SIMULATION OF DESIGN-UNBIASED POINT-TO-PARTICLE SAMPLING AND ALTERNATIVES ON PLANTATION ROWS

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Plantation row sampling and design unbiased fixed 2*k* (particle sample size) sampling on lines

- Mark Ducey NEMO 2012 – Design unbiased point to particle sampling on lines.
- Ducey - Given in the context of a generalized forest, not plantation. Based on distance along line between trees in strips.
- Bruce Borders SOMENS 2012 – Plantation row sampling. Row lengths with remote sensing, ground sampling for sample trees
- Borders - Fixed length plots with variable tree numbers or fixed tree numbers with variable length plot. Latter not design unbiased. Ratio estimation.
- Combine. Ducey's estimator can be adapted to plantation rows. Row lengths determined by remote sensing.

Ducey's (2012) Estimator

$$\hat{Y}_D = \sum_{i=1}^{N} [w_i^{+k}\delta^{+k}(z) + w_i^{-k}\delta^{-k}(z)]y_i$$

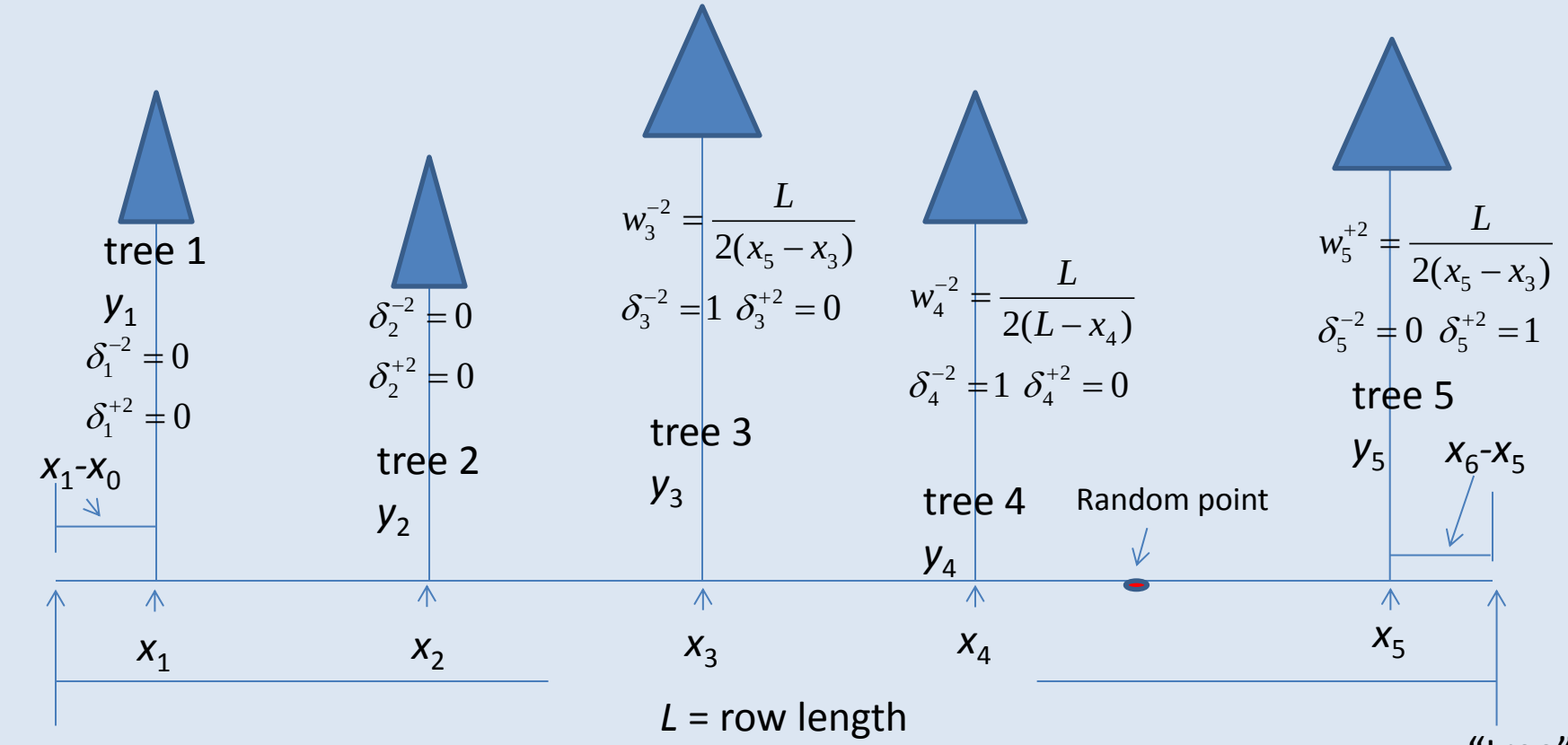
where

$$w_i^{+k} = \begin{cases} \dfrac{L}{2(x_i - x_{i-k})} \text{ if } x_i < L \\ \dfrac{L}{(L - x_{i-k})} \text{ if } x_i = L \end{cases} \qquad w_i^{-k} = \begin{cases} \dfrac{L}{2(x_{i+k} - x_i)} \text{ if } x_i > 0 \\ \dfrac{L}{x_{i+k}} \text{ if } x_i = 0 \end{cases}$$

$$\delta_i^{+k} = \begin{cases} 1 \text{ if } x_{i-k} \le z < x_i \\ 0 \text{ otherwise} \end{cases} \qquad \delta_i^{-k} = \begin{cases} 1 \text{ if } x_i \le z < x_{i+k} \\ 0 \text{ otherwise} \end{cases}$$

L = row length, y_i = attribute of tree i, x_i = distance along row to tree i, z = random point location on row.

Ducey's Estimator for $k = 2$ trees 3, 4 and 5 are in this sample and "tree" 6 is a "false particle"

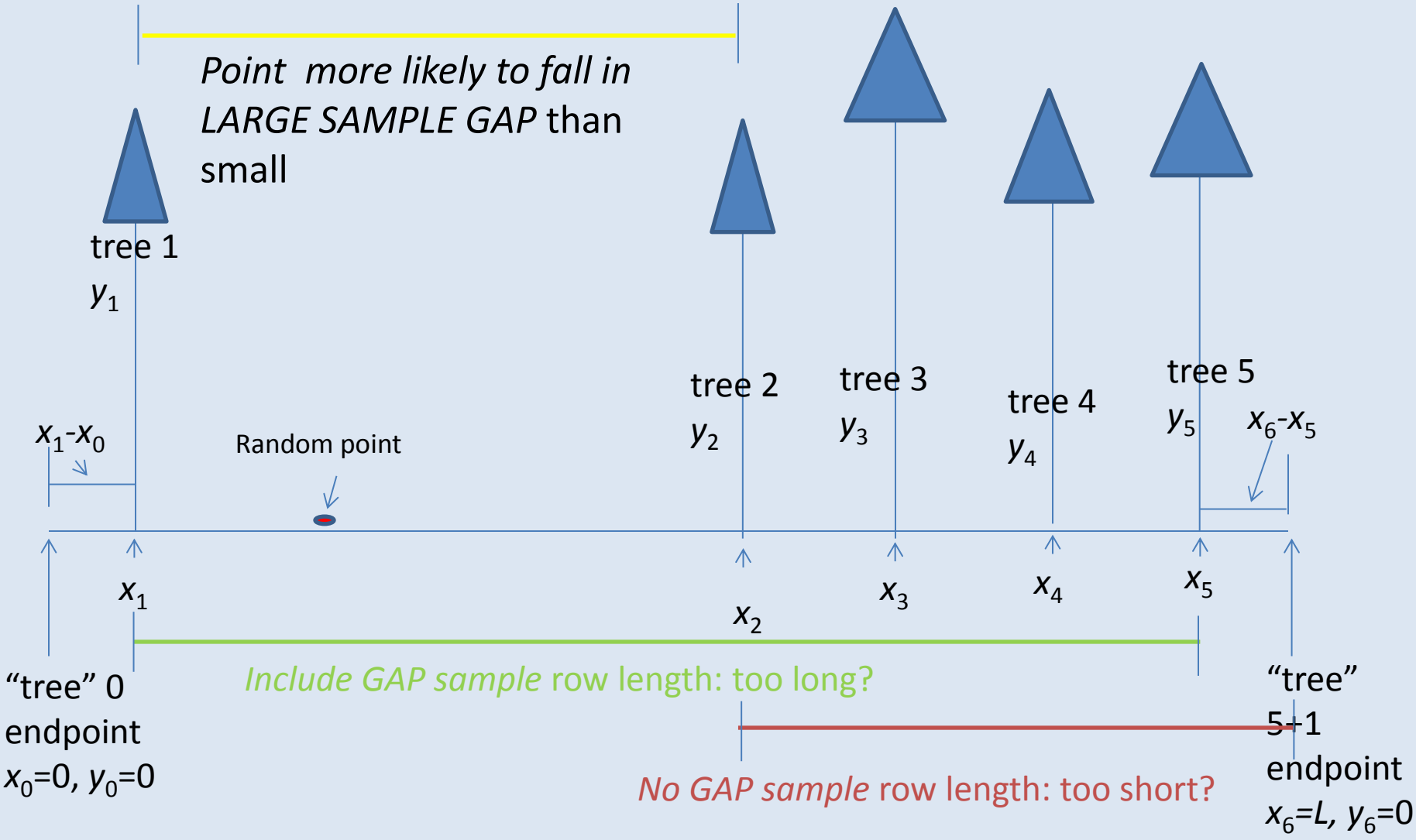


Pr(select trees 4 and 5) = $(x_5\text{-}x_4)/L$

Implementation

- Find plantation row length (remote sensing)
- Plantation -one continuous row, or strata
- Randomly locate sample point *along row*
  NOT nearest tree a 2D random point
- Nearest *k* trees right and left of random point. Measure distances & attributes (e.g., basal area, volume) of sample trees
- Tape Breast Height (BH) midpoint “left -most” tree to “right-most” tree.
- Record distance from left-most tree to each tree BH midpoint along the row. Or laser, vertex.
- Apply Ducey’s estimator. Average *n* values of Ducey’s estimator from *n* randomly sample points
- Estimate sample variance - SRS formula

Alternative Estimators - Measuring one distance including 4 sample trees: to gap or not to gap?



Alternatives: "Mean of Ratios"

$$\hat{Y}_{MEAN\ OF\ RATIOS} = L \frac{1}{\#\text{sample rows}} \sum_{\#\text{sample rows}} \frac{\text{sum attributes on sample row}}{\text{length of sample row}}$$

Including the sample gap:

$$\hat{Y}_{G-MR} = \frac{L}{n} \sum_{h} \frac{\sum_{i=h-1}^{h+2k-1} y_i}{x^*_{h-1} - x^*_{h+2k}}$$

x^*_{h-1} sample from the x_i just left of sample point ground location

y_i = attribute of tree i

n = number of sample points h

$2k$ = fixed number of sample trees

$\hat{Y}_{G-MR}$ mean of ratios estimator of the total that includes the sample gap

Not including the sample gap:

$$\hat{Y}_{NG-MR} = \frac{L}{n} \sum_{h} \frac{\sum_{i=h}^{h+2k} y_i}{x^*_{h} - x^*_{h+2k+1}}$$

x^*_{h} sample from the x_i just right of sample point ground location

$\hat{Y}_{NG-MR}$ mean of ratios estimator of the total that does not include the sample gap

Alternatives: "Ratio of Means"

$$\hat{Y}_{RATIO\ \ OF\ MEANS} = L\frac{\sum_{\#\,sample\,rows}\text{sum of attributes on sample row}}{\sum_{\#\,sample\,rows}\text{length of sample row}}$$

Including the sample gap:

$$\hat{Y}_{G-RM} = L\frac{\frac{1}{n}\sum_{h}\sum_{i=h-1}^{h+2k-1} y_i}{\frac{1}{n}\sum_{h}\left(x^*_{h-1} - x^*_{h+2k}\right)}$$

x^*_{h-1} sample from the x_i just left of sample point ground location

y_i = attribute of tree i

n = number of sample points h

$2k$ = fixed number of sample trees

$\hat{Y}_{G-RM}$ mean of ratios estimator of the total that includes the sample gap

Not including the sample gap (Borders 2012):

$$\hat{Y}_{NG-RM} = L\frac{\frac{1}{n}\sum_{h}\sum_{i=h}^{h+2k} y_i}{\frac{1}{n}\sum_{h}\left(x^*_{h} - x^*_{h+2k+1}\right)}$$

x^*_h sample from the x_i just right of sample point ground location

$\hat{Y}_{NG-RM}$ mean of ratios estimator of the total that includes the sample gap

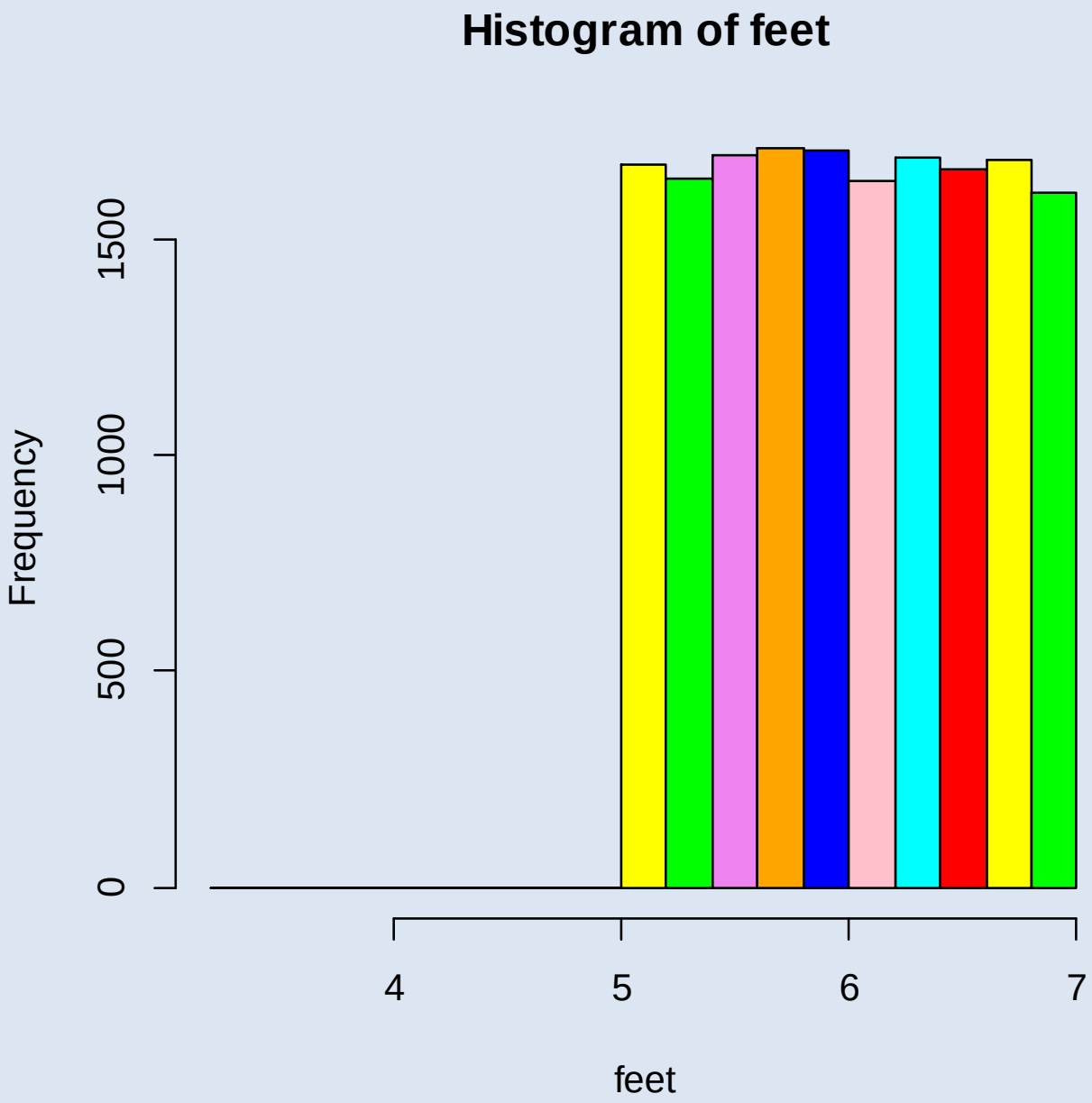
Estimator simulation and variance computation

- Two simulated plantation rows: “Gappy” and “Not Gappy”
- “Not Gappy” tree positions have a small amount of random error
- “Gappy” – large row gaps – thinning/mortality
- Ducey and Mean of Ratios – exact bias/variances of estimators computed on each row
- Ratio of means – R Simulation script: 1 million random row locations used to estimate bias/variance of estimators
- Fixed-length rows – R Simulation script: 1 million random row locations used to estimate variance of estimator

Not Gappy row population

- Target row length: 100,000 feet
- Mean inter-tree distance: 6 feet
- Standard deviation inter-tree distance: 3.5 feet
- Minimum inter-tree distance: 3.6 feet
- Maximum inter-tree distance: 7 feet
- Total number of trees: 16,667

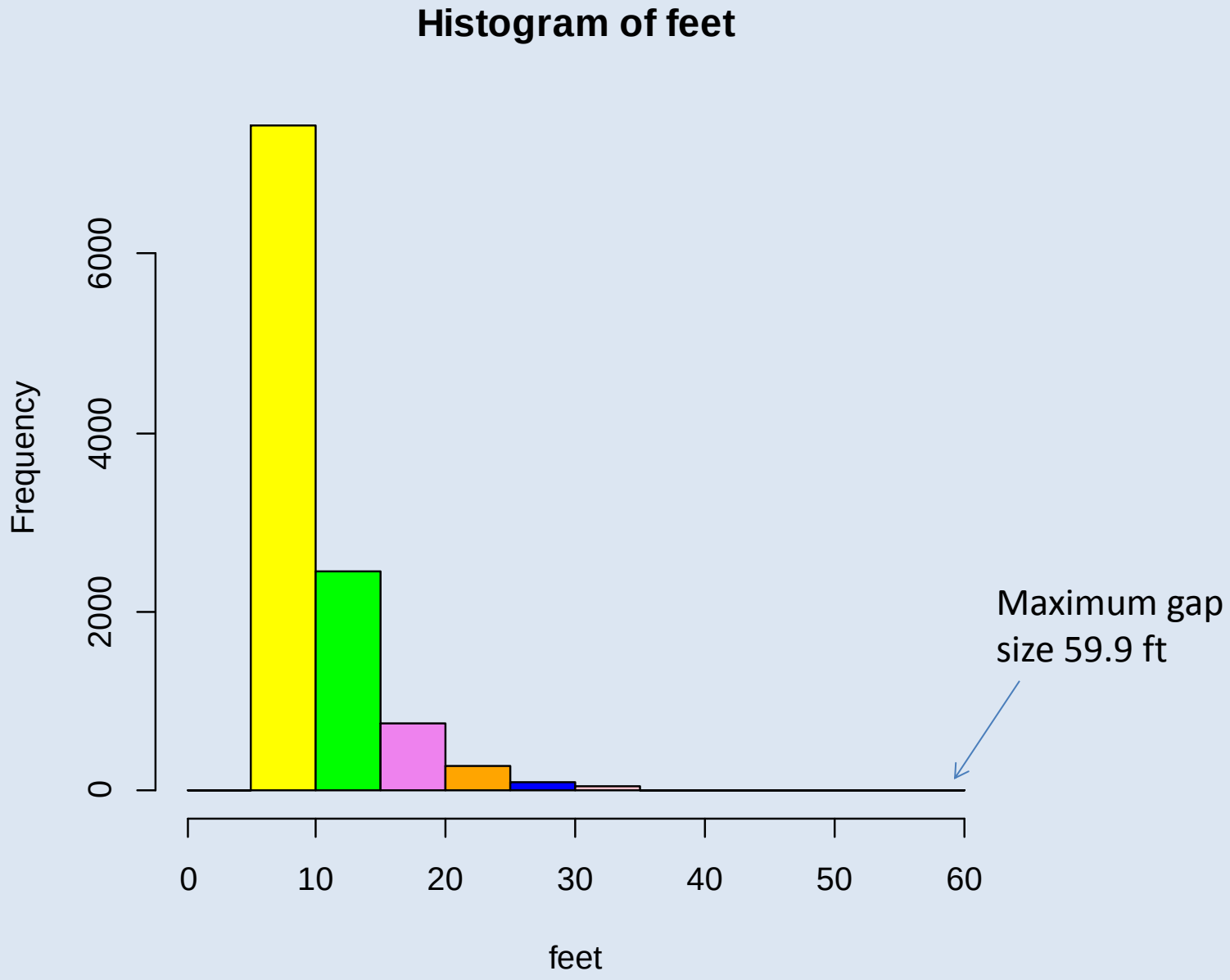
Gap size histogram for “Not Gappy” row



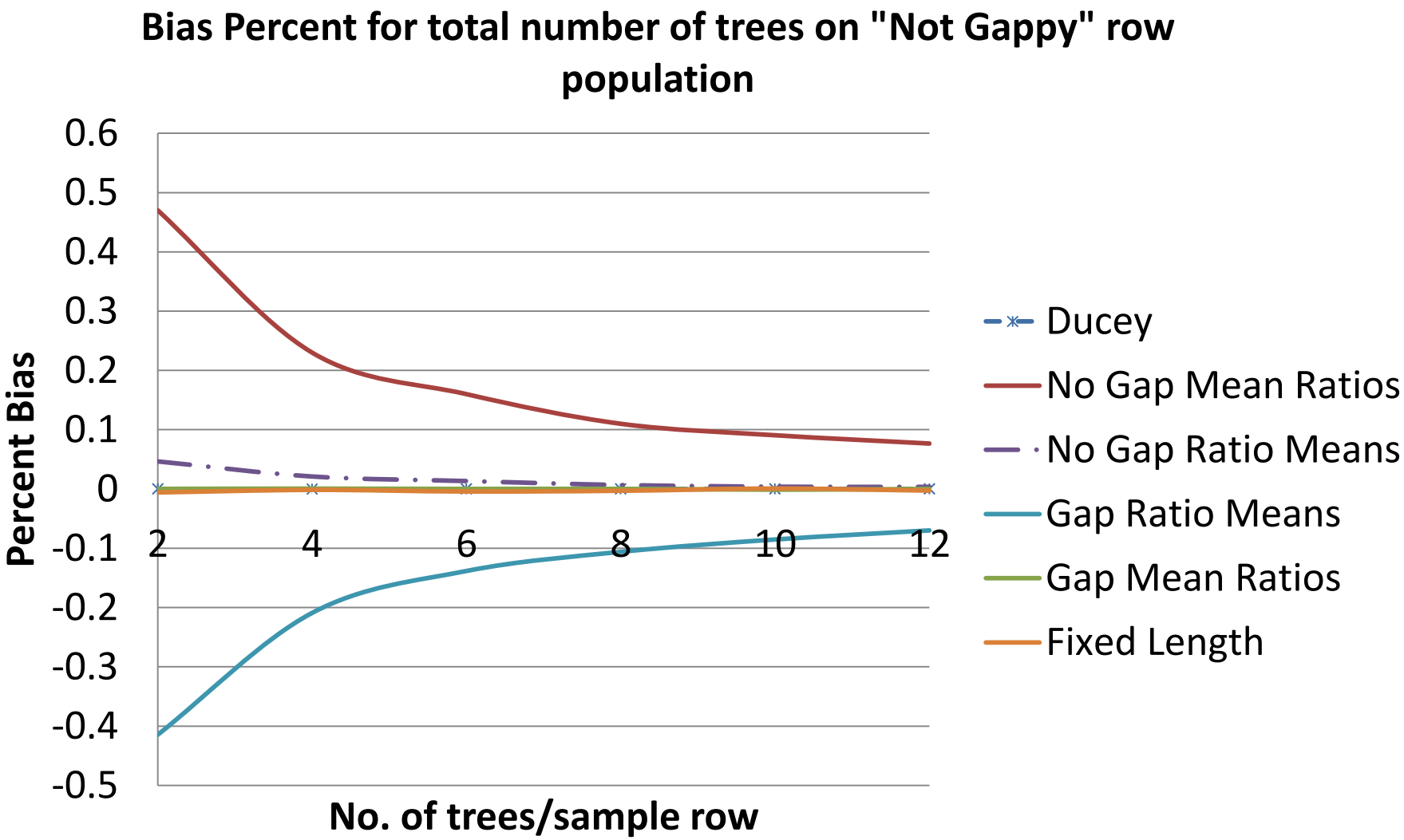
Gappy row population

- Target row length: 100,000 feet
- Mean inter-tree distance: 9 feet
- Standard deviation inter-tree distance: 7.4 feet
- Minimum inter-tree distance: 3.6 feet
- Maximum inter-tree distance: 59.9 feet
- Total number of trees: 11,109

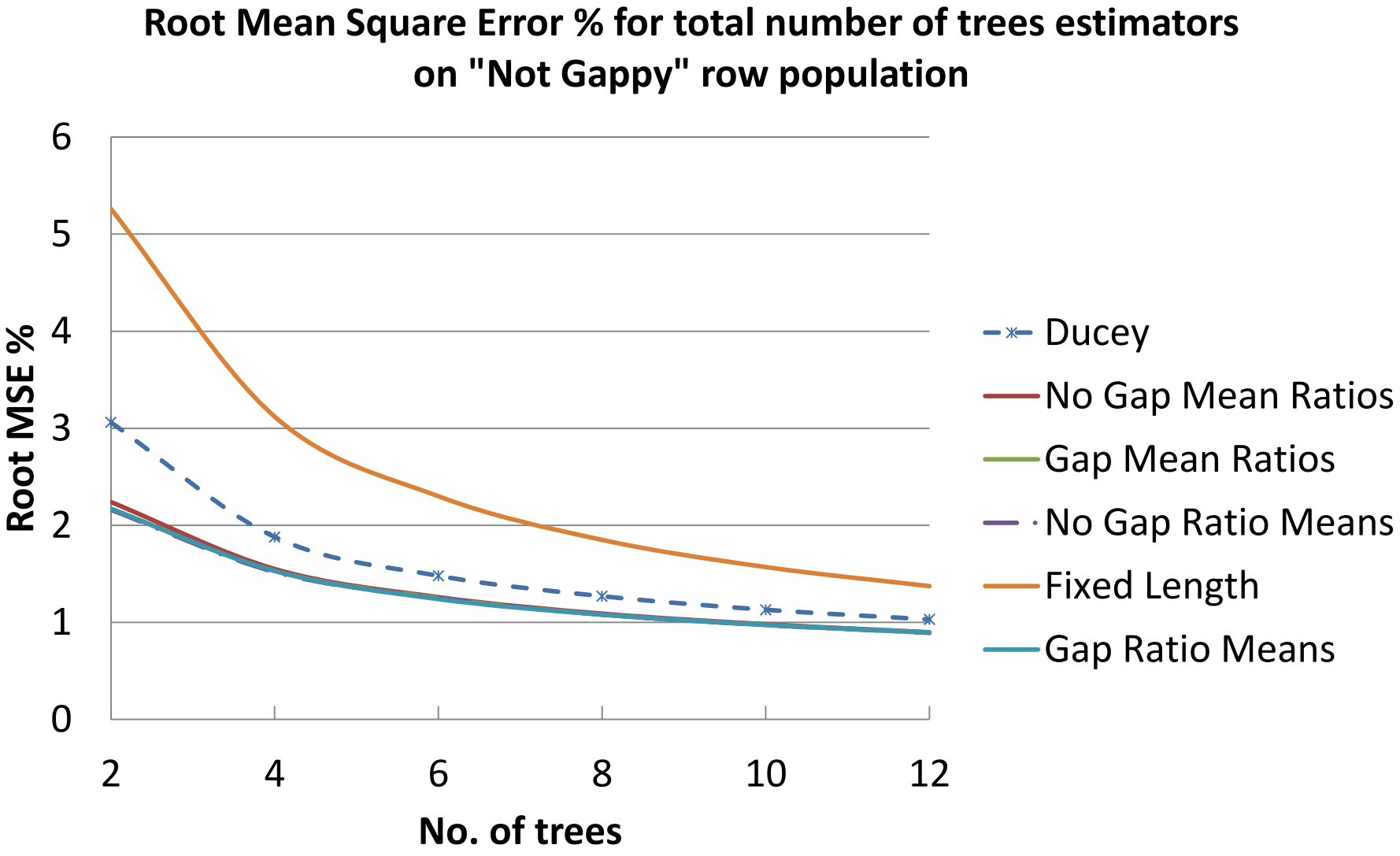
Gap size histogram for “Gappy” row



Not Gappy Bias, estimators for total number of trees based on a sample size of *n*=10 row locations, 1 million simulations or exact



Not Gappy Root Mean Square Error%, estimators for total number of trees based on a sample size of *n*=10 row locations, 1 million simulations or exact



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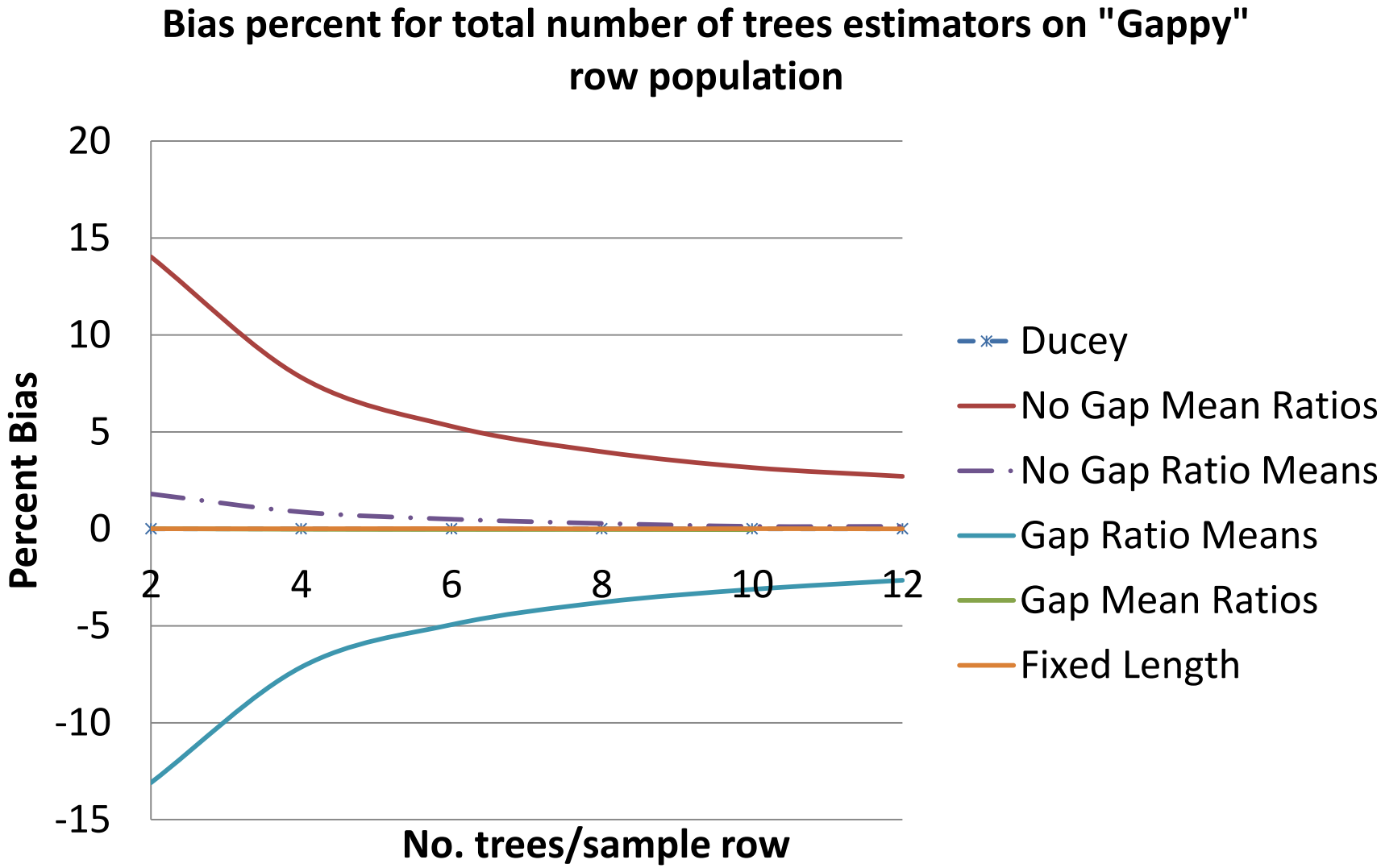

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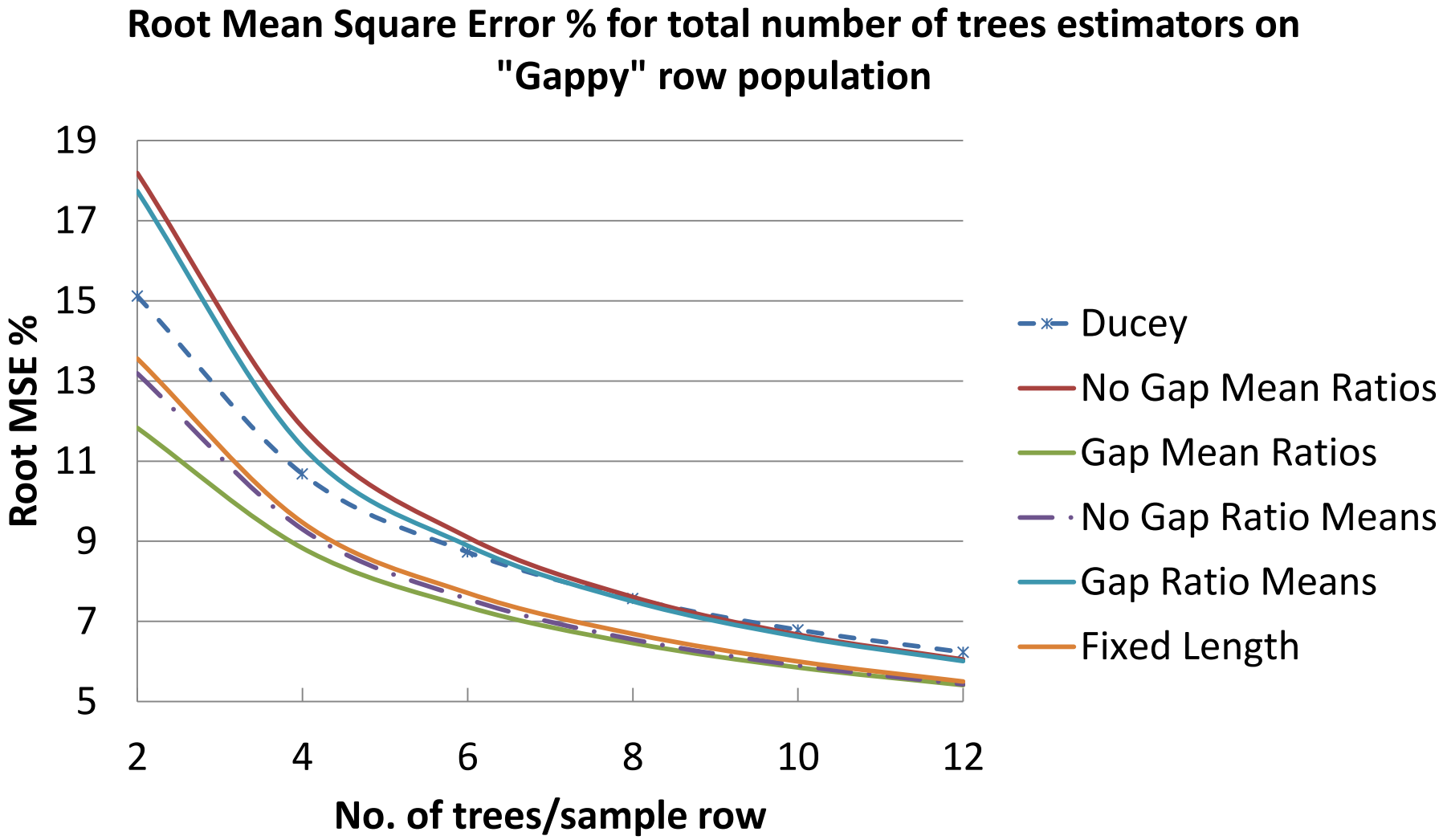
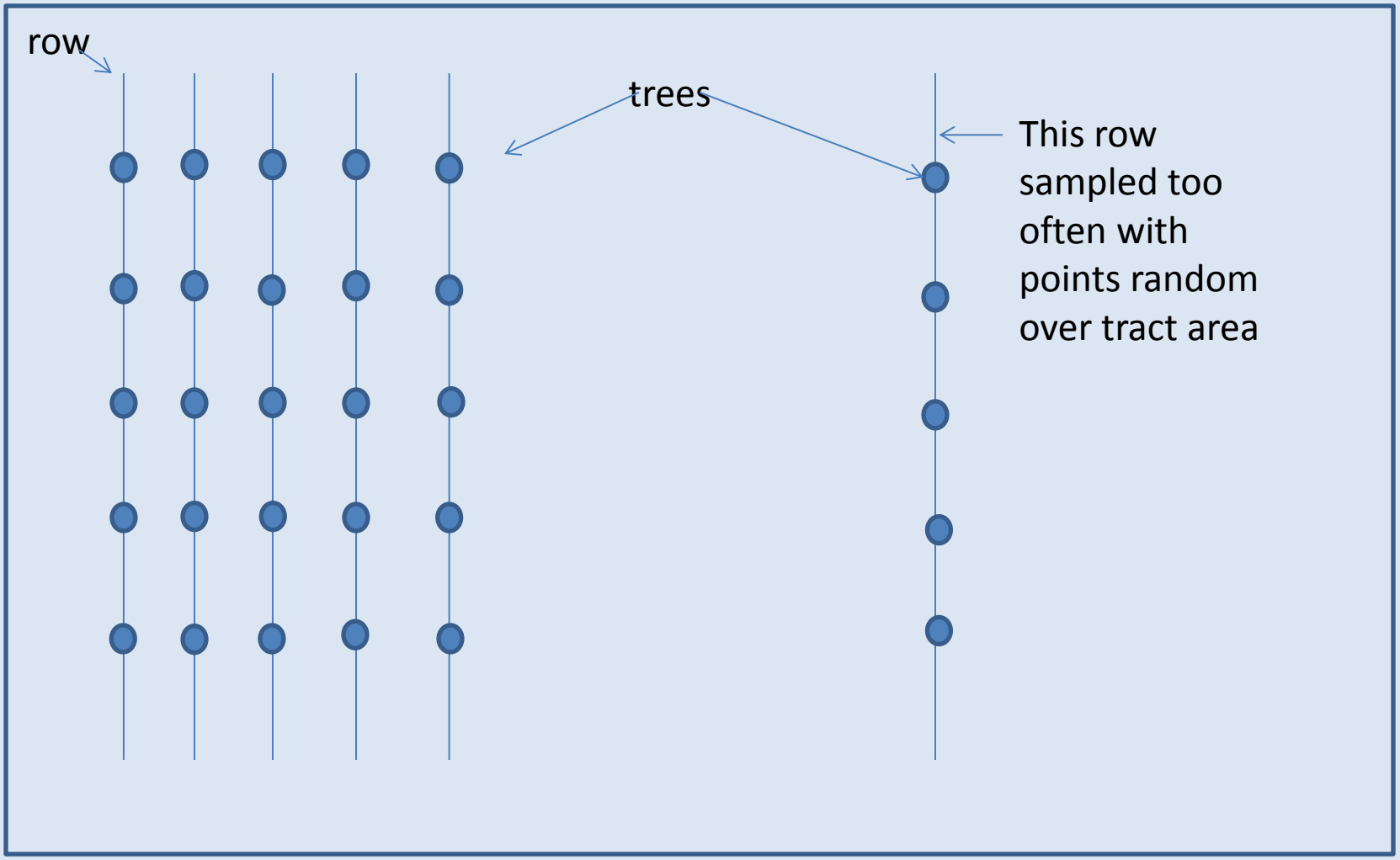


Simulation Summary

- Not Gappy row – all methods had bias < 0.5%
- Gappy row – The “No Gap Mean of Ratios” and the “Gap Ratio of Means” had substantial bias >5% for 6 sample trees or less, down to 2.5% for 12 trees
- Fixed row length – highest RMSE% for “Not Gappy” but 3rd lowest for “Gappy” row
- “Gap Mean of Ratios” and “No Gap Ratio of Means” - low bias and RMSE% both Gappy and Not Gappy row.
- Ducey not most precise method but unbiased any spatial arrangement. Precision not substantially greater.

Random number location along line vs. closest random point in tract area



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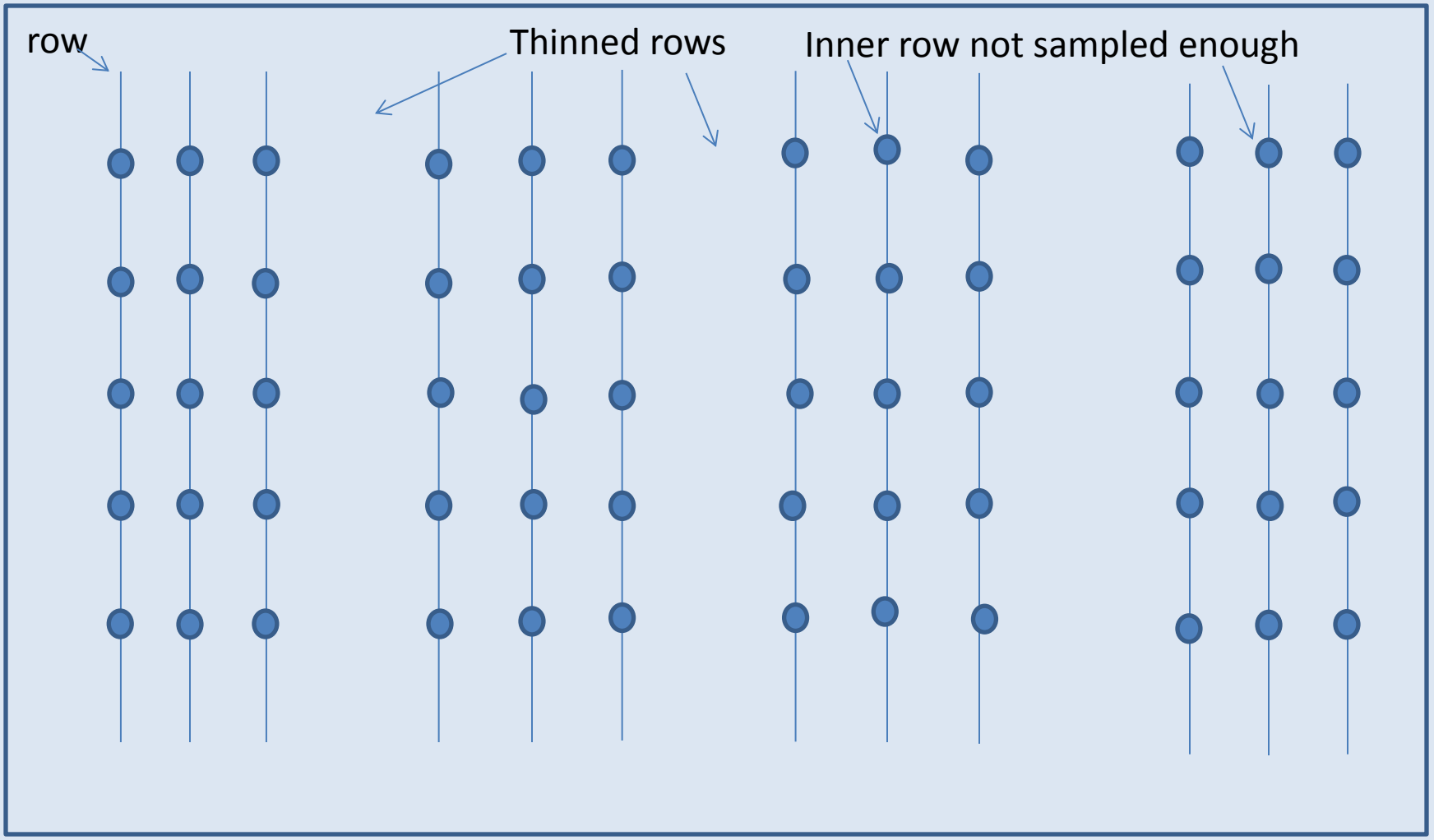
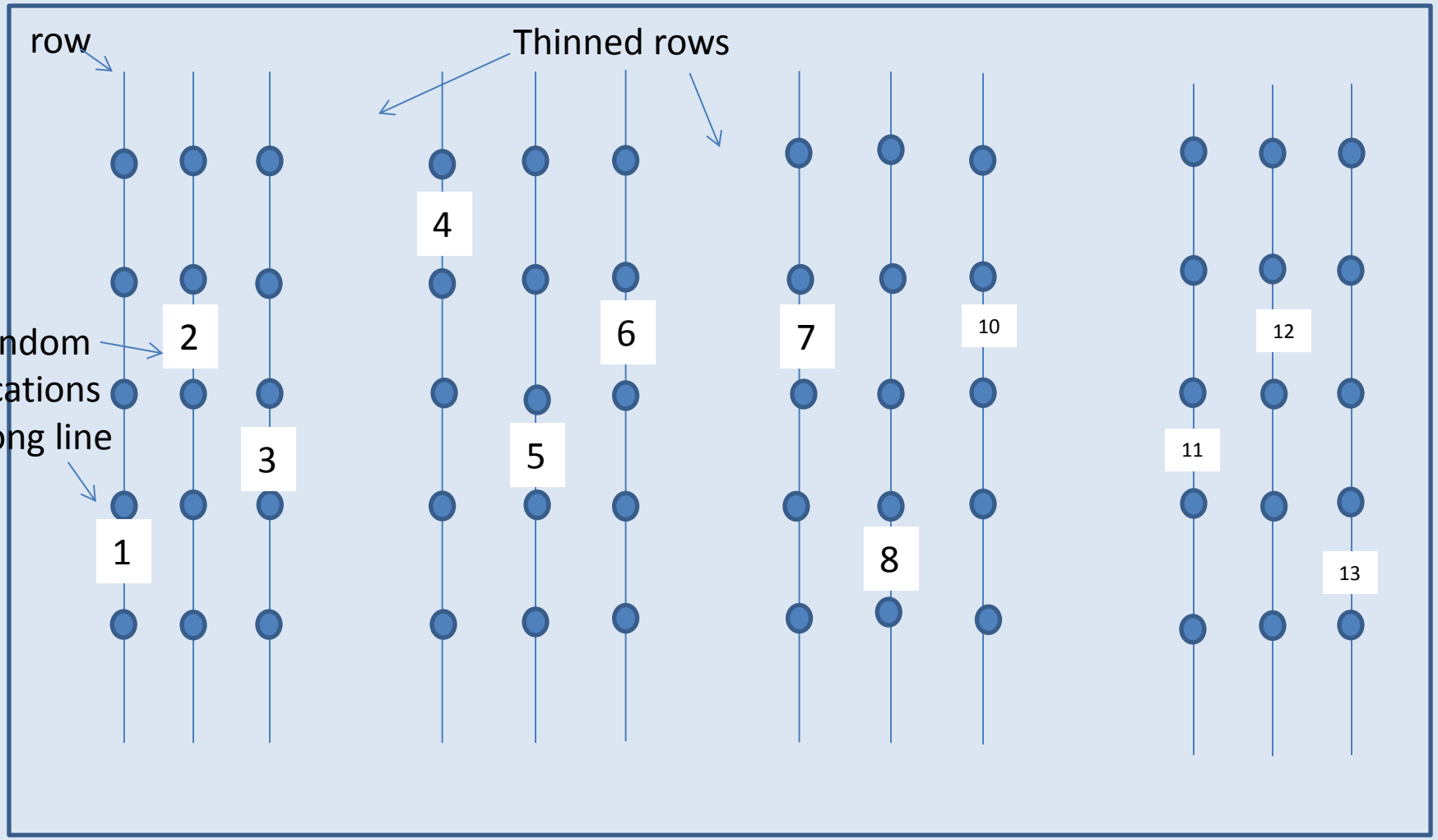


Random number location along line (uniform on (0, L)) – generate GPS location? And photo overlay?



Conclusions

- RMSE – Gap Mean of Ratios and No Gap Ratio of Means best
- Substantial BIAS Gappy row – Gap Ratio of Means and No Gap Mean of Ratios
- Ducey's method - guaranteed unbiased any spatial distribution - slightly higher RMSE
- Place random (or systematic) sample points along ROW
- Random point in 2D – possible bias row thinned plantations.