FOR 274: Forest Measurements and Inventory

Fixed Area Plots and Plot Boundaries

- Fixed Area Plots
- Slope Correction
- Stand Boundaries
- Strip & Line-Plot Cruising
- Permanent Plots

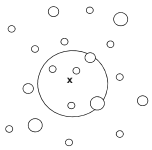
Fixed Area Plots: Overview

Plot: Small area sampling unit that are normally a square, rectangle, or circle

Strip or Transect: Rectangular plot that's length is very much greater than its width

Individuals are selected by probability proportional to frequency (the more common it occurs the more likely it is measured)

Fixed Area



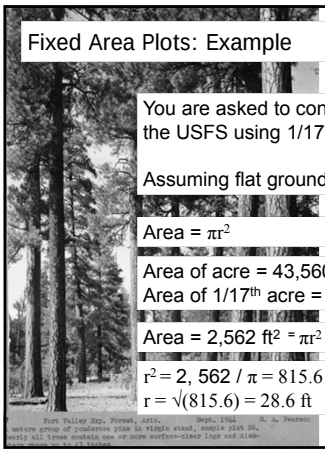
Fixed Area Plots: Common Sizes

TABLE 11-1 Dimensions of Commonly Used Fixed-Area Plots

Plot Area as a Fraction of Per Unit Area	English System: Plot Area (ft^2)	English System: Circular Radius (ft)	English System: Square Side (ft)	Metric System: Plot Area (m^2)	Metric System: Circular Radius (m)	Metric System: Square Side (m)
1/1000	43.56	3.7	6.6	10	1.78	3.16
1/500	87.12	5.3	9.3	20	2.52	4.47
1/250	174.24	7.4	13.2	40	3.57	6.32
1/100	435.6	11.8	20.9	100	5.64	10.00
1/50	871.2	16.7	29.5	200	7.98	14.14
1/25	1,742.4	23.6	41.7	400	11.28	20.00
1/20	2,178	26.3	46.7	500	12.62	22.36
1/10	4,356	37.2	66.0	1,000	17.84	31.62
1/5	8,712	52.7	93.3	2,000	25.23	44.72
1/4	10,890	58.9	104.4	2,500	28.21	50.00
1/2	21,780	83.3	147.6	5,000	39.89	70.71
1	43,560	117.8	208.7	10,000	56.42	100.00

Source: Husch Beers and Kershaw

Fixed Area Plots: Example



You are asked to conduct a forest inventory for the USFS using 1/17th acre plots.

Assuming flat ground, what is the plot's radius?

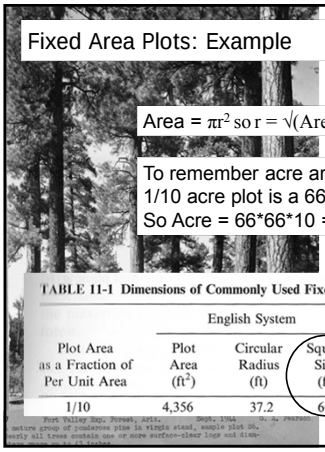
Area = πr^2

Area of acre = 43,560 ft^2
Area of 1/17th acre = 43,560/17 = 2,562 ft^2

Area = 2,562 ft^2 = πr^2

$r^2 = 2, 562 / \pi = 815.6$
$r = \sqrt{(815.6)} = 28.6$ ft

Fixed Area Plots: Example



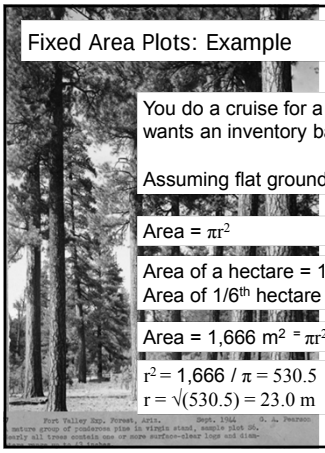
Area = πr^2 so $r = \sqrt{(Area / \pi)}$

To remember acre area:
1/10 acre plot is a 66 x 66 ft square.
So Acre = 66*66*10 = 43,560 ft^2

TABLE 11-1 Dimensions of Commonly Used Fixed-Area Plots

	English System			Metric System		
Plot Area as a Fraction of Per Unit Area	Plot Area (ft^2)	Circular Radius (ft)	Square Side (ft)	Plot Area (m^2)	Circular Radius (m)	Square Side (m)
1/10	4,356	37.2	66.0	1,000	17.84	31.62

Fixed Area Plots: Example



You do a cruise for a Canadian landowner who wants an inventory based on 6th hectare plots

Assuming flat ground, what is the plot's radius?

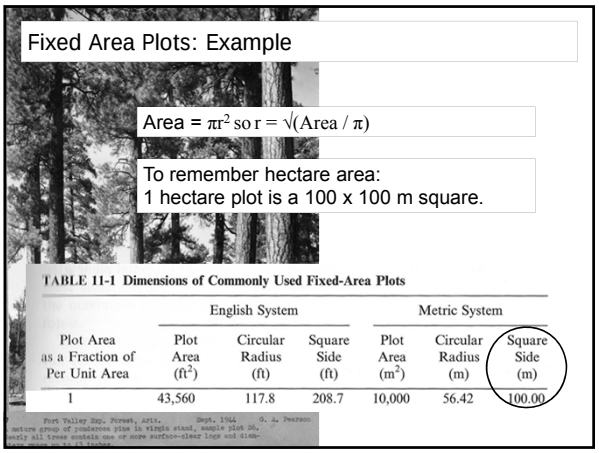
Area = πr^2

Area of a hectare = 10,000 m^2
Area of 1/6th hectare = 10,000/6 = 1,666 m^2

Area = 1,666 m^2 = πr^2

$r^2 = 1,666 / \pi = 530.5$
$r = \sqrt{(530.5)} = 23.0$ m

Fixed Area Plots: Example



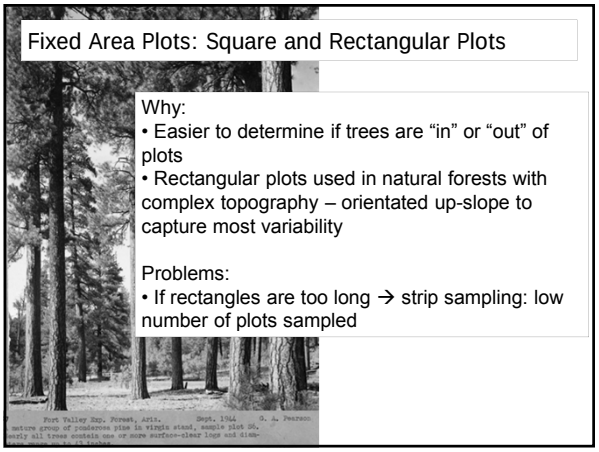
Area = πr^2 so $r = \sqrt{(Area / \pi)}$

To remember hectare area:
1 hectare plot is a 100 x 100 m square.

TABLE 11-1 Dimensions of Commonly Used Fixed-Area Plots

	English System			Metric System		
Plot Area as a Fraction of Per Unit Area	Plot Area (ft^2)	Circular Radius (ft)	Square Side (ft)	Plot Area (m^2)	Circular Radius (m)	Square Side (m)
1	43,560	117.8	208.7	10,000	56.42	100.00

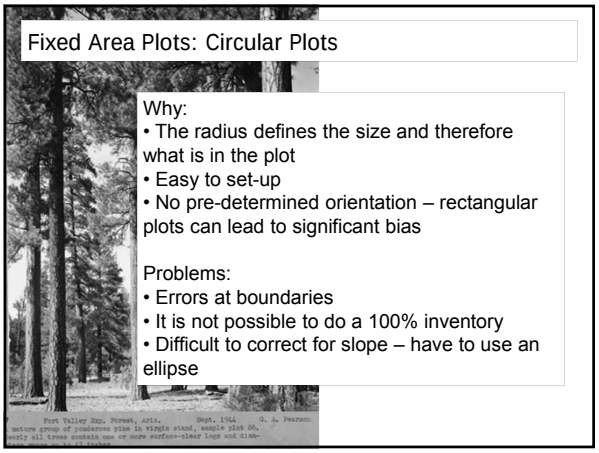
Fixed Area Plots: Square and Rectangular Plots



Why:
- Easier to determine if trees are "in" or "out" of plots
- Rectangular plots used in natural forests with complex topography – orientated up-slope to capture most variability

Problems:
- If rectangles are too long → strip sampling: low number of plots sampled

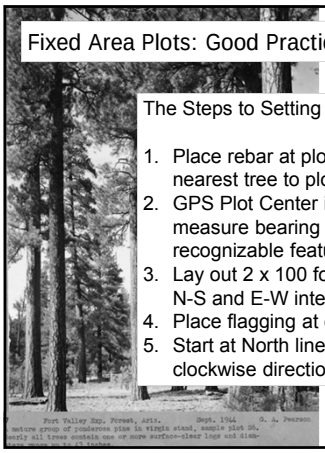
Fixed Area Plots: Circular Plots



Why:
- The radius defines the size and therefore what is in the plot
- Easy to set-up
- No pre-determined orientation – rectangular plots can lead to significant bias

Problems:
- Errors at boundaries
- It is not possible to do a 100% inventory
- Difficult to correct for slope – have to use an ellipse

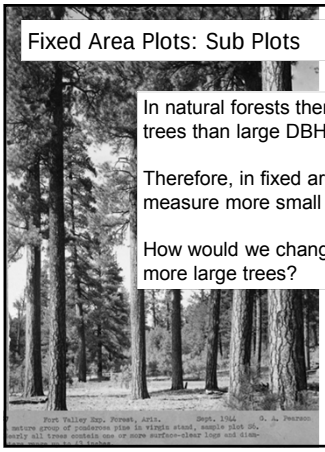
Fixed Area Plots: Good Practices



The Steps to Setting up Fixed Radius Plots:

1. Place rebar at plot center – or flag branch or nearest tree to plot center
2. GPS Plot Center if you have one – or measure bearing and distance to a recognizable feature
3. Lay out 2 x 100 foot tapes in a cross going N-S and E-W intersecting at the plot center
4. Place flagging at each of the N,S,E,W ends
5. Start at North line and measure trees in a clockwise direction

Fixed Area Plots: Sub Plots

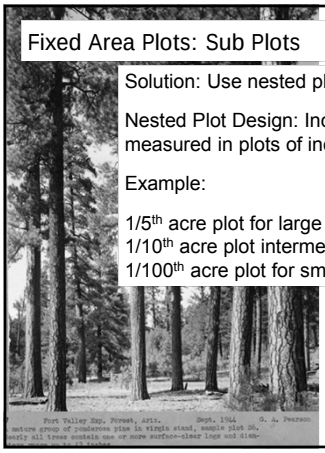


In natural forests there are more small DBH trees than large DBH trees.

Therefore, in fixed area plots you will always measure more small trees than large ones

How would we change our design to measure more large trees?

Fixed Area Plots: Sub Plots

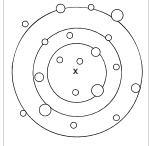


Solution: Use nested plot design

Nested Plot Design: Increasing size classes are measured in plots of increasing area

Example:

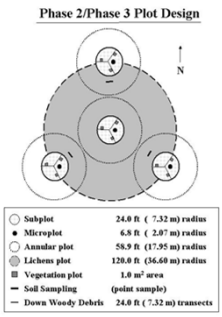
1/5th acre plot for large DBH trees (sawtimber)
1/10th acre plot intermediate DBH trees (pulpwood)
1/100th acre plot for small DBH trees (regeneration)



Fixed Area Plots: Nested Plot Designs

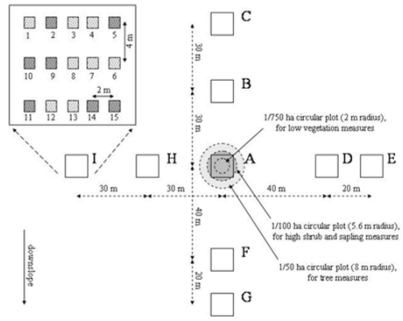
Example: Forest Inventory Analysis

Phase 2 – One site every 6,000 acres. Field crews collect data on forest type, site attributes, tree species, tree size, and overall tree condition on accessible forest land.
Phase 3 – One plot every 96,000 acres. These attributes include tree crown conditions, lichen community composition, understory vegetation, down woody debris, and soil attributes.



Fixed Area Plots: Nested Plot Designs

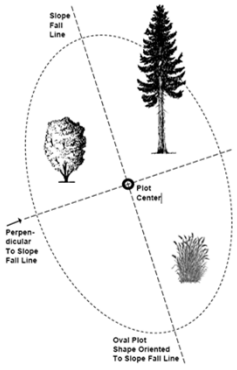
Example: Fire Effects Monitoring



Hudak et al 2007 - JFE

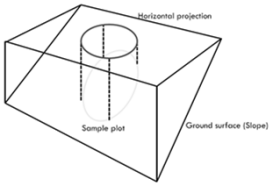
Circular Plots: Slope Correction

- On sloping ground, plots have an oval shape with their long axis parallel to the slope (called the "slope fall line").
- Note that a line perpendicular to the slope forms a "right angle" with the slope fall line.
- Plots on sloping ground need to have their radius adjusted using a factor that converts slope distance to what is called horizontal distance.



Circular Plots: Slope Correction

To adjust the radius (on the slope) to always measure a fixed area on the horizontally projected slope we use the equation:



From Trig:

$L_{slope} = L_{horz} / \cos \alpha$

Example:

1/10 ac plots, slope of 25°

$Radius_{slope} = 37.2 / \cos 25$

In Excel: = cos (RADIANS(25)) = 0.906

= 41.1 ft (not 37.2!)

Circular Plots: Slope Correction

Slope Percent	Correction Factor
0 – 9	1.00
10 – 17	1.01
18 – 22	1.02
23 – 26	1.03
27 – 30	1.04
31 – 33	1.05
34 – 36	1.06
37 – 39	1.07
40 – 42	1.08
43 – 44	1.09
45 – 47	1.10
48 – 49	1.11
50 – 51	1.12
52 – 53	1.13
54 – 55	1.14
56 – 57	1.15
58 – 59	1.16
60 – 61	1.17

Generalized corrections when adjusting for slope.

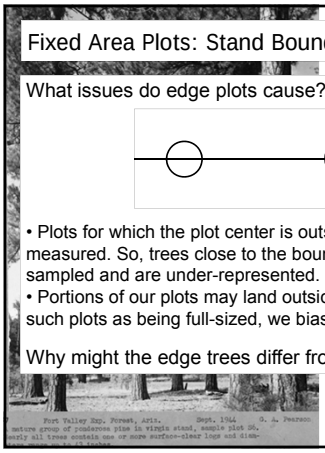
Example:

1/10 acre plot on 35% slope:

No slope radius = 37.2 feet

Short axes (perpendicular to slope) = 37.2 feet
Long axes (parallel to slope) = 37.2 * 1.06 = 39.4 feet

Fixed Area Plots: Stand Boundaries



What issues do edge plots cause?

• Plots for which the plot center is outside the boundary will not be measured. So, trees close to the boundary are less likely to be sampled and are under-represented.
• Portions of our plots may land outside the population. If we count such plots as being full-sized, we bias our statistics.

Why might the edge trees differ from the central trees?

Fixed Area Plots: Stand Boundaries

Edge trees can exhibit:
- Less competition
- More wind impacts

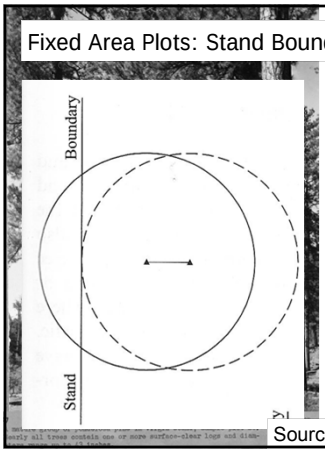
Fixed Area Plots: Stand Boundaries

Solution 1: Ignore it.

When large stands are cruised with small circular plots – the bias can be considered negligible

But when cruised tracts are narrow and long – i.e. more likely to have edge plots there are several methods that can be used

Fixed Area Plots: Stand Boundaries



Solution 2: Move plot so it falls within boundary

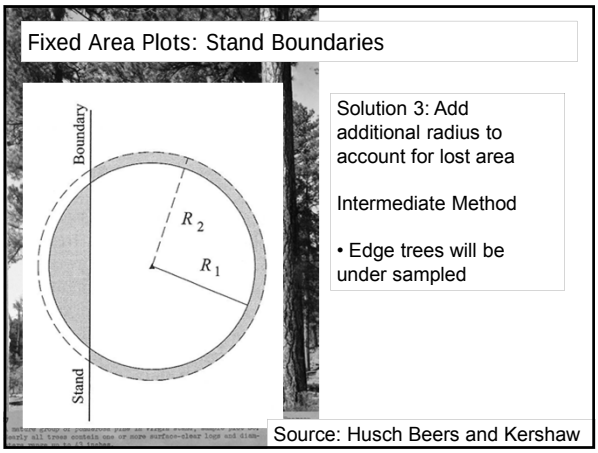
Worst Method!

• Edge trees will be under sampled

• Can lead to significant bias if stand has lots of edges!

Source: Husch Beers and Kershaw

Fixed Area Plots: Stand Boundaries



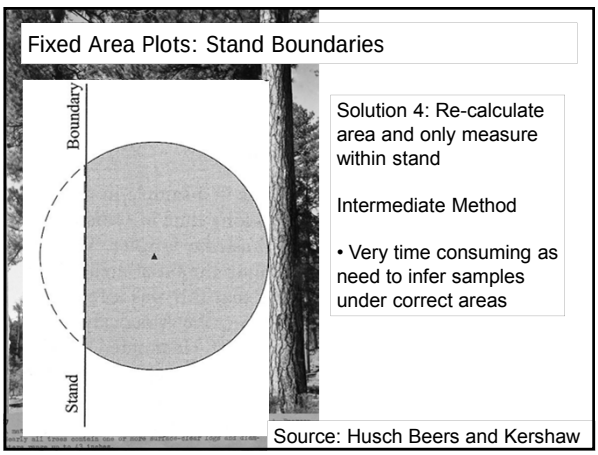
Solution 3: Add additional radius to account for lost area

Intermediate Method

• Edge trees will be under sampled

Source: Husch Beers and Kershaw

Fixed Area Plots: Stand Boundaries



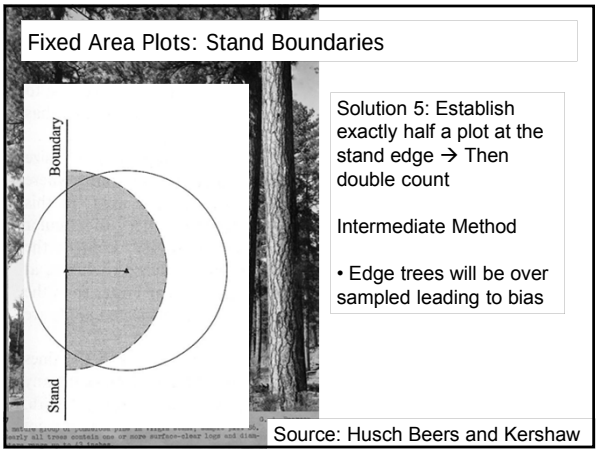
Solution 4: Re-calculate area and only measure within stand

Intermediate Method

• Very time consuming as need to infer samples under correct areas

Source: Husch Beers and Kershaw

Fixed Area Plots: Stand Boundaries



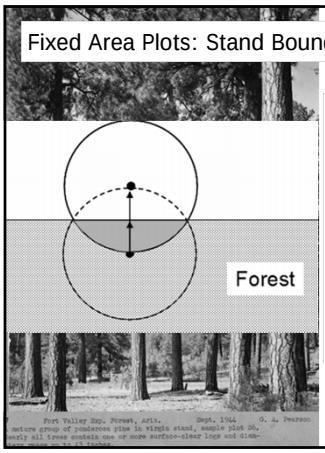
Solution 5: Establish exactly half a plot at the stand edge → Then double count

Intermediate Method

• Edge trees will be over sampled leading to bias

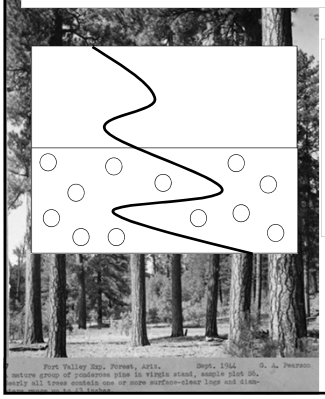
Source: Husch Beers and Kershaw

Fixed Area Plots: Stand Boundaries



Solution 6: Mirage Plots
Intermediate method
• Lay out your plot and measure all the “in” trees
• Imagining the stand edge a mirror, lay out the mirror image of your plot with the plot centre outside the stand and measure the “in” trees
• Edge trees will be over sampled leading to bias

Fixed Area Plots: Stand Boundaries



Solution 7: Don’t Place a Plot at the edge in the first place!

Use Buffers around edges, roads, and rivers

• Biases against edge trees

FOR 274: Forest Measurements and Inventory

Fixed Area Plots and Plot Boundaries

- Fixed Area Plots
- Slope Correction
- Stand Boundaries
- Strip & Line-Plot Cruising
- Permanent Plots

Fixed Area Plots: Strip Cruising

In strip cruising, parallel strips (long thin rectangular plots) are used where the spacing between the steps are constant

Advantages:
- Continuous sample
- Travel time is low (as compared to visiting randomly located plots)
- Strips have fewer boundary trees

Disadvantages:
- Errors easily introduced if correct strip width is not maintained
- Need at least 2 people
- Brush, windfalls, and surface debris are more of a hazard (as cruisers must cruise along a fixed compass bearing)

Fixed Area Plots: Strip Cruising

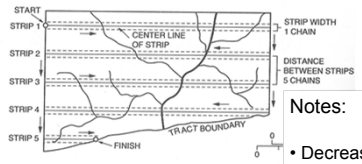


FIGURE 10-1
Diagrammatic plan for a 20 percent systematic strip cruise. Sample strips spaced at regular intervals of 5 chains.

TABLE 10-1
EXAMPLE OF CRUISING INTENSITIES FOR 1-CHAIN SAMPLE STRIP WIDTHS

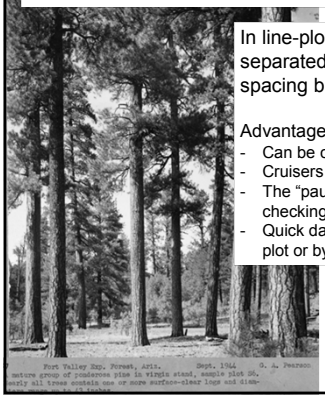
Distance between strip centerlines		No. of strips per "forty"	Nominal cruise percent
ft	chains		
1,320	20	1	5
660	10	2	10
330	5	4	20
165	2½	8	40

Notes:

• Decrease width in young stands with high stem count
• Increase width in more scattered high value timber
• Cross drainages at right angles
• In theory all timber conditions are samples and a representative sample taken
• Sampling intensity = (W/D)*100

Source: Avery and Burkhart Chapter 10

Fixed Area Plots: Line-Plot Cruising

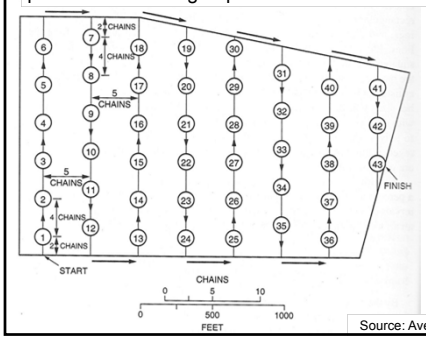


In line-plot cruising the plots are equally separated on each line, with equal spacing between each line – i.e. a grid

Advantages:
- Can be cruised by 1 person
- Cruisers less hindered by brush and windfall
- The "pause" at plot center enables better checking of borderline trees
- Quick data summaries can be obtained per plot or by stand / condition classes.

Fixed Area Plots: Line-Plot Cruising

In line-plot cruising a systematic tally of timber is taken from plots laid out on a grid pattern



Source: Avery and Burkhart Chapter 10

Fixed Area Plots: Cruising

Notes:

- Circular ¼ and 1/5 ac plots commonly used for timber tallies
- 1/10 ac for pulpwood trees
- 1/100 ac for regeneration counts

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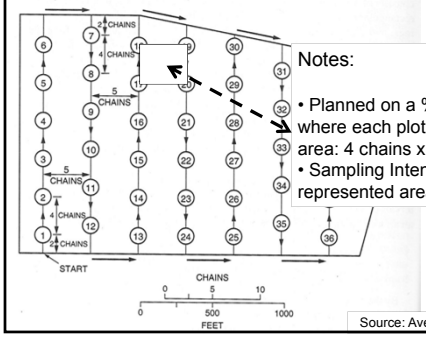
TABLE 10-2
RADII FOR SEVERAL SIZES OF CIRCULAR SAMPLE PLOTS

Plot size (acre)	Plot radius (ft)	Plot size (ha)	Plot radius (m)
1	117.8	1	56.42
⅛	83.3	½	39.89
¼	58.9	¼	28.21
⅕	52.7	⅛	25.23
1/10	37.2	1/10	17.84
1/15	26.3	1/25	12.62
1/20	23.5	1/50	11.28
1/40	18.6	1/100	8.92
1/50	16.7	1/200	7.98
1/100	11.8	1/400	5.64
1/200	6.8	1/1000	3.26
1/500	5.3	1/2000	2.52
1/1000	3.7	1/4000	1.78

Source: Avery and Burkhart Chapter 10

Fixed Area Plots: Cruising

FIGURE 10-2
Diagrammatic plan for a 10 percent systematic line-plot cruise utilizing ¼-acre circular sampling units.

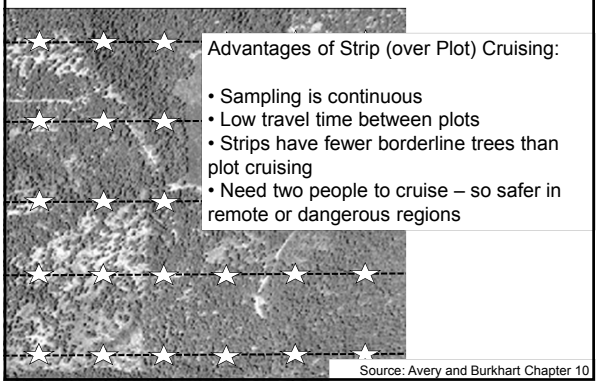


Notes:

- Planned on a % cruise basis, where each plot "represents" an area: 4 chains x 5 chains = 2 ac
- Sampling Intensity = plot size / represented area = 0.2/2 = 10%

Source: Avery and Burkhart Chapter 10

Fixed Area Plots: Cruising

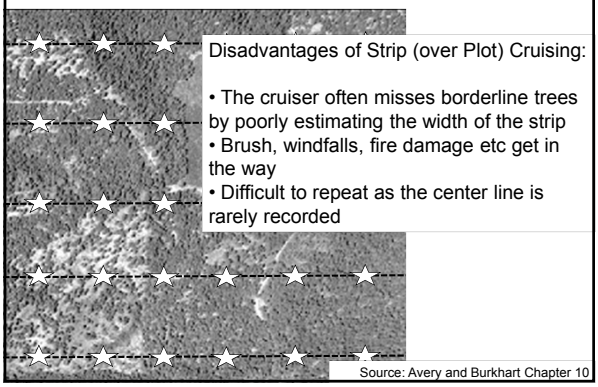


Advantages of Strip (over Plot) Cruising:

- Sampling is continuous
- Low travel time between plots
- Strips have fewer borderline trees than plot cruising
- Need two people to cruise – so safer in remote or dangerous regions

Source: Avery and Burkhart Chapter 10

Fixed Area Plots: Cruising

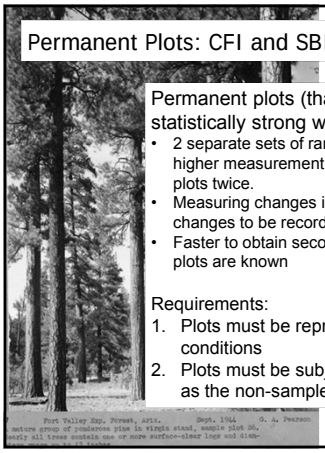


Disadvantages of Strip (over Plot) Cruising:

- The cruiser often misses borderline trees by poorly estimating the width of the strip
- Brush, windfalls, fire damage etc get in the way
- Difficult to repeat as the center line is rarely recorded

Source: Avery and Burkhart Chapter 10

Permanent Plots: CFI and SBI



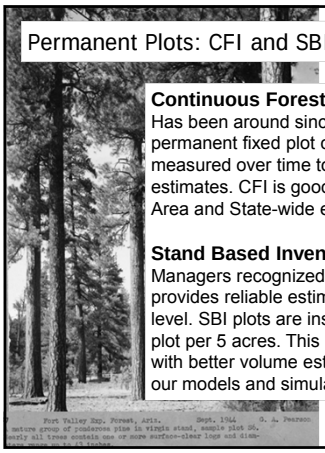
Permanent plots (that are re-measured) provide statistically strong ways to evaluate changes

- 2 separate sets of random samples in a stand will have higher measurement errors that measuring the same plots twice.
- Measuring changes in the same place allows actual changes to be recorded
- Faster to obtain second inventory as general location of plots are known

Requirements:

1. Plots must be representative of stand / forest conditions
2. Plots must be subjected to the same treatments as the non-sampled parts of the forest

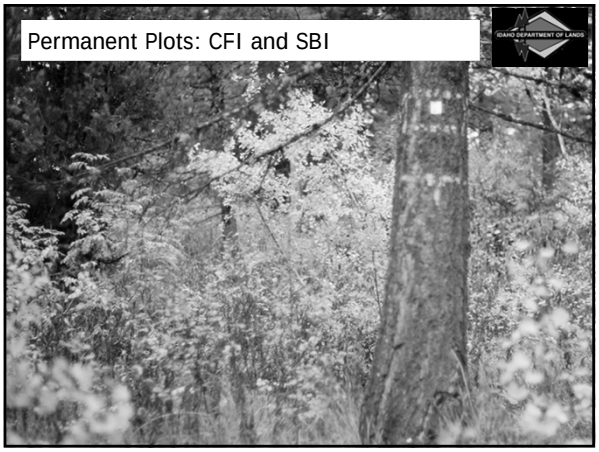
Permanent Plots: CFI and SBI



Continuous Forest Inventory (CFI):
Has been around since the 1950s. Involves permanent fixed plot centers – the same trees are measured over time to obtain growth and yield estimates. CFI is good at estimating volumes at the Area and State-wide endowment (IDL) level.

Stand Based Inventory (SBI):
Managers recognized the need for an inventory that provides reliable estimates of volume at the stand level. SBI plots are installed by stand at a level of 1 plot per 5 acres. This provides resource managers with better volume estimates and provides many of our models and simulators better data to model.

Permanent Plots: CFI and SBI



Permanent Plots: CFI and SBI

Payette Lakes CFI South Map
Contract 12-238-000034

CFI

Clearwater Local Map #1 - 284 Plots
Contract No. 12-237-401092

SBI

Permanent Plots: CFI and SBI

Payette Lakes CFI South Map
Contract 12-238-000034

CFI

Notes on CFI:

Often CFI is applied to a rigid systematic grid, where each plot represents equal proportion of the total forest area.

BUT systematic grids are inflexible to changing management priorities.