FOR 274: Forest Measurements and Inventory

- Numbers and Errors
- Communication

Numbering Scales: Its not just a matter of 0-9

At last, the mystery of the Mayan calendar revealed.

The modern world uses several number systems:

The Decimal system for Currency:

i.e. 10 cents in a dime

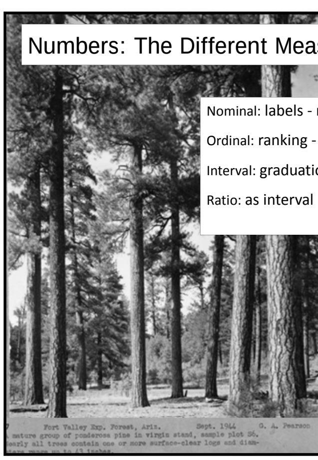
The Duodecimal System in Natural Resources:

i.e. 12 inches in a foot

The Sexagesimal System in Time:

i.e. 60 seconds in a minute

Numbers: The Different Measurement Scales



Nominal: labels - numbering of objects for ID

Ordinal: ranking - first, second, third, grades, etc

Interval: graduations at uniform intervals

Ratio: as interval but zero included

Numbers: The Different Measurement Scales

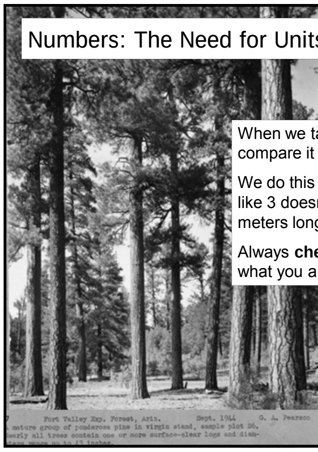
Permissible Statistics: Can use each statistic listed at or above that level

TABLE 2-1. Classification of Scales of Measurement

Scale	Basic Operation	Mathematical Group Structure	Permissible Statistics	Examples
Nominal	Determination of equality (numbering and counting)	Permutation group $X' = f(X)$, where $f(X)$ means any one-to-one substitution	Number of cases Mode Contingency correlation	Number of forest stand types Assignment of code numbers to species in studying stand composition
Ordinal	Determination of greater or less ranking	Isotonic group $X' = f(X)$, where $F(X)$ means any increasing monotonic function	Median Percentiles Order correlation	Lumber grading Tree and log grading Site class estimation
Interval	Determination of the equality of intervals or of differences (numerical magnitude of quantity, arbitrary origin)	Linear group $X' = aX + b$, where $a > 0$	Mean Standard deviation Correlation coefficient	Fahrenheit temperature Calendar time Available soil moisture Relative humidity
Ratio	Determination of the equality of ratios (numerical magnitude of quantity, absolute origin)	Similarity group $X' = cX$, where $c > 0$	Geometric mean Harmonic mean Coefficient of variation	Length of objects Frequency of items Time intervals Volumes Weights Absolute temperature Absolute humidity

Source: Husch Beers and Kershaw

Numbers: The Need for Units



When we take a measure we must always compare it to a **standard** measurement.

We do this by **assigning units** as a number like 3 doesn't mean anything by itself: 3 meters long means "3 x lengths of one meter"

Always **check** that your units make sense for what you are describing

Measurement Systems: English and Metric

Conversion Factor Table

	Multiple	by	To Get
	inch	2.54	cm
	This can also be written as: 1 inch = 2.54 cm		
A	acre	43,560	ft^2
	ampere-hr (A·h)	3,600	coulomb (C)
	ångström (Å)	1x10^{-10}	m
	atm (atmosphere)	1.01325	bar
	atm, std	76.0	cm of Hg
	atm, std	760	mm of Hg at 0
	atm, std	33.90	ft of water
	atm, std	29.92	in of Hg at 30
	atm, std	14.696	lbf/in^2 abs (p
	atm, std	101.325	kPa
	atm, std	1.013x10^5	Pa
	atm, std	1.03323	kgf / cm^2
	atm, std	14.696	psia
B	bar	0.9869	atm, std
	bar	1x10^5	Pa
	Btu	778.169	ft·lbf
	Btu	1055.056	J
	Btu	5.40395	psia·ft^3
	Btu	2.928x10^{-4}	kWh
	Btu	1x10^{-5}	therm
	Btu / hr	1.055056	kJ / hr
	Btu / hr	0.216	ft·lbf / sec
	Btu / hr	3.929x10^{-4}	hp
	Btu / hr	0.2931	W
	Btu / lbm	2.326*	kJ / kg
	Btu / lbm	25,037	ft^2 / s^2
	Btu / lbm·R	4.1868	kJ / kg·K
	Btu / lbm·°F	4.1868	kJ / kg·°C
	Btu / lbmol·R	4.1868	kJ / kmol·K
C	cal (g-calorie)	3.968x10^{-3}	Btu
	cal	1.560x10^{-6}	hp·hr

In Natural Resources we use both the **English** and **Metric** measurement systems

The English system is used by land/resource managers

The Metric system is used in scientific reports and proceedings

Its essential to know both systems and how to convert between them

The standard CNR conversion sheet is on the course website

A Metric World: The SI System

These are standard measures that have been repeated in multiple observations. We use these 4 in natural resources (others are the ampere, mol, and candela):

- Length, meter (m): The length of light traveled in a vacuum in 1/299792458 seconds
- Mass, kilogram (kg): The mass of a certain cylinder of platinum-iridium alloy held in a vault in Sevres, France
- Time, seconds (s): 9192631770 vibrations of the radiation emitted a s specific wavelength of cesium-133
- Temperature, Kelvin (K): 1/273.15 of the thermodynamic temperature of the triple point of water

A Metric World: The SI System

Three common supplementary units that are commonly used in natural resources are:

- The radian (rad): The angle between two radii of any circle where the section of the circumference that is cut off (i.e. the arc) equals the circle's radius

<u>In all circles:</u> 1 rad = 57.29578

- The steradian (sr): The solid angle that projects an area on the sphere equal to the square of the sphere's radius
- The degree ( ): Defined as 1 = (π/180) rad

A Metric World: Derived Units

TABLE 2-2. Examples of Derived Units

Quantity	SI Unit	Symbol
Area	square meter	m^2
Volume	cubic meter (the liter, 0.001 cubic meter, is not an SI unit although commonly used to measure fluid volume)	m^3
Specific volume	cubic meter per kilogram	$m^3 \cdot kg^{-1}$
Force	newton ($1 N = 1 kg \cdot m \cdot s^{-2}$)	N
Pressure	pascal ($1 Pa = 1 N \cdot m^{-2}$)	Pa
Work	joule ($1 J = 1 N \cdot m$)	J
Power	watt ($1 W = 1 J \cdot s^{-1}$)	W
Speed	meter per second	$m \cdot s^{-1}$
Acceleration	(meter per second) per second	$m \cdot s^{-2}$
Voltage	volt ($1 V = 1 W \cdot A^{-1}$)	V
Electric resistance	ohm ($1 = 1 V \cdot A$)	Ω
Concentration (amount of substance)	mole per cubic meter	$mol \cdot m^{-3}$

Source: Husch Beers and Kershaw

A Metric World: The Fundamental Units

The SI units are often called fundamental units. In natural resources we often only use:

- M = Mass, kilogram (kg)
- L = Length, meter (m)
- T = Time, seconds (s)

These units can produce “Derived Units” that can always be broken down into M, L and T.

A Metric World: The Fundamental Units

Example: What is Energy in M, L, and T?

Energy = ½ Mass * Velocity^2

Velocity = Meters / Second

Energy = ½ M * L^2 * T^{-2}

It is very important that you can always quickly double check that you are using the correct units!

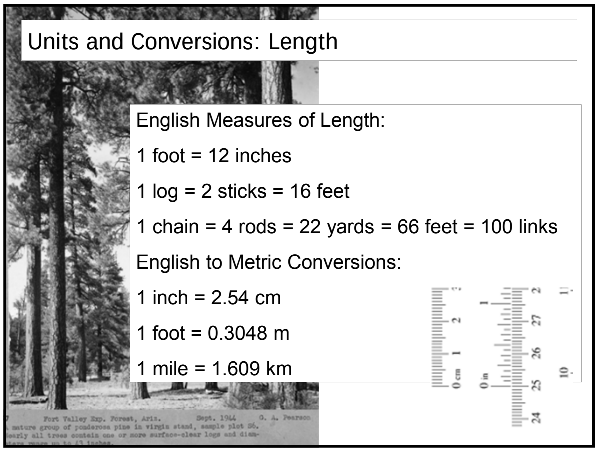
Units: SI Prefixes

TABLE 2-4. SI Prefixes and Abbreviations

Prefix	Symbol	Factor	
yotta	Y	10^{24}	1 000 000 000 000 000 000 000 000
zetta	Z	10^{21}	1 000 000 000 000 000 000 000
exa	E	10^{18}	1 000 000 000 000 000 000
peta	P	10^{15}	1 000 000 000 000 000
tera	T	10^{12}	1 000 000 000 000
giga	G	10^{9}	1 000 000 000
mega	M	10^{6}	1 000 000
kilo	k	10^{3}	1 000
hecto	h	10^{2}	100
deca	da	10^{1}	10
deci	d	10^{-1}	0.1
centi	c	10^{-2}	0.01
milli	m	10^{-3}	0.001
micro	μ	10^{-6}	0.000 001
nano	n	10^{-9}	0.000 000 001
pico	p	10^{-12}	0.000 000 000 001
femto	f	10^{-15}	0.000 000 000 000 001
atto	a	10^{-18}	0.000 000 000 000 000 001
zepto	z	10^{-21}	0.000 000 000 000 000 000 001
yocto	y	10^{-24}	0.000 000 000 000 000 000 000 001

Source: Husch Beers and Kershaw

Units and Conversions: Length



English Measures of Length:

1 foot = 12 inches

1 log = 2 sticks = 16 feet

1 chain = 4 rods = 22 yards = 66 feet = 100 links

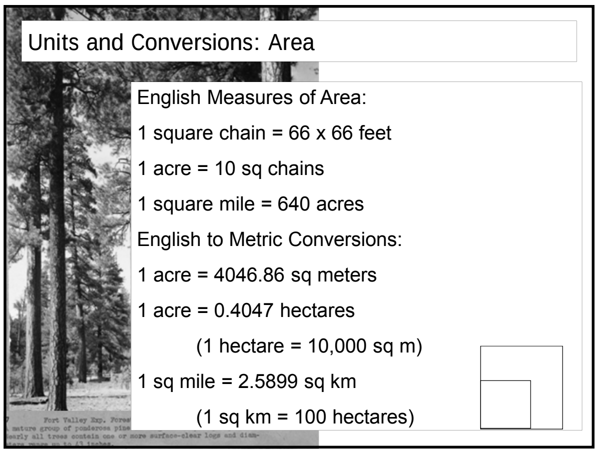
English to Metric Conversions:

1 inch = 2.54 cm

1 foot = 0.3048 m

1 mile = 1.609 km

Units and Conversions: Area



English Measures of Area:

1 square chain = 66 x 66 feet

1 acre = 10 sq chains

1 square mile = 640 acres

English to Metric Conversions:

1 acre = 4046.86 sq meters

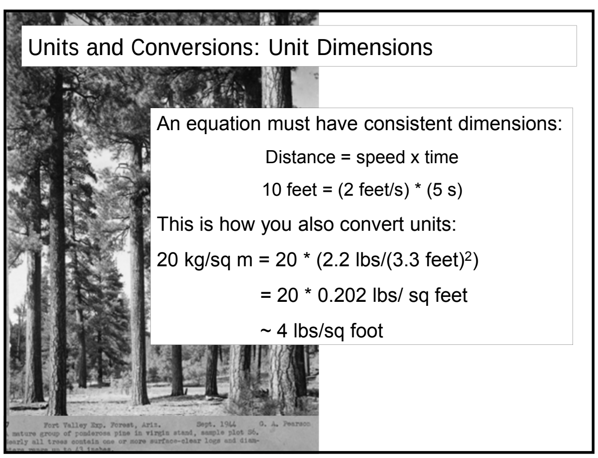
1 acre = 0.4047 hectares

(1 hectare = 10,000 sq m)

1 sq mile = 2.5899 sq km

(1 sq km = 100 hectares)

Units and Conversions: Unit Dimensions



An equation must have consistent dimensions:

Distance = speed x time

10 feet = (2 feet/s) * (5 s)

This is how you also convert units:

20 kg/sq m = 20 * (2.2 lbs/(3.3 feet)^2)

= 20 * 0.202 lbs/ sq feet

~ 4 lbs/sq foot

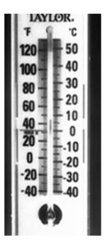
A Qualitative Measure: How Hot is it?

Imagine a thermometer without a scale and then measure outside in summer then winter

You only know that Here & Now may be hotter or colder than the previous measure but you do not know by how much?

All you can get is a Relative Difference without units this measure has no context

A Quantitative Measure: How Hot is it?

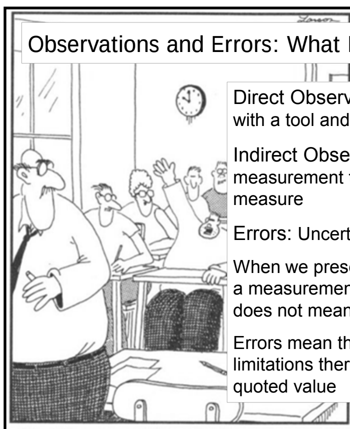


Quantitative measurements:

- Provide context for the qualitative measure – I.e. not as hot as the sun!
- Provide defensible physical quantities
- Comparable data between different scenarios
- Might be slower and more difficult to acquire

A **physical quantity** is any number that is used to describe a ecological or biophysical phenomena

Observations and Errors: What Does it All Mean?



"Mr. Osborne, may I be excused? My brain is full."

Direct Observation: Measuring something with a tool and can read off a number

Indirect Observation: Using another measurement to infer the metric we can't measure

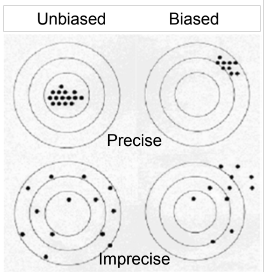
Errors: Uncertainty within a measure

When we present an error (e.g. 5cm) with a measurement (780 cm) the word "Error" does not mean a mistake

Errors mean that due to experimental limitations there is some uncertainty in the quoted value

Pentz and Shott(1994)

Errors: Accuracy and Precision



Accuracy:

The closeness of a measurement or estimate to the TRUE value

Precision (or variance):

The degree of agreement for a series of measurements

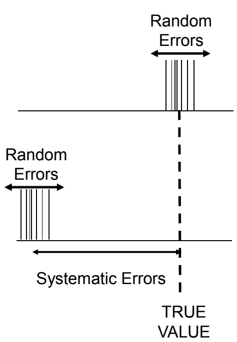
The clustering of samples about their own average (Standard Deviation)

The reproducibility of an estimate in repeated sampling (Standard Error)

The difference between observed value and true value are errors:

$$E = X - \bar{X}$$

Errors: Bias and Random Errors



Bias:

Bias refers to the tendency of measures to systematically shift in one direction from the true value

Bias is often caused by poorly calibrated instruments

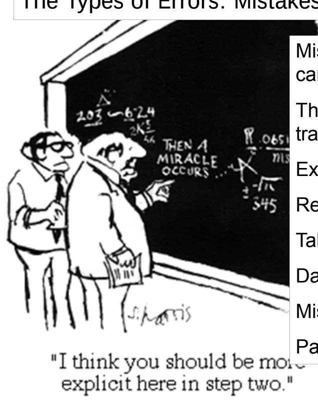
Random Errors:

In many cases repeating a measure produces a different result

These random (statistical) errors set the variability in the measurement

Pentz and Shott(1994)

The Types of Errors: Mistakes!



Mistakes are human errors that can occur at any time.

They can be minimized through training and taking care.

Examples:

Reading a scale incorrectly

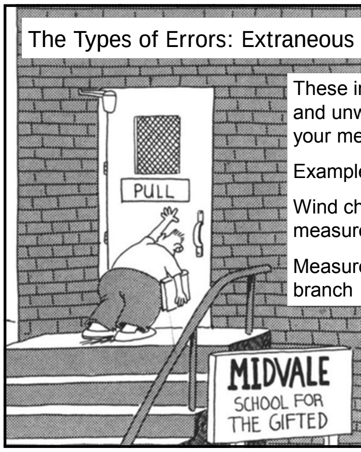
Tallying up trees incorrectly

Data entry errors

Misidentifying a species

Parallax errors

The Types of Errors: Extraneous Influences



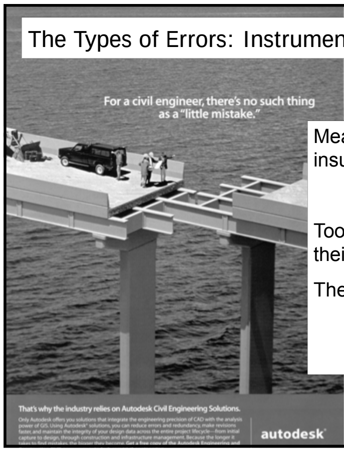
These include all the unexpected and unwanted effects that change your measurement

Examples:

Wind changing values on measurement scales

Measurement tape snagged on branch

The Types of Errors: Instrument Limitations



Measurement scales may have insufficient detail

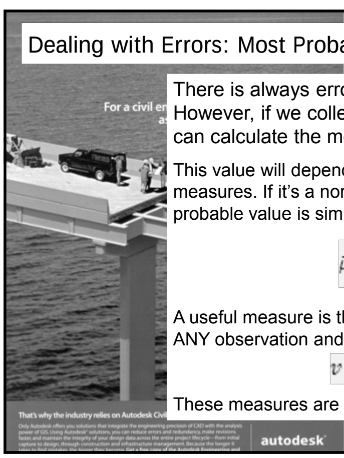
&

Tools may be consistently off in their measures: i.e Bias

These can include:

- Stretched tapes
- Uncalibrated Tools

Dealing with Errors: Most Probable Value



There is always error in measurements. However, if we collect enough measures, we can calculate the most probable value.

This value will depend on the distribution of the measures. If it's a normal distribution, the most probable value is simply the mean.

$$\bar{\mu} = \frac{\sum M}{n}$$

A useful measure is then the difference between ANY observation and this most probably value:

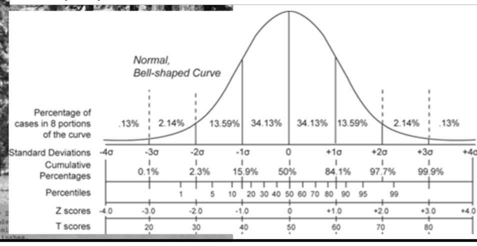
$$v = \bar{\mu} - M$$

These measures are called residuals.

Dealing with Errors: Forestry Distributions

The most commonly used distributions in forestry are normal, *Poisson*, and Weibull.

Normal (Gaussian): These distributions come with a series of easy to operate statistics. The “hope” of most people is that their data follows this distribution.



Representative Measures: The Arithmetic Mean

This is the most commonly used and is also called the mean or average.

	N	Samples
1	N	Samples
2		
3	1	3
4	2	4
5	3	10
6	4	2
7	5	8
8	6	18
9	7	5
10	8	17
11	9	9
12	10	10
13		
14	=AVERAGE(B3:B12) = 8.6	
15		

Population:

$$\mu = \frac{\sum_{i=1}^{N} y_i}{N}$$

Sample:

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

Representative Measures: The Arithmetic Mean

When dealing with per unit area data collected in stands of variable area we need to use a weighted mean

C13 =SUM(C2:C11)/SUM(A2:A11)

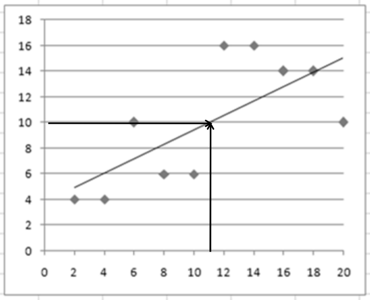
	A	B	C	D	E
1	Stand Area	Mean V per Acre	A*V		
2	40	202	8080		
3	35	170	5950		
4	42	194	8148		
5	37	260	9620		
6	41	170	6970		
7	39	190	7410		
8	20	204	4080		
9	35	186	6510		
10	28	150	4200		
11	30	156	4680		
12					
13		188.2	189.2		

$$\bar{y}_w = \frac{\sum_{i=1}^{n} A_i y_i}{\sum_{i=1}^{n} A_i}$$

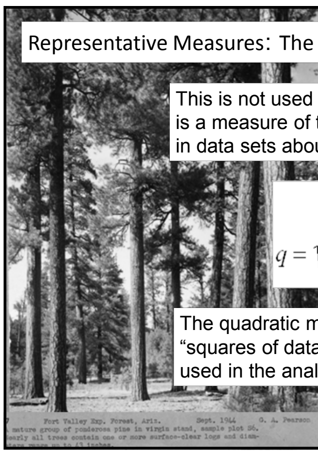
Representative Measures: The Arithmetic Mean

The mean of both your X and Y data should produce a X-Y coordinate is a real value on the function fitted to your data

	A	B
1	N	Samples
2	2	4
3	4	4
4	6	10
5	8	6
6	10	6
7	12	16
8	14	16
9	16	14
10	18	14
11	20	10
12		
13	11	10



Representative Measures: The Quadratic Mean



This is not used as an "average" but rather is a measure of the variability or dispersion in data sets about the arithmetic mean

$$q = \sqrt{\frac{\sum_{i=1}^{n} y_i^2}{n}}$$

The quadratic mean is used when the "squares of data", rather than the raw data is used in the analysis

Johnson

Representative Measures: The Geometric Mean

The geometric mean is used when the values of the distribution approximate those of a geometric series:

B11 =GEOMEAN(B1:B8)

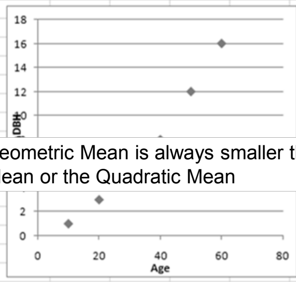
	A	B
1	1	1
2	2	2
3	3	4
4	4	8
5	5	16
6	6	32
7	7	64
8	8	128
9		
10	Arithmetic	31.88
11	Geometric	11.31

$$g = \left(\prod_{i=1}^{n} y_i\right) = (y_1 * y_2 * y_3 * \ldots * y_n)^{1/n}$$

Representative Measures: Geometric Mean

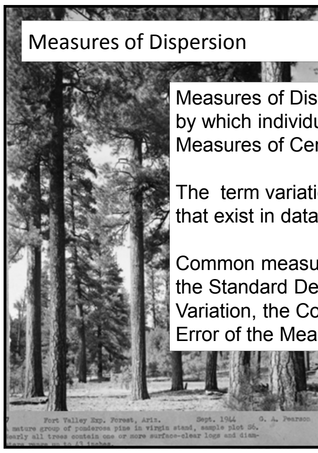
Assessing average PIPO growth (e.g., DBH) in a stand over a period of 60 years may look like this:

Age	ΔDBH
10	1
20	3
30	5
40	8
50	12
60	16



Note: The Geometric Mean is always smaller than both the Arithmetic Mean or the Quadratic Mean

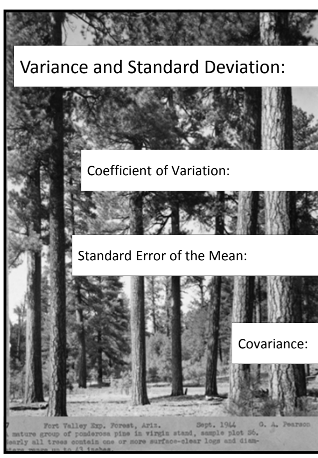
Measures of Dispersion



Measures of Dispersion define the amount by which individual data points vary from the Measures of Central Tendency.

The term variation describes the differences that exist in data that make up a population.

Common measures include the Variance, the Standard Deviation, the Coefficient of Variation, the Covariance, and the Standard Error of the Mean.



Variance and Standard Deviation:

$$\sigma^2 = \frac{1}{N}\sum_{i=1}^{N}(x_i - \mu)^2$$

Coefficient of Variation:

$$CV = 100 * \frac{\sigma}{\mu}$$

Standard Error of the Mean:

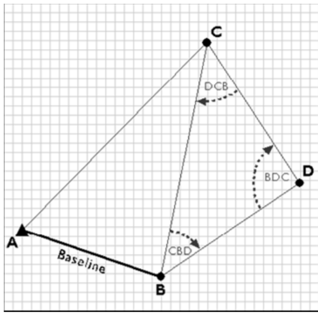
$$SE_{\bar{x}} = \frac{s_x}{\sqrt{n}}$$

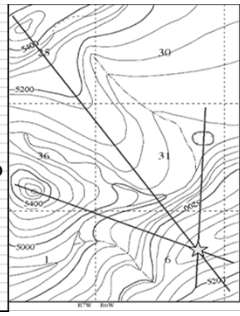
Covariance:

$$S_{xy} = \frac{\sum_{i=1}^{N}(x_i - \bar{x})(y_i - \bar{y})}{N - 1}$$

Forest Measurements: A World of Triangles

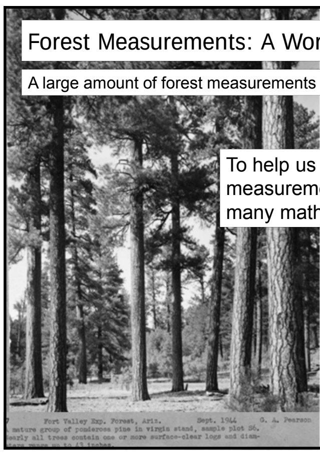
A large amount of forest measurements uses the mathematics of Triangles:





Forest Measurements: A World of Triangles

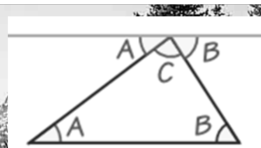
A large amount of forest measurements uses the mathematics of Triangles

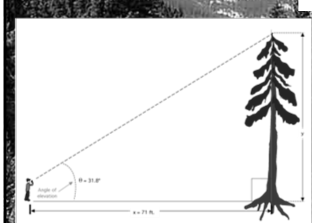


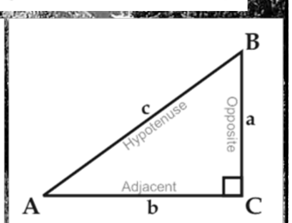
To help us take easier (or fewer) measurements we need to know as many mathematical tricks as possible.

Triangles: Remembering Angles

This simple proof shows that the 3 angles in a triangle add up to 180 .



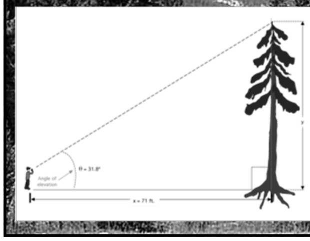


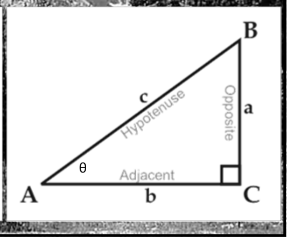


Triangles: Right Angled Triangles

Remembering SOH CAH TOA:

Sin θ = Opposite / Hypotenuse (SOH)
Cos θ = Adjacent / Hypotenuse (CAH)
Tan θ = Opposite / Adjacent (TOA))

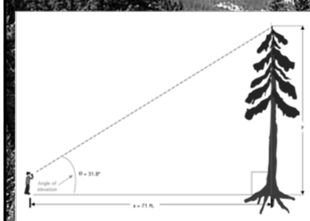


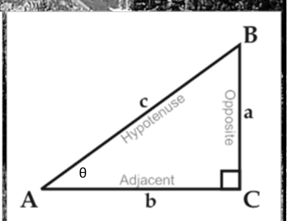


Triangles: Pythagoras

Remembering Pythagoras:

$a^2 + b^2 = c^2$

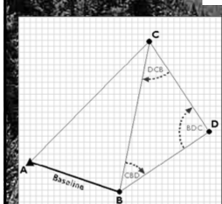


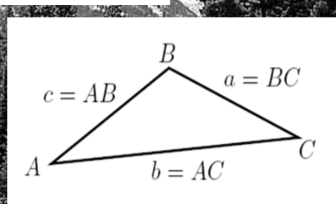


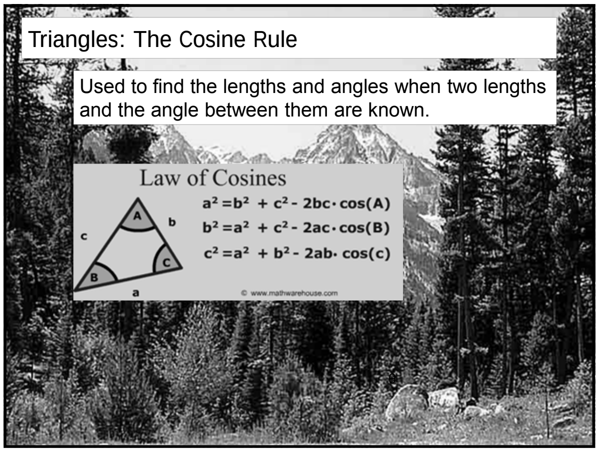
Triangles: The Sine Rule

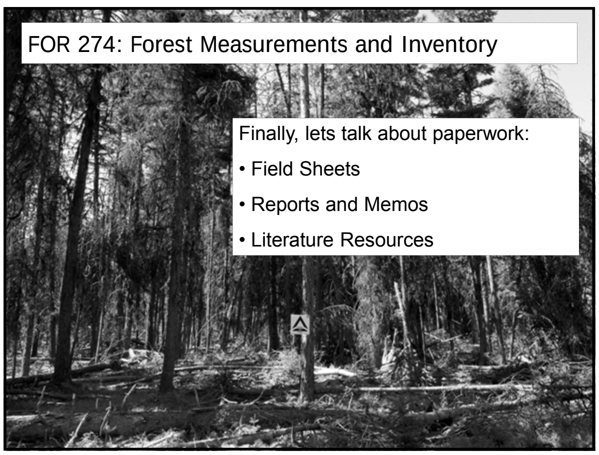
Used to find the lengths of each side and all its angles when we know either a) two angles and one side, or b) two sides and an opposite angle.

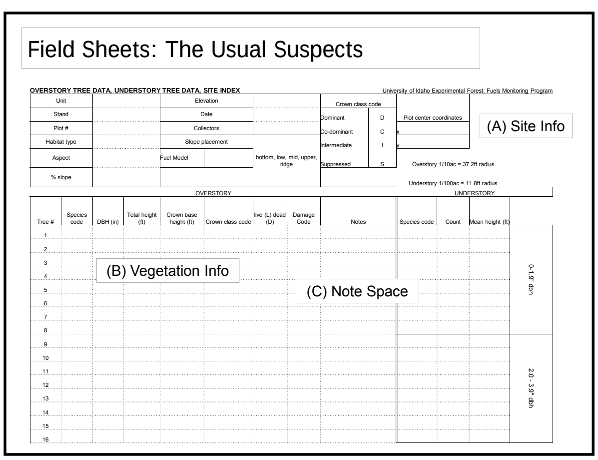
$$\frac{a}{\sin A} = \frac{b}{\sin B} = \frac{c}{\sin C}$$











OVERSTORY TREE DATA, UNDERSTORY TREE DATA, SITE INDEX

University of Idaho Experimental Forest: Fuels Monitoring Program

				Crown class code		
Unit		Elevation		Dominant	D	Plot center coordinates
Stand		Date		Co-dominant	C	x
Plot #		Collectors		Intermediate	I	y
Habitat type		Slope placement		Suppressed	S	
Aspect		Fuel Model	bottom, low, mid, upper, ridge			
% slope						

Overstory 1/10ac = 37.2ft radius

Understory 1/100ac = 11.8ft radius

OVERSTORY									UNDERSTORY			
Tree #	Species code	DBH (in)	Total height (ft)	Crown base height (ft)	Crown class code	live (L) dead (D)	Damage Code	Notes	Species code	Count	Mean height (ft)	
1												0-1.9" dbh
2												
3												
4												
5												
6												
7												
8												
9												2.0 - 3.9" dbh
10												
11												
12												
13												
14												
15												
16												

Forest Measurements: Communication

Forestry is a professional career where communication skills are highly valued.

Many new foresters make reports too short. Many times the report is the only evidence that any work was done. To communicate professionally you need to:

1. Use correct grammar and spelling
2. Use appropriate analysis methods
3. Use jargon sparingly. If you must, do so correctly
4. Take care and time to neatly present your results

Take Care: Many forestry professors will grade your essays / reports with a zero if they contain more than 1 spelling mistake!

Always use word processor spellcheckers and read the essays over before handing them in.

Forest Measurements: Reporting Data

Main Elements of a Report

- Title Page
- Table of Contents
- Introduction
- Review of Prior Work
- Study Area Description
- Collection of Field Data and Other Analysis
- Analysis of Results
- Summary and Conclusions
- Literature Cited

Reports and Memos: Title Page

Typical to often include authors name and date completed.

Reports and Memos: Contents

Table of Contents

Forest Measurements: Proper Use of Tables

Table 1. Common lidar sensor parameters for natural resource applications.

Parameter	Value
Wavelength	1.064 µm
Pulse Repetition Rate (PRF)	~50–150 kHz
Returns per pulse	3–4
Pulse width	10 nano-seconds
Beam divergence	10–80 m rad
Scan angle	<15° off-nadir, 30° total look
Scan pattern(s)	Ziz-zag, parallel, elliptical, sinusoidal
GPS frequency	1–2 Hz
INS frequency	50 Hz (200 Hz max)
Operating altitude	100–3,000 m (6,000 m max), average ~2,000 m
Footprint size	0.10–0.30 cm
Pulse Density	> 4 pulse/m^2
Accuracy (Vertical/Elevation)	<0.15 m
Delivery format	Binary lidar exchange format (LAS)

Forest Measurements: Proper Use of Figures

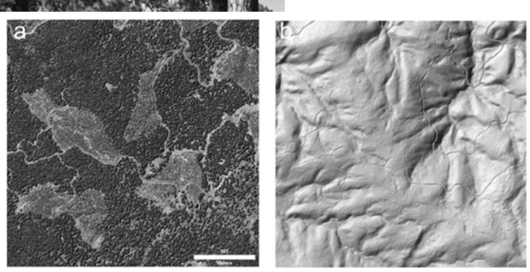
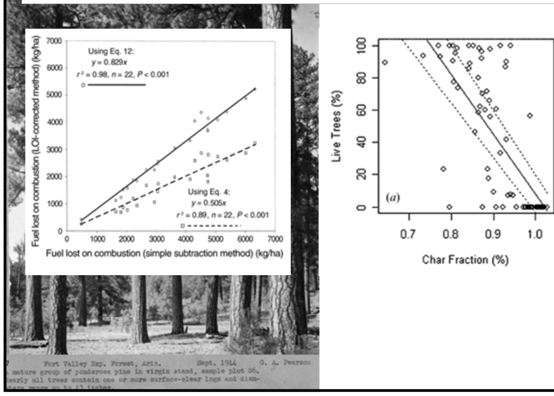
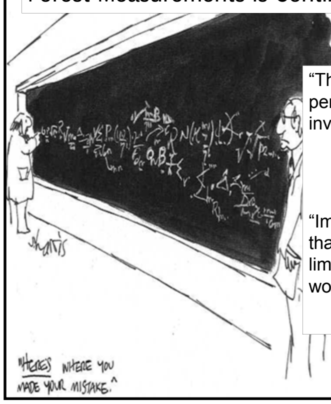


Figure 1. Shaded relief of: **(a)** all return Digital Surface Model (DSM), and **(b)** ground return Digital Elevation Model (DEM).

Forest Measurements: Proper Use of Graphs



Forest Measurements is Continually Changing



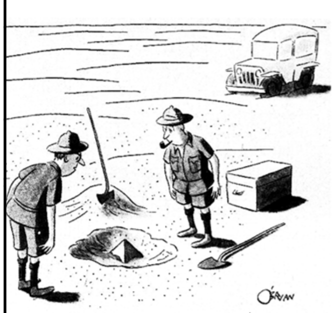
"The continued need for forestry personnel with imagination and inventiveness is clearly apparent"

Avery and Burkhart

"Imagination is more important than knowledge: Knowledge is limited, Imagination encircles the world."

Albert Einstein

Some Parting Thoughts:



"This could be the discovery of the century. Depending, of course, on how far down it goes."

"There is no harm in doubt and skepticism, for it is through these that new discoveries are made."

- Dr Richard Feynman