Skills Essential for the Successful Completion of the Forest Measurements Section of the MSU Forestry Summer Field Program

Community College students who transfer to the MSU Forestry program are expected to enroll in the Summer Field Program course, FO3015, during the summer immediately after they transfer. To successfully complete this course, students must have had a course in basic Statistics and a course in Forest Measurements. The Forest Measurements course must cover content that is similar to that covered in the Forest Measurements course at MSU. The MSU Forest Measurements course outline is given in Appendix I. The following is a summary of the essential skills:

A. General Skills

- Report writing
- Use of Microsoft Word to write and edit text and Tables
- Use of the functionalities in Microsoft Excel. At a minimum - sum, average, sort, use of the formula function, producing and editing graphs
- Basic algebra and arithmetic – add, subtract, multiply, divide, and their order of operation

B. Basic Statistics and Linear Regression

- Calculate:
  - Mean
  - Variance
  - Standard Deviation
  - Coefficient of Variation
  - Standard Error of a mean
  - Confidence Interval of a mean
- Do a linear regression to estimate the coefficients of an equation of the form

  $Y = b_0 + b_1X$

  where b_0 and b_1 are the coefficients

Useful basic Statistics and Regression formulas are given in Appendix II.

C. Forest Land Measurement

- Map reading and interpretation
- Map scale representation and calculation
- Area estimation from maps and aerial photographs
- Estimating area and precision of the area estimate from a closed traverse - Use of the Double Meridian Distance (DMD) method
- General Land Office (GLO) description of land tracts

Useful formulas are given in Appendix III.

D. Individual Tree Measurement

- Calculate for a given tree:
  - Error in height measurement
  - Girard Form Class
  - Bark ratio and inside bark diameter (DIB)
  - Basal Area
  - Cubic foot or Board foot volume using:
    - Huber's, Smalian's, or Newton's cubic foot volume formulas
    - Doyle, Scribner, or International board foot volume formulas
    - A volume equation

Some of the useful formulas are given in Appendix III.

E. Measurement of Forest Stands

- Calculate site index from a site index equation
- Knowledge of sampling techniques for estimating stand level attributes e.g. number of trees and volume of timber in a stand
  - Strip cruise
  - Plot cruise
  - Point cruise

- Construct stand and stock tables
- Calculate sampling error
- Calculate quadratic mean diameter of a stand
- Do a stand table projection

Some of the useful formulas are given in Appendix IV.

Further information can be found on the MSU Forestry Courses website at http://www.cfr.msstate.edu/students/forestrypages/fo2213.asp and http://www.cfr.msstate.edu/students/forestrypages/fo3015.asp

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Appendix I

Outline of the MSU Forest Measurements Course

- Introduction to Forest Measurements
- Fundamentals of Forest Measurements
- Land Measurements – Horizontal Distances
- Land Measurements – Bearings and Azimuths
- Land Measurements – Maps and Scales
- Land Measurements – Area Determination
- Land Measurements – The GLO Land Subdivision System
- Tree Height, Diameter, and Crown Measurements; Age Determination
- Tree Cubic Foot Volume Determination
- Tree Board Foot Volume Determination
- Tree Biomass Determination
- Volume Tables; Tree Volume and Biomass Functions
- Application of Simple Linear Regression to Tree Measurement Problems: Volume Equations, Biomass Equations
- Application of Simple Linear Regression to Tree Measurement Problems: Volume Table Construction, DIB-DOB Relationship, DBH-BA Growth Relationship
- Application of Simple Linear Regression to Tree Measurement Problems: Height – DBH Equations
- Forest Stand Level Measurements
- Stand Density Measurements
- Site Index Curves and Equations
- Site Index Curve Construction
- Introduction to Forest Inventory
- Statistical Methods Applied to Forest Inventory
- Forest Inventory With Fixed Area Plots: Stand & Tract Estimates
- Forest Inventory With Fixed Area Plots: Stand & Stock Tables
- Forest Inventory With Variable Area Plots: Stand & Tract Estimates
- Forest Inventory With Variables Area Plots: Stand & Stock Tables
- Forest Inventory Using Strips
- Forest Inventory With Point Samples: Concepts & Nomenclature
- Forest Inventory With Point Samples: Implementation
- Forest Inventory With Point Samples: Stand & Stock Tables
- Forest Inventory: Sample Size Determination
- Forest Inventory: Stratification
- Forest Inventory: Stratification Computations
- Stand Table Projection: Concept and Implementation
- Stand Table Projection: Computations
- Conducting a Forest Inventory – Planning & Implementation
- Conducting a Forest Inventory – Computations & Reporting
- Application of Computing & Geospatial Technology to Forest Inventory Problems: An Overview

Appendix II

Basic Statistics and Linear Regression Formulas

Basic Statistics

Given n observations $x_1, x_2, \ldots, x_n$;

1. Mean ($\bar{x}$)

$$\bar{x} = \frac{\sum_{i=1}^{n} x_i}{n}$$

2. Variance (s^2)

$$s^2 = \frac{\sum_{i=1}^{n} x_i^2 - \frac{(\sum_{i=1}^{n} x_i)^2}{n}}{n-1}$$

3. Standard Deviation (s)

$$s = \sqrt{s^2}$$

4. Coefficient of Variation (CV)

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

$$CV\% = CV \times 100$$

5. Standard error of the mean ($s_{\bar{x}}$)

$$s_{\bar{x}} = \sqrt{\frac{s^2}{n}}$$

6. Confidence interval of a mean (CI)

$$CI = \bar{x} \pm t_{(\alpha,\ df)} \times s_{\bar{x}}$$

where $t_{(\alpha,\ df)}$ is the value of the t statistical distribution (see Appendix V) for an α % significance level and df, where $df = n-1$, number of degrees of freedom. The confidence interval is described as the (1- α) % confidence interval.

Linear Regression

Given n dependent observations $y_1, y_2, \ldots, y_n$ and n independent observations $x_1, x_2, \ldots, x_n$ that can be related by a linear equation of the form

$$y_i = b_0 + b_1 x_i;$$

$$b_1 = \frac{SP_{xy}}{SS_x}$$

and

$$b_0 = \bar{y} - b_1 \bar{x}\ ,$$

where

$$SP_{xy} = \sum_{i=1}^{n} x_i y_i - \frac{(\sum_{i=1}^{n} x_i)(\sum_{i=1}^{n} y_i)}{n}$$

and

$$SS_x = \sum_{i=1}^{n} x_i^2 - \frac{(\sum_{i=1}^{n} x_i)^2}{n}$$

<u>Computing R^2 of the regression</u>

$$R^2 = \frac{RSS}{TSS}$$

where $RSS = b_1 \times SP_{xy}$

and

$$TSS = SS_y = \sum_{i=1}^{n} y_i^2 - \frac{(\sum_{i=1}^{n} y_i)^2}{n}$$

Appendix III

Land and Individual Tree Measurement Formulas

Land Measurement

Closed traverse area calculation by the DMD method:

DMD EQ.

$$Dep = (CourseLength) * Sin(Azimuth)$$

$$Lat = (CourseLength) * Cos(Azimuth)$$

$$ErrorClosure = \sqrt{SumofDep^2 + SumofLat^2}$$

$$Precision = 1: \frac{(TotalCourseLength)}{(ErrorClosure)}$$

$$Dep_{Adj} = Dep - \left(\frac{Course\,Length}{Total\,Course\,Length}\right) Sum\,of\,Dep$$

$$Lat_{Adj} = Lat - \left(\frac{Course\,Length}{Total\,Course\,Length}\right) Sum\,of\,Lat$$

$$AdjDists = \sqrt{Dep_{Adj}{}^2 + Lat_{adj}{}^2}$$

$$AdjBearingAngle = ArcTan\left(\frac{Dep_{Adj}}{Lat_{adj}}\right)$$

$$ShiftedX = Acc.Dep - MinAcc.Dep$$

$$ShiftedY = Acc.Lat - MinAcc.Lat$$

$$DMD = ShiftedX * ShiftedXPevious$$

$$DoubleArea = DMDforCourse(Lat_{adj})$$

where:
Dep is departure
Lat is latitude
Dep_{Adj} is adjusted departure
Lat_{Adj} is adjusted latitude
Acc.Dep is Accumulated departure
Acc.Lat is Accumulated latitude

$$Area = \frac{DoubleArea}{2}$$

Individual Tree Measurement

1. Bark Ratio = $\mathbf{1} - \frac{\mathbf{DBH_{ib}}}{\mathbf{DBH_{ob}}}$
where $\mathrm{DBH_{ib}} = \mathrm{DBH_{ob}} - (2 \times \mathrm{BT})$

2. Girard Form Class (FC_g)

$\mathbf{FC_g} = \frac{\mathbf{DIB@17'}}{\mathbf{DBH}}$ if no allowance for trim
and
$\mathbf{FC_g} = \frac{\mathbf{DIB@17.3'}}{\mathbf{DBH}}$ with a 0.3 ft trim allowance

3. Log cubic foot volume

Huber's Formula

$$V = A_{0.5} \times L$$

Smalian's Formula

$$V = \frac{A_{LE} + A_{SE}}{2} \times L$$

Newton's Formula

$$V = \frac{A_{LE} + 4A_{0.5} + A_{SE}}{6} \times L$$

where
A_{LE} is the large end section area, A_{SE} is the small end section area, $A_{0.5}$ is the section area at half the log length, and L is the log length

4. Board foot volume

DOYLE: $\left(\frac{(D-4)}{4}\right)^2 L$

SCRIBNER: $\frac{(0.79\,D^2 - 2\,D - 4)L}{16}$

INTERNATIONAL:
$= 0.199\,D^2 - 0.6426\,D$ 4 ft. log
$= 0.398\,D^2 - 1.0850\,D - 0.2713$ 8 ft. log
$= 0.597\,D^2 - 1.3290\,D - 0.7143$ 12 ft. log
$= 0.796\,D^2 - 1.3740\,D - 1.2295$ 16 ft. log

Int'l 1/4 Equation Taper = 0.5 inches per 4 ft. section

where D is the log scaling diameter

Appendix IV

Formulas for Measurement of Forest Stands

Sample size (n) determination

1. Finite population

$$n = \frac{1}{\frac{1}{N} + \left(\frac{ASE\%}{t_{(\alpha,\ df)} \times CV\%}\right)^2}$$

2. Infinite population

$$n = \left(\frac{t_{(\alpha,\ df)} \times CV\%}{ASE\%}\right)^2$$

where:

$t_{(\alpha,\ df)}$ is the value of the *t* statistical distribution (see Appendix V) for an α % significance level and *df*, where $df = \infty$

CV% is the percent coefficient of variation

ASE% is the percent allowable sampling error

Strip Cruise

1. Percent Nominal Cruise Intensity (*NC%*)

$$NC\% = \frac{Strip\ Width}{Strip\ Interval} \times 100$$

2. Actual Cruise Percentage (*AC%*)

$$AC\% = \frac{Acres\ in\ the\ Strip}{Acres\ in\ the\ Tract} \times 100$$

3. Per Acre Expansion Factor (*EF*)

$$EF = \frac{100\%}{AC\%} = \frac{Acres\ in\ Tract}{Acres\ in\ Strip}$$

Plot Cruise

1. Radius of a circular plot (in ft)

$$Radius = \sqrt{\frac{43\,560 \times Plot\ Area}{\pi}}$$

2. Acres to be sampled (*Sample Area*)

$$Sample\ Area = DNC\% \times Tract\ Area$$

where *DNC*% is the desired nominal cruise intensity

3. Number of Acres represented by 1 sample plot (*Rep Acres*)

$$Rep\ Acres = \frac{Tract\ Area}{Number\ of\ sample\ plots}$$

4. Per Acre Expansion Factor (*EF*)

$$EF = \frac{1}{Plot\ Area}$$

Point Cruise

1. A tree's plot Area (in acres)

$$Plot\ size\ for\ tree = \frac{0.005454 \times DBH^2}{BAF}$$

where *BAF* is the prism's basal area factor

2. Plot Radius Factor (*PRF*)

$$PRF = \frac{8.696}{\sqrt{BAF}}$$

3. Per Acre Expansion Factor (*EF*)

$$EF = \frac{1}{Plot\ size\ for\ tree}$$

Appendix IV

Formulas for Measurement of Forest Stands

Sampling Error

For a cruise on *n* strip segments, sample plots, or sample points;

Percent Sampling Error ($SE\%$)

$$SE\% = \left(\frac{t_{(\alpha,\ df)} \times s_{\bar{V}}}{\bar{V}}\right) \times 100$$

where

$t_{(\alpha,\ df)}$ is the value of the *t* statistical distribution (see Appendix V) for an α % significance level and *df*, where $df = n\text{-}1$, number of degrees of freedom

$\bar{V}$ is the mean value (based on the *n* observations) of the stand attribute e.g. volume

$s_{\bar{V}}$ is the standard error of the mean stand attribute

Appendix V

Table of Probabilities for the t-Distribution

Degrees Of Freedom (df)	Two-Tailed Probablility of Obtaining a Larger Value									Degrees Of Freedom (df)
	0.5	0.4	0.3	0.2	0.1	0.05	0.02	0.01	0.001	
1	1.000	1.376	1.963	3.078	6.314	12.706	31.821	63.656	636.578	1
2	0.816	1.061	1.386	1.886	2.920	4.303	6.965	9.925	31.600	2
3	0.765	0.978	1.250	1.638	2.353	3.182	4.541	5.841	12.924	3
4	0.741	0.941	1.190	1.533	2.132	2.776	3.747	4.604	8.610	4
5	0.727	0.920	1.156	1.476	2.015	2.571	3.365	4.032	6.869	5
6	0.718	0.906	1.134	1.440	1.943	2.447	3.143	3.707	5.959	6
7	0.711	0.896	1.119	1.415	1.895	2.365	2.998	3.499	5.408	7
8	0.706	0.889	1.108	1.397	1.860	2.306	2.896	3.355	5.041	8
9	0.703	0.883	1.100	1.383	1.833	2.262	2.821	3.250	4.781	9
10	0.700	0.879	1.093	1.372	1.812	2.228	2.764	3.169	4.587	10
11	0.697	0.876	1.088	1.363	1.796	2.201	2.718	3.106	4.437	11
12	0.695	0.873	1.083	1.356	1.782	2.179	2.681	3.055	4.318	12
13	0.694	0.870	1.079	1.350	1.771	2.160	2.650	3.012	4.221	13
14	0.692	0.868	1.076	1.345	1.761	2.145	2.624	2.977	4.140	14
15	0.691	0.866	1.074	1.341	1.753	2.131	2.602	2.947	4.073	15
16	0.690	0.865	1.071	1.337	1.746	2.120	2.583	2.921	4.015	16
17	0.689	0.863	1.069	1.333	1.740	2.110	2.567	2.898	3.965	17
18	0.688	0.862	1.067	1.330	1.734	2.101	2.552	2.878	3.922	18
19	0.688	0.861	1.066	1.328	1.729	2.093	2.539	2.861	3.883	19
20	0.687	0.860	1.064	1.325	1.725	2.086	2.528	2.845	3.850	20
21	0.686	0.859	1.063	1.323	1.721	2.080	2.518	2.831	3.819	21
22	0.686	0.858	1.061	1.321	1.717	2.074	2.508	2.819	3.792	22
23	0.685	0.858	1.060	1.319	1.714	2.069	2.500	2.807	3.768	23
24	0.685	0.857	1.059	1.318	1.711	2.064	2.492	2.797	3.745	24
25	0.684	0.856	1.058	1.316	1.708	2.060	2.485	2.787	3.725	25
26	0.684	0.856	1.058	1.315	1.706	2.056	2.479	2.779	3.707	26
27	0.684	0.855	1.057	1.314	1.703	2.052	2.473	2.771	3.689	27
28	0.683	0.855	1.056	1.313	1.701	2.048	2.467	2.763	3.674	28
29	0.683	0.854	1.055	1.311	1.699	2.045	2.462	2.756	3.660	29
30	0.683	0.854	1.055	1.310	1.697	2.042	2.457	2.750	3.646	30
32	0.682	0.853	1.054	1.309	1.694	2.037	2.449	2.738	3.622	32
34	0.682	0.852	1.052	1.307	1.691	2.032	2.441	2.728	3.601	34
36	0.681	0.852	1.052	1.306	1.688	2.028	2.434	2.719	3.582	36
38	0.681	0.851	1.051	1.304	1.686	2.024	2.429	2.712	3.566	38
40	0.681	0.851	1.050	1.303	1.684	2.021	2.423	2.704	3.551	40
45	0.680	0.850	1.049	1.301	1.679	2.014	2.412	2.690	3.520	45
50	0.679	0.849	1.047	1.299	1.676	2.009	2.403	2.678	3.496	50
75	0.678	0.846	1.044	1.293	1.665	1.992	2.377	2.643	3.425	75
100	0.677	0.845	1.042	1.290	1.660	1.984	2.364	2.626	3.390	100
∞	0.674	0.842	1.036	1.282	1.645	1.960	2.326	2.576	3.290	∞