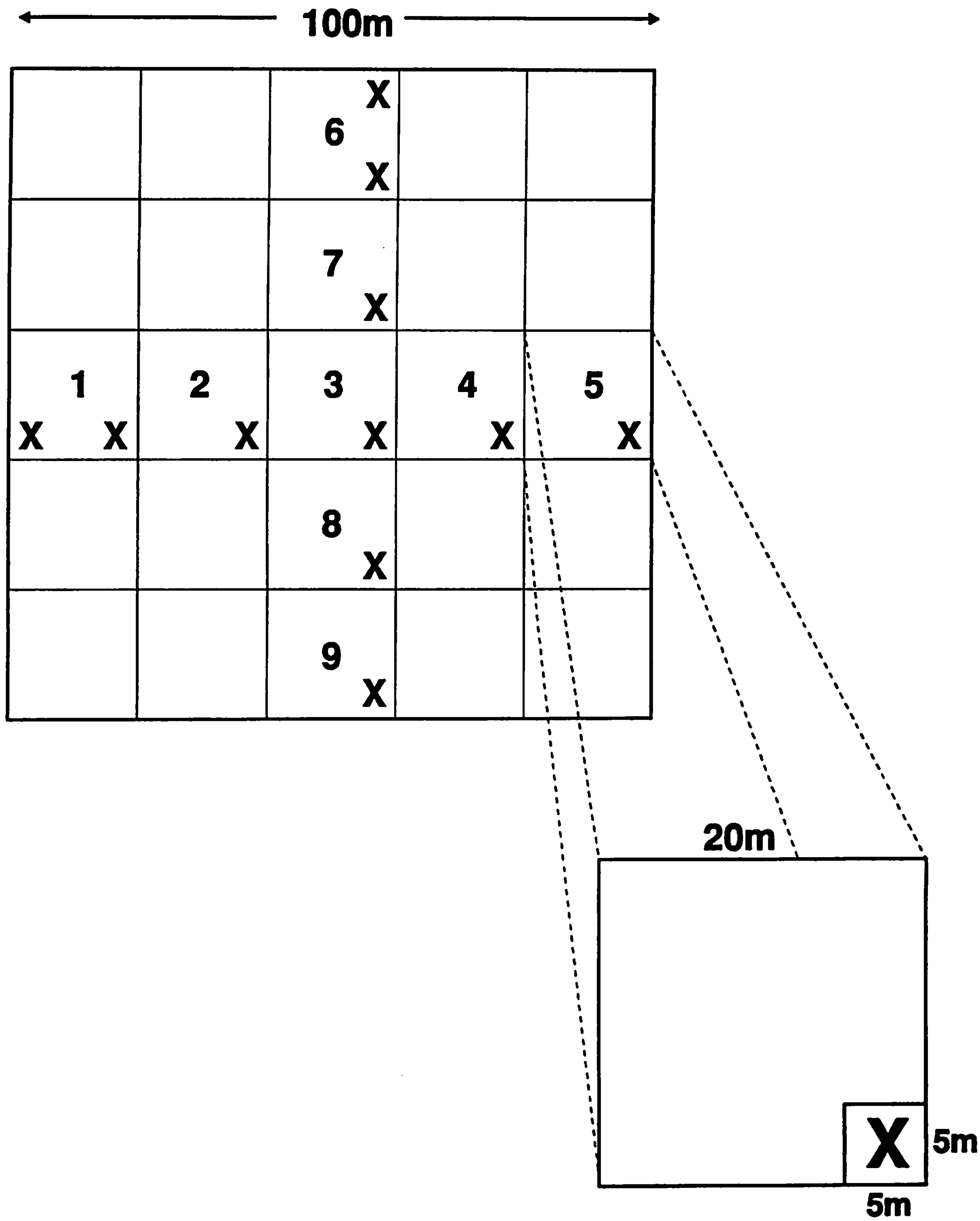

Figure 6. Location of nine 20 m x 20 m sub-plots for biomass study.

Study II. Determination of the impact of harvesting on nutrient leaching rates using porous cup, fritted glass plate and zero-tension lysimeters

Objective: To determine the impact of harvesting on nutrient leaching rates using porous cup (Figure 7), fritted glass plate (Figure 8) and zero-tension lysimeters (Figure 9).

This study required preparing and randomly installing 108 porous cup lysimeters[1] (12 per treatment plot x 3 treatment plots per site x 3 sites). Porous cup lysimeters were installed in 10 cm diameter holes augured to a depth of 50 cm. A slurry of sieved soil was packed around the porous cup, and then the hole was backfilled with sieved soil corresponding to the appropriate horizon within the hole. A tension of 50 kPa (50 centibars) was applied to the lysimeters, and soil solution was collected every two weeks. For the winter season, the cork assemblies were removed and the tops of the lysimeters were securely sealed to prevent the entry of rain and snow, thus guarding against possible damage from freezing.

In addition, 54 fritted glass plate lysimeters[2] (2 per horizon x 3 horizons per sampling location x 1 sampling location per treatment plot x 3 treatment plots x 3 sites) were installed in the centre of each treatment plot (Figure 10). The fritted glass plates were installed horizontally from the sides of installation pits (1.5 m x 1.5 m x 1 m deep). Soil profile descriptions and samples by horizon were taken from each installation pit, which were located in the centre of each treatment plot. Glass plates were installed under the LFH, Ae and upper B horizons on two adjacent faces of each pit. Small diameter tunnels were dug horizontally for an arm's length. Sieved soil from the tunnel was used to make a slurry, which was placed on top of the fritted glass plates. The plates were then pressed against the ceiling of the tunnel, and the tunnels were backfilled. The horizontal tunnels were not dug directly below each other, but were off-set to minimize experimental error caused by soil disturbance. In the winter the fritted glass plates were filled with alcohol (95% ethanol) to prevent freezing (Figure 7). A hanging water column was used to maintain a tension on each fritted glass plate as water siphoned from an elevated 4 L bottle to a second 4 L collection bottle situated 1 m below the first (after Riekerk and Morris 1983).

Two zero-tension lysimeters were installed beneath the LFH horizon at each fritted glass installation pit. The zero-tension lysimeters were constructed from plastic trays with a screen and drainage outlet, and thus possessed 4 vertical walls. An excised soil humus horizon was placed in each tray, and the tray counter-sunk so that the surface of the humus inside and outside the trays was at the same level. Leachate was collected by gravity in a collection bottle at a lower elevation.

Throughfall was collected using 15 cm diameter funnels fixed to the top of 4 L bottles. These were placed on the forest floor at 12 randomly located positions in each of the control plots. Stemflow was collected using split garden hose spiralled around the tree trunks through which water was channelled to 20 L bottles or buckets (Figure 11). Four each of representative dominant, co-dominant and intermediate trees were sampled per control plot. Rainfall was sampled using the same collectors as for throughfall. Four samplers were placed on each of the whole-tree and conventional harvested treatment plots on each of the three sites. Throughfall, stemflow and rainfall measurements were used to estimate nutrient inputs to the sites.

Water samples from all of the above instruments were collected every two weeks for immediate laboratory analysis of NH_4-N, NO_3-N, P, K, Ca, Mg and pH.

Study III. Inventory of understory vegetation and description of disturbance plots and soils

Objective: To quantify understory vegetation and to determine soil humus type.

Percent cover of all vascular and non-vascular understory plants was estimated using 1 m^2 quadrats laid out systematically along five 20 m transects every 20 m in each of the 1 ha treatment plots as outlined in Study 1 (Figure 3), for a total of 36 quadrats for each 1 ha treatment plot. In addition, 36 phytosociological lists of the ground vegetation were made, centred on the 1 m^2 quadrats, and were analyzed using the modified Braun-Blanquet technique (Damman 1964) to define vegetation associations. This vegetation analysis was performed using both phytosociological tables and ordination techniques. All quadrats were permanently marked with metal pins at each corner. Percent cover in each of the 1 m^2 quadrats is measured and photographed annually.

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[1] Soil Moisture Equipment model 1900-100L24 soil water sampler, with round-bottomed cup of B2M2 ceramic. All cups were washed prior to use by drawing approximately 1 L of 1 M HCl through the porous cup, and then rinsed by drawing through several washings of distilled water. Samplers were modified by replacing the small connecting sleeve in the neoprene stopper with a rigid tube of polycarbamate that extended to the bottom of the porous cup. A tension of > 50 kPa (centibars) was applied with a hand-pump to remove water samples with a vacuum trap. This same tension was then adjusted back to 50 kPa and the pinch clamp closed again, so that sample removal and application of tension were carried out in one step, thus facilitating field operations.

[2] Available from Verre H and S, 44 Anwoth Rd., Westmount, Québec, Canada, H3Y 2E7

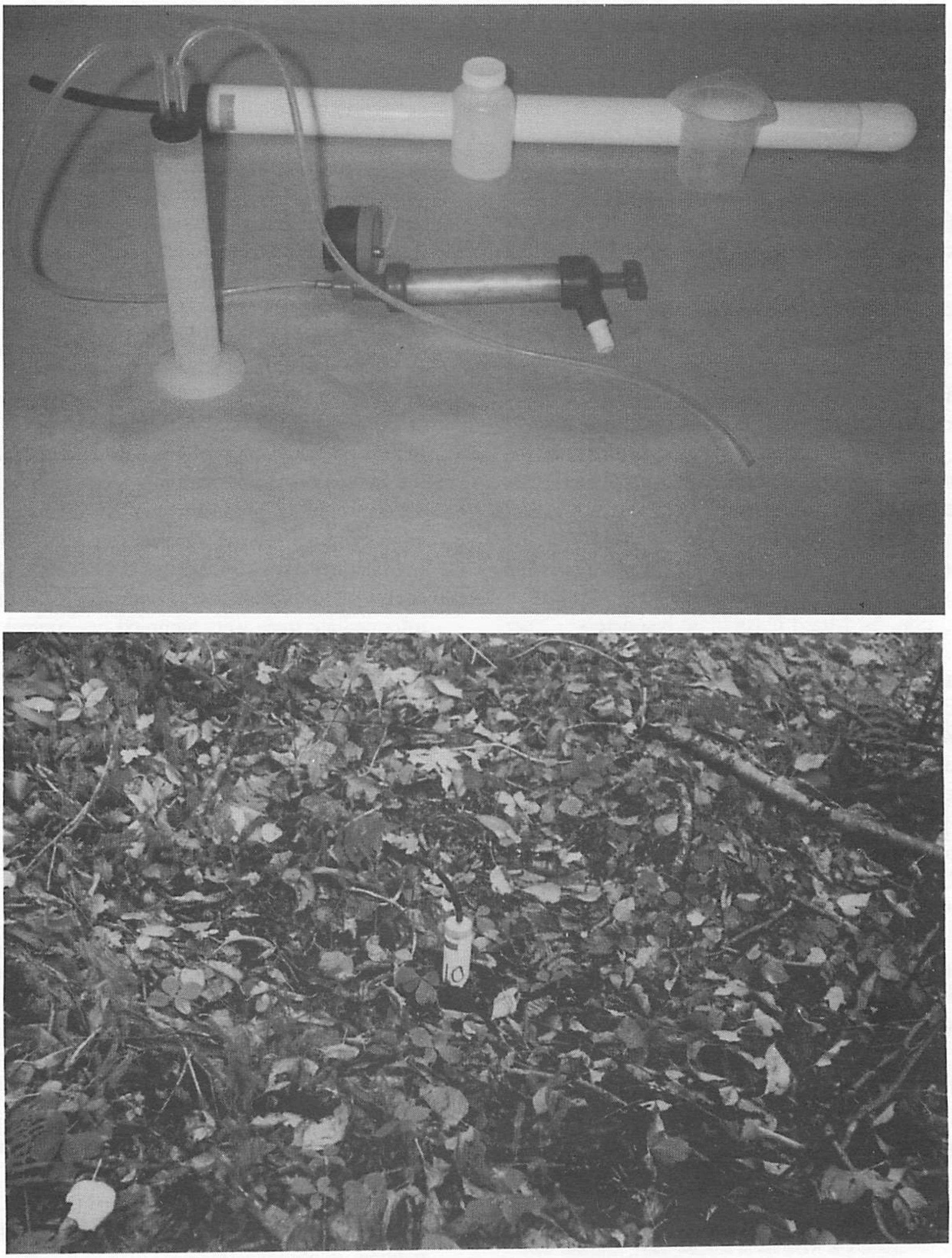

Figure 7. Porous cup lysimeter: (a) lysimeter with hand pump and vacuum trap sampler; (b) lysimeter installed to 50 cm in white birch control treatment plot.

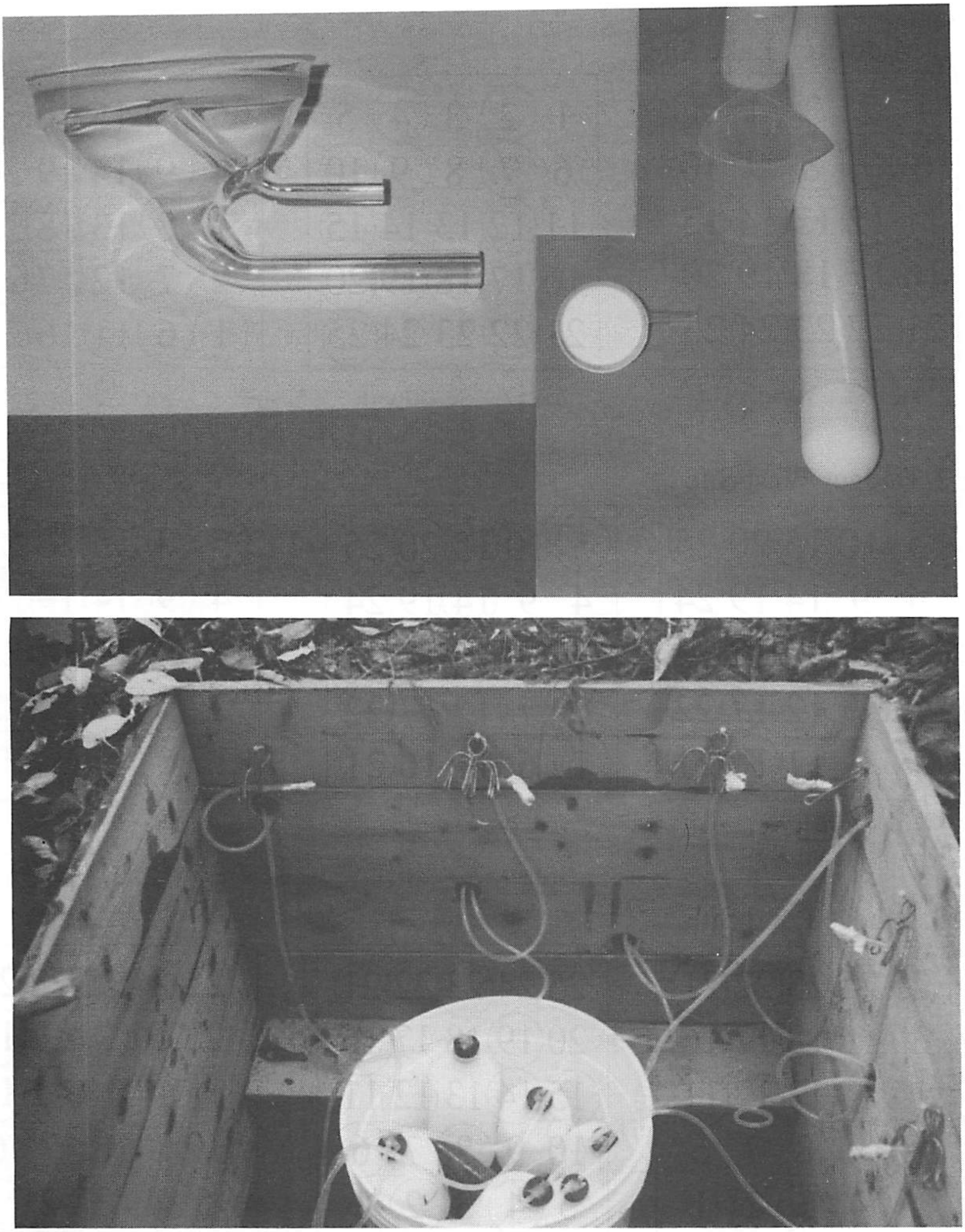

Figure 8. Fritted glass funnel lysimeter: (a) fritted glass compared to porous cup; (b) finished installation pit, with tubing connecting fritted glass plates to sample collection bottles; note installation on both pit faces.

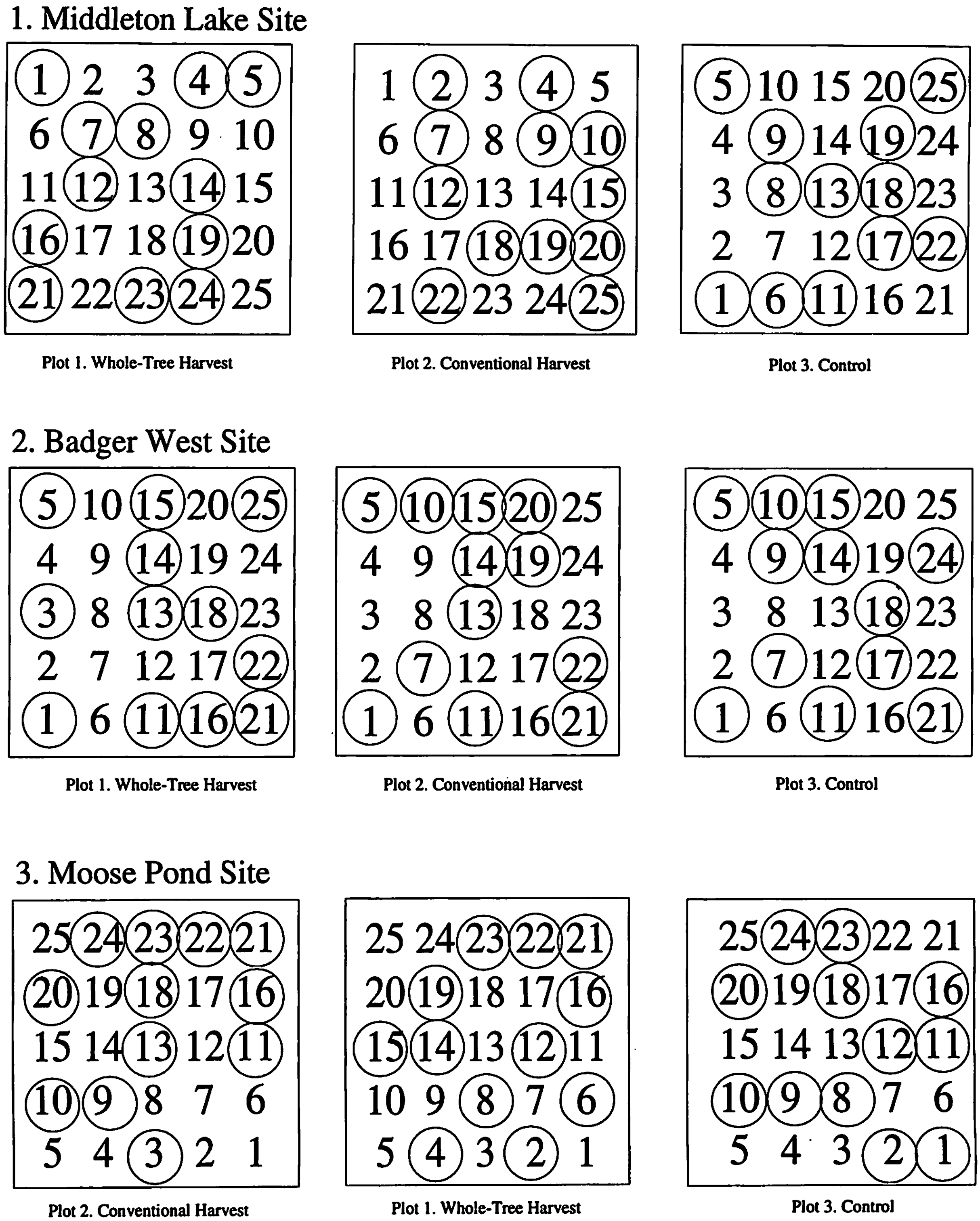

Figure 9. Porous cup lysimeter random installation locations

Figure 10. Zero-tension lysimeter in the field.

Figure 11. Stemflow appartus.

At each of the 36 quadrats (1 m^2) per 1 ha treatment plot (Figure 6) the humus was sampled using a 10 cm diameter steel cylinder. Humus depth was recorded at 4 points in the resultant hole, and humus was classified by type (Bernier 1968). Humus samples were dried and prepared for a subsequent nutrient analysis.

Study IV. Determination of litter and slash decomposition rates

Objective: To determine the rates at which white birch leaf litter and slash decompose.

Introduction: Decomposition is the process by which decaying biomass is reduced to its fundamental components, thus returning previously immobilized nutrients to the available soil nutrient pool. In this EnFor study there are two "pulsed" inputs of detritus that are of interest: *(i)* annual leaf litterfall under the control stands, and *(ii)* the slash left on the conventional harvest treatments. A quantification of nutrient return to the available soil nutrient pool through decomposition of annual litterfall will help to describe part of the annual nutrient budgets for undisturbed stands. In the case of the harvested treatments, the difference between the two treatments is the presence or absence of slash, which represents a potential long-term nutrient source on the clearcut treatment that is absent from the whole-tree harvested treatment. Hypothetically, it might be expected that any increase in nutrient leaching through the soil in conventional harvested treatments as compared with whole-tree harvested treatments might be explained in part by the rate of nutrient mobilisation from this slash pool.

However, not all differences in nutrient leaching will be simply a function of pulsed inputs of detritus. The decomposition of the humus will also be an important source of leached nutrients, and rates of release will be a function of decomposition rates, which in turn will be a function of microclimate, as well as substrate quality. It can thus be assumed that the forest floor in each of the three treatments will experience different microclimates as a result of the presence of a mature canopy, or the lack of a canopy but presence or absence of the moderating influence of slash. It would be reasonable to hypothesize that the greatest range of temperature and moisture extremes would be found on the whole-tree harvested sites, followed by the conventional harvested sites, and then the undisturbed control stands. The influence on decomposition will then be dependent on the effect of the different microclimates on decomposer populations. Although the use of litterbags and tethered slash can be used to quantify decomposition of pulsed inputs, the substrate quality of leaves resulting from natural abscission and harvesting will be different and are thus not directly comparable. Further, there is no input of leaves to whole-tree harvested sites with which to compare treatments. The decomposition of a standard material (*i.e.* white birch veneer strips) will thus be used to compare all three treatments. The quantification of the decomposition of cellulose either through weight loss (Binkley 1984) or loss of tensile strength (Harrison *et al.* 1988; Latter and Shaw 1988) has been used elsewhere in similar studies. However, cellulose is an easily decomposable substrate and thus not representative of the more recalcitrant fractions of organic matter that make up much of the forest floor. Also, the former technique requires very careful cleaning of the material, and the latter technique requires specialized equipment. The use of white birch veneer strips partially overcomes some of these objections as the wood will contain recalcitrant fractions, and is easy and economical to use.

1. Decomposition of leaf litter in control stands: A collection of leaf litter was made at the onset of litterfall in the autumn in the control stands on each of the three sites (Oct. 1991 at Middleton Lake; Oct. 1992 at Badger West and Moose Pond). Leaves were collected in nets suspended between trees or retrieved from the surface of an unseasonably early snowfall before they could be leached by rain or come into contact with the soil surface. All leaves were air dried to a constant weight, and approximately 10 g were weighed out, the exact weight recorded, and the leaves were placed in 15 cm x 15 cm small-meshed (1 mm x 1 mm) litterbags made of "Bridal veil" material.

Twenty bags were laid out in 1 m x 1 m plots at 10 randomly selected collection stations at each of the three sites to allow for annual collections for 10 years. Samples were retained for determinations of moisture content and initial nutrient content. All samples were transported to the field in paper bags. A check of the paper bags after litterbag layout indicated that no measurable quantities of leaves were lost through the mesh, and therefore no correction factor was needed to account for lost fragments in transport.

2. Decomposition of slash in conventionally harvested treatments: A collection of slash was made immediately after felling on each of the conventionally harvested treatment plots and samples were laid out to air dry. Leaves were then removed, and the woody slash was divided into 3 categories: twigs, small branches (< 2.5 cm) and large branches (≥ 2.5 cm). Samples from the two branch size categories were cut into 30 cm lengths before drying.

Approximately 10 g of leaves were weighed out after drying, the exact weight recorded, and placed in litterbags

(15 cm x 15 cm) in two different series based on two different mesh sizes. The first series were constructed of small-mesh material with a square mesh size of 1 mm ("Bridal veil"). The second series were constructed with a bottom of small-mesh but a top of large-mesh material with a hexagonal mesh size of 3-4 mm ("tulle"). Two mesh size series of twigs were likewise constructed, but using approximately 20 g of twigs. The two mesh sizes were used for the slash decomposition study as a compromise in the problem of defining appropriate mesh size. There is no "ideal" litterbag mesh size, because if a mesh is too small, important decomposer organisms can be excluded and weight loss under-estimated, but if a mesh size is too large, detritus can be lost from the litterbag during handling, and weight loss over-estimated. Financing did not allow for repeating the mesh size trial in the control stands.

In each of the two size categories of branches, samples were graded to give as uniform a morphological form as possible. Five small branches were bundled together after their combined weight was recorded, as well as their individual diameters (2 reading) at both ends. Single samples were used for the large category, and lines attached after weights and diameters at the ends of the segments were recorded. All branch samples were tethered rather than confined in litterbags.

Samples were retained from each category of slash for determination of moisture and initial nutrient concentrations.

Ten random collection stations were established on each of the three conventionally harvested treatment plots. Enough litterbags and tethered branches were laid out in 2 m x 2 m plots for samples to be collected annually for 10 years. All samples were transported to the field in paper bags. A check of bags after litterbag layout indicated that no measurable quantities of leaves were lost through the mesh, and therefore no correction factor was needed to account for lost fragments in transport. The litterbags and tethered slash were laid back out in the field as soon as possible after slash collection.

3. Decomposition of standard material in the forest floor in all treatments: White birch veneer strips (1.8 cm wide x 14.75 cm long) that had been commercially prepared for use as tongue depressors[3] were used as a standard material for comparing decomposition rates in the humus of all treatments on all sites. A small hole was drilled in one end for tethering, and strips were numbered with a felt pen and weighed after being oven dried to a constant weight at 105°C (24-48 hrs). Any strips that cracked as a result of drying or which were stained or anomalous in any way were discarded. Nylon fly fishing line was tied to a strip, threaded through two more strips, and an aluminum "Dymo" label attached so that three strips could be inserted at different levels in the humus profile (just beneath the humus surface, halfway down the humus profile, and at the humus/mineral interface) at each of 12 random sampling locations on each of the 3 treatment plots on each of the three sites. Strips were inserted by making a vertical cut in the humus with a shovel, pushing the strips in horizontally at the appropriate depth, and closing the cut with a firm press with a foot. Strips were put out in the spring and retrieved in the fall, as past experience has shown that some strips can totally decompose in a full calendar year. Strips were carefully cleaned to remove adhering soil, re-dried to a constant weight at 105°C, and re-weighed.

Study V. Quantification of litter production in white birch stands

Objective: To quantify foliar nutrient content, litterfall and associated nutrient flows.

Foliage, as estimated using biomass equations from this study, accounts for about 6% of the total tree biomass, and in these pure stands can exceed 1 tonne ha^{-1}. Green foliage was sampled every two weeks to estimate nutrient reserves in different crown classes in order to give estimates of potential nutrient removal in foliage for whole-tree harvesting during different stages of the growing season. Twelve small (63.5 cm x 63.5 cm) and 12 large (1 m^2) litter traps were placed in each control stand to estimate litter production and to determine how litterfall was distributed across the control stands.

[3] Wooden tongue depressors (Senior 6") manufactured by John Lewis Industries Ltd., 10300 Ray Lawson, Montreal, Quebec, HIJ IM1. The white birch is obtained from an approximately 160 km radius of their mill in Latuque, northern Quebec. White birch trees are winter harvested and cut into 140 cm logs, thawed in the mill, re-cut to 67 cm logs and veneered in sheets 1.8 mm thick. Tongue depressors are then stamped out of 3-4 sheets of green veneer, and dried in a rotary drier at 104.4°C for 1 hr to remove interstitial water and lower water content to approximately 9%. Soapstone fragments are added for the drying process to lightly "polish" the strips as they are tumble-dried. All strips are inspected on packing, and cracked and stained ones are removed. Strips for use in the food industry (*e.g.* "popsickle" sticks) were deemed to be unsuitable, as these are coated with a very fine layer of USDA-approved wax to prevent them sticking together in industrial processes.

PROGRESS TO DATE

The sites were located and treatment plots were laid out in November 1989. The biomass survey was begun, and site conditions were assessed.

Lysimeters (108 porous cup, 54 fritted glass, and 18 zero-tension) were installed in 1990. Leachate collections were made from June until November 1990. White birch veneer strips were used to evaluate decomposition rates over the summer. Throughfall and stemflow water samples were collected, and litter traps were used to quantify litterfall. Automated weather stations were installed on all three treatment plots on the Middleton Lake site.

The work continued in 1991 and 1992 much as in the previous year, with the exception that porous cup lysimeters on the harvesting treatment plots were removed prior to cutting (mid-August to mid-September 1991) and then re-installed afterwards. Harvesting was carried out using chainsaws, and wood was forwarded by contractors from Abitibi-Price using a conventional wheeled skidder. Sampling was completed after harvesting to determine the quantities of slash left on the conventional cutting treatment plots on each of the three sites. Additional measurements of stand characteristics, stem analysis and height/age were also completed. Vertical and oblique air photos were taken from a helicopter after cutting, using two different film combinations to estimate slash, ground disturbance and drainage changes after sites were harvested.

Preliminary results indicate that there was little variation in white birch biomass between pre-harvested treatment plots on any given site and between the 3 sites. Total white birch biomass varied from 92 to 133 tonnes ha^{-1} and averaged more than 105 tonnes ha^{-1}. Total biomass of all species showed more variation due to the occasional presence of aspen (*Populus tremuloides* Michx.) white spruce (*Picea glauca* Moench Voss.) and black spruce (*Picea mariana* Mill. B.S.P.). The biomass data from central Newfoundland are comparable to above ground estimates of 100 to 120+ tonnes ha^{-1} for white birch in Alaska (van Cleve *et al.* 1983) and compare favourably with estimates of 108 tonnes ha^{-1} for northern boreal stands dominated by white birch (Rutkowski *et al.* 1993).

Foliage accounted for 5-8% of the total biomass, branches accounted for 12-14% of the total biomass, bark 11-12% and wood 66-68% of the total above-ground biomass.

The Badger West site had the greatest stem density (1786-2131 stems per ha^{-1}) followed by the Moose Pond site (716-964 stems per ha^{-1}) and the Middleton Lake site (594-688 stems per ha^{-1}). The Middleton Lake site had the greatest height/diameter 15 m/22 cm dbh. Stand ages ranged from 55 to 60 years for all three sites (Table 2).

SUMMARY

This report outlines the objectives and describes the establishment of five major field studies being conducted to assess the impact of whole-tree and conventional harvesting of white birch on future site productivity in central Newfoundland. The five major studies include:

(i) Site selection, experimental layout and biomass inventory;

(ii) Determination of the impact of harvesting on nutrient leaching rates using porous cup, fritted glass plate and zero-tension lysimeters;

(iii) Inventory of understory vegetation and description of disturbance plots and soils;

(iv) Determination of litter and slash decomposition rates;

(v) Quantification of litter production in white birch stands.

Biomass in each treatment plot was estimated before harvesting took place. Wood, branches, bark and foliage made up approximately 66, 14, 12 and 7% of the total biomass, respectively, in all three stands. Total biomass on the three sites was greater than 100 tonnes per hectare. Stem densities ranged from 594 to 2131 stems per hectare, and heights ranged from 10 to 20 m at ages 55 to 60 years.

Similar studies are being carried out elsewhere in black spruce (Gordon *et al.* 1993) and jack pine stands (Jeglum pers. comm.[4]) in Ontario and mixedwood stands in New Brunswick (Mahendrappa 1990) and other stands of commercial importance in the Maritime Provinces (Mahendrappa and Kingston 1994). These studies will complement past work (Weetman and Webber 1972, Gordon 1983, Maliondo 1988, Maliondo *et al.* 1990) in determining the environmental impacts of different harvesting methods in major Canadian ecosystems.

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