

FOR 274: Forest Measurements and Inventory



Tree Heights and Crowns

- Tree Heights
- Height to Live Crown
- Crown Class
- Crown Size
- Canopy Bulk Density

---

---

---

---

---

---

---

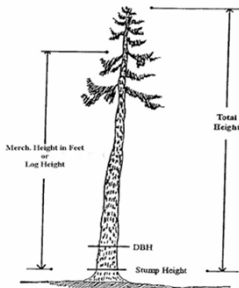
---

---

---

Tree Height: Definitions

Different types of height exist in timber cruising.



Total Tree Height: Length from stump height to the tip of the leader  
 Merchantable Height: Length from stump height to the contract minimum diameter and recorded in feet  
 Log Height: Length from stump height to the contract minimum diameter and recorded to the nearest one-half log  
 Stump height varies (by region and company) but it is often 12" as measured on the high side.

---

---

---

---

---

---

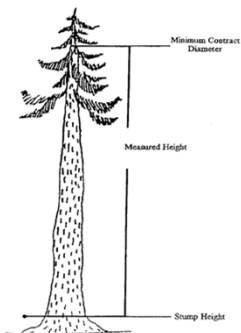
---

---

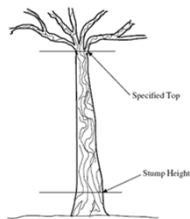
---

---

Tree Height: Definitions



The contract minimum diameter is often called the Top Diameter Inside Bark (Top DIB). Above this point no merchantable products are possible.




---

---

---

---

---

---

---

---

---

---



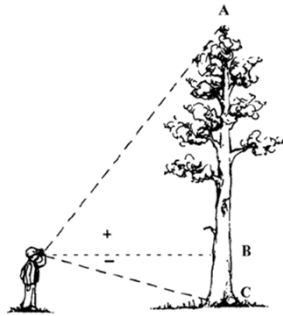
Tree Heights: How to use clinometers!

General Formula::

$$H = (H_T - H_B) * (HD/BD)$$

Where,

- H<sub>T</sub> = Height to top (BC)
- H<sub>B</sub> = Height to Base (BA)
- HD = Distance from person to B
- BD = clinometer scale 66 (for 1/66) and 100 (for %)




---

---

---

---

---

---

---

---

Tree Heights: What would you do here?




---

---

---

---

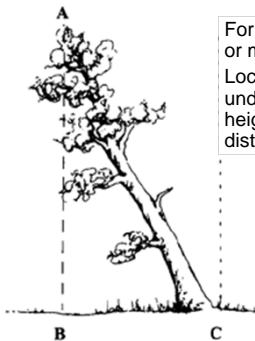
---

---

---

---

Tree Heights: Leaning Trees



For trees leaning 25% (about 15°) or more from vertical:  
 Locate point on ground directly under tip of leaning tree. Measure height A B. Measure horizontal distance B C:

$$\text{Tree Height} = \sqrt{AB^2 + BC^2}$$

---

---

---

---

---

---

---

---

### Tree Heights: Leaning Trees



For trees leaning 25% (about 15°) or more from vertical:  
 Locate point on ground directly under tip of leaning tree. Measure height A B. Measure horizontal distance B C:

Example: Measured height (AB) = 120'  
 Horizontal distance (BC) = 40'

$$\text{Corrected tree height} = \sqrt{120^2 + 40^2} = 126.49$$

---

---

---

---

---

---

---

---

---

---

### Tree Heights: Leaning Trees

Or, use the following table:

		Horizontal Distance - tip to center of bole at ground (B C)																	
MS HT	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	
40	40	41	43	45															
50	50	51	52	54	56														
60	60	61	62	63	65	67													
70		71	72	73	74	76	78												
80		81	81	82	84	86	87	89											
90		91	91	92	94	95	97	98	101										
100		101	101	102	103	104	106	108	110	112									
110			111	112	113	114	116	117	119	121	123								
120			121	122	123	124	125	126	128	130	132	134							
130			131	131	132	133	135	136	138	139	141	143	145						
140			141	141	142	143	144	146	147	149	150	152	154	157					
150			151	151	152	153	154	155	157	158	160	162	164	166	168				
160			161	161	162	163	164	165	166	168	169	171	173	175	177	179			
170			171	171	172	173	174	175	176	177	179	180	182	184	186	188	190		
180			181	181	182	183	183	184	176	187	188	190	191	193	195	197	199	201	
190				191	192	192	193	194	195	196	198	200	201	203	204	206	208	210	
200				201	202	202	203	204	205	206	208	209	211	212	214	215	217	219	

MS HT = (A B) Measured Height

---

---

---

---

---

---

---

---

---

---

### Tree Heights: What would you do with forks?




---

---

---

---

---

---

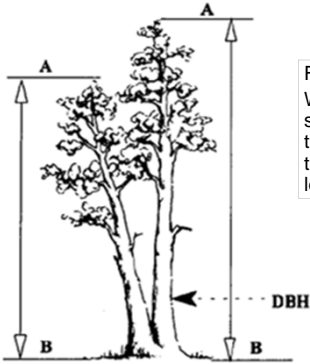
---

---

---

---

Tree Heights: Forks



For trees forked below DBH:  
We treat the two forks as two separate trees and measure the height of each stem from the tree base to the tip of the leader

---

---

---

---

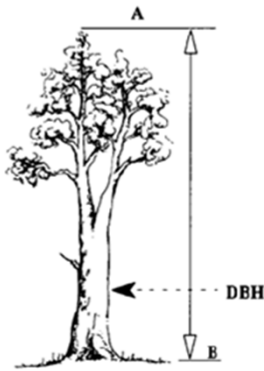
---

---

---

---

Tree Heights: Forks



For trees forked above DBH:  
If the fork occurs at or above 4.5 feet on the high ground side, we treat the tree as only a single tree and measure the height of the tallest fork.

---

---

---

---

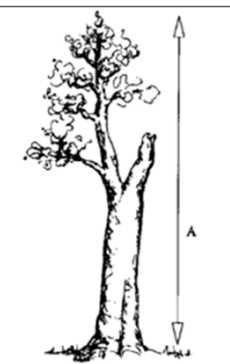
---

---

---

---

Tree Heights: Forks



For trees with a broken tip:  
The height of the tallest fork is measured and recorded as the total height,  
Make a note that the tree is damaged and has a "broken tip"

---

---

---

---

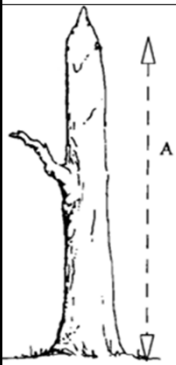
---

---

---

---

Tree Heights: Forks



For trees with a missing top:  
We measure the height of the  
stub as the total tree height,  
We record damage as  
"missing top"

---

---

---

---

---

---

---

---

Tree Heights: What would you do here?



---

---

---

---

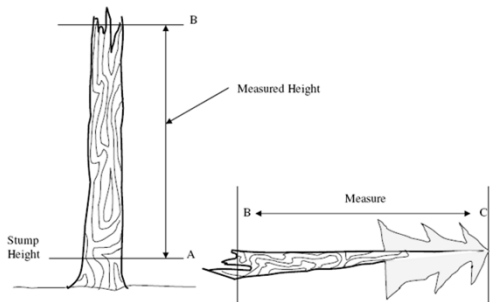
---

---

---

---

Tree Heights: Broken off trees



---

---

---

---

---

---

---

---

FOR 274: Forest Measurements and Inventory



Tree Heights and Crowns

- Tree Heights
- Height to Live Crown
- Crown Class
- Crown Size
- Canopy Bulk Density

---

---

---

---

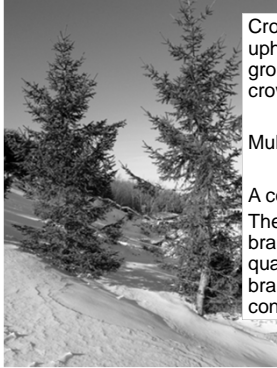
---

---

---

---

Height to Live Crown: Definitions



Crown height is measured on the uphill side of the tree, from the ground line to the base of the live crown

Multiple definitions exist!

A common definition:  
The lowest branch whorl with live branches in at least two quadrants exclusive of epicormic branches and whorls not continuous with the main crown

---

---

---

---

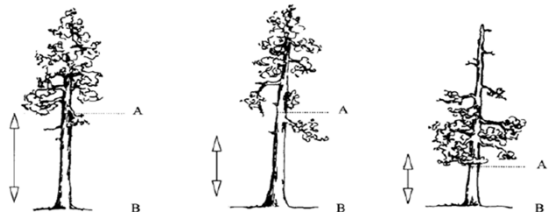
---

---

---

---

Height to Live Crown: Definitions



---

---

---

---

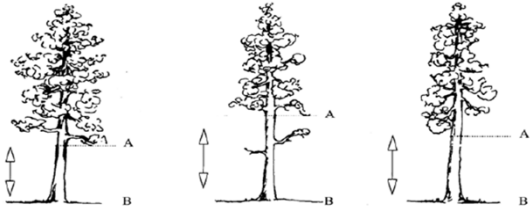
---

---

---

---

Height to Live Crown: Definitions



---

---

---

---

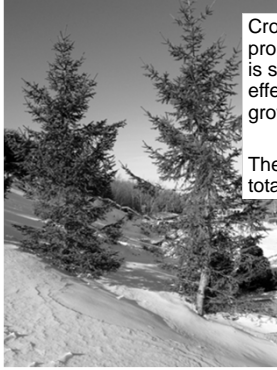
---

---

---

---

Crown Ratio: Definitions



Crown height is measured as the proportion of the total height that is supporting live foliage that is effectively contributing to tree growth:

The ratio of live crown length to total tree height

---

---

---

---

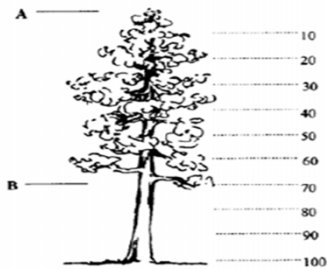
---

---

---

---

Crown Ratio: Examples



---

---

---

---

---

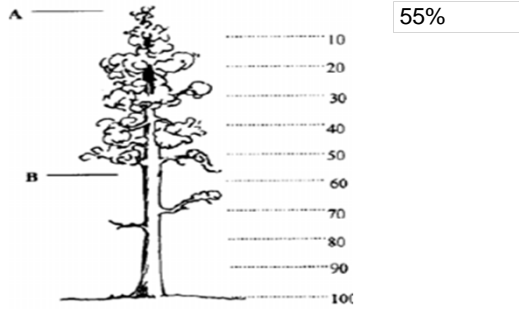
---

---

---



Crown Ratio: Examples



---

---

---

---

---

---

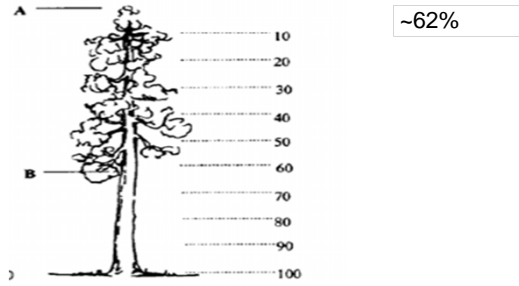
---

---

---

---

Crown Ratio: Examples



---

---

---

---

---

---

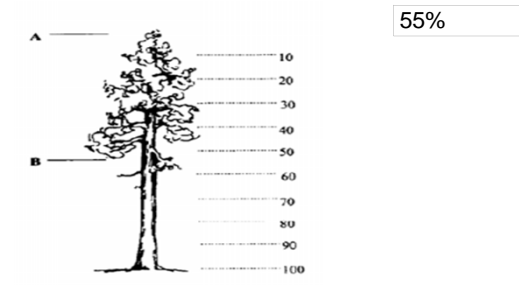
---

---

---

---

Crown Ratio: Examples



---

---

---

---

---

---

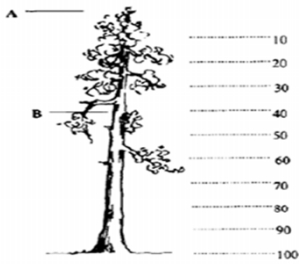
---

---

---

---

Crown Ratio: Examples



---

---

---

---

---

---

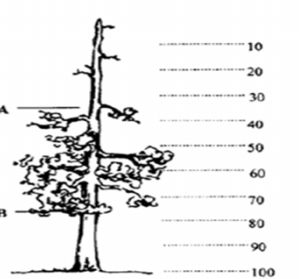
---

---

---

---

Crown Ratio: Examples



---

---

---

---

---

---

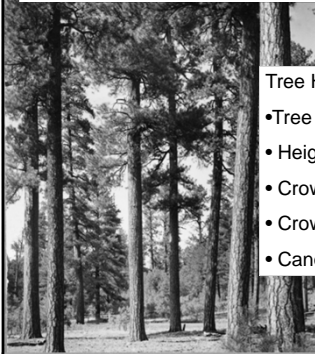
---

---

---

---

FOR 274: Forest Measurements and Inventory



Tree Heights and Crowns

- Tree Heights
- Height to Live Crown
- Crown Class
- Crown Size
- Canopy Bulk Density

Fort Valley Exp. Forest, Ariz. Sept. 1944. J. A. Pearson  
nature group of ponderosa pine in virgin stand, sample plot 50,  
height all trees available now or more accurate than last year's data

---

---

---

---

---

---

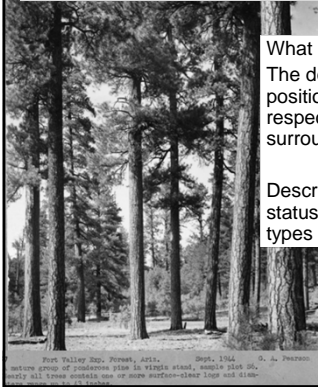
---

---

---

---

Crown Class: Introduction



What is Crown Class:  
The description of the relative  
position of the tree crown with  
respect to competing vegetation  
surrounding the tree

Descriptors of the competitive  
status of trees in all structural  
types of stands

---

---

---

---

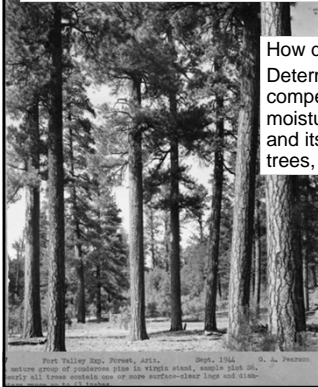
---

---

---

---

Crown Class: Introduction



How do we Measure Crown Class:  
Determined in the context of  
competition for sunlight or  
moisture between the subject tree  
and its immediate environment,  
trees, or shrubs

---

---

---

---

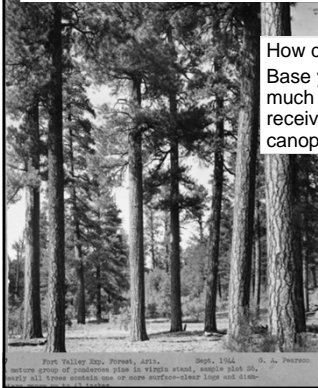
---

---

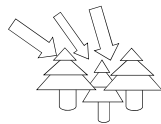
---

---

Crown Class: Introduction



How do we Measure Crown Class:  
Base your classification on how  
much light the tree's crown is  
receiving, not its position in the  
canopy



---

---

---

---

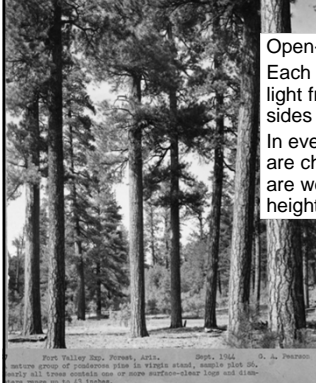
---

---

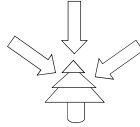
---

---

Crown Class: The Classes



**Open-grown or Isolated:**  
Each tree crown receives full sunlight from both above and from all sides  
In even-aged stands, these trees are characterized by crowns that are well above the main canopy height



---

---

---

---

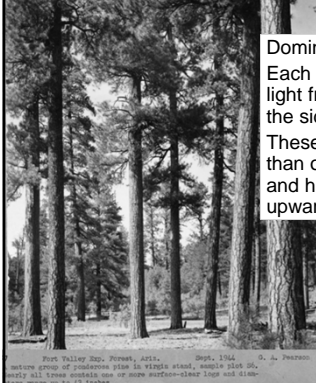
---

---

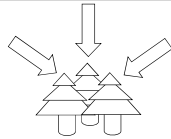
---

---

Crown Class: The Classes



**Dominant:**  
Each tree crown receives full sunlight from above and partly from the sides  
These crowns are generally higher than others in the same stratum and have nothing blocking their upward growth



---

---

---

---

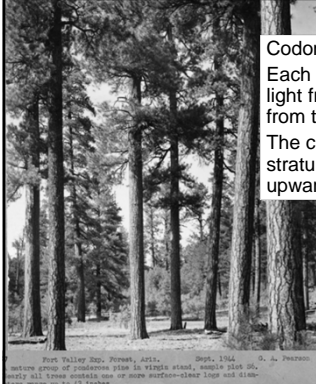
---

---

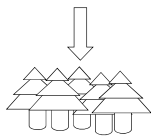
---

---

Crown Class: The Classes



**Codominant :**  
Each tree crown receives full sunlight from both above but very little from the sides  
The crowns form a level crown stratum and are not restricted from upward growth



---

---

---

---

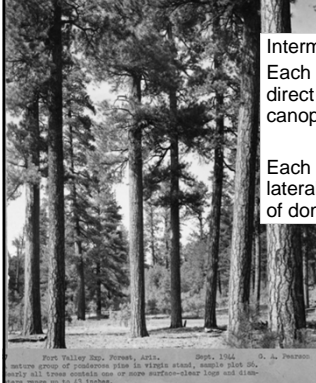
---

---

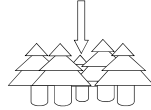
---

---

Crown Class: The Classes



**Intermediate:**  
Each tree crown receives a little direct light from holes in the canopy and no light from the sides.  
Each crown is subject to strong lateral competition from the crowns of dominants and codominants.



---

---

---

---

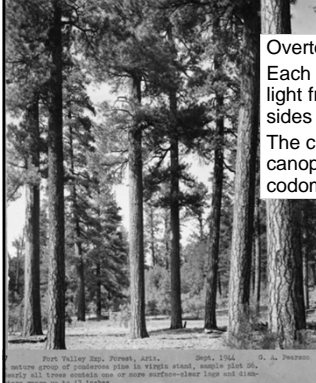
---

---

---

---

Crown Class: The Classes



**Overtopped:**  
Each tree crown receives no sunlight from either above or from all sides  
The crowns are entirely below the canopy stratum of dominant and codominant trees



---

---

---

---

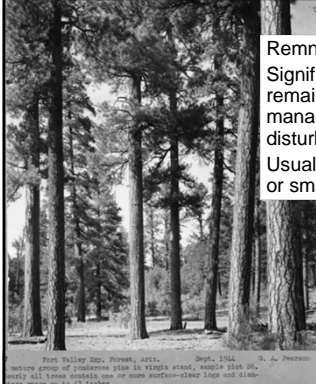
---

---

---

---

Crown Class: The Classes



**Remnant:**  
Significantly older trees that remain from a previous management activity or a disturbance event  
Usually isolated individual crowns or small clumps



---

---

---

---

---

---

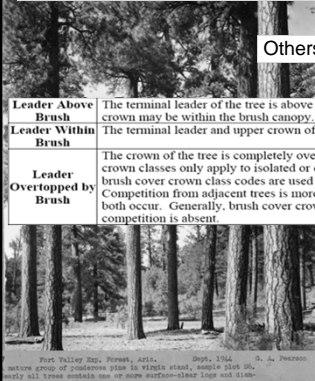
---

---

**Crown Class: The Classes**

Others:

<b>Leader Above Brush</b>	The terminal leader of the tree is above the surrounding brush while the middle or lower crown may be within the brush canopy.
<b>Leader Within Brush</b>	The terminal leader and upper crown of the tree is within the brush canopy.
<b>Leader Overtopped by Brush</b>	The crown of the tree is completely overtopped by the surrounding brush. Brush cover crown classes only apply to isolated or dominant trees with brush competition; therefore, brush cover crown class codes are used as modifiers for open-grown or dominant trees. Competition from adjacent trees is more important than competition from shrubs if they both occur. Generally, brush cover crown codes are used in stands where overstory tree competition is absent.



Fort Valley Spr. Forest, Ariz. Sept. 1944. J. A. Peabody  
 mature group of ponderosa pine in virgin stand, sample plot 20.  
 nearly all trees contain one or more surface-clear logs and clump  
 of brush in the canopy.

---

---

---

---

---

---

---

---

---

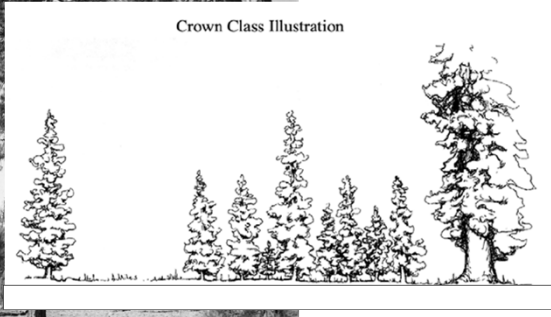
---

---

---

**Crown Class: What would you record?**

**Crown Class Illustration**



Fort Valley Spr. Forest, Ariz. Sept. 1944. J. A. Peabody  
 mature group of ponderosa pine in virgin stand, sample plot 20.  
 nearly all trees contain one or more surface-clear logs and clump  
 of brush in the canopy.

---

---

---

---

---

---

---

---

---

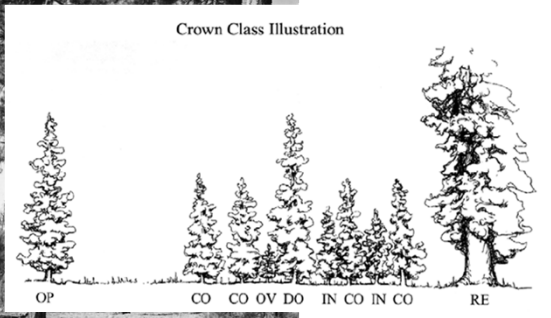
---

---

---

**Crown Class: What would you record?**

**Crown Class Illustration**



Fort Valley Spr. Forest, Ariz. Sept. 1944. J. A. Peabody  
 mature group of ponderosa pine in virgin stand, sample plot 20.  
 nearly all trees contain one or more surface-clear logs and clump  
 of brush in the canopy.

---

---

---

---

---

---

---

---

---

---

---

---

## FOR 274: Forest Measurements and Inventory



### Tree Heights and Crowns

- Tree Heights
- Height to Live Crown
- Crown Class
- Crown Size
- Canopy Bulk Density

---

---

---

---

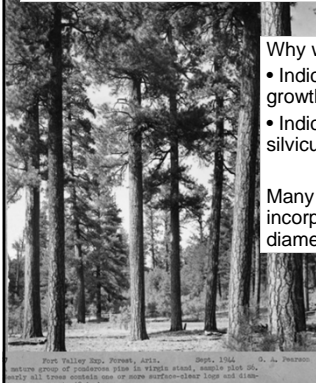
---

---

---

---

## Crown Sizes: Introduction



### Why we measure crown sizes:

- Indicator of productivity and growth
- Indicator of response to a specific silvicultural treatment

Many growth and yield models incorporate crown size information: diameters and heights

---

---

---

---

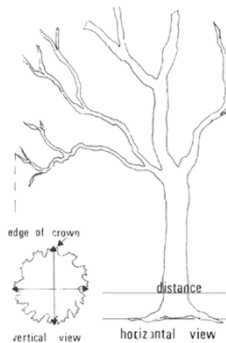
---

---

---

---

## Crown Diameter: Definition



### Commonly used definitions:

- Average of maximum and minimum diameter
- Average of maximum and diameter measured at right angles to the maximum
- Average of a random orientation and a second measure at right angles to the first measure

For highly irregular crowns an average of multiple measures may be used

---

---

---

---

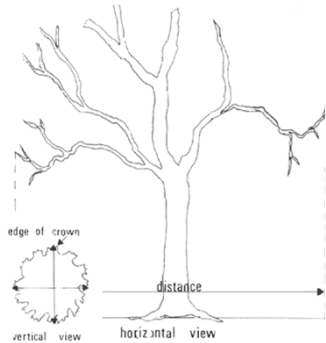
---

---

---

---

Crown Diameter: Measurement



- 1 person:
- Connect loggers tape to center of tree stem
  - Walk out to longest observed branch
  - Keep tape horizontal
  - Measure distance to branch tip
  - Repeat in opposite direction

---

---

---

---

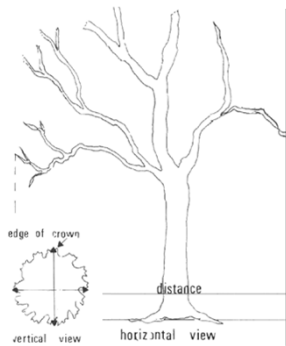
---

---

---

---

Crown Diameter: Measurement



- 2 people:
- Along the widest part of the tree crown - hold tape horizontally and extend until each person is vertically under the tip of the longest branch on their side
- Record this as maximum width
- Turn tape by 90° and repeat measurement along the thinnest part of the tree crown
- Record this as minimum width

---

---

---

---

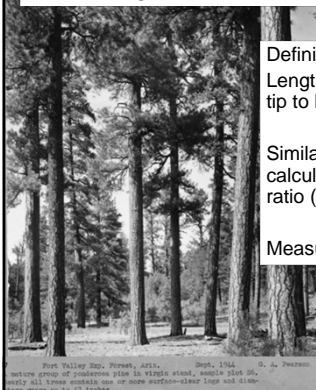
---

---

---

---

Crown Length: Introduction



- Definition:  
Length of green crown from leader tip to lowest live foliage
- Similar to measure used to calculate % live crown or crown ratio (I.e. last lecture)
- Measurement: Clinometer

---

---

---

---

---

---

---

---



### Crown Sizes: Surface Area and Volume



From crown diameter and crown length we can assume the tree shape is a cone to model surface area and volume:

Surface area (ft<sup>2</sup>, m<sup>2</sup>)

$$SurfaceArea = \frac{\pi d_b}{2} \sqrt{L^2 + \left(\frac{d_b}{2}\right)^2}$$

Volume (ft<sup>3</sup>, m<sup>3</sup>)

$$Volume = \frac{\pi d_b^2 L}{12}$$

where

$d_b$  = crown base diameter

L = crown length

Fort Valley State Forest, Ariz., Sept. 1964. Mature group of ponderosa pine in single stand, sample plot 20. Nearly all trees contain one or more surface-bleed logs and clear-

---

---

---

---

---

---

---

---

---

---

---

---

### FOR 274: Forest Measurements and Inventory



#### Tree Heights and Crowns

- Tree Heights
- Height to Live Crown
- Crown Class
- Crown Size
- Canopy Bulk Density

Fort Valley State Forest, Ariz., Sept. 1964. Mature group of ponderosa pine in single stand, sample plot 20. Nearly all trees contain one or more surface-bleed logs and clear-

---

---

---

---

---

---

---

---

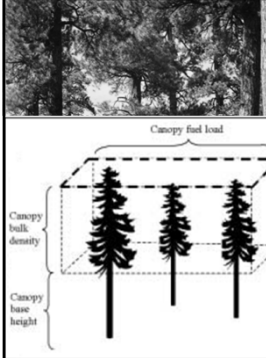
---

---

---

---

### Canopy and Crown Bulk Density: Introduction



#### Definitions:

Crown Bulk Density is the dry weight of the available canopy fuel per unit of the crown volume of an individual tree.

Canopy Bulk Density is dry weight of the available canopy fuel per unit of canopy volume.

$$CBD = loading / canopy\ depth$$

Figure from Cruz et al. 2003

---

---

---

---

---

---

---

---

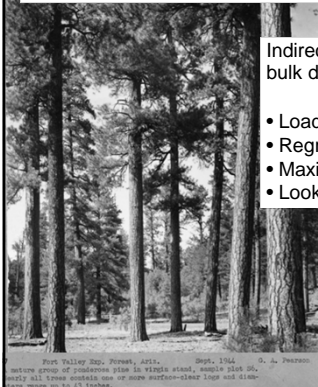
---

---

---

---

### Canopy Bulk Density: Methods



Indirect methods to estimate crown bulk density include:

- Load over depth method
- Regression
- Maximum running mean
- Lookup tables

---

---

---

---

---

---

---

---

### Canopy Bulk Density: Load Over Depth Method

This approach simply divides the canopy fuel load by depth of the canopy. This method assumes a uniform vertical distribution of canopy fuel (i.e. not a cone).



The canopy depth can be estimated by:

1. Mean crown length over all trees in a plot: crown length = tree height - crown base height
2. 90<sup>th</sup> percentile tree height - median crown base height
3. Height range where 90% of the fuel loading occurs >> thus CBH is where 10% of fuel occurs.

Cruz et al (2003); Reinhardt et al (2007)

---

---

---

---

---

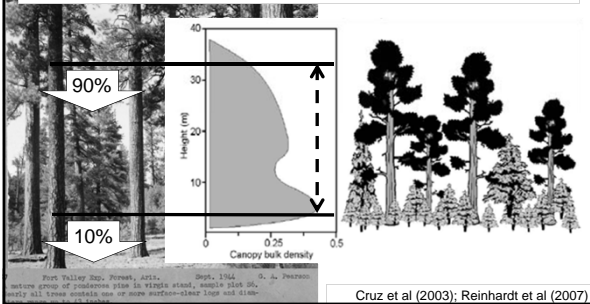
---

---

---

### Canopy Bulk Density: Canopy Profiles

You can create these profiles by hand (!) or by using software like FVS (Forest Vegetation Simulator). Lidar produces similar data that can be used to estimate CBD.



Cruz et al (2003); Reinhardt et al (2007)

---

---

---

---

---

---

---

---

## Canopy Bulk Density: Regression

Allometric equations are relations between easy to measure tree measurements (heights, DBH, etc) and difficult to measure quantities (volume, CBD, etc)

$$CBD = BO + B1 LN G + B2 LN TPH$$

Cruz et al (2003)

Method	Correlation	Bias = mean (observed - predicted)
Canopy fuel load (kg/m <sup>2</sup> )		
Allometric equations <sup>a</sup>	0.297	-0.1716
Regressions <sup>b</sup>	0.385	0.0286
Adjusted allometric equations <sup>c</sup>	0.985	0.0726
Canopy bulk density (kg/m <sup>3</sup> )		
Load-over-depth		
Mean <sup>d</sup>	0.700	-0.0362
Biomass percentile <sup>e</sup>	0.987	0.0019
Height percentile <sup>e</sup>	0.966	0.0172
Lookup tables <sup>f</sup>	0.549	-0.0704
Allometric equations <sup>g</sup>	0.546	-0.0152
Regressions <sup>h</sup>	0.616	-0.0618
Adjusted allometric equations <sup>c</sup>	0.996	0.0102

---

---

---

---

---

---

---

---