## Appendix C:

### PERFORMING A FOREST STAND INVENTORY

This Appendix has been abridged from:
*Making Cents out of Forest Inventories: A guide for small woodlot owners.* Science Development and Transfer Series No. 002. Copies of this publication are available from the OMNR Natural Resources Information Center in Peterborough, Ontario. Telephone: 1-800-667-1940; French: 1-800-667-1840. Fax: (705) 755-1677
email: mnr.nric@mnr.gov.on.ca. webpage: www.mnr.gov.on.ca

This document provides more specific information than this appendix. It includes discussions about the prerequisite skills for conducting forest inventories (e.g., how to map significant features, measure and mark trees, design and locate a sample plot, and compile the forest inventory data).

The main steps to performing a stand inventory are briefly described below. Readers are urged to work through the tables and the calculations.

#### *Step 1:*

#### Obtain all important background information about the site

This information will be used to establish property boundaries, prepare management and forest compartment maps, and plan forest operations.

Useful maps include:

- topographical maps
- Forest Resource Inventory (FRI) maps, available from the OMNR
- Ontario Base Maps, available from the OMNR
- County Soils maps are available from Ontario Ministry of Agriculture, Food, and Rural Affairs (OMAFR)

Other useful information includes:

- aerial photographs (black and white or color infrared) of the site and surrounding landscape, available from the Natural Resources Information Center (1-800-667-1940)
- past land use information (previous and local landowners are often sources of this information)
- local climatic information (e.g., frost-free days, rainfall), available from Environment Canada and OMAFRA offices
- Canada Land Inventory information and maps, available from Environment Canada in Ottawa
- wildlife habitat information, available from local OMNR and Conservation Authority offices

- location of rare species, available from OMNR district ecologists
- forest management and silvicultural background information contained in various *Extension Notes* that are available from the Landowner Resource Center in Manotick, Ontario (1-800-387-5304)

### Step 2:

### Begin to prepare maps of site

The site boundaries are mapped. Use one transparent overlay for each site resource (e.g., forest cover, soils, roads, topography, water, important wildlife habitat) to map major zones and combine these to develop an overall map of the site. This process helps to identify the resource potential of site, identify potential conflicts, and visualize some effects of proposed forestry activities.

### Step 3:

### Decide on more specific information to collect

Information that is most commonly collected includes:

- tree species composition and distribution across the site
- overall health and quality of trees
- tree age, diameter, size (DBH)
- stand height, density, volume
- site characteristics and their location (e.g., soil type, drainage, topography, access, microclimates, potentially sensitive areas)
- environmental sensitivity of the site and parts of the site to potential logging damage
- significant wildlife habitats (e.g., raptor nests, patches of conifer cover, woodland ponds, seepage areas)
- presence of rare species or species of conservation concern (e.g., plants such as ginseng, declining species, nesting birds of conservation concern)
- history of the forest (e.g., past management, natural disturbances such as fire, storms)

### Step 4:

### Design the forest inventory cruise

The most important components of a typical forest inventory cruise are:

- the number and location of sample plots

- the provision of accurate information that reflects the character of the forest stand on the site

In general, more plots are required for variable terrain and when more accurate information is required. Also a larger budget for an inventory is usually allotted for sites with high timber value. Sampling intensity varies from 0.5 to1 % of the total woodlot area for a reconnaissance survey of large forested areas, to approximately 2 to 10 % of the total area of smaller woodlots.

The number of sample units required depends on the sampling intensity and size of the sample unit. The most popular plot size used in forest surveys is 0.04 hectares. If it is circular, this plot has a radius of 11.28 meters.

A commonly used formula to calculate sampling intensity is:

*SI % = AS (hectare)/AR (hectare) X 100 %*

where: SI % = sampling intensity in percent
AS = total area to be sampled, in hectares (i.e., total area of sample plots)
AR = total area represented by the sample, in hectares (i.e. total area of woodlot)

An example (from *Making Cents out of Forest Inventories*):

The circular 0.04 hectare sample plot will be used to sample a woodlot of 4 hectares in area with a sampling intensity of 5 %. Use the formula from above,

5 % = AS (hectare)/4 (hectare) X 100 %

to derive AS (hectare) = 0.25 hectare/0.04 hectare

= the total area to be sampled

Take this result and divide it by the area of 1 plot (0.04 hectare) to get the number of required plots, always rounding up (i.e., 0.25 hectare/0.04 hectare = 6.25 plots, rounded up to 7 plots required to provide slightly higher than a 5 percent sampling intensity).

There are several ways to locate the sample plots. Normally plots are placed at equal distances along lines across the site (i.e., transects), with equal distances between the lines in a layout designed to cover the entire forested area. Usually the distances between plots and lines are equal, but they can vary.

To calculate plot and line intervals, the amount of forest represented by one1 sample plot is required and is the product of the plot and line intervals.

Using the above example with 5 % sampling intensity and 0.04 hectare plots:

5 % (or 0.05) = 0.04 (hectare)/ AR (hectare) X 100 % and re-arranging this to get

AR (hectare) = 0.04 hectare/ 0.05 = 0.8 hectares or 1 plot is 0.80 hectare or 8000 $m^2$

If the line interval were to equal the plot interval, the value would be the square root of 8000 $m^2$ which is 89.44 meters, an inconvenient distance. However this could be reduced to 80 meters for the plot interval and 100 meters for the line interval (80 m X 100 m = 8000 $m^2$).

On a map, a line starting from an area boundary such as a road and running through the center of the forested area is drawn. A second line is placed at right angles to the first line at the middle of the stand. Other lines can be offset from these 2 lines at the required distance to create a grid and sample plots are placed at the line intersections. Wherever possible, it is preferable that these cruise lines run against the contour lines (i.e., up and down hills rather than along ridges).

Plot centers should be marked with small stakes or flagging tape and fixed area sample plots should be clearly demarcated to ensure accurate data collection.

## Step 5:

## Collecting data

At the center of each plot, suggested measurements/calculations for the plot include:

- basal area per hectare (BA) by species, to help interpret the composition and density of trees in the stand
- soil depth, texture, and moisture regime
- descriptions of dominant understory vegetation
- significant wildlife habitats (e.g., nest, mast, or cavity trees)
- presence and description of environmentally sensitive areas (e.g., intermittent streams, seepage areas).

Within each sample plot, suggested measurements for each tree include:

- tree species
- tree diameter, measured at 1.3 meters above the ground, above a specified minimum DBH (e.g., all trees greater than or equal to 10 cm in DBH)
- tree age
- tree height and/or merchantable tree length
- tree condition (e.g., stem and crown quality, presence of insects or disease). Often trees are coded as AGS or “acceptable growing stock” or UGS or “unacceptable growing stock”
- wildlife value (e.g., presence of cavity holes, stick nests, snags, conifer patches, seeps, mast trees)

## Step 6:

## Recording data

Forest inventory tally sheets are used to record collected data accurately and legibly. See **Table C-1** entitled "Forest Inventory Tally Sheet for Fixed Area Plot Cruise" from *Making Cents out of Forest Inventories*.

## Step 7:

## Compiling forest inventory data

Data from the tally sheets is used to create stand, stock, and estimate tables, as well height/diameter curves for each species on the site.

## Step 8:

## Creating a stand table

A stand table converts stem counts from sample plots to estimates of the number of trees per unit area (e.g., hectare) by diameter-class. The method used depends on the type of sample unit. Using the same example from Step 4:

*Woodlot size:* 4 hectares

*Plot size:* 400 $m^2$ (0.04 hectares)

*Plot radius:* 11.28 meters

*Plot type:* Fixed Area

*Sampling Intensity:* 5 %

*Number of plots to be measured:* 7

Use **Table C-2** entitled "Multi Species Stand Table" to summarize all DBH data, grouped into 2 cm DBH classes, starting at the 11 cm DBH class (i.e., **10 cm to 11.99 cm**). Smaller diameter DBH classes could be included but they will contribute little additional volume. Values in this table are presented only to show how data is recorded.

Use the following formula to calculate the conversion factor that will be used with fixed area plots, to convert the stem count for the plots by diameter-class to the number of trees per hectare:

$$\text{Stem count (per hectare by DBH class)} = \frac{\text{stem count (DBH class)}}{\text{number of plots}} \times \frac{1.0}{\text{plot size (hectare)}}$$

$$= \frac{\text{stem count (DBH class)}}{7} \times \frac{1.0}{.04}$$

For the example described above, the conversion factor is 3.6.

To calculate the trees per hectare by DBH class, multiply each stem count for all plots by the conversion factor of 3.6, rounding values to the nearest whole tree.

(e.g., Stem count (per hectare by DBH class) = Stem count (DBH class) x 3.6)

## Step 9: Creating height-diameter curves

Height-diameter curves are used to calculate the volume of a particular tree species in a stand. In forest stands with numerous species and no single dominant species, height-diameter curves can still be created by combining some species.

From the sample tree data, some merchantable lengths and diameters are known, but not for all size classes found in the stand, and there is no height data for most of the trees measured for diameter. However, to estimate volume, tree heights must be estimated by deriving a height-diameter curve and using the estimated height-diameter relationships in volume equations. It is only necessary to estimate tree height for each diameter-class. The following guidelines can be used to develop a height-diameter curve:

- Record separately and by species, the merchantable lengths (or total height) and associated diameters of selected trees.
- Using standard metric graph paper, mark DBH values in cm along the *x* axis (horizontal) in increments of 2 cm, beginning from 0 and extending 10 cm beyond the largest tree. Mark tree height values in meters along the *y* axis (vertical), beginning at 0 and extending 10 meters beyond the height of the tallest tree. See **Figure C-1**.
- Mark a data point at 0 cm DBH and 1.3 m that will be the beginning of the height curve. Plot the DBH and height values for each tree.
- Draw a smooth curve through the middle of the data points, trying to assure that all data points above the curve are the same distance away from it.
- If unsure where to place the curve, it is preferable to draw it slightly lower than higher. Then all heights estimated from the curve will be lower, resulting in lower rather than higher volume estimates.

To improve the curve, consider adding another anchor point by calculating and then plotting the Quadratic Mean Diameter (QMD). After this value is calculated, the height of a tree or trees in the stand with this DBH must be measured.

To calculate the QMD:

1. Square the DBH class value by species (A) to get a $DBH^2$ value (B) (e.g., 11 x 11=121).
2. Multiply the value in (B) by the tree count for all plots (C) for that DBH class to get the value (D) (e.g., 121 x 5= 605).

3. Add all the squared values in (D) to get the sum of the squared values (E).
4. Divide the sum of the squared values by the total number of trees used in step 2.
5. Take the square root of the value obtained in step 4, to get the QMD for hard maple.
6. Measure a sample of trees with this QMD value to find their average height.
7. Plot these coordinates (i.e., *x* axis value is QMD; *y* axis value is average tree height).

## Step 10:

## Creating a stock table

A stock table combines stand and volume table information to estimate timber volume per hectare. The following steps and **Table C-3** entitled "Multi Species Stock Table" provide an example of how stock tables are produced and used.

Fill out fields #s 1-9 as outlined in **Table C-2**, the "Multi Species Stand Table."

Field # 10 of **Table C-3**- Average tree height

Record the average tree height, by species, for each diameter-class for which a volume calculation is desired. The average height of the diameter-class is required when using the Form Class 79 Table (**Table C-4)** to calculate individual tree volumes.

Field # 11- Merchantable volume per tree ($m^3$)

Use the Form Class 79 standard or a local volume table (**Table C-4)**, to record the volume per tree ($m^3$). This form class table provides an estimate of gross merchantable volume for all coniferous and deciduous species.

Field # 12- Trees per hectare

Transfer these values from Field # 11 of **Table C-2**, for each species by DBH class.

Field # 13- Merchantable Volume per hectare ($m^3$) by DBH class for each species

To create this table, the following formula is applied to each DBH class by species:

Volume (per ha for DBH class) = tree volume (in $m^3$ for DBH and merchantable length) x stem count (DBH class)

Where: Tree volume = volume obtained from the Form Class 79 volume table **(Table C-4)** for the appropriate tree species and DBH class

Multiply the value recorded in Field # 11 (merchantable volume per tree in $m^3$) by Field # 12 (trees per hectare) and record the product.

Field # 14- Fuelwood volume per hectare

This refers to the tree tops (i.e., unmerchantable volume) that can be used for fuelwood. Since this normally represents about 80 % of the merchantable volume, the fuelwood conversion factor is 0.8.

Multiply the merchantable volume value recorded in Field # 13 by 0.8 and record the product in Field # 14.

Field # 15- Merchantable volume by DBH class for all species

Record the sum of the values recorded in Field # 13 for all species by DBH class.

Field # 16- Fuelwood volume by DBH class for all species

Record the sum of the values from Field # 14 for all species by DBH class.

Field # 17- Stems per hectare by species for all DBH classes

Record the sum of the values from Field # 12.

Field # 18- Merchantable/fuelwood volume per hectare by species

Record the sum of the values from Field # 13 to obtain the sub-total of merchantable volume per hectare by species. Do the same for Field # 14 to obtain the sub-total of fuelwood volume per hectare by species.

Field #19- Merchantable volume per hectare for species

Record the sum of the merchantable volume per hectare summed values from Field # 15**.**

Field # 20- Fuelwood volume per hectare for all species

Record the sum of the fuelwood volume per hectare (summed values obtained from Field # 16).

## Step 11:

## Compiling data to create estimate tables

**Table C-5**, “Estimate Table for Wood Volume”, and **Table C-6**, “Estimate Table for Basal Area” incorporate information from the stand and stock tables to provide estimates of wood volume and basal area respectively for the entire woodlot.

**Table C-5** can be used to estimate the wood volume for the woodlot.

Fields # 8- Woodlot size (hectares)

Record the size the woodlot in hectares.

Field # 9- Tree species

Record both the alpha and numerical codes for each species (see **Table C-7** “Trees of Ontario”). Use more than one tally sheet when there are more than 3 tree species.

Field # 10- DBH class (centimeters)

The DBH classes in this table have been set at 2-cm intervals beginning with the 11-cm DBH class because trees with smaller diameters do not contribute significantly to volume calculations. DBH classes can begin at any level.

Field # 11- Merchantable volume per hectare

Transfer the values recorded in Field # 13 of **Table C-3**, the “Multi Species Stock Table” to the appropriate DBH class in **Table C-5.**

Field # 12- Merchantable volume for the woodlot

Multiply the valued recorded in Field # 11 of **Table C-5** by the woodlot size in Field # 8 and record the product.

Field # 13- Fuelwood volume per hectare

Transfer the values recorded in Field # 14 of **Table C-3** to the appropriate DBH class in **Table C-5.**

Field # 14- Fuelwood volume for the woodlot

Multiply the value recorded in Field # 13 of **Table C-5** by the woodlot size and record the product.

Field # 15- Trees per hectare

Transfer the values recorded in Field # 12 of **Table C-2**, the "Multi Species Stand Table" to the appropriate DBH class in **Table C-5**.

Field # 16- Total trees for the woodlot by DBH class by species

Multiply the value recorded in Field # 15 of **Table C-5** by the woodlot size and record the product.

Field # 17- Total merchantable volume for the woodlot by DBH class

Sum values recorded in Field # 12 of **Table C-5** for each species and record this value.

Field # 18- Total fuelwood volume for the woodlot by DBH class

Sum values recorded in Field # 14 of **Table C-5** for each species and record this value.

Field # 19- Total trees for the woodlot by DBH class

Add up the values recorded in Field # 16 of **Table C-5** for each species and record the sum**.**

Field # 20- Total trees for the woodlot by species (stems)

Add up the values recorded in Field # 16 of **Table C-5** for each DBH class by species and record the sum.

Field # 21- Total merchantable/fuelwood volume for the woodlot by species

Add the values recorded in Field # 12 for each DBH class by species to obtain the total merchantable volume for the woodlot by species. Also add the values recorded in Field # 14 for each DBH class by species to obtain the total fuelwood volume for the woodlot by species. Record this sum.

Field # 22- Total merchantable volume for the woodlot for all species

Add the values recorded in Field # 21 for each species to obtain the total merchantable volume for the woodlot for all species and record this sum.

Field # 23- Total fuelwood volume for the woodlot for all species

Add the values recorded in Field # 21 for each species to obtain the total fuelwood volume for the woodlot for all species and record this sum.

Field # 24- Total stems for woodlot

Add the values recorded in Field # 20 for each species to obtain the total number of trees in the woodlot. Record the sum.

**Table C-6** can be used to estimate the basal area of the woodlot.

Field # 11- Basal area per tree

Record the basal area per tree for all diameter-classes found in the woodlot.

Field # 12- Trees per hectare

Transfer these values from Field # 12 in **Table C-3.**

Field # 13- Basal area per hectare

Multiply each basal area per tree value recorded in Field # 11 by the trees per hectare value recorded in Field # 12 to determine the basal area per hectare for each DBH class by species. Record the product.

Field # 14- Total basal area per species for the woodlot

Multiply the basal area per hectare value recorded in Field # 13 by the total woodlot size (in hectares) recorded in Field # 8. Record the product.

Field # 15- Total basal area for the woodlot

Add all the values recorded in Field # 14 for each DBH class for all species and record this sum.

Field # 16- Basal area per hectare

Add all the values recorded in Field # 13 by DBH class and record this sum. This value is the total basal area per hectare by species.

Field # 17- Basal area for the woodlot

Add all the values recorded in Field # 14 by DBH class and record this sum. This value is the total basal area by species for the woodlot.

Field # 18- Total basal area per hectare

Add all the values recorded in Field # 16 and record this sum. This value represents the total basal area for all species per hectare.

Field # 19- Total basal area for the woodlot

Add all the values recorded in Field # 17 and record this sum. This value represents the total basal area for all species for the entire woodlot.