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TREE IMPROVEMENT AND THE CLONE ADOPTION DECISION:

A STOCHASTIC SIMULATION MODEL OF EARLY SELECTION

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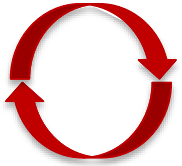
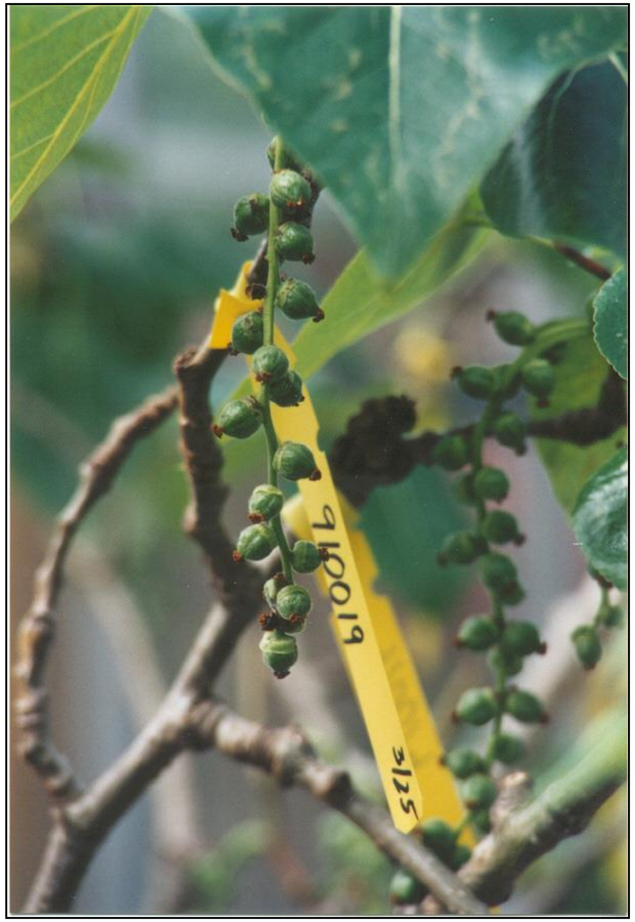
Background and motivation

- Major efforts to develop improved plant material
  - Organizations
    - Cooperative tree improvement programs (e.g., NC State, Oregon State)
    - Proprietary research and development (e.g., Weyerhaeuser, ArborGen, GreenWood Resources)
  - Species
    - Western conifers
    - Southern pine
    - Tropical hardwoods

- Conventional tree improvement program – a continuous process
  - Selection of parents and hybridization
  - Testing and verification
  - Commercial deployment



- Tree improvement does not necessarily mean “GMO”



Background and motivation

- Potential benefits of improved plant material
  - Improved yields, stem form, wood properties, and disease resistance—all increase economic returns
  - The ***earlier*** improved plant material can be deployed, the greater the economic gains (e.g., Lambeth 1980; McKeand 1988)

- Question: How early can we accurately select top-performing individuals from a trial of many?

- Applied ecology literature—tree improvement and early selection
  - Early selection literature relies heavily on empirical data and field-based experiments (e.g., Goncalves et al. 2005, Osario et al. 2003, Ares 2002, Kumar and Singh 2001) recognizing that successful early selection hinges on the ***correlation*** between juvenile and mature traits
  - Stochastic simulation models of tree improvement programs tend to focus on breeding strategies—which crosses will produce the greatest gain—rather than on the timing of the selection decision (see for example Kerr et al. 2004, Danusevicius and Lindgren 2002, Mullin and Park 1996)

Organization

1. Background
2. Trial data and model
3. Results
4. Concluding remarks

Clonal Trial Data

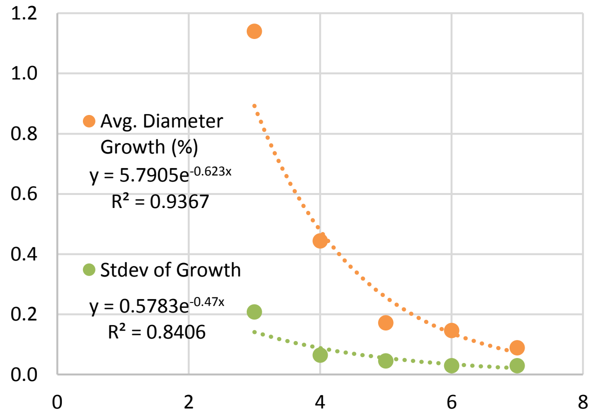
- Annual diameter growth observations from hybrid poplar **clonal** trials at Santa Julia Farm, Chile (study of clonal variation over time within the same trial).

	Total Obs.	No. of Clones	Avg. No. of Individuals per Clone
Ages 2-5	266	40	7
Ages 4-7	259	35	7

- For each clone we estimate functions describing diameter growth and standard deviation of growth over time

Clone 4206

	Avg. Diameter Growth (% Change Y/Y)	Stdev of Growth
Age 3	1.1401	0.2079
Age 4	0.4438	0.0640
Age 5	0.1717	0.0447
Age 6	0.1457	0.0293
Age 7	0.0882	0.0293



Stochastic Model

- Assume individual clone diameter growth in each time period is i.i.d. $N{\sim}(\mu,\sigma)$ and:

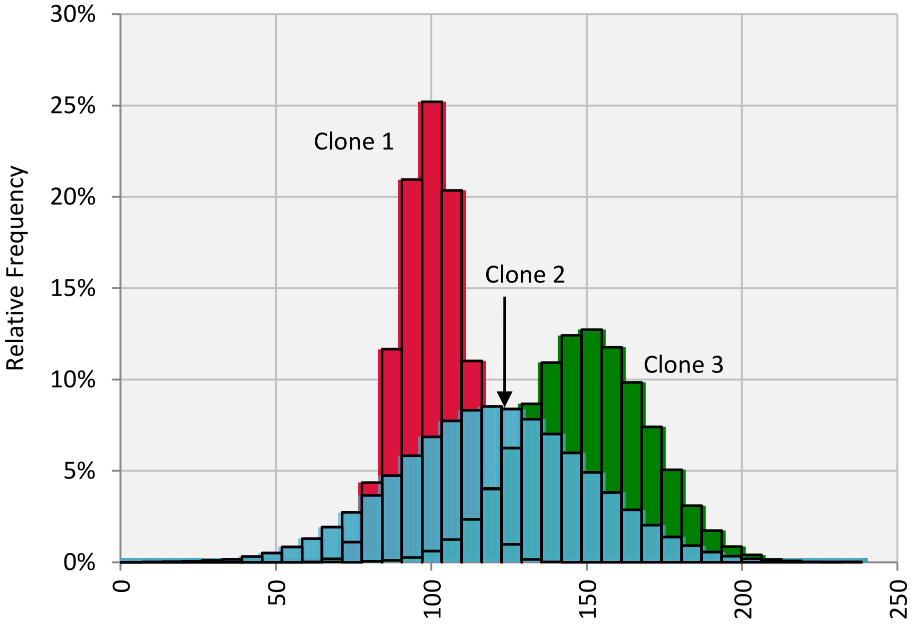
  Clones indexed $k = 1,2,\ldots,n$

  Time indexed $t = 1,2,\ldots,T$

- For each iteration of the simulation, clones are ranked annually and the correlation of rankings across years is calculated.

- Rank 1 assigned to individual with greatest *cumulative growth* at time *t*.

Distribution of diameter growth in time = *t*



Stochastic Model

- Correlation of rankings in consecutive time periods and with ranking at T (i.e., rotation age) calculated as:

Spearman Rank Correlation Coefficient

$$\rho_{t_1 t_2} = 1 - \frac{6\sum_{k=1}^{n} d_{t_1 t_2}^2}{n(n^2-1)}$$

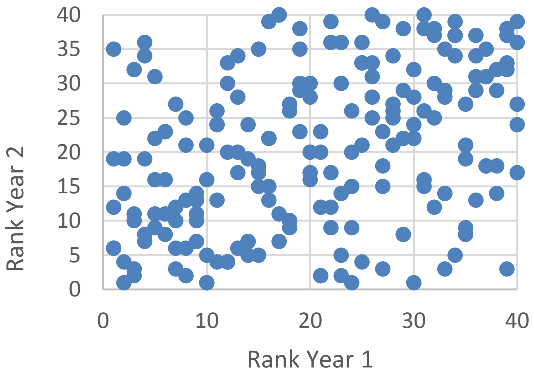
where

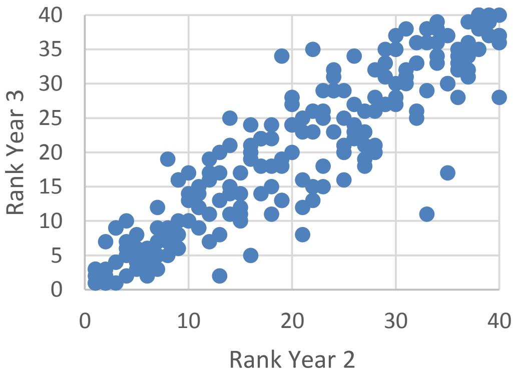
$d_{t_1 t_2}$= clone k’s rank in year t_1 – clone k’s rank in year t_2

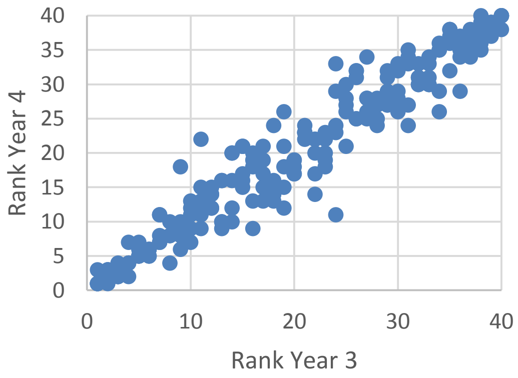
n = Total number of clones ranked

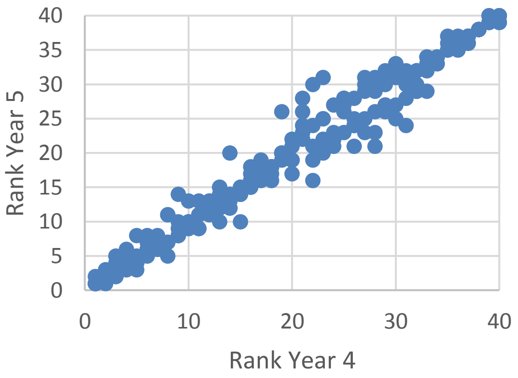
- Monte Carlo simulation
  - @Risk (Palisade, 2013)
  - Parameters set to reflect hybrid poplar management (*n*=40; *T*=11)

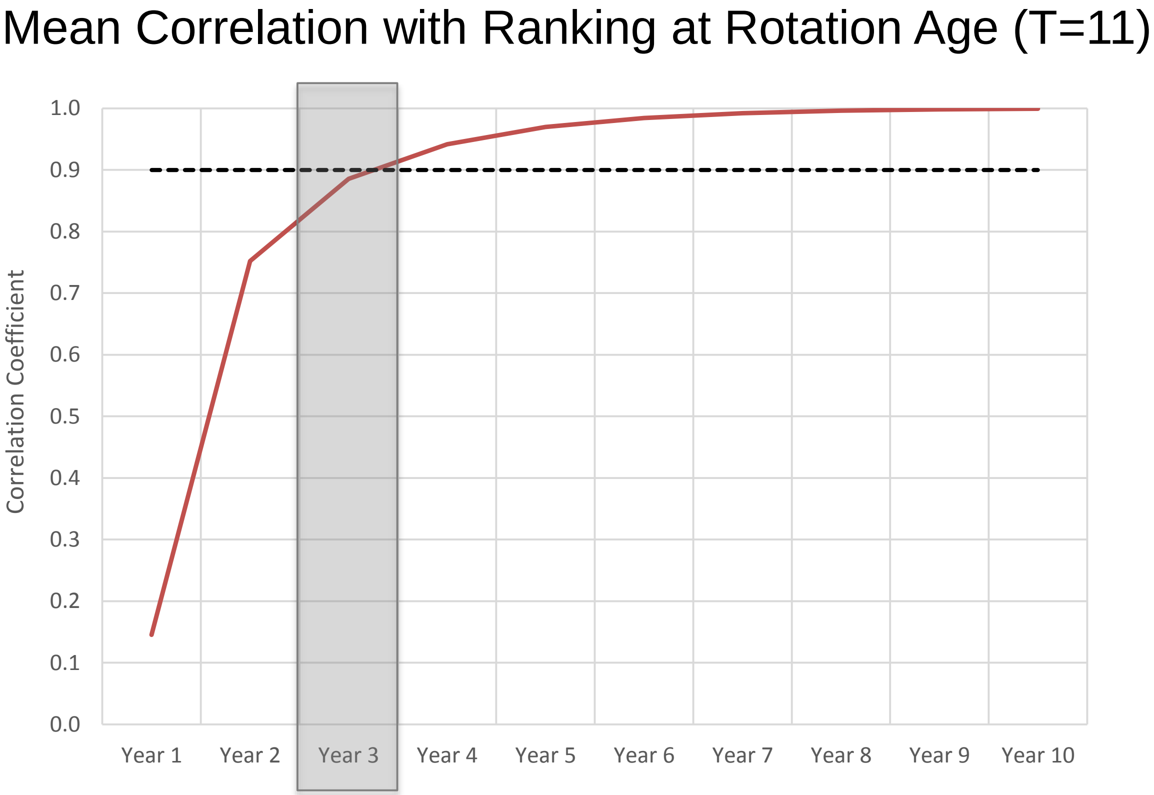
Results – Correlation



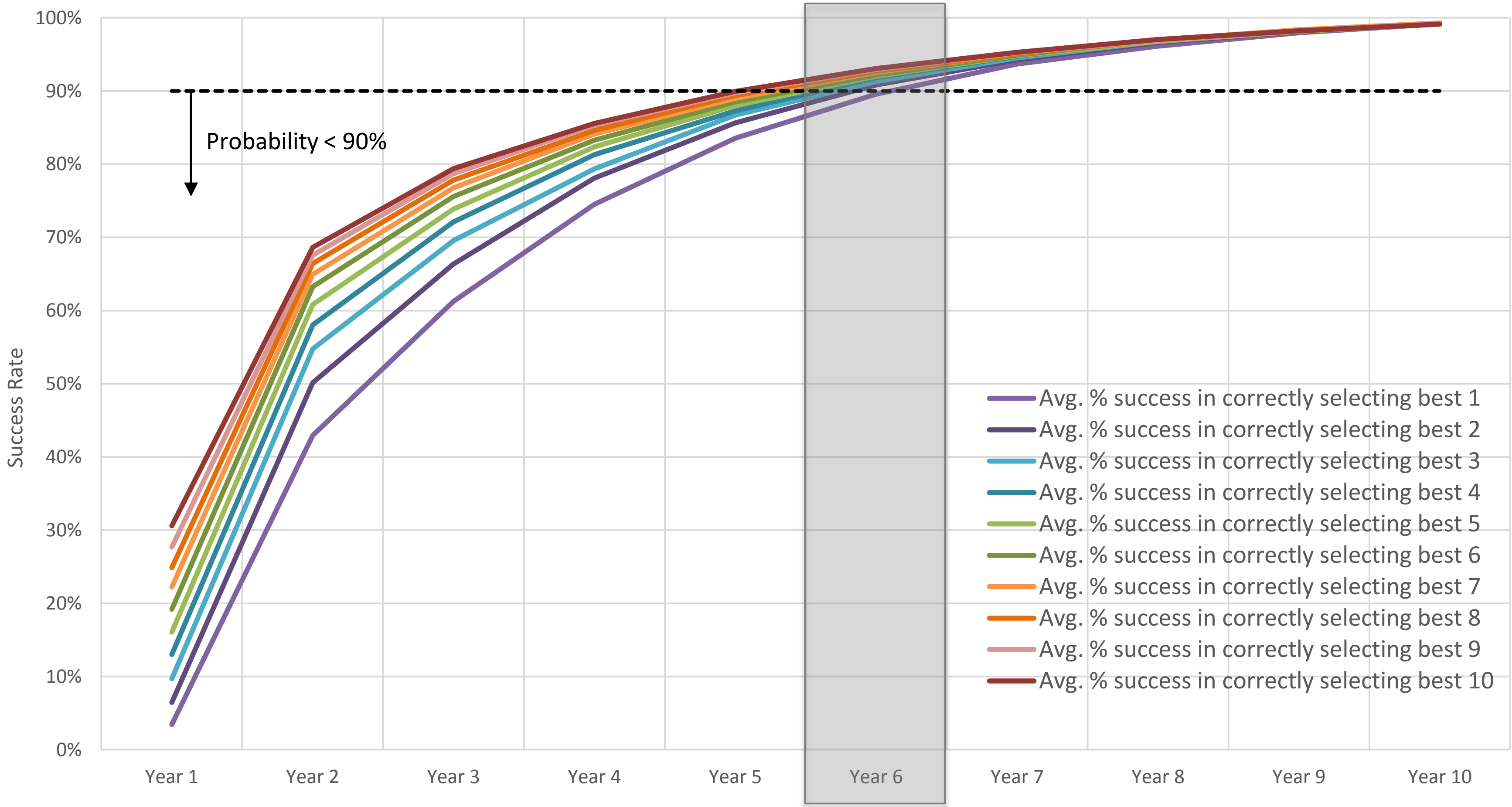








Results – Success selecting top clones



Results Summary and Next Steps

- Over time, we learn more about clones' growth
  - Mean correlation with ranking at rotation age increases with number of years in trial
  - Ability to select top-performing clones improves with number of years in trial

- After just three years in trial, hybrid poplar clone ranking is highly correlated (> 0.90) with ranking at rotation age of 11 years

- After six years in trial, the top 2.5% of clones can be identified with a 90% success rate
  - Suggests it is possible to cut trial period to just over half of a full rotation
  - This is significantly less time in trial than would be typical following conventional management

- Next steps
  - Apply stochastic model to an economic framework that incorporates the cost and benefits of time in trial
  - Economically efficient clone adoption may occur even earlier