Inventorying Christmas Trees in Natural Stands

Prepared for the Christmas Tree Council of Nova Scotia

by

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Introduction

Christmas tree cultivation, formerly under the Department of Natural Resources, has recently been recognized as an agricultural commodity. One of the major objectives of this project is to develop an efficient mapping and sampling procedure for Christmas tree growers that would meet the inventory requirements of business risk management programs under the Department of Agriculture. Accurate maps and inventories will aid growers in many other aspects of Christmas tree cultivation.

Partial funding for this project was provided by Agriculture and Agri-Food Canada through Agri-Futures, Nova Scotia’s Canadian Agricultural Adaptation Program (CAAP) Council.

Department of Agriculture Programs available to Christmas Tree Growers

There are various programs through the Provincial Department of Agriculture, Federal Department of Agriculture and Agri-food Canada, and the Nova Scotia Federation of Agriculture.

Most of the Provincial Programs are available for a limited time and have closed for the 2013/4 year, but growers should check the website (www.gov.ns.ca/agri) or call the local office for details.

The Federal Department of Agriculture and Agri-Food Canada programs that may help growers are the Advanced Payment Programs, AgriInvest, AgriStability and AgriInsurance. Growers should check their web site www.agr.gc.ca.

The Federation of Agriculture has various programs such as the Environmental Farm Plan, and this year they offered a sprayer calibration program. The web site is http://www.nsfa-fane.ca or phone 902-893-2293.

Although coverage to Christmas tree growers is not currently provided by the Nova Scotia Crop & Livestock Insurance Commission ("Crop Insurance"), we understand that the Christmas Tree Council of Nova Scotia will be pursuing this in the near future.

Determining a Mapping Strategy

An important first step in obtaining an inventory of Christmas trees is to map the land being inventoried and to determine the area of that land. Two basic methods of mapping were considered. One was the use of aerial photography with some ground truthing and the other was the use of a GPS (Global Positioning System) and GIS (Geographic Information System) software.

The use of aerial photography was tried on one woodlot. Although it can be a great tool to assist with mapping it was decided not to focus on it as an important tool for growers for some of the following reasons. It would be very difficult for a photo interpreter (who wasn't the grower) to delineate accurately on a photograph which areas are in Christmas tree production. For example, on the lot we looked at an area had been taken out of production but the interpreter would have no way of knowing that from looking at the photo alone. It would be difficult for a grower to work with photos on his/her own. There are certain 'GIS' skills that are required to work with photos. Once the photography has been obtained and the Christmas tree boundaries delineated the photographs would have to be geo-referenced and then the stands digitized before maps could be produced and areas determined. These GIS skills and the supporting mapping software are not available to most growers. There was some thought given to having a GIS person work with a grower and have them send digital versions of photos and maps back and forth but this was considered too cumbersome. Aerial photography can be a valuable tool to growers in many ways but for the purpose of this sampling project it was decided to focus on the use GPS and GIS.

The method settled on was using a GPS (Global Positioning System) unit to walk and/or drive the boundaries of the Christmas tree stands and then to produce maps and determine areas using a combination of GPS software and GIS (Geographic Information System) software. The growers can map and determine areas themselves using the GPS units purchased for this project and free downloadable software and upgrade the maps by sending files to an office with GIS capability.

Choosing a GPS unit and Mapping Software

<u>GPS Unit</u>

There are a wide variety of GPS units available which can be, for purposes here, grouped into four categories.

1) Non-ruggedized consumer devices - an example would be a Smartphone or tablet computer with an integrated GPS receiver. These units can be utilized for navigation and basic data collection but are susceptible to damage from water, dust and shock. These units generally utilize integrated software and are relatively simple to use. These devices are inexpensive.

2) Ruggedized consumer devices - examples include devices from Garmin, Magellan and Delorne. These devices are generally resistant to water, dust and shock. They are primarily designed for navigation and collection of basic GPS data (points and lines without attribute data). These units use integrated software exclusively and are simple to use. These devices are inexpensive.

3) Professional Grade devices - examples include Trimble GeoExplorer series and Juniper Archer series. These devices are typically ruggedized. They utilize a windows operating system, typically Windows Mobile 6.x. These devices require additional software to be purchased (selected based on the end use application). These devices allow for the collection of more precise data with attribute collection linked to the data collected. These devices are somewhat to very expensive depending on the features selected. They require in-depth specific training to utilize effectively.

4) Survey grade devices - very precise when used correctly by a trained individual. These devices are very expensive and utilize proprietary software. Precision exceeds the requirements of this sampling procedure.

We chose a Garmin Montana 600 unit. This is a "higher end" device within the ruggedized consumer category. This device is simple to use, has a large, bright, touch screen display, is readily available, includes all of the software required and has a "home" screen that can be customized to display only the features require for the sampling process. This device has free software available to transfer the data collected from the device to a computer.

A consumer device was chosen over a professional device due to reduced cost and complexity. A ruggedized device was chosen over a non-ruggedized device due to the environment it will be utilized in.

GIS Software

The Garmin BaseCamp software described in the appendix was chosen based on its ability to interface with the GPS unit chosen, the simplicity of the interface and cost (free).

The software chosen is very basic, but allows for editing of data, printing of maps and exporting of data in a format that can be utilized in a more sophisticated GIS software application.

This software is available for Windows (XP or later) and Mac (10.6 or higher) operating systems running on a variety of computers. This allowed one piece of software to be utilized and supported regardless of the computer preference of the grower.

More advanced analysis of the data and creation of a database containing data collected on all of the lots sampled could be carried out utilizing ArcGIS software from Esri.

GPS Methodology

The GPS device will be used to determine the area of the lot to be sampled and to record the location of the sample points.

The grower will receive the device and ensure the battery is completely charged. They will then proceed to the lot to be sampled. Turn on the unit, wait for the device to track a sufficient number of satellites to provide a position, and then turn on the GPS track log.

The GPS track log will record where the grower walks and can be used to determine the area of any closed traverse the grower walks around.

The grower will clear the track log to ensure points from a previous lot will not be utilized in the area calculation. They can then walk around the area to be sampled and using the Area Calculation tool can determine the area. The track log can then be saved for reference during sampling, mapping and submission of the completed sample.

The grower can then display the track on the map for reference during sampling. A waypoint will be marked at sample location.

When all of the areas to be sampled have been measured and all of the sample points recorded, the device can be turned off and returned to the office.

Once in the office the data collected can be transferred from the device to the grower's computer and sent to the program coordinator.

Inventory Design and Methodology

Attributes to Sample

A grower can of course sample any attribute of his or her tree lot that they deem of interest. For the purpose of this project discussions were held with various Christmas tree growers and with personnel from Crop Insurance regarding which attributes to sample.

It was decided to sample tree lots for the stocking of regeneration (below 4 feet) and for the density of Christmas trees (above 4 feet). It was decided to sample the trees above 4 feet in 2-foot height intervals (4 to 6 feet, 6 to 8 feet, etc). This category was further subdivided into marketable or nonmarketable this year (see sample tally sheets Appendix "C" & "D").

The sampling procedures discussed below are very general and should be modified to take account of a grower's particular cultivation practices and inventory needs. Any inventory that is to be used for crop insurance purposes should of course be reviewed with the Department of Agriculture to reconfirm that it meets their requirements once a plan has been created.

Stocking of Regeneration

Stocking is used to determine how many of the 'areas' or sites that are available for regeneration are actually occupied by acceptable regeneration. For example, if a grower were attempting to establish seedlings every 6 feet each tree would occupy 36 square feet and there would be room for 1210 of these 'areas' per acre. The grower would place plots throughout the sample area having an area of 36 square feet. For ease of sampling most plots are circular. A 36 square foot plot would have a radius of 3' 4.5". If for example the grower put in 100 of these plots and 80 of them had acceptable regeneration he/she could say that according to his samples his/ her tree lot was 80 percent stocked at 6 x 6 foot spacing. Some other common plot radiuses are 2' 10" for 5 x 5 feet desired regeneration and 3' 1.2" for 5.5 x 5.5 feet desired regeneration. When tallying a plot for stocking, you only need to record whether a plot has acceptable regeneration in it or not. There is no need to count the regeneration in a stocking plot, for example, if a plot has three seedlings in it you still only record it as stocked.

Density of Christmas trees over four feet in height

Density is a measure of how many trees there are per given unit of area. In the case of density you record every acceptable tree you find in the plot. An acceptable tree is one that you believe has a reasonable chance to make it to market. The average number of trees found in all the plots is then multiplied by the number of plots that would fit in a certain area to give the number of trees in that area. For example, if you select a plot size of 1/300 of a hectare and have an average count of seven per plot you would multiply by 300 to get a density of 2100 trees per hectare.

Plot Size

Plot size for determining stocking was mentioned above. Three plot sizes were used in field trials to determine density during this project. A plot size of 1/100th of a hectare with a radius of 5.64 meters was discarded early on because it required the use of a long string or stick which was cumbersome and in dense stands there was a greater chance of missing or double counting trees. The preferred plot sizes were 1/200 hectare with a radius of 3.99 meters and 1/300 hectare with a radius of 3.26 meters. It was felt the 1/300 hectare plot might work best in well stocked Christmas tree lots and the 1/200 hectare plot in more open Christmas tree lots. Any plot size can be made to work, so again it is whatever the grower is comfortable with.

Sample Size or Number of Plots Required

Generally speaking the more plots the better but this has to be weighed against the time required to establish more plots. Also, generally speaking the more variable or patchy the areas to be sampled the more plots that will be required. Note the size of the area to be sampled has less influence on the number of plots required than one might think. Larger lots would tend to have more plots than required as a grower would of course want to sample all portions of their lot and would tend to put in at least a minimal number of plots per hectare since they have to walk the area anyway. There are statistical methods available to estimate the number of plots required to give you desired levels of accuracy. There are also statistical methods to give you an estimate of the accuracy of your final sample. Accuracy is discussed in Appendix “A”. It is felt that one person can comfortably put in about 20 plots per hour.

Sample Plot locations

Once the plot centers are determined it is recommended that they serve as the location for both the stocking and density plots. Plot locations should of course be as random and non- biased as possible. Once a Christmas tree lot has been mapped, the area to sample can be calculated and the number of desired plots determined. The grower can then plot sample lines on a map with the objective of obtaining a reasonable coverage of the lot. The length of those lines can be measured on the map or computer. The distance between plots could then be approximated by dividing the length of all sample lines divided by the number of plots desired. A grower can use the GPS and a compass to help navigate along the sample lines. He or she could pace, measure with a string box or use a GPS to help determine when the distance between plots has been reached. During field trials in this project a compass was often used to navigate along a sample line and a certain number of paces used to determine where the plot center would fall. Plot locations should be recorded with a GPS and mapped for future reference.

Tally Sheets

Tally sheets are useful to aid in the recording of plot attributes. They help ensure all required data is recorded before leaving the plot. If designed properly they can make data entry simpler and less prone to error. (See Appendix "C" for a sample tally sheet.)

Spreadsheets

An excel spreadsheet has been built to help record and analyze the data recorded on the tally sheets. This spreadsheet can be obtained from the CTCNS.

Sample Accuracy

The number of samples or plots required to produce an estimate of the population mean (the average or mean number of trees per plot for the *entire* lot) within a certain percentage of is actual value and expressed with a certain level of confidence can be calculated using statistical methods. The specifics of this technique are explained in Appendix "A". Most growers may choose to skip this calculation and go ahead and put in the number of plots they feel will give them a good inventory of their lot. Note: a table (not based on statistics) providing a suggested number of plots for various sizes of tree lots can be found in Appendix "F".

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Once a sample has been gathered, a numerical value (within a certain interval) estimating the population mean can be calculated using the statistical methods explained in Appendix "A". This will allow a grower to express the level of confidence they should have in their mean population density within a certain interval. In our case the estimated average number of trees per plot is shown in the tables with an upper and lower boundary expressed with a 90% level of confidence.

Sample Results

Eight different Christmas tree lots were visited. Various numbers of sample plots were established on each lot. At each sample point center stocking of regeneration (trees under four feet) as well as the density of trees over four feet were taken. Depending on stand conditions and grower's wishes different plot sizes were used. The density results are summarized in the first three tables 'All Plots', '4 to 6' and '6 to 8'. The stocking results are summarized in the fourth table 'Regeneration Stocking'.

Densities were tallied by two foot height classes and separated into merchantable and non-merchantable categories (see tally sheets Appendix "C"). There were few trees over eight feet and they were included in 'All Plots'. For ease of analysis merchantable and non-merchantable trees were combined in the tables. Also, the sample results from the various plot sizes were all converted to trees per hectare.

To understand the data table, it is important to distinguish between two key words: "sample" and "population". "Population" refers to the *entire* lot the grower is working with, and "sample" refers to some smaller subset of that entire population. A grower can take different samples of the population. Using statistical methods samples can be representative of populations. For example, in our analysis we took a small sample of a population and then used statistical methods to determine what is called a "coefficient of variance" or "CV" (the sample deviation divided by the sample mean). Using the CV we could then determine the number of plots we would need if we were to take a *new* sample which would determine the population mean (trees per plot) within 10% of its actual value with 90% confidence.

The first two columns of our data table show this as 'N', the number of samples that would be required to give an 'average or mean' within +/- 15% and +/- 10% of the population mean (trees per plot) at a 90% confidence level. For example, looking at 'All plots' for 'Lot A(2)' 143 plots are estimated to be needed to produce an estimate of the population mean (trees per plot) - within +/- 10% of its actual value with 90% confidence while on 'Lot H' only 38 plots are required. The reason for the large difference in the number of plots required is that 'Lot H' is a uniform reasonably well stocked lot and 'Lot A (2) is a very patchy.

The second form of analysis we did, again using the sample mean, 'x', from our original sample we determined an interval within which the mean number of trees per plot for the population is located with a 90% confidence level. This interval is presented in the table under the headings "upper" and "lower boundaries" or simply by considering the sample mean, 'x', plus or minus the 'interval (+/-)'. For example for 'All Plots' 'Lot H' the average number of trees per hectare was found to be 1,468.6 +/- 114 .4 with a 90% confidence level.

It is significant to note that although we took samples with a variety of different sizes (1/100th, 1/200th, and 1/300th of a hectare) for clarity we converted all the data in the table to trees per hectare. Although this may seem counterintuitive, statistically speaking the area of the sampling unit does not have an impact on the sample size, it is the variation of the sample that does.

Stocking of acceptable regeneration was recorded at every plot center. The plots were either tallied as having at least one acceptable tree or not. The results are shown in table 4 ‘Regeneration Stocking’. From the table it can be seen that on some lots stocking was assessed at a 5 x 5 foot spacing and on others at a 6 x 6 foot spacing. The percentage of stocked plots is shown and based on that number and the plot size the number of ‘trees per acre’ was calculated.

ALL PLOTS	N (+/- 15%)	N (+/- 10%)	CV	+/–	upper bound	lower bound	$\bar{x}$	n	s	$t_{\frac{\alpha}{2}}$
Lot A (100)	21	48	0.398	126	851	599	725	16	288.7	1.746
Lot A (200)	44	99	0.57	199	999	601	800	16	456	1.746
Lot A (300)	33	73	0.49	184.4	1046.9	678.1	862.5	16	422.4	1.746
Lot B	48	108	0.609	215.1	1293	862.8	1077.9	27	656.4	1.703
Lot C	46	104	0.584	291.8	1435.7	852.1	1143.9	16	668.4	1.746
Lot D (200)	9	21	0.268	161.5	1721.5	1398.5	1560	20	418.6	1.725
Lot D (300)	12	28	0.307	161.4	1526.4	1203.6	1365	20	418.5	1.725
Lot Db (300)	16	35	0.351	166.6	1750.9	1417.7	1584.3	32	555.9	1.695
Lot E (300)	92	207	0.848	191.8	921.7	538.1	729.9	30	618.9	1.697
Lot Eb (300)	76	172	0.778	152.3	887.3	582.7	735	40	572.1	1.684
Lot E (200)	73	163	0.753	155.5	822.1	511.1	666.6	30	502	1.697
Lot Eb (200)	61	137	0.695	121.2	776.2	533.8	655	40	455.2	1.684
Lot F	33	75	0.511	170.9	1391.9	1050.1	1221	38	623.4	1.69
Lot G	19	44	0.387	392.1	3356.1	2571.9	2964	25	1146.6	1.71
Lot H	17	38	0.369	107.9	1576.5	1360.7	1468.6	70	541.4	1.668
Lot A (2)	64	143	0.739	114.4	1021	792.2	906.6	90	669.9	1.62

4 to 6	N (+/- 15%)	N (+/- 10%)	CV	+/–	upper bound	lower bound	$\bar{x}$	n	s	$t_{\frac{\alpha}{2}}$
Lot A (100)	42	96	0.56	103.9	528.9	321.1	425	16	238	1.746
Lot A (200)	230	518	1.304	261.9	721.9	198.1	460	16	600	1.746
Lot A (300)	68	153	0.708	156.5	662.9	349.9	506.4	16	358.5	1.746
Lot B	85	192	0.814	109.6	520.6	301.4	411	27	334.5	1.703
Lot C	68	152	0.706	196.4	833.9	441.1	637.5	16	450	1.746
Lot D (200)	30	67	0.473	158.8	1028.8	711.2	870	20	411.8	1.725
Lot D (300)	36	80	0.52	156.6	936.6	623.4	780	20	405.9	1.725
Lot Db (300)	37	83	0.537	137.2	990.4	716	853.2	32	457.8	1.695
Lot E (300)	168	378	1.145	106.4	406.4	193.6	300	30	343.5	1.697
Lot Eb (300)	113	255	0.948	85.2	422.7	252.3	337.5	40	320.1	1.684
Lot E (200)	93	210	0.853	67	320.4	186.4	253.4	30	216.2	1.697
Lot Eb (200)	66	149	0.726	55.1	340.1	229.9	285	40	207	1.684
Lot F	91	205	0.847	92.8	492.8	307.2	400	38	338.6	1.69
Lot G	53	120	0.64	436.2	2428.2	1555.8	1992	25	1275.3	1.71
Lot H	59	132	0.689	69.5	575.3	436.3	505.8	70	348.4	1.668
Lot A (2)	142	319	1.102	69	435.6	297.6	366.6	90	404.1	1.62

6 to 8	N (+/- 15%)	N (+/- 10%)	CV	+/–	upper bound	lower bound	$\bar{x}$	n	s	$t_{\frac{\alpha}{2}}$
Lot A (100)	36	81	0.516	67.6	367.6	232.4	300	16	154.9	1.746
Lot A (200)	55	124	0.639	94.1	431.7	243.5	337.6	16	215.6	1.746
Lot A (300)	67	150	0.702	109.2	465.6	247.2	356.4	16	250.2	1.746
Lot B	67	151	0.721	157.4	824	509.2	666.6	27	480.3	1.703
Lot C	131	296	0.985	217.6	724	288.8	506.4	16	498.6	1.746
Lot D (200)	19	43	0.382	101.6	791.6	588.4	690	20	263.4	1.725
Lot D (300)	57	127	0.654	147.7	732.7	437.3	585	20	382.8	1.725
Lot Db (300)	51	115	0.633	138.8	870.2	592.6	731.4	32	463.2	1.695
Lot E (300)	140	316	1.047	139.5	569.4	290.4	429.9	30	450.3	1.697
Lot Eb (300)	149	334	1.086	114.9	512.4	282.6	397.5	40	431.7	1.684
Lot E (200)	126	283	0.992	127	540.4	286.4	413.4	30	410	1.697
Lot Eb (200)	137	308	1.043	102.7	472.7	267.3	370	40	385.8	1.684
Lot F	82	184	0.803	117	648.6	414.6	531.6	38	426.8	1.69
Lot G	64	144	0.701	221.5	1145.5	702.5	924	25	647.7	1.71
Lot H	44	99	0.596	82.8	780	614.4	697.2	70	415.2	1.668
Lot A (2)	88	199	0.87	74.8	578.2	428.6	503.4	90	438	1.62

Christmas Tree Inventory Sample - Regeneration Stocking

Lot Name	Total Number of Plots	Number of Stocked plots	Percent Stocked	Trees per Acre (5' X 5' Spacing = 1740 trees/acre)	Trees per Acre (6' X 6' Spacing = 1200 trees/acre)
Lot A (100)	16	8	50.00%	870	
Lot A (200)	16	10	62.50%		750
Lot A (300)					
Lot B (300)	27	10	37.00%		444
Lot C (300)	16	8	50.00%		600
Lot D (200)	20	8	40.00%	696	
Lot D (300)	20	8	40.00%	696	
Lot D (300)	32	16	50.00%	870	
Lot E (300)	30	8	26.67%	464	
Lot E (300)	40	12	30.00%	522	
Lot E (200)	30	8	26.67%	464	
Lot E (200)	40	12	30.00%	522	
Lot F (200)	38	19	50.00%	870	
Lot G (300)	25	23	92.00%	1600	
Lot H (200)	70	28	40.00%	696	
Lot A (2) (300)	90	46	51.11%		613

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Note: A plot had to have one free growing seedling up to four feet in height to be classified as stocked.

Grower Input

Grower survey

Since the start of the project I have met with approximately 20 growers and industry personnel. The inventory system has been demonstrated on five grower lots using various plot sizes. Sampling was done on three other lots to test and modify the system before the grower demonstrations. All growers stated that the system must be easy to use and grower friendly.

GPS and computer

Most growers had some experience with GPS and computers. Most of the larger growers have access to personnel with good computer skills, though it is important to note that, given the aging demographic of growers, some growers either do not own a computer or are not comfortable using one. We recommended that CTCNS make a staff member available with a laptop computer to assist smaller growers. Everyone found the GPS instructions very good and the GPS easy to use. Some growers will need assistance with downloading the files and printing the sketches.

Size of operation and time willing to spend on inventory

The larger growers were very interested in this inventory project and plan to complete it on their lots. Other growers were surprised by the results and would like to complete the project. All growers would like to measure and map their lots. Some growers are required to complete inventories to qualify for some programs while others saw the value in having this information in order to better manage their operations.

Time required

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The lot can be measured at walking speed so the length of the outside boundary will determine the time. Plots can be done at the rate of 15 to 25 plots per hour depending on stocking, plot size and distance between plots.

Plot size

The plot size tested where the 1/100 hectare 5.64 meter radius, 1/200 hectare 3.99 meter radius and 1/300 hectare 3.26 meter radius. The 1/100 hectare plot was very difficult to get accurate measurement of the trees on the edge of the plot and would require two people. The 1/200 hectare plot works well on the sites with stocking below

1500 trees per hectare and a golf ball retriever was used to measure the radius. This size appears to be more accurate. The 1/300 hectare plots are the best on the lots with stocking above 1500 trees per hectare.

Knowledge of agriculture programs available to growers

Some growers have a limited knowledge of the programs offered by the Provincial and Federal Departments of Agriculture and the Nova Scotia Federation of Agriculture.

Other comments

The growers surveyed indicated a need for the inventory and mapping programs for their lots. The maps need the roads, lot boundaries, water courses and areas managed for Christmas trees. This inventory could be used to qualify for various programs such as crop insurance, and also used in the management of their lots, examples are fill planting, fertilizer and chemical applications.

Steps to complete an inventory of a tree lot

1. GPS the outer boundaries of the tree lot and produce a track log

Figure 1: Christmas tree sampling

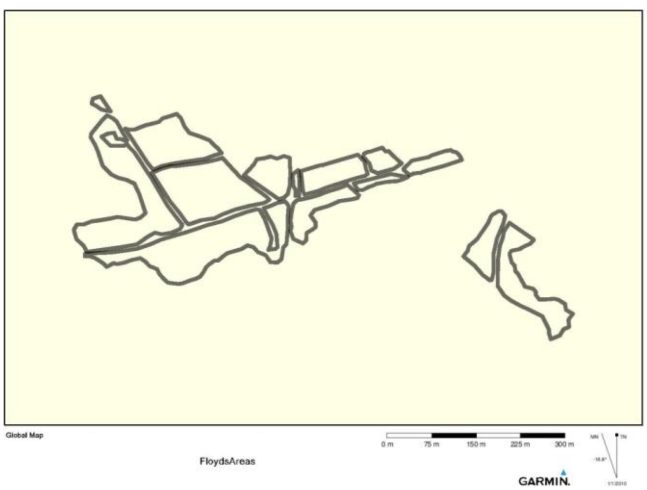

Figure 2: Track Log on Map in BaseCamp

2. Use GPS or GIS software to determine the total area of the tree lot
3. Decide on how many plots to put in based on the variability of the lot etc.

4. Draw the sample lines on a map and determine the total length of all sample lines

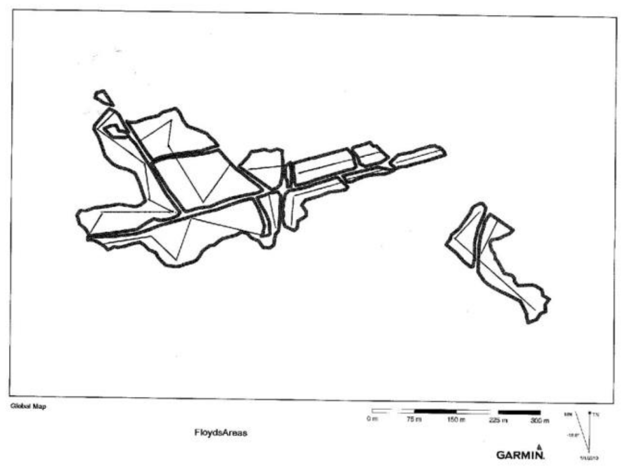

Figure 3: Sample lines on Basecamp map

5. Determine the distance between plots by dividing the total length of the sample lines by the number of plots
6. Decide on a sample radius based on the density of the lot
7. Establish plots and record data on tally sheets

Figure 4: Sampling Stocking

Figure 5: Sampling Density

8. Determine the average stocking as well as densities and convert to totals for the lot
9. Utilize spreadsheet to determine level of accuracy
10. Produce maps using GIS software

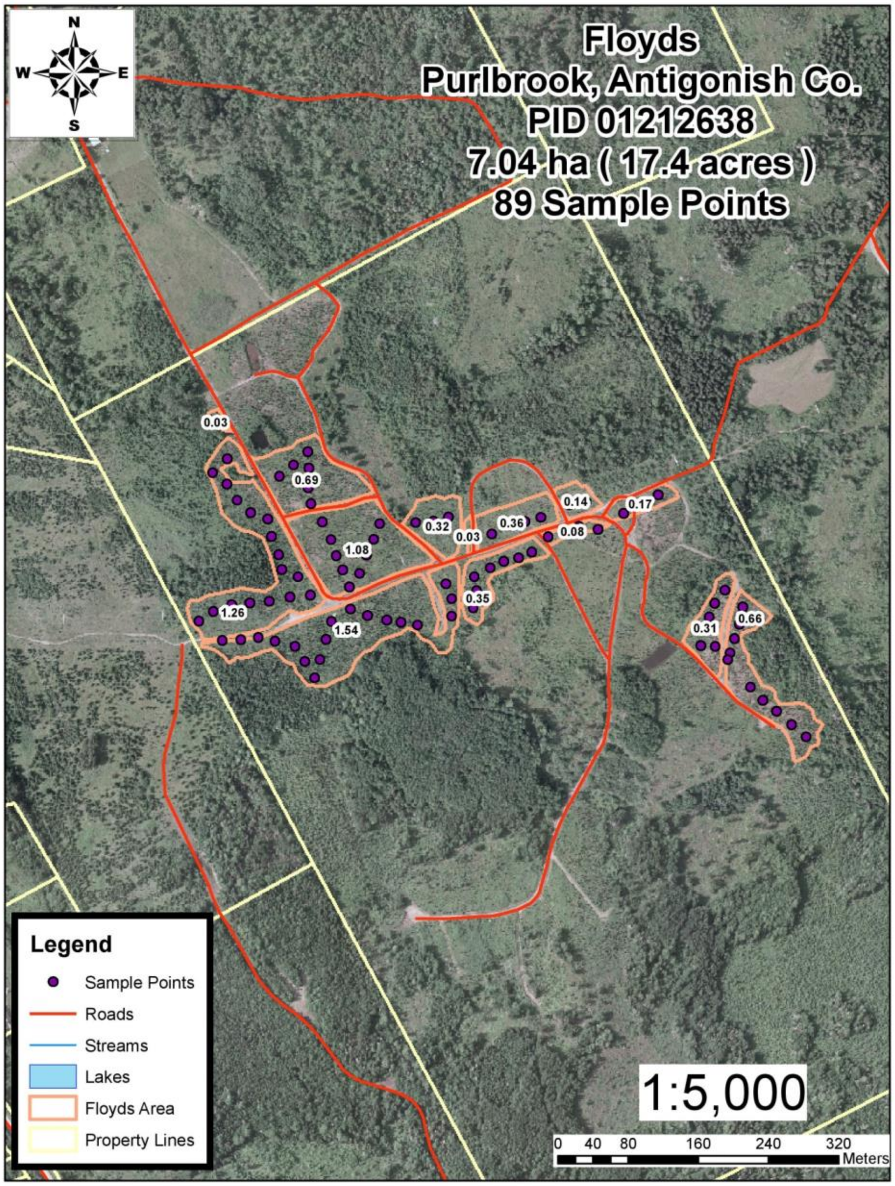

Figure 6: Final map produced using GIS software

Summary

The objective of this project was to establish and pilot a statistical model to calculate the 'stocking' or inventory of natural Christmas Tree stands in Nova Scotia. It was hoped that this inventory could be carried out in most cases by the grower themselves, or their employees, at a reasonable cost and utilize technology that is easily available and user friendly. The inventory model and resulting output was developed in consultation with the Department of Agriculture to meet the requirements of the Crop Insurance Program. It was further hoped that having good maps and inventories would aid growers in many of their other cultivation tasks.

GPS units were selected and purchased and are now available to growers through the CTCNS. Instructions on how to use these units to map and determine the areas of Christmas tree lots is provided. Note: in field visits the GPS units were well received as were the instructions. As growers try these units on their own it is likely that questions will arise that could be incorporated into future revised instructions.

A mapping strategy utilizing the selected GPS units and free downloadable software was decided upon. The instructions on how to prepare the maps and determine areas can be found in Appendix "A" GPS Instructions.

An inventory system that can be used by growers is described in the report under 'Inventory Design and Methodology'. Sample tally sheets can be found in Appendices "C" and "D".

Determining a suggested number of plots required to meet certain accuracy levels using the Statistical Methods (Appendix "B") are discussed in the report as well as a method of analyzing the accuracy of the final sample inventory. An excel spreadsheet has been provided as part of this project for the use of growers and can be obtained from the CTCNS office and will soon be available through www.ctcns.com to members.

Finally during the field visits and from discussions with growers it seems that there is a need for a mapping and inventorying system. The authors hope that this report will help growers towards that end.

Appendix "A"

GPS Instructions

See separate file (attached)

Appendix "B"

Statistical Methods

The following two sections describe (1) how the mean population density of the entire lot is estimated within certain bounds for a certain confidence level, and (2) how the number of samples required to express the population mean for a certain confidence level is determined.

Mean population density

To estimate the mean population density, μ , for a specific confidence interval, 100(1 – α)%, the following equation was used

$$\mu = \bar{x} \pm t_{\frac{\alpha}{2}} \frac{s}{\sqrt{n}}$$

Where $t_{\frac{\alpha}{2}}$ is the t -value with an area $\frac{\alpha}{2}$ to its right and having n – 1 degrees of freedom, s is the sample deviation, $\bar{x}$ is the sample mean, and n is the number of samples.

For the purposes of our analysis a degree of confidence of 90% was chosen by the group to be applied to all the different plots. Because 90 = 100(1 – 0.10), a 90% confidence interval means that α = 0.10. Clearly, if α = 0.10, then, α/2 = 0.05. This means that we needed to find $t_{\frac{\alpha}{2}} = t_{\frac{0.10}{2}}$ = $t_{0.05}$; $t_{0.05}$ is the t -value that locates the area 0.05 in the upper most portion of the normal distribution and possessing a dependence on n – 1 degrees of freedom. Our samples contained a variety of different plots numbers, 16 ≤ n ≤ 40, and the corresponding degrees of freedom. The t -value was determined by referencing these two factors, the degrees of freedom and the degree of confidence, in a table found in any basic statistics book. It can be seen from a t -value table that for this range of degrees of freedom 1.684 ≤ $t_{0.05}$ ≤ 1.746.

The sample deviation, *s*, gives the square root of the mean of the squares of the deviations of a set of data and is given by the formula

$$s = \sqrt{\frac{\Sigma(x - \bar{x})^2}{n - 1}}$$

In our analysis x is the density of single plot, $\bar{x}$ is the mean sample density, and n is the number of plots.

Number of samples

To calculate the number of samples required to be able to place the population mean within a certain range for a certain confidence level the following equation was used

$$N = \left(\frac{t_{\frac{\alpha}{2}} \times CV}{E\%}\right)^2$$

Where $t_{\frac{\alpha}{2}}$ is the t -value with an area $\frac{\alpha}{2}$ to its right and having n – 1 degrees of freedom, CV is the coefficient of variance, $E\%$ is the percentage within which the population mean is estimated, and N is the number of samples required to determine the population mean within that error percentage.

The error percentage was set by the group to be 10%. This goal meant that the group wanted to be able to state the population mean within 10% of its actual value, $\mu \pm 0.1\mu$. Therefore, for all our calculations $E\% = 0.1$.

The coefficient of variance was calculated using the formula

$$CV = \frac{s}{\bar{x}}$$

Where s is the sample deviation calculated from the data as described in the previous section and $\bar{x}$ is the sample mean. The higher the variation between plots the more samples needed to achieve the level of accuracy we set as our goal.

The means by which $t_{\frac{\alpha}{2}}$ was determined is described in the previous section.

Appendix "C"

Christmas Inventory Tally Sheet (Sample)

1/300 ha Plot Radius 3.26 meters 1/200 ha Plot Radius 3.99 meters
Stocking 6' X 6' 1200 trees/acre 1.03 meter Radius
Stocking 5' X 5' 1740 trees/acre 0.86 meter Radius
N = Not marketable this year, marketable in future M = Marketable this year
Cull trees are NOT tallied

Plot or Waypoint #	Stocking 5' X 5'		4' - 6'		6' - 8'		8' - 10'		10' Plus		Total
Plot Size 1/200	Yes	No	N	M	N	M	N	M	N	M	
1	1		3	0	2	3	0	1		0	9
2		0	4	0	1	2	0	0		1	8
3		0	0	1	3	2	0	1		0	7
4	1		3	0	2	1	0	0	1	0	7
5	1		2	0	1	3	1	0		0	7
6	1		4	0	0	2	0	1		0	7
7	1		3	0	2	1	0	0		0	6
8	1		2	1	1	3	0	0		0	7
9		0	3	1	1	0	1	1		0	7
10		0	2	0	2	1	0	0		0	5
11	1		4	0	0	1	0	0	1	0	6
12	1		2	0	0	1	1	1		0	5
13	1		3	0	3	0	0	0		0	6
14	1		1	0	1	2	0	0		0	4
15		0	3	0	1	2	0	0		0	6
Total	10		39	3	20	24	3	5	2	1	97
Ave	0.67		2.6	0.2	1.33	1.6	0.2	0.33	0.13	0.67	6.47
Trees/ha	2878		520	40	266	320	40	66	26	13	1294

***Instruction*:** Stocking was based on a 5' X 5' spacing which gives a maximum of 1740 trees/acre. 10 of 15 plots had at least one good seedling (between 6" & 4' tall) within 0.86 meter of the plot center. This gives a stocking of 67%. 67% X 1740 trees/acre = 1165 tree/acre 1165 trees/acre X 2.471 (2.471 acres = 1 hectare) = 2878 trees/ hectare. For the rest of the tally the average number of trees in a plot X 200 gives trees/hectare (i.e.: 6'-8' marketable: 24 trees/15 plots = 1.6 avg. X 200 = 320 trees/hectare).

Metric Conversion: 1 meter = 3.28 feet 1 hectare = 2.471 acres

Appendix "D"

Christmas Inventory Tally Sheet

1/300 ha Plot Radius 3.26 meters 1/200 ha Plot Radius 3.99 meters
Stocking 6' X 6' 1200 trees/acre 1.03 meter Radius
Stocking 5' X 5' 1740 trees/acre 0.86 meter Radius
N = Not marketable this year, marketable in future M = Marketable this year
Cull trees are NOT tallied

Plot or Waypoint #	Stocking 5' X 5'		4' - 6'		6' - 8'		8' - 10'		10' Plus		Total
	Yes	No	N	M	N	M	N	M	N	M	
1											
2											
3											
4											
5											
6											
7											
8											
9											
10											
11											
12											
13											
14											
15											
Total											
Ave											
Trees/ha											

Appendix “E”

Notes to Spreadsheet

An excel spreadsheet has been provided as part of this project for the use of growers. The spreadsheet can be obtained from the CTCNS office.

The two things the spread sheet will calculate are (1) the interval (X +/- Y) in which the population mean resides stated with 90% confidence, and (2) the estimated number of samples the grower will need to take in order to estimate the population mean within 10% of its actual value with 90% confidence.

Appendix “F”

Suggested Number of Plots

Suggested Average Number of Plots (Reduce by 25% for Uniform Density Lots)

Area	1-5 acres minimum # plots	5-10 acres	10-20 acres	20-50 acres	50-100 acres	100 acres plus
1/200 ha plots	25	25 plus 5 plots for each acre over 5	50 plus 3 plots for each acre over 10	80 plus 1 plot for each acre over 20	100 plus 1 plot for each acre over 50	150 plots
1/300 ha plot	30	30 plus 6 plots for each acre over 5	60 plus 4 plots for each acre over 10	100 plus 1 plot for each acre over 20	130 plus 1 plot for each acre over 50	180 plots

Appendix "G"

Christmas Tree Inventory Metric Conversion Chart

1 Hectare = 2.47 Acres	1 Acre = 0.4047 Hectares
1 Meter = 3.28 Feet	1 Foot = 0.3048 Meters

1/300 hectare plot with a 3.26 meter radius = 1/100 acre plot with a 11' 9.5" radius

1/200 hectare plot with a 3.99 meter radius = 1/80 acre plot with a 13' 2" radius

5' X 5' stocking with a 0.86 meter radius = 2' 10" radius

6' X 6' stocking with a 1.03 meter radius = 3' 4.5" radius