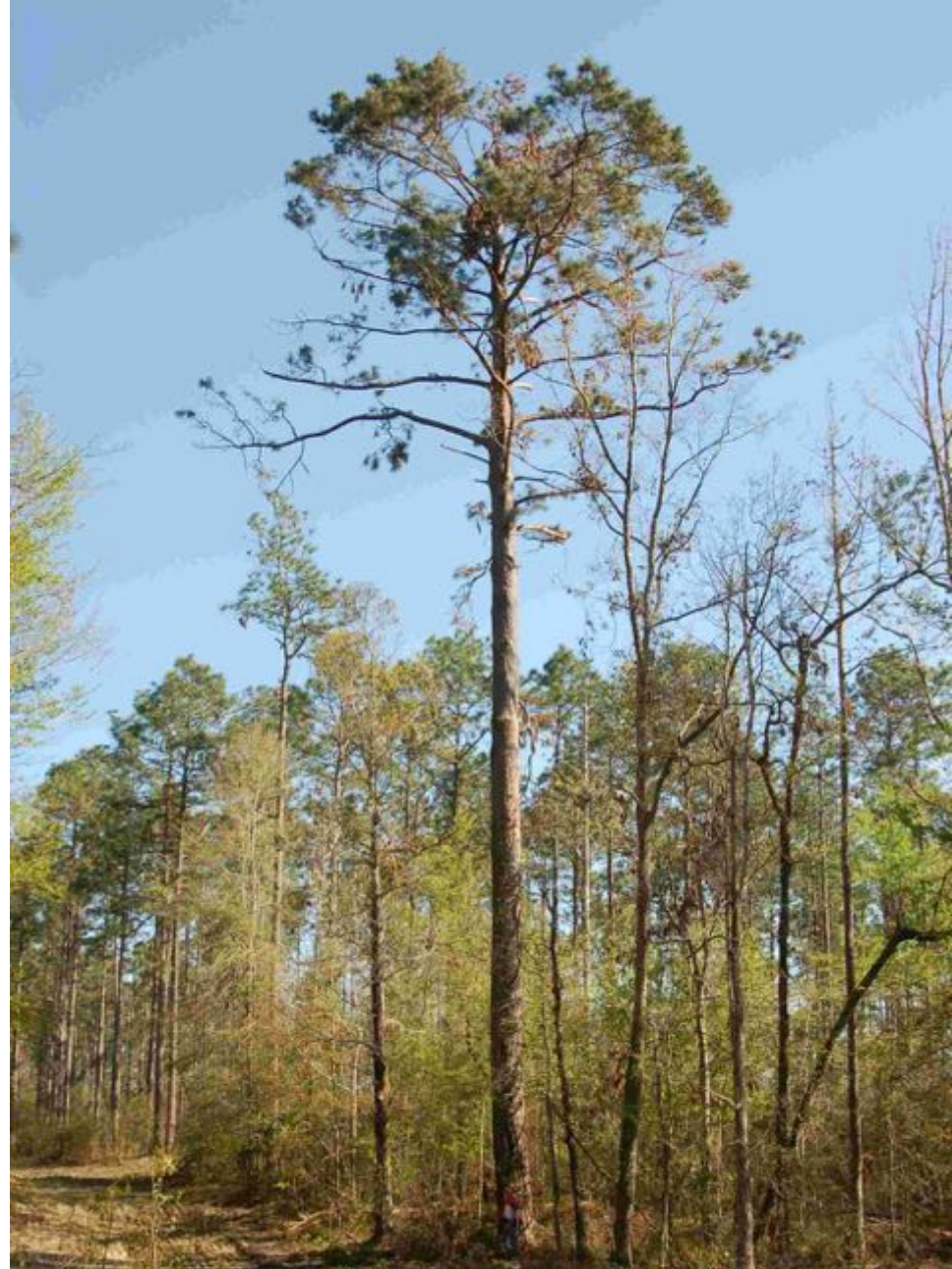


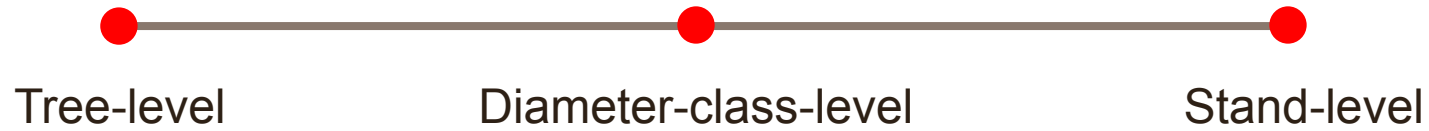
# An Integrated System for Modeling Tree and Stand Survivals

Quang V. Cao



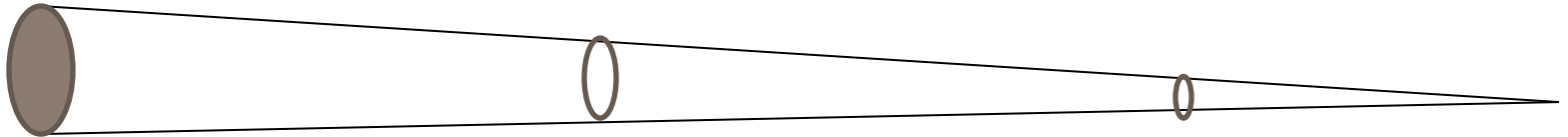
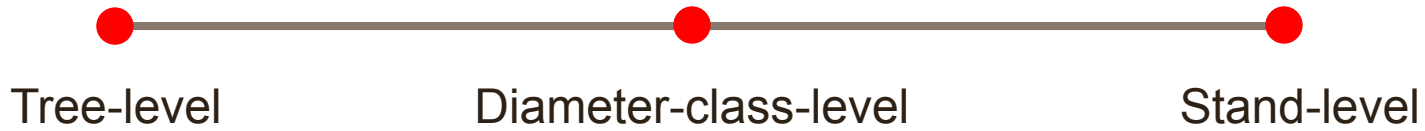
*School of*  
**Renewable Natural Resources**  
*Louisiana State University*

# Introduction



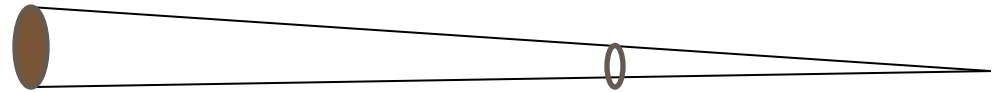
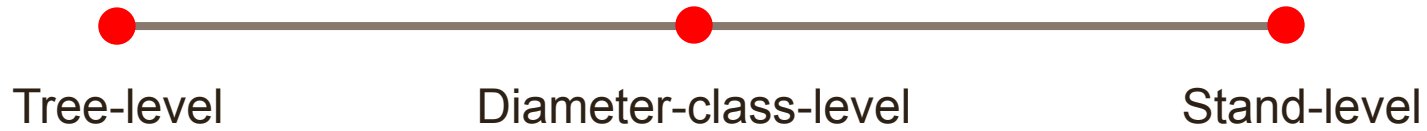
# Introduction

Daniels and Burkhardt (1988)



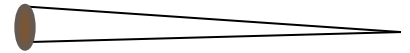
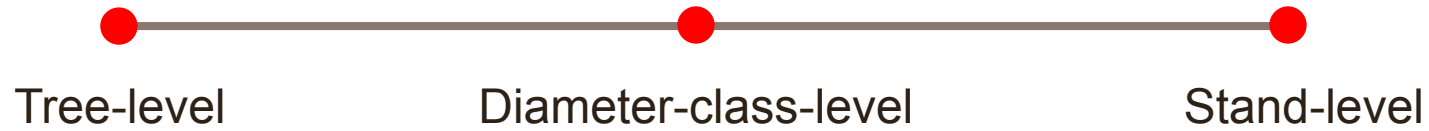
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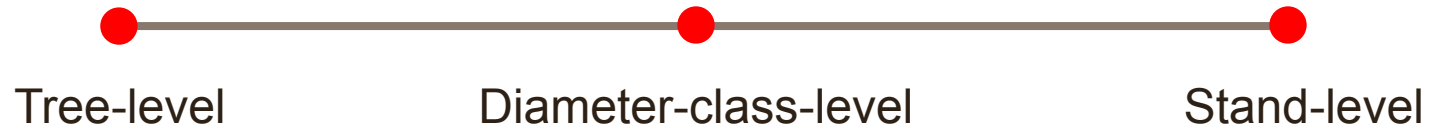


# Introduction

Daniels and Burkhardt (1988)

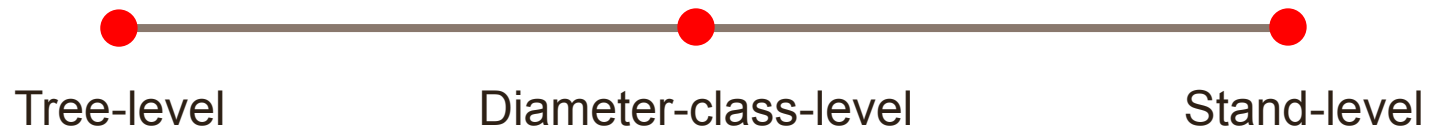


# Introduction



*APA*

# Introduction



*APA*

$1/N$

# Approaches

1. From a tree model,  
derive a stand model



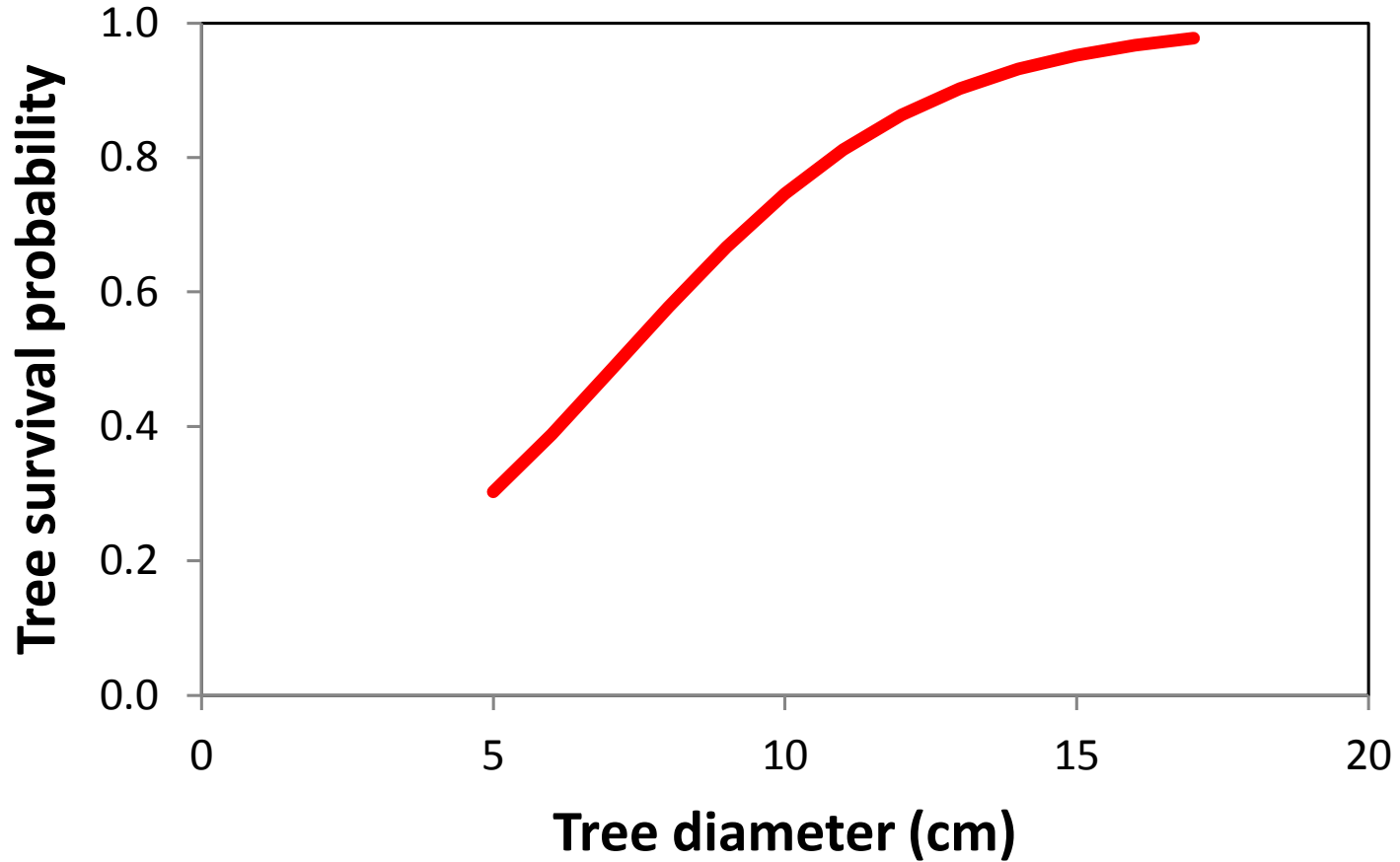
# Approaches

1. From a tree model,  
derive a stand model
2. From a stand model,  
derive a tree model

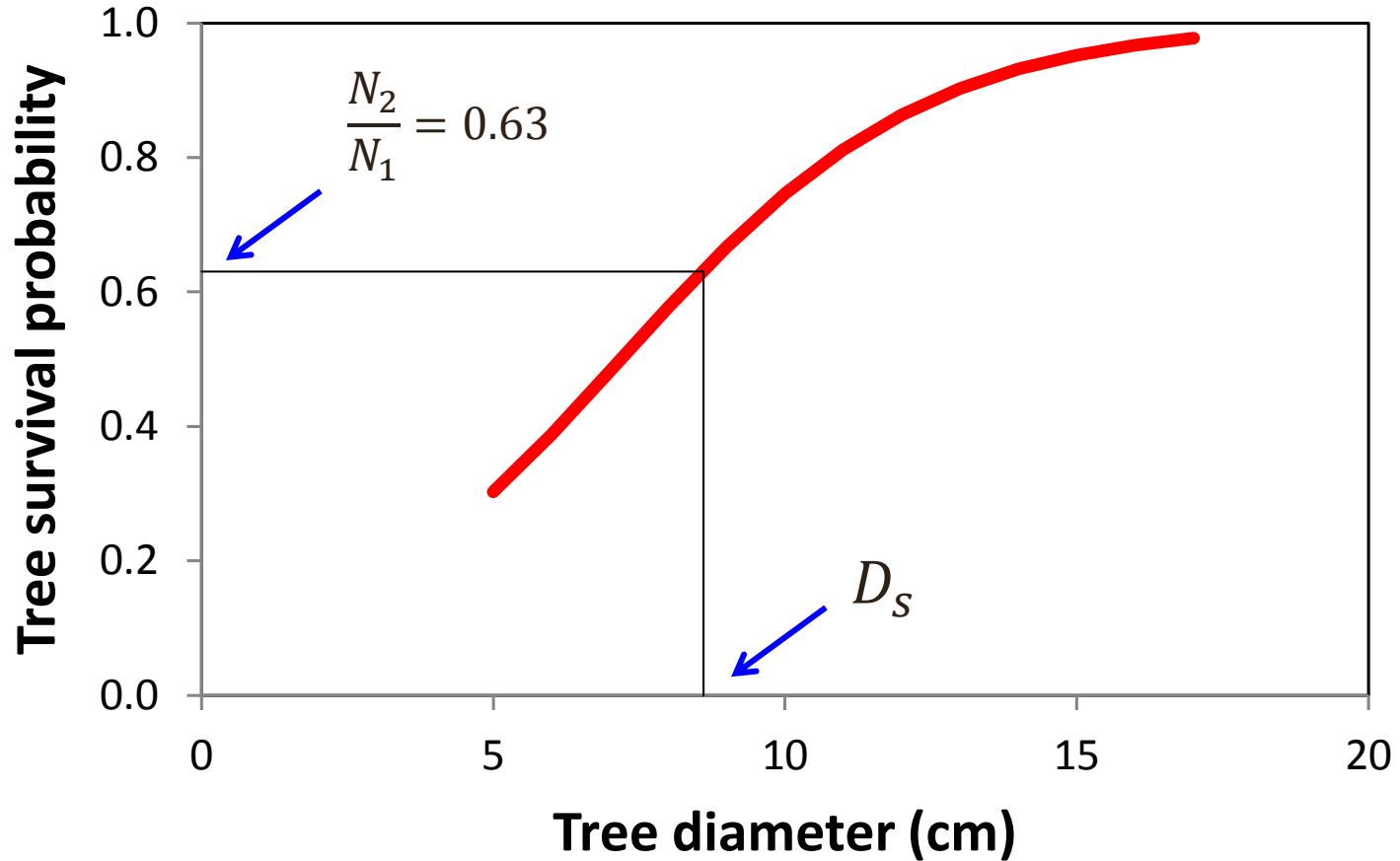
# Approach 1: Tree Model

$$p = \frac{1}{1 + \exp(b_0 + b_1 H_1 + b_2 RS_1 + b_3 N_1/A_1 + b_4/A_1 + b_5 d_1)}$$

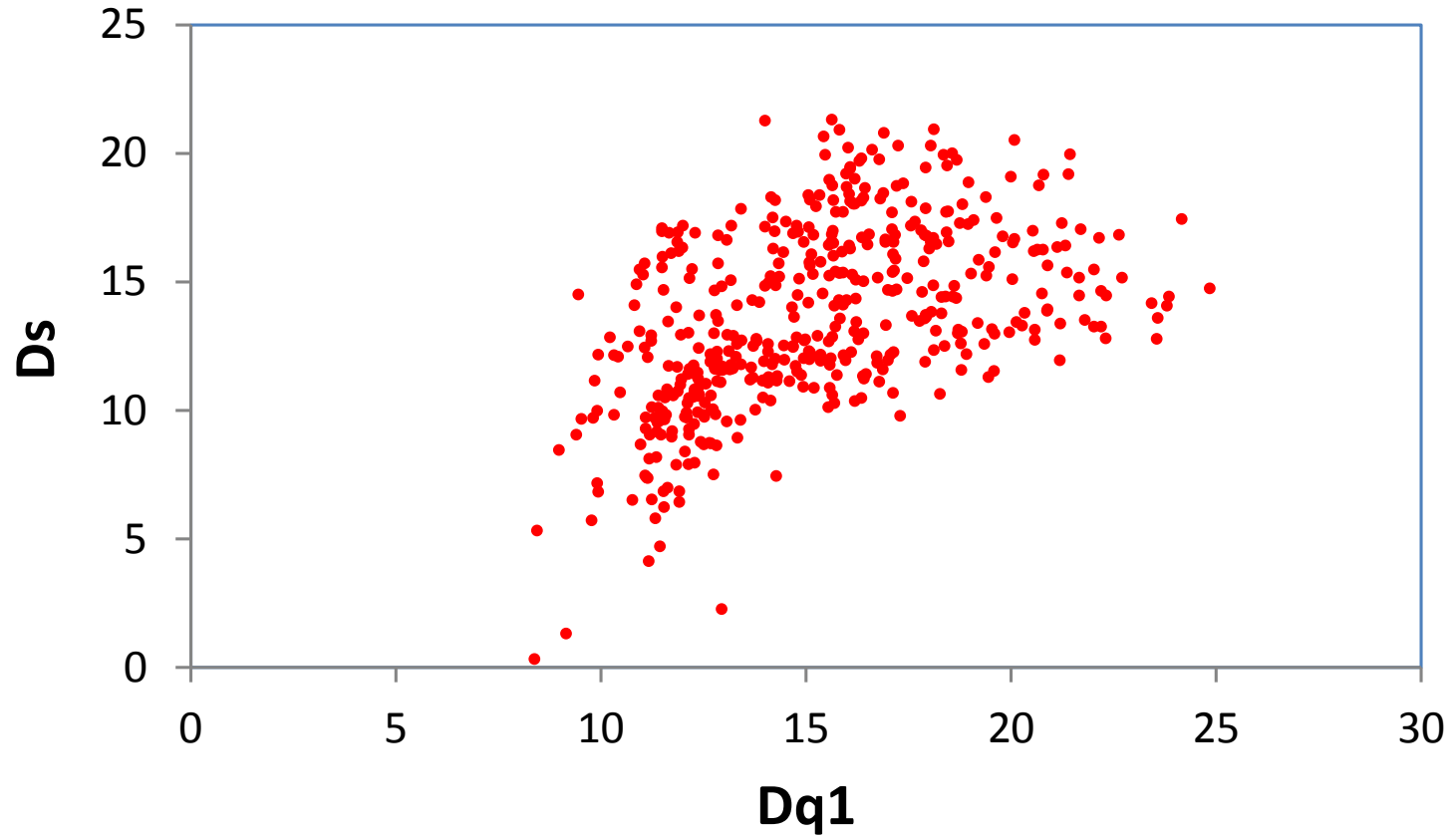
# Approach 1: Tree Model



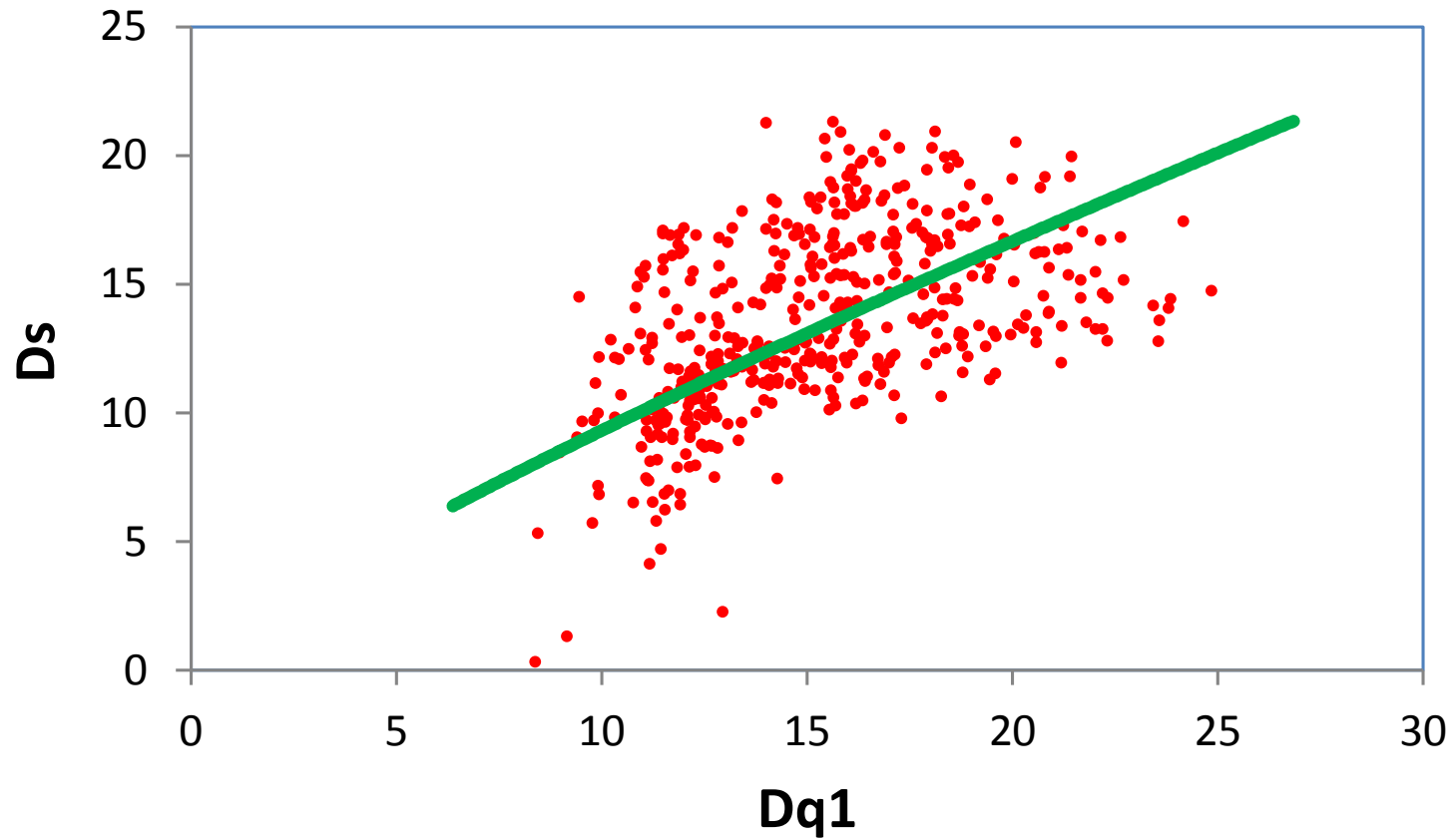
# Approach 1: Tree Model



# Approach 1: Tree Model



# Approach 1: Tree Model



# Approach 1: Derived Stand Model

$$p = \frac{1}{1 + \exp(b_0 + b_1 H_1 + b_2 R S_1 + b_3 N_1 / A_1 + b_4 / A_1 + b_5 d_1)}$$

# Approach 1: Derived Stand Model

$$p = \frac{1}{1 + \exp(b_0 + b_1 H_1 + b_2 RS_1 + b_3 N_1/A_1 + b_4/A_1 + b_5 d_1)}$$

$$N_2 = \frac{N_1}{1 + \exp(b_0 + b_1 H_1 + b_2 RS_1 + b_3 N_1/A_1 + b_4/A_1 + b_5 D_s)}$$

where

$$D_s = c_1 D_{q1}^{c_2}$$



# Approach 1: Parameter Estimation

## ❖ Sequential estimation

- Tree model: Maximum likelihood

$$p = \frac{1}{1 + \exp(b_0 + b_1 H_1 + b_2 RS_1 + b_3 N_1/A_1 + b_4/A_1 + b_5 d_1)}$$

- Derived stand model: Least squares

$$N_2 = \frac{N_1}{1 + \exp(b_0 + b_1 H_1 + b_2 RS_1 + b_3 N_1/A_1 + b_4/A_1 + b_5 D_s)}$$

where

$$D_s = c_1 D_{q1}^{c_2}$$

# Approach 1: Parameter Estimation

- ❖ Sequential estimation
- ❖ **Simultaneous estimation:** Maximum likelihood

$$\max \ln L = \frac{\ln L_1}{\ln L_{1max}} + \frac{\ln L_2}{\ln L_{2max}},$$

where  $\ln L_1 = \sum_i \sum_j \ln(z_{ij})$ ,

$z_{ij} = p_{ij}$  if alive and  $(1 - p_{ij})$  if dead ,

$$\ln L_2 = -\frac{1}{2} \ln(2\pi\sigma^2) - \frac{1}{2\sigma^2} \sum_i (N_{2i} - \hat{N}_{2i})^2 .$$

# Approach 2: Stand Survival Model

$$N_2 = \frac{N_1}{1 + \exp(b_0 + b_1 H_1 + b_2 RS_1 + b_3 N_1/A_1 + b_4/A_1)}$$

# Approach 2: Stand Survival Model

$$N_2 = \frac{N_1}{1 + \exp(b_0 + b_1 H_1 + b_2 R S_1 + b_3 N_1 / A_1 + b_4 / A_1)}$$

$$p = \frac{1}{1 + \exp[b_0 + b_1 H_1 + b_2 R S_1 + b_3 N_1 / A_1 + b_4 / A_1 + b_5 (d_1 - D_s)]}$$

where

$$D_s = c_1 D_{q1}^{c_2}$$

# Approach 2: Parameter Estimation

- ❖ Sequential estimation
  - Stand model: Least squares

$$N_2 = \frac{N_1}{1 + \exp(b_0 + b_1 H_1 + b_2 R S_1 + b_3 N_1 / A_1 + b_4 / A_1)}$$

- Derived tree model: Maximum likelihood

$$p = \frac{1}{1 + \exp[b_0 + b_1 H_1 + b_2 R S_1 + b_3 N_1 / A_1 + b_4 / A_1 + b_5 (d_1 - D_s)]}$$

where

$$D_s = c_1 D_{q1}^{c_2}$$

# Approach 2: Parameter Estimation

- ❖ Sequential estimation
- ❖ Simultaneous estimation: Maximum likelihood

$$\max \ln L = \frac{\ln L_1}{\ln L_{1max}} + \frac{\ln L_2}{\ln L_{2max}},$$

where  $\ln L_1 = \sum_i \sum_j \ln(z_{ij})$ ,

$z_{ij} = p_{ij}$  if alive and  $(1 - p_{ij})$  if dead ,

$$\ln L_2 = -\frac{1}{2} \ln(2\pi\sigma^2) - \frac{1}{2\sigma^2} \sum_i (N_{2i} - \hat{N}_{2i})^2.$$

# Data

## Southwide Seed Source Study

- 2 groups
- Each group has 100 plots
- Each plot has 3 growth periods:
  - ❖ 10 – 15 years
  - ❖ 15 – 20 years
  - ❖ 20 – 25 years
- Leave-one-out validation scheme

# Evaluation

- MD: Mean difference
- MAD: Mean absolute difference
- Stand-level:  $R^2$ : Fit index
- Tree-level: AUC: Area under the curve



# Results -- Tree level

Approach	Model	MD	MAD	AUC
1	Tree model	0.0000	0.2253	0.8036
	Simultaneous	0.0064	0.2292	0.8010
2	Derived Tree model	-0.0006	0.2172	0.8024
	Simultaneous	-0.0091	0.2169	0.8058

# Results -- Stand level

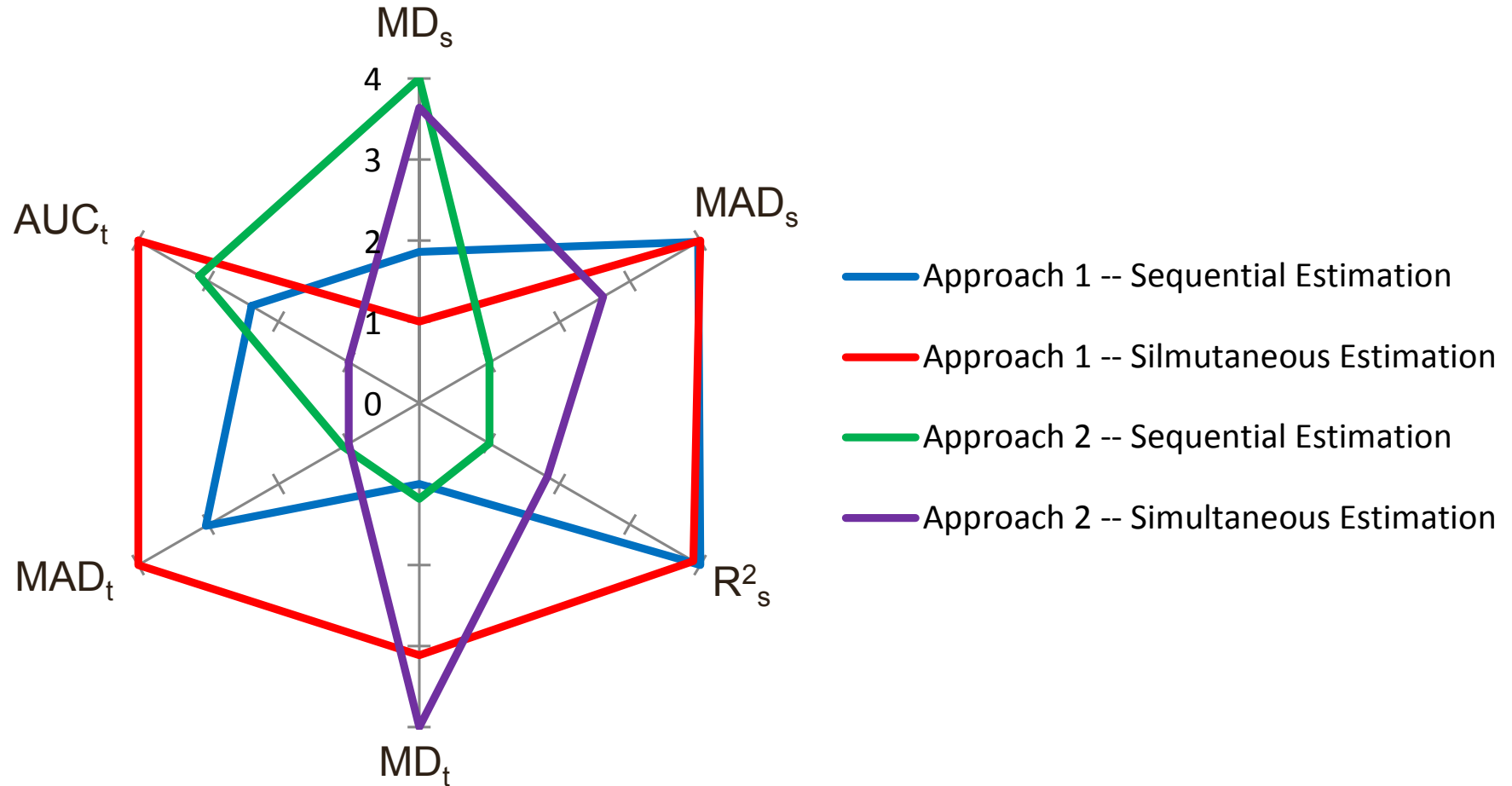
Approach	Model	MD	MAD	R <sup>2</sup>
1	Derived Stand-level	-6.82	171.58	0.8070
	Simultaneous	-0.32	171.72	0.8078
2	Stand-level	-22.96	157.83	0.8330
	Simultaneous	-20.24	165.32	0.8259

# Results -- Rankings

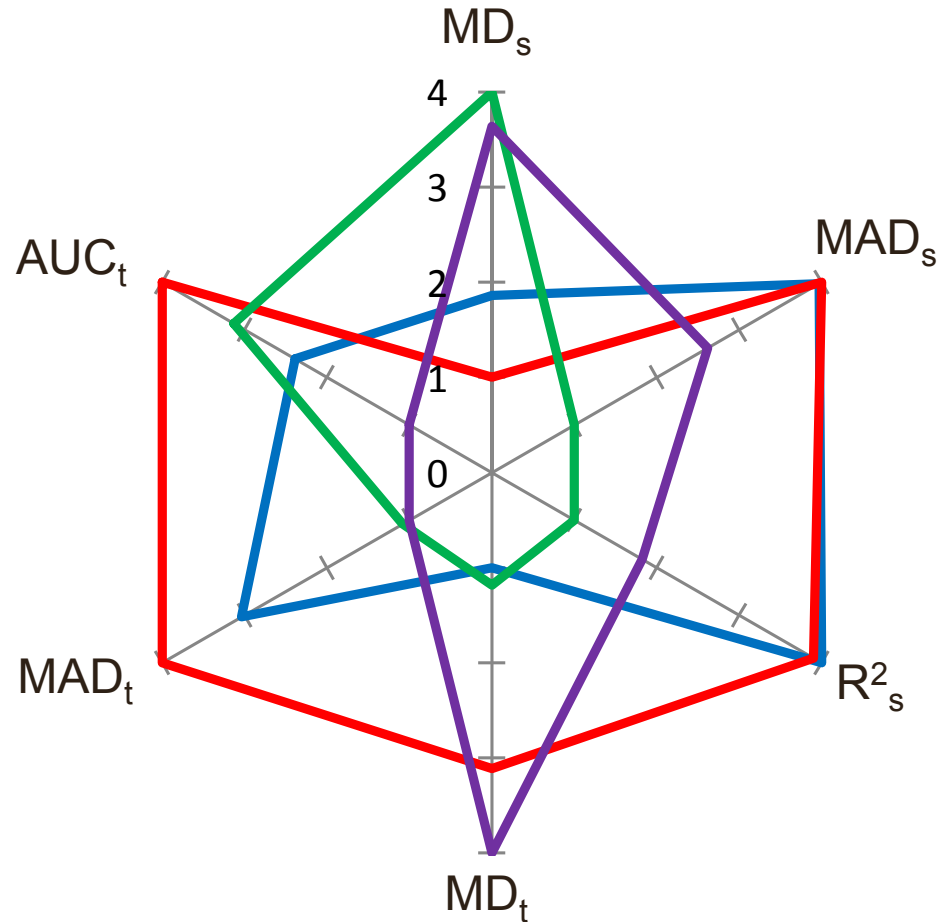
MD	MAD	AUC	MD	MAD	R <sup>2</sup>
0.0000	0.2253	0.8036	-6.82	171.58	0.8070
0.0064	0.2292	0.8010	-0.32	171.72	0.8078
-0.0006	0.2172	0.8024	-22.96	157.83	0.8330
-0.0091	0.2169	0.8058	-20.24	165.32	0.8259

1.00	3.04	2.39	1.86	3.97	4.00
3.11	4.00	4.00	1.00	4.00	3.91
1.19	1.08	3.13	4.00	1.00	1.00
4.00	1.00	1.00	3.64	2.62	1.83

# Results



# Results



- Approach 1 -- Sequential Estimation **2.69**
- Approach 1 -- Simultaneous Estimation **4.00**
- Approach 2 -- Sequential Estimation **1.00**
- Approach 2 -- Simultaneous Estimation **1.93**

# Summary

- Approach 2 > Approach 1

# Summary

- Approach 2 > Approach 1
- Sequential > Simultaneous estimation

# Summary

- Approach 2 > Approach 1
- Sequential > Simultaneous estimation
- **Conceptually compatible**



# Summary

- Approach 2 > Approach 1
- Sequential > Simultaneous estimation
- Conceptually compatible
- **Not numerically compatible**