



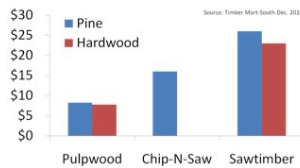
## Pop Quiz 1

What is the **primary** goal of forest fertilizer application?

- A. Increase financial returns
- B. Increase diameter growth rates
- C. Shift product distribution from pulpwood to sawtimber
- D. Shorten rotation length

## What is the goal of fertilization?

- Increase growth
  - Crop trees
  - Improves product class
  - Shortens rotation



## What is the goal of fertilization?

- Fertilizer application is an investment
- All investments are subject to risk
  - Stand may not respond
  - Stand may not respond enough
  - Stand may respond, but then is subject to disturbance



## Outline

- A. Is your stand nutrient limited?
- B. When should you fertilize?
- C. How much should you fertilize?
- D. How is fertilizer applied?



## Pop Quiz 2

Who is applying the most fertilizer to forests?

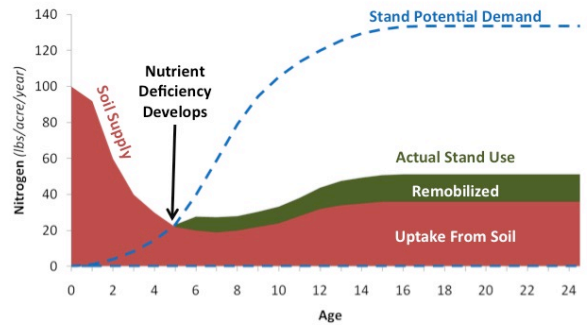
- A. Industry in the Pacific Northwest
- B. Industry in South America
- C. Industry in the US South
- D. Private Forest Landowners Globally

# Who is applying fertilizer?

- More than 16 Million acres fertilized in US South 1969 – 2004 by industrial forest landowners
- 91% of applications were in loblolly pine plantations
- 80% of applications were on the coastal plain
- Exceeds all other forest fertilization combined

Source: Albaugh, T. J., Allen, H. L., Fox, T. R. (2007). Historical patterns of forest fertilization in the southeastern United States from 1969 to 2004. *Southern Journal of Applied Forestry*, 31(3), 129-137.

# Is your stand nutrient limited?

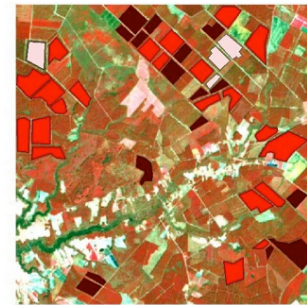


Adapted from: Fox, T. R., Allen, H. L., Albaugh, T. J., Rubilar, R., & Carlson, C. A. (2007). Tree nutrition and forest fertilization of pine plantations in the southern United States. *Southern Journal of Applied Forestry*, 31(1), 5-11.

# Is your stand nutrient limited?

- What tools does 'industry' use?
  - LAI
  - Soil data models
- What tools can consultants or non-industrial private landowners use?
  - Foliar nutrient tests
  - Soil tests
  - Simplified soil models

# Estimated Stand Peak LAI

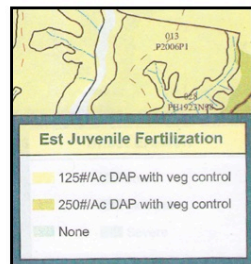


**Peak LAI**  
 1.3 - 2.3  
 2.3 - 3.3  
 > 3.3

Flores, F. J., Allen, H. L., Cheshire, H. M., Davis, J. M., Fuentes, M., & Kelting, D. (2006). Using multispectral satellite imagery to estimate leaf area and response to silvicultural treatments in loblolly pine stands. *Canadian Journal of Forest Research*, 36(6), 1587-1596.

# Soil Data Models

Soil	Recommendation	Acres
<b>Establishment &amp; Juvenile Fertilization</b>		
B13cf5CUX	125#/Ac DAP w/ veg control	12.1
C25cf6CYx	250#/Ac DAP w/ veg control	24.8
<b>Mid Rotation Fertilization Response</b>		
B13cf5CUX	High	12.1
C25cf6CYx	Medium	24.8



Courtesy of Campbell Timberland Management, LLC.

# Critical Levels of Foliar Nutrients

Table 1—Foliar nutrient guidelines (minimum) for southern pines

Nutrient	Slash pine	Loblolly pine
	----- percent -----	
N	1.0	1.2
P	0.09	0.12
K	0.25 - 0.30	0.30
Ca	0.08 - 0.12	0.15
Mg	0.06	0.08
S	0.08	0.10
----- parts per million -----		
B	4 - 8	4 - 8
Zn	10 - 20	10 - 20
Cu	1.5 - 3	2 - 3
Mn	20 - 40	20 - 40
Fe	15 - 35	20 - 40

Source: Allen (1987); Pritchett and Comerford (1983); Wells and others (1973).

Source: Jokela, E. J. (2004). Nutrient management of southern pines. *Slash pine: still growing and growing*, 27-35.



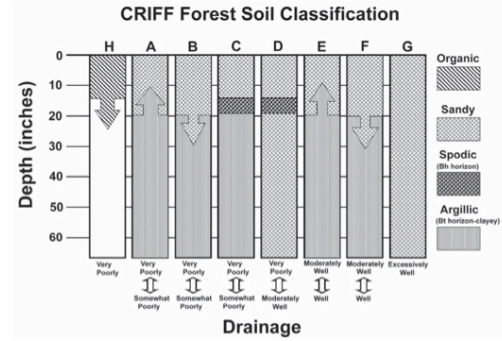
## Soil Tests

- Mehlich-3 results indicating stand may respond:
  - P < 6 ppm
  - K < 12 ppm
  - Ca < 40 ppm
  - Mg < 10 ppm
- Nitrogen much more difficult to predict from soil testing
- This is a MAJOR barrier to NIPF landowners fertilizing



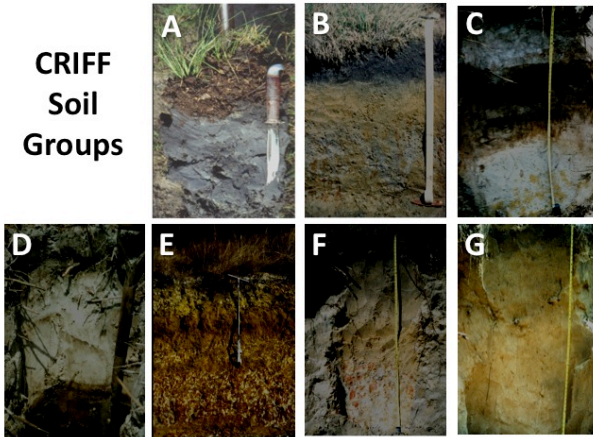
[https://instruct1.cit.cornell.edu/Courses/csv412/mod3/ext\\_m3\\_pg4.htm](https://instruct1.cit.cornell.edu/Courses/csv412/mod3/ext_m3_pg4.htm)

## Simplified Soil Models



Jokela, E. J., & Long, A. J. (2010). Using soils to guide fertilizer recommendations for southern pines. Circular 1230, University of Florida: IFAS Extension.

## CRIFF Soil Groups



Slide provided by Tom Fox

CRIFF A: Severely P deficient soils tend to occur in a band near the coast



## Objective A Review

- The US South leads the world in forest fertilizer application.
- Most forests in the US South are nutrient limited, primarily by N and P, but also by K, B, or other micronutrients.
- It is important to determine what nutrients are limiting on your stand as a first step in prescribing fertilizer application.

## Outline

- Is your stand nutrient limited?
- When should you fertilize?
- How much should you fertilize?
- How is fertilizer applied?



## Pop Quiz 3

When should you apply nitrogen fertilizer in a rotation?

- A. During site prep
- B. Two years before thinning
- C. Right after thinning
- D. One year before clearcutting

## When should you apply fertilizer?

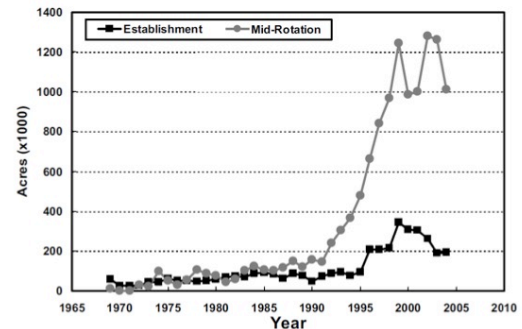
- When are nutrients limiting?
- How long does a stand take to respond?
- How long is the duration of the response?



## When are nutrients limiting?

- P, K, or micronutrients may be limiting at establishment.
  - If such a deficiency exists, a site-prep or establishment application may be recommended.
- N is usually not limiting until a stand approaches canopy closure.
  - Industry has moved away from establishment applications of N, and more towards midrotation treatments.

## When are nutrients limiting?



Source: Albaugh, T. J., Allen, H. L., Fox, T. R. (2007). Historical patterns of forest fertilization in the southeastern United States from 1969 to 2004. *Southern Journal of Applied Forestry*, 32(3), 129-137.

How long does a stand take to respond to a fertilizer application?

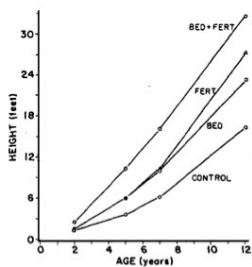
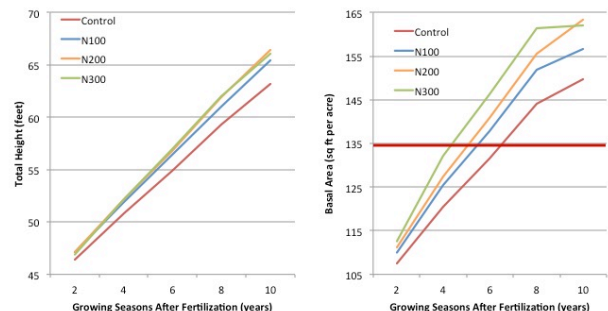


Figure 1. Cumulative mean height growth (ft) over time for five poorly drained clay sites located in the Lower Coastal Plain of North Carolina.

Gent, J. A., Allen, H. L., Campbell, R. G., & Wells, C. G. (1986). Magnitude, duration, and economic analysis of loblolly pine growth response following bedding and phosphorus fertilization. *Southern Journal of Applied Forestry*, 10(3), 124-128.

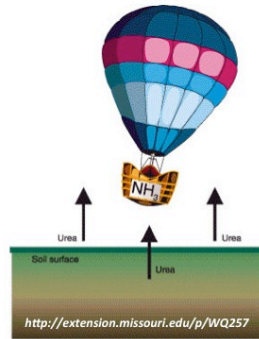
How long is the duration of the growth response?



Data from: Amateis, R. L., Liu, J., Ducey, M. J., & Allen, H. L. (2000). Modeling response to midrotation nitrogen and phosphorus fertilization in loblolly pine plantations. *Southern Journal of Applied Forestry*, 24(4), 207-212.

## When do you apply each year?

- Avoid hot weather
  - N volatilization of urea
  - Can be reduced by combining with boron
  - Various products
    - Efficacy TBD
- Apply during growing season
- March – May ideal

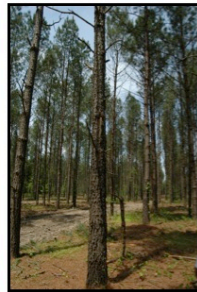


## Objective B Review

- Fertilize with P at establishment on poorly drained clayey soils in the lower coastal plain
- Fertilize with N and P at midrotation
  - Midrotation applications should be at least 5 years before a harvest (thin or clearcut)
  - Midrotation treatments can be spaced at ~5-8 year intervals
  - The goal of midrotation treatments should be to increase diameter of the final crop trees

## Outline

- Is your stand nutrient limited?
- When should you fertilize?
- How much should you fertilize?**
- How is fertilizer applied?

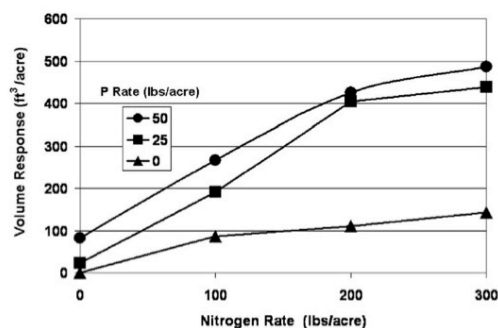


## Pop Quiz 4

What is a typical rate of nitrogen applied at midrotation?

- 38 pounds per acre
- 75 pounds per acre
- 150 pounds per acre
- 300 pounds per acre

## How much fertilizer should you apply?



Source: Fox, T. R., Allen, H. L., Albaugh, T. J., Rubilar, R., & Carlson, C. A. (2007). Tree nutrition and forest fertilization of pine plantations in the southern United States. *Southern Journal of Applied Forestry*, 31(1), 5-11.

## Determining Fertilizer Rates



	N	P	K
Expressed	elemental N	P <sub>2</sub> O <sub>5</sub>	K <sub>2</sub> O
Elemental Weight	14.00	30.97	39.10
Atoms of Target Element	1	2	2
Weight of Target Element Only	14.00	61.94	78.20
Weight of Entire Molecule*	14.00	141.94	94.20
<b>Conversion to Elemental</b>	<b>100%</b>	<b>44%</b>	<b>83%</b>

\* Atomic weight of oxygen = 16.00

## Determining Fertilizer Rates

Material	Analysis	Comments
<b>Nitrogen Materials</b>		
urea	45-0-0	Volatilization an issue
ammonium nitrate	33-0-0	Hydroscopic & explosive (no longer sold)
diammonium phosphate (DAP)	18-46-0	Primary P source
<b>Phosphorous materials</b>		
Concentrated superphosphate	0-44-0	Common water-soluble P-fertilizer
DAP	18-46-0	Water soluble N & P
Rock phosphate	0-15-0	Not water soluble, but soluble in acids
<b>Potassium Materials</b>		
Muriate of potash	0-0-60	Common K fertilizer; water soluble

## Determining Fertilizer Rates

Prescribe (i.e. What do you need per acre)							Apply	
Element	Fert Rate	Fert Source	Elemental Ratio	Element Source			Scale Factor	Source (lbs)
				N	P	K		
<b>N</b>	200	Urea 45-0-0 N	45-0-0 N	177.5	0	0	0.45	395
<b>P</b> <small>Start here b/c DAP contains N and P</small>	25	DAP 18-46-0 N-P <sub>2</sub> O <sub>5</sub>	18-20-0 N-P	22.5	25	0	0.20	125
<b>K</b>	50	Potash 0-0-60 K <sub>2</sub> O	0-0-50 K	0	0	50	0.50	100

P<sub>2</sub>O<sub>5</sub> = 43.6% P      K<sub>2</sub>O = 83.3% K

## Objective C Review

- Fertilize with P at establishment on poorly drained clayey soils in the lower coastal plain
- Fertilize with N and P at midrotation
  - Midrotation applications should be at least 5 years before a harvest (thin or clearcut)
  - Midrotation treatments can be spaced at ~5-8 year intervals
  - The goal of midrotation treatments should be to increase diameter of the final crop trees

## Outline

- Is your stand nutrient limited?
- When should you fertilize?
- How much should you fertilize?
- How is fertilizer applied?**



## Pop Quiz 5

How is most fertilizer applied operationally in the US South?

- By hand
- By helicopter
- By fixed wing aircraft
- By skidder

## Ground Fertilizer Equipment



## Ground Fertilizer Equipment



## Ground Fertilizer Equipment



## Ground Fertilizer Equipment



## Aerial Fertilizer Equipment



## Aerial Fertilizer Equipment



## Application Considerations

- Application over canopy?
- Abundant shrubs?
- Tract location?
  - Near chicken houses or horse farms?



## Environmental Considerations

- Drift less of an issue than herbicides
  - Little mortality, although longleaf can be damaged or killed by loblolly rates
  - Still should avoid
- Almost any SMZ will keep nutrients out of streams
- Can leach on sandy soils



[http://tjswater.blogspot.com/2002\\_06\\_01\\_archive.html](http://tjswater.blogspot.com/2002_06_01_archive.html)

## Checking Contractors

- Collect calibration data
- Collect catch data
  - Place a number of containers of known area in stand
  - Weigh fertilizer collected during or following operation
  - Scale to per acre basis



[http://www.caes.uga.edu/Publications/pubDetail.cfm?pk\\_ID=6393](http://www.caes.uga.edu/Publications/pubDetail.cfm?pk_ID=6393)

## Objective D Review

- Fertilize with P at establishment on poorly drained clayey soils in the lower coastal plain
- Fertilize with N and P at midrotation
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## Synthesis

- On average, fertilizer application increases growth in southern pine stands
  - It does not increase the growth of all stands the same
  - Different stands are limited by different nutrients
  - There are tools available to determine if a stand is nutrient limited, and by what nutrients
- Fertilizer application can yield economic returns, but not without risks

## Questions?

