

## Outline

- Biology and ecology of forest tree temperature response
- Managing for temperature and water



### Temperature Response of Photosynthesis

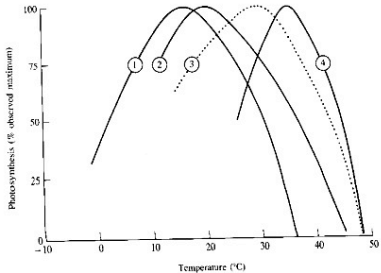


FIGURE 5.24. Effect of temperature on photosynthesis of temperate-zone species (curve 1, Swiss stone pine; curve 2, European beech) and tropical species (curve 3, *Balsa lauro*; curve 4, acacia). After Larcher (1969); from Kozlowski et al. (1991).

### Direct Effects of Temperature on Leaf-Level Carbon Balance

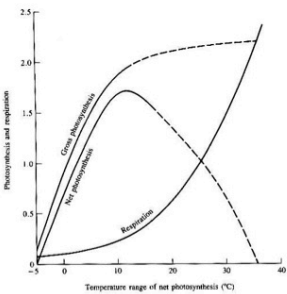
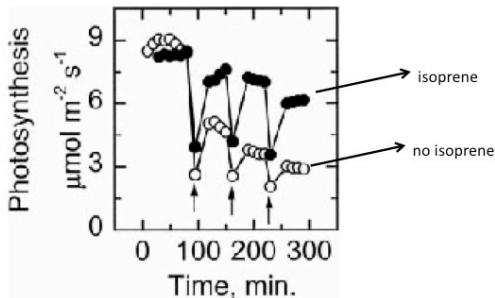


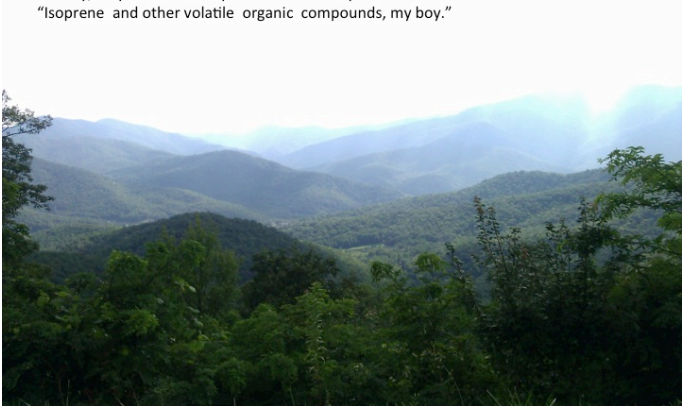
FIGURE 5.23. Effects of temperature on gross photosynthesis, respiration, and net photosynthesis of Swiss stone pine seedlings. Solid parts of lines are from actual measurements; dashed parts are estimated. From Tranquillini (1955) with permission of Springer-Verlag.

- Respiration increases faster with increasing temperature than does photosynthesis
- “Carbon starvation” is a possible outcome, especially in water-limited forests
- At very high temps (e.g. > 100F) membrane damage can occur

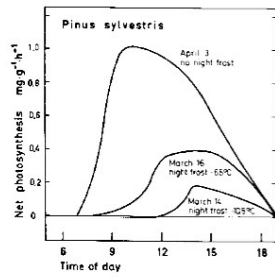
### Isoprene Protects Broadleaf Photosynthetic Membranes from Heat Damage



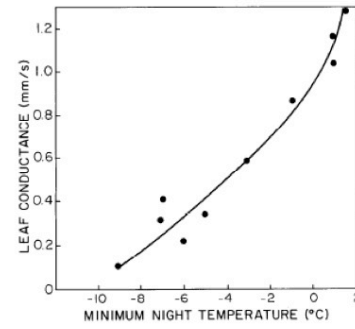
“Daddy, why are the Smoky Mountains smoky?”  
 “Isoprene and other volatile organic compounds, my boy.”



## Frost – Scots pine

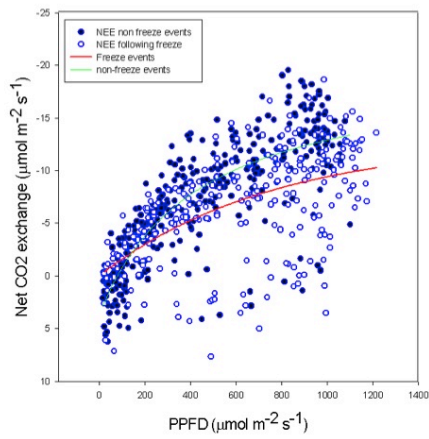


## Frost – loblolly pine



Teskey et al. 1987, Tree Physiology 3:41

Slash pine ecosystem response to frost



## Loblolly cold hardiness is inversely related to seedling growth

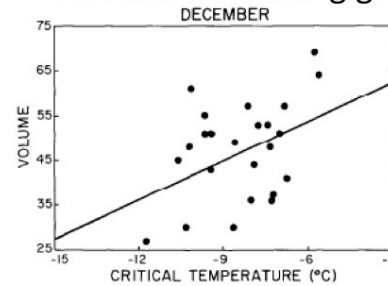


Figure 12. Critical killing temperature of foliage as a function of progeny growth (Bongarten, unpublished data).

Teskey et al. 1987, Tree Physiology 3:41

## Loblolly range and AET

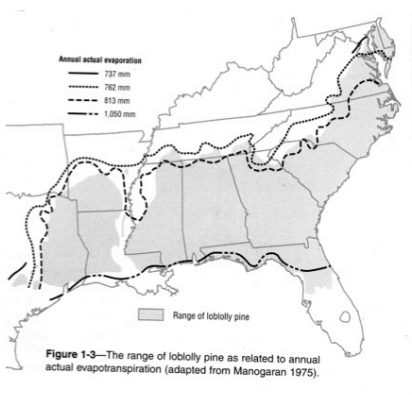


Figure 1-3—The range of loblolly pine as related to annual actual evapotranspiration (adapted from Manogaran 1975).

## Loblolly range and AET

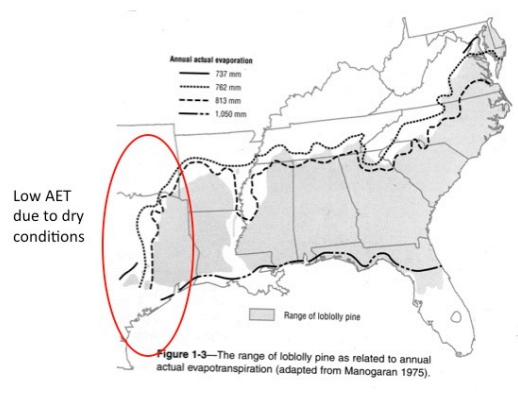
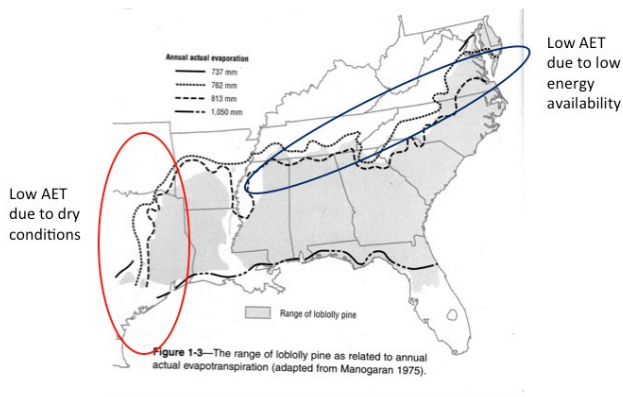
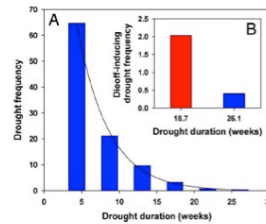


Figure 1-3—The range of loblolly pine as related to annual actual evapotranspiration (adapted from Manogaran 1975).

## Loblolly northern range and AET



## Interaction of Temperature and Drought



- Drought-associated *Pinus edulis* dieoff events predicted to become five times more common under elevated temperature



Adams et al. 2009. PNAS 106:7063-7066.

## Forest Disturbance - Wildfire



2007 Georgia Wildfires  
GA Forestry Commission

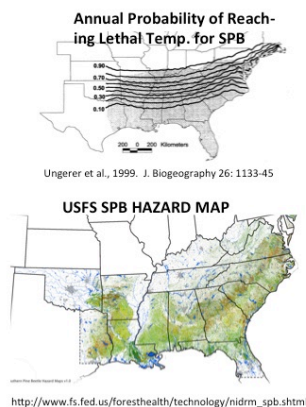
## Forest Disturbance – Southern Pine Beetle



SPB Infestation, Sabine Nat'l Forest, TX  
R. Billings

## Southern Pine Beetle

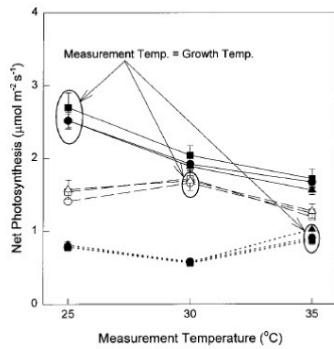
- Winter minimum temperature is a good predictor of the northern limit of the SPB range
- USFS has developed hazard maps for SPB using a multi-criteria framework
- Temperature changes may directly impact SPB population dynamics



## Temperature Acclimation

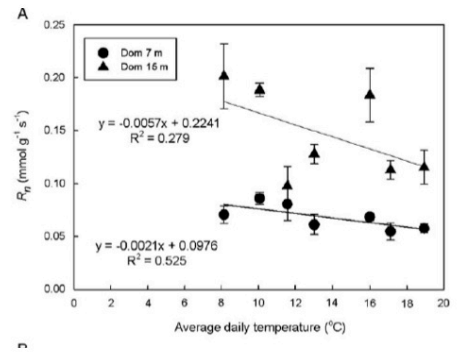
- Acclimation = physiological adjustment to short term changes in the environment
  - Individuals
  - Short term
- Adaptation = genetic changes in populations in response to selection pressure in the environment
  - Populations
  - Long term

## Photosynthesis Temperature Acclimation



Teskey and Will 1999, Tree Physiology 19:519

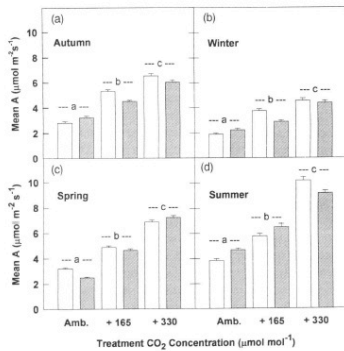
## Respiration Temperature Acclimation



O'Grady et al. 2010, Tree Physiology 30:957

## Interaction of CO<sub>2</sub> and Temperature

- There is some evidence that positive effects of elevated CO<sub>2</sub> may compensate for negative effects of elevated temperature



Teskey 1997, Plant, Cell and Environ. 20:373

## Managing For Temperature

- Not a manipulatable variable in many situations
- Genetic selection and deployment is primary tool



## Shelterwood Regeneration

- By definition, modifies understory microclimate



David Moorhead, Forestry Images

## Water Relations of Regeneration

Table 1. Effects of overstory basal area on mean predawn and midday water potentials of loblolly pine seedlings at Site I. Means within a column followed by different letters are significantly different at  $P = 0.0066$  for predawn and  $P = 0.0001$  for midday  $\Psi_w$  (Duncan's multiple range test).

Basal area ( $\text{m}^2 \text{ha}^{-1}$ )	Mean water potential ( $\Psi_w$ )	
	Predawn <sup>1</sup> (MPa)	Midday <sup>2</sup> (MPa)
0	-0.50 a	-1.07 a
4.6	-0.44 b	-0.82 b
9.2	-0.37 c	-0.69 c

↑ More water stress

Dalton and Messina 1994 Tree Physiology 15:19

# Water Relations of Regeneration

- Water relations, gas exchange, survival improved under shelterwood
- Trenching had little effect, suggesting competition with overstory was minimal
- Viable option on very harsh sites

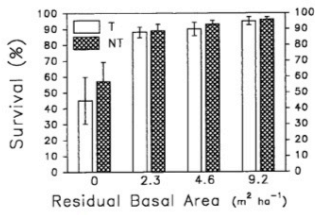
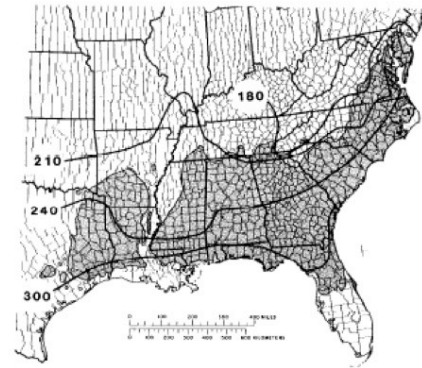


Figure 8. Seedling survival as affected by overstory basal area and trenching (Site I). Vertical bars are standard errors.

Dalton and Messina 1994 Tree Physiology 15:19

# Loblolly pine growing season length



Teskey et al. 1987, Tree Physiology 3:41

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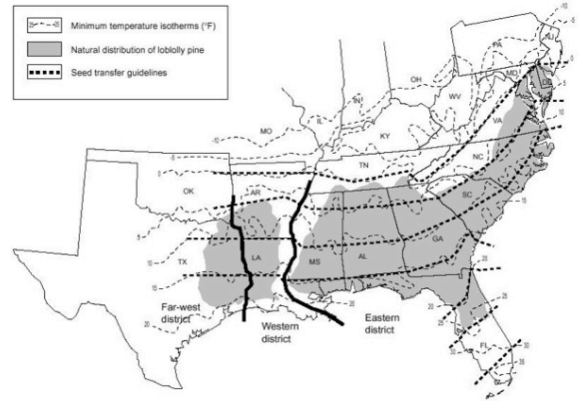


Figure 2—Loblolly pine distribution with seed transfer guidelines. Natural distributions of species adapted from Critchfield and Little (1966); minimum temperature isotherms from USDA (1990).

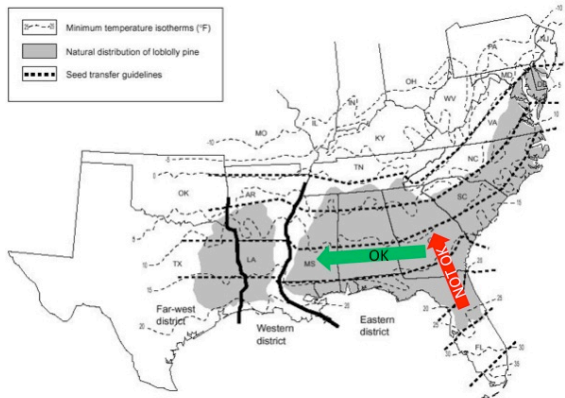
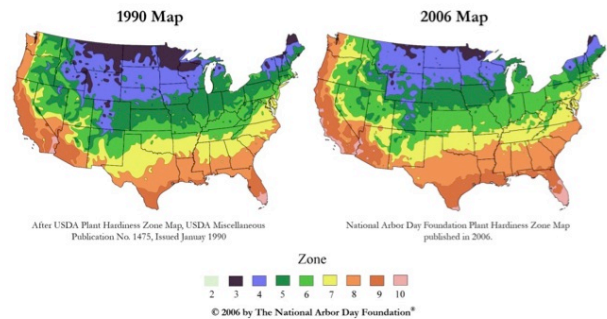


Figure 2—Loblolly pine distribution with seed transfer guidelines. Natural distributions of species adapted from Critchfield and Little (1966); minimum temperature isotherms from USDA (1990).

# USDA Plant Hardiness zones are changing



After USDA Plant Hardiness Zone Map, USDA Miscellaneous Publication No. 1475, Issued January 1990

National Arbor Day Foundation Plant Hardiness Zone Map published in 2006.



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# The Exceptions Prove the Rule

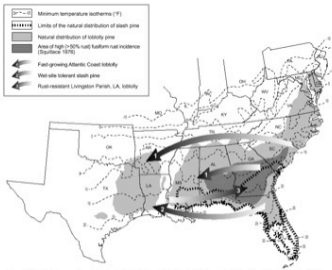


Photo courtesy of a grower in the Southeast. Photo of a 20-year-old slash pine (Wells and Lambeth 1983). The trees on the right are from the nearby, southern Oklahoma seed source; those on the left are from the Coastal Plain of South Carolina.

Figure 1. Major seed and movement corridors across the Great Depression. Natural distribution of slash pine adapted from Clark and Lutz (1995). Movement corridors courtesy from Lutz (2004, 1995).

# Choosing the Right Seed Source

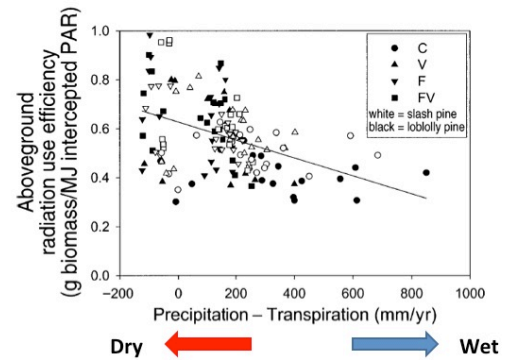
- Ask questions:
- What level of genetic improvement? First, second, third generation?
- Half-sib? Full-sib? Clone?
- Improvement for growth? Disease resistance?
- What is the provenance?
- Where can I deploy this material?



# Managing for Soil Moisture

- Excessive soil moisture
- Regeneration
  - Species selection
  - Seedling quality and type
  - Rooting volume
  - Competition
- Density management
- Resilience to disturbance

# Too Much Water



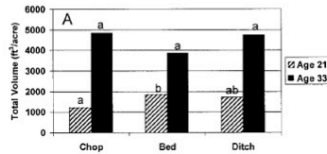
Martin and Jokela 2004, Ecological Applications 14:1839





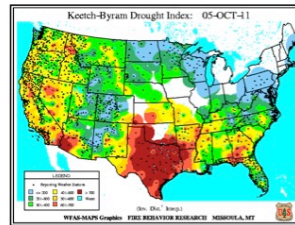
## Bedding

- Improves seedling root aeration; effects primarily early in stand development
- Incorporates surface soil into rooting zone
- Reduces shrubby competition



Kyle et al. 2006, SJAF 29:205

## Effects of Decreased Soil Moisture



- Impacts on growth and carbon gain
- Effects likely to be greater on edges of ranges where water balance may already be marginal

## Potential moisture effects



Betula drought mortality – Wisconsin USFS

- Mortality, esp. in severe droughts, in seedlings, and in forests where water balance is already marginal

## Potential moisture effects



David Stephens, Forestry Images

- Regeneration / seedling stage is most vulnerable stage
- It's hard to be a bareroot seedling...

## Regeneration Considerations

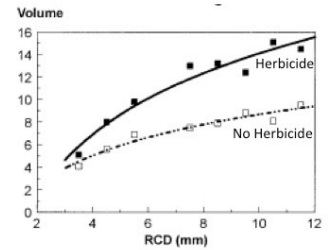
- Species selection
- Seedling quality
- Bareroot vs. containerized
- Planting depth
- Time of planting
- Subsoiling
- Competition control



REMEMBER: Improper seedling handling procedures can nullify all other efforts.

## Seedling quality / size

- Bigger initial seedling size = bigger age 4 yr volume (South et al. 2001)
- Note interaction with weed control



South et al. 2001 New Forests 22:97

## Stock Types



- In dry years, containerized seedlings may stretch the period of survival between rain events
- Moist soil volume in plug
- Less root damage

## Deep Planting May Increase Survival In Well Drained Soils

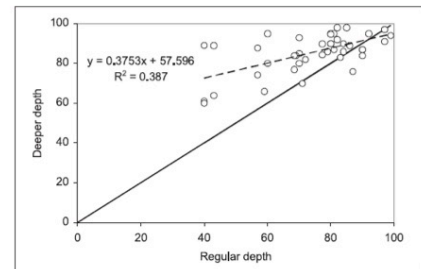
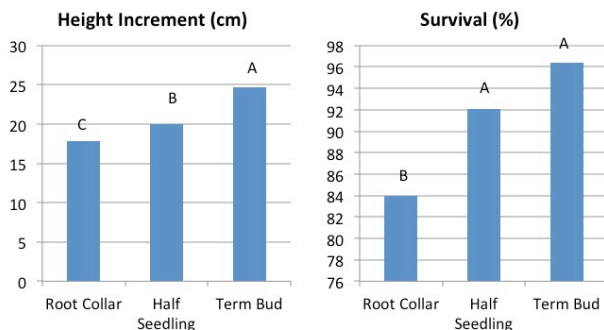


FIGURE 1. Comparison in survival between regular planting depth (root collar just below ground) and deeper planted *P. taeda* or *P. milleri* pine seedlings on well-drained sites. The dashed line represents the regression equation ( $n = 43$ ). The solid diagonal line represents equal survival of the two treatments. Points above the solid line represent cases where deeper planting increased survival.

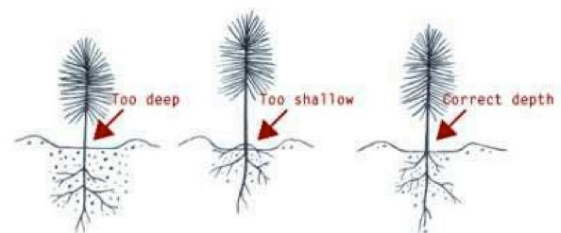
VanderSchaaf and South 2003, S. Afr. For. J. 198:63

## Deep Planting May Aid Survival and Early Growth on Upland Sites



Schuler 2007 J. AR Academy Sci. 61:90

## Good advice for droughty sites?



## Good advice for droughty sites?



## Fall Planting Often Pays Off



Figure 4. Comparison of containerized loblolly pine planted in mid-October (left) versus bare-root loblolly pine planted the following spring (right).

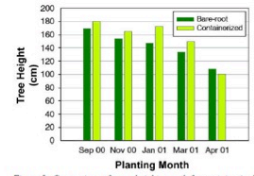


Figure 5. Comparison of mean height growth for containerized loblolly pine stock versus bare-root stock over five planting dates (adapted from Aigel et al., 2004).

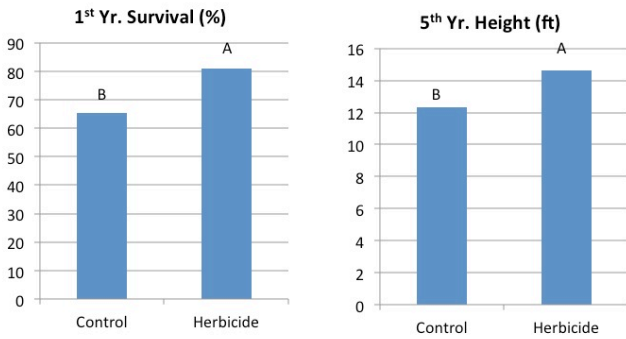
Taylor et al. 2006, SREF Bulletin FM-003

## Subsoiling

- Increases rooting volume on heavy soils
- Breaks plow pan on old field sites
- Concentrates surface water
- May allow deeper planting
- Must manage slash prior to ripping
- Soil must be dry to fracture



## Competition Control – AR and OK



Yeiser and Williams 1996 SJAF 20:53

## Regeneration Recap – Hedges Against Water Stress

- Highest quality, largest seedlings you can find
- Containerized seedlings
- Rip if appropriate
- Plant deep
- Plant “early” if soil moisture is adequate
- Control competition



USFS, Forestry Images

## Density Management and Water Stress

- Initial stocking
- Thinning



## Initial Stocking

- Don't attempt to anticipate mortality by over-planting
- Expensive
- Trees don't die evenly
- Plan for good survival (see: “hedges against water stress”)

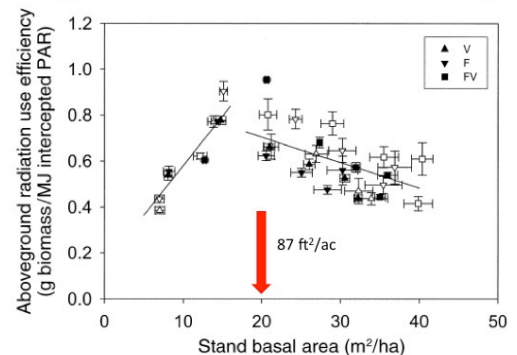


## Density Management

- In general, standard density management principles should apply when we're considering managing for soil moisture
- The goal is to avoid intense inter-tree competition for resources, including water

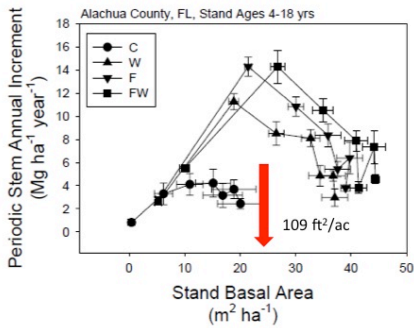


## Density Management – Growth Declines Begin Well Before Self-Thinning



Martin and Jokela 2004 Ecological Applications 14:1839

## Density Management – Growth Declines Begin Well Before Self-Thinning



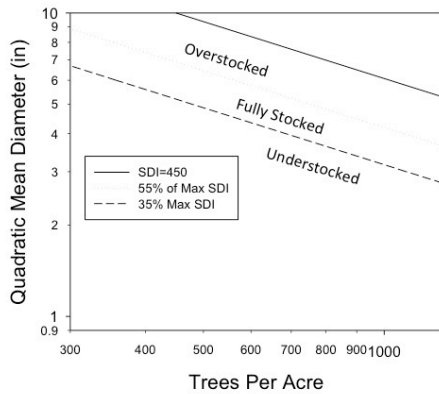
Martin and Jokela 2004 Ecological Applications 14:1839

## Overstocked Stands

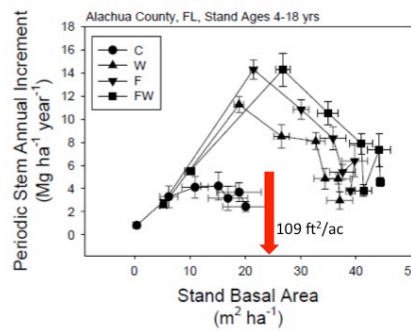
- Inter-tree competition intensifies
- Growth slows
- Density-dependent mortality
- Susceptibility to insects and disease



## Density management diagram



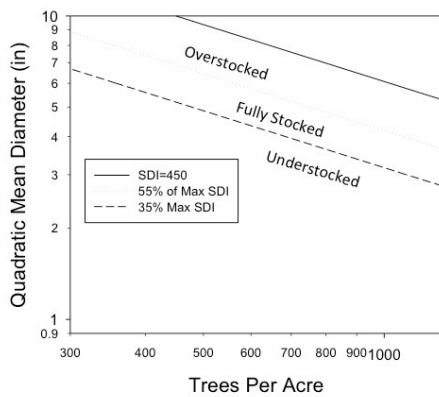
## From our previous example:



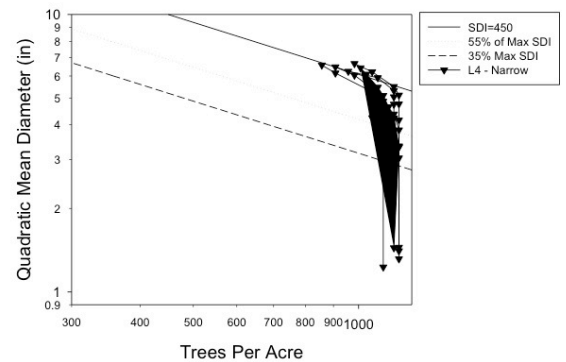
- Growth declines begin around 109 ft<sup>2</sup>/ac BA
- 109 ft<sup>2</sup>/ac at 605 tpa = SDI of 248
- Loblolly maximum SDI=450
- 248/450 = 0.55 = 55%
- Reinecke was right!

Martin and Jokela 2004 Ecological Applications 14:1839

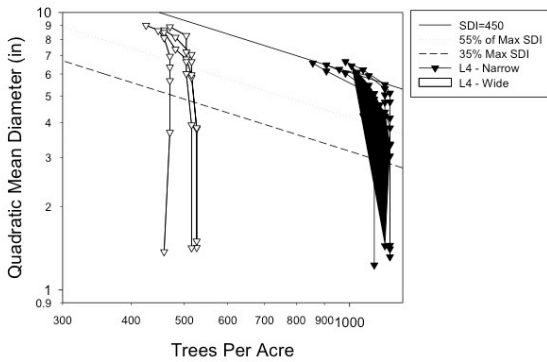
## Density management diagram



## Density management diagram



## Density management diagram

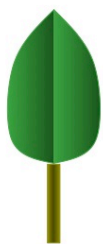


## Density Management Diagrams

- Slash pine: Dean and Jokela 1992, SJAF 16:178
- Loblolly pine: Dean and Baldwin 1993, USFS Research Paper SO-275
- Longleaf pine: Shaw and Long 2007, SJAF 31:28



## Can we manipulate competitive dynamics with genetics?



### Competition Ideotype

- Large, spreading crown
- Aggressive root system
- **Rapid growth through aggressive competition with neighbors**



### Crop Ideotype

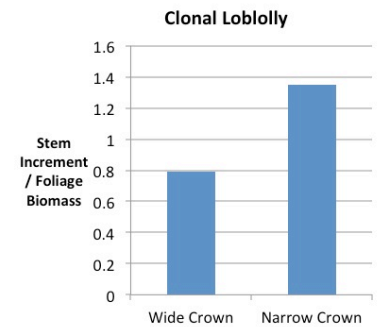
- Narrow, compact crown
- "Contained" root system
- **Rapid growth through efficient conversion of resources**
- Less aggressive competition with neighbors

Cannell 1978

## Maybe: Narrow-crowned loblolly clone is more efficient



Productive, narrow-crown ArborGen clone



## Take Home Messages

- Seedling stage is most vulnerable; manage appropriately
- Interventions which aid survival also generally increase productivity
- Use planting density to control spacing and stand development, not to anticipate mortality
- Monitor and control stand density through thinning to avoid overstocking to maintain resilience to water stress and other disturbances

