FOREST PRODUCTIVITY COOPERATIVE

North Carolina State University · Virginia Polytechnic Institute and State University · Universidad de Concepción

Fertilization of Pine Plantations in the Southern United States

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Tim Albaugh, Colleen Carlson, and Lee Allen

www.forestproductivitycoop.org

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VirginiaTech
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Forest Productivity Cooperative

A partnership among North Carolina State University, Virginia Polytechnic Institute and State University, the Universidad de Concepción, Instituto de Pesquisas e Estudos Florestais (**IPEF**) and forest industry and landowners in the US and Latin America

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IPEF

Our Goal is to Help our Members Increase the Productivity, Profitability and Sustainability of Plantation Silviculture in the Americas

Cooperative Research and Technology Transfer Program

(Translational Research)

Forest Productivity Cooperative
62 Members October 2012

41 Full Members

Agropical
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Arauco – Bioforest
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Rayonier
Refocosta
Resource Management Service
RMK Timberlands
Smurfit Cartón de Colombia y Venezuela
Superior Pine
Suzano
Timberland Investment Resources
Valor Florestal
Westervelt
Weyerhaeuser

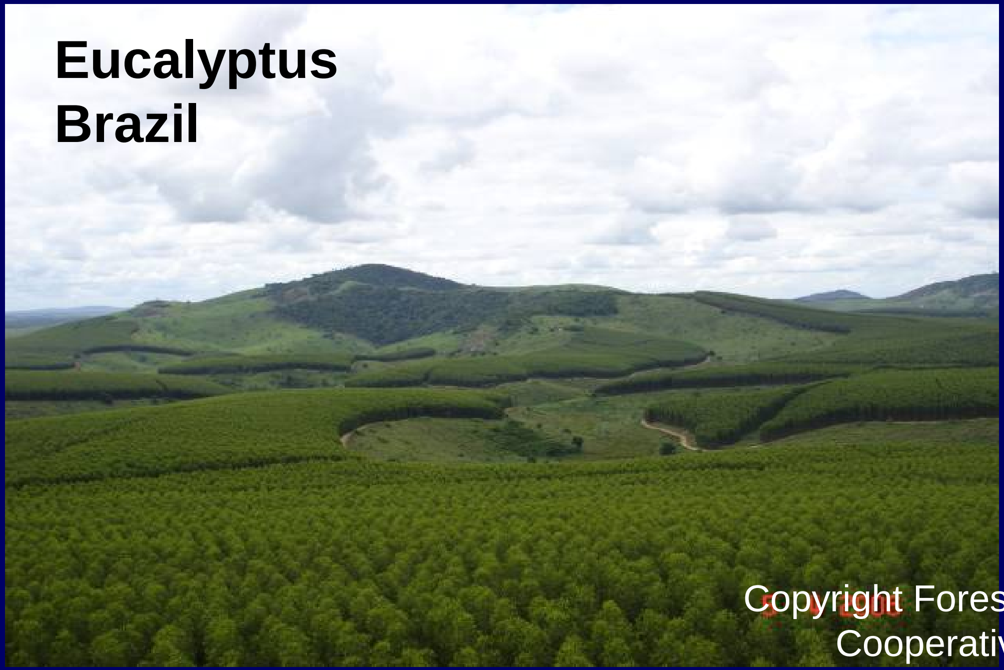
5 Sustaining

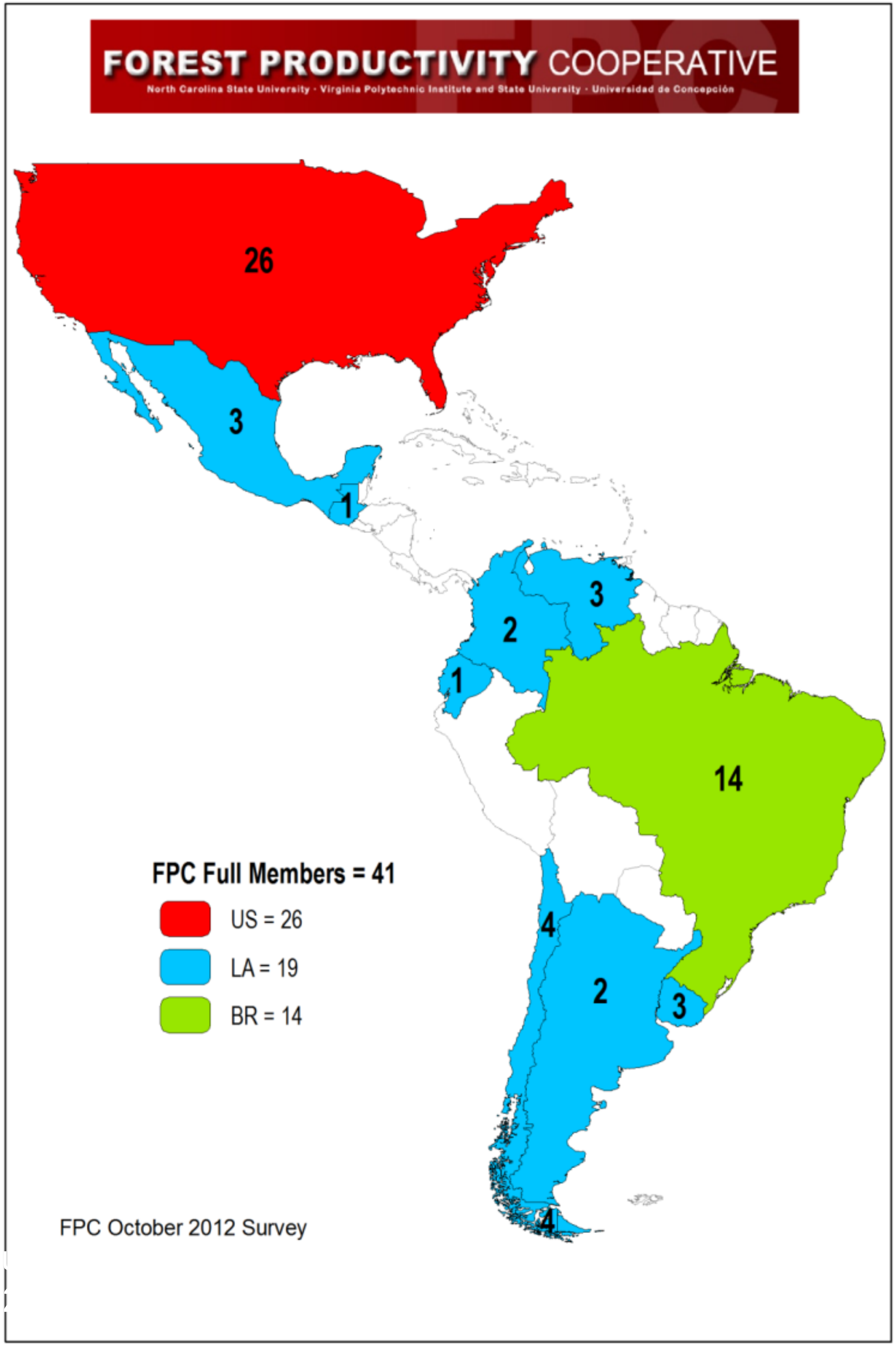
Agrium
Aprilasia
CONIF
North Carolina Division of Forest Resources
Virginia Department of Forestry

16 Corresponding

AgXplore
ArborGen
Carolina Soil
COMPO
DuPont
Florida Grown
Forestry & Land Resource
Gavilon
Green Technologies
IFCO
International Plant Nutrition Institute
Koch Agronomic Services
Mosaic
Payne's Flying
Syngenta
Thrash Aviation


Loblolly Pine
Southern US


Eucalyptus
Brazil


FOREST PRODUCTIVITY COOPERATIVE
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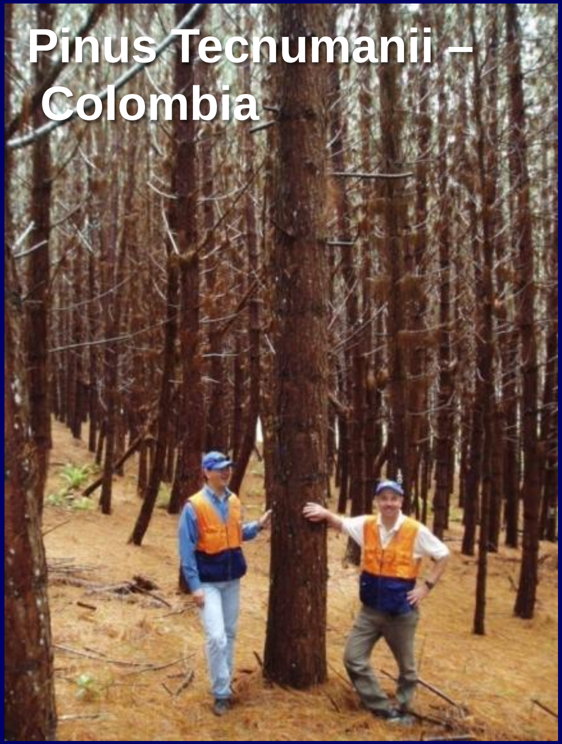
26
3
1
3
2
1
14
4
2
3
4
FPC Full Members = 41
US = 26
LA = 19
BR = 14
FPC October 2012 Survey


Loblolly Pine - US


Radiata Pine - Chile

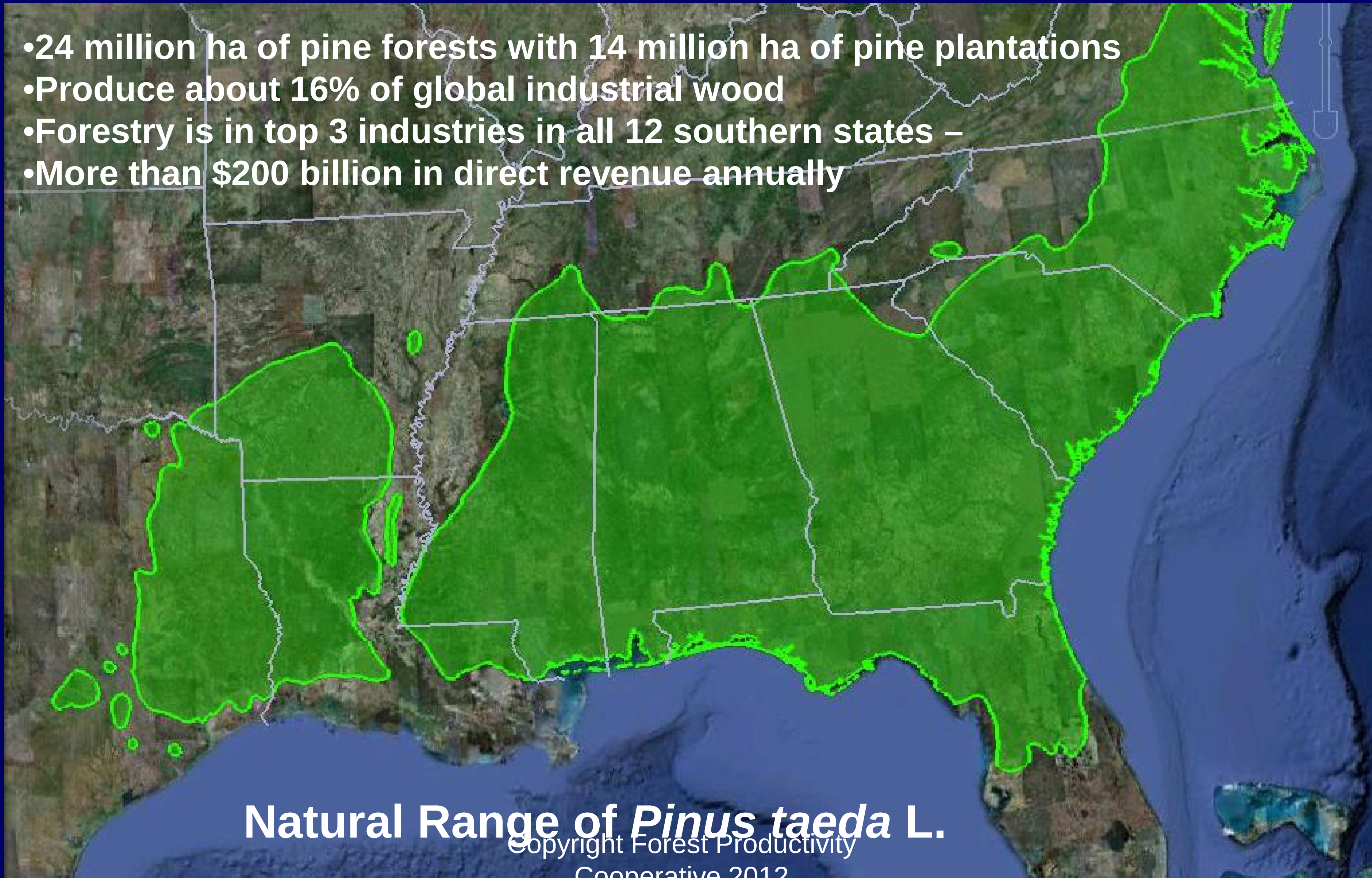

Pinus Techumanii –
Colombia


Eucalyptus Grandis - Brazil


Eucalyptus Globulus - Chile

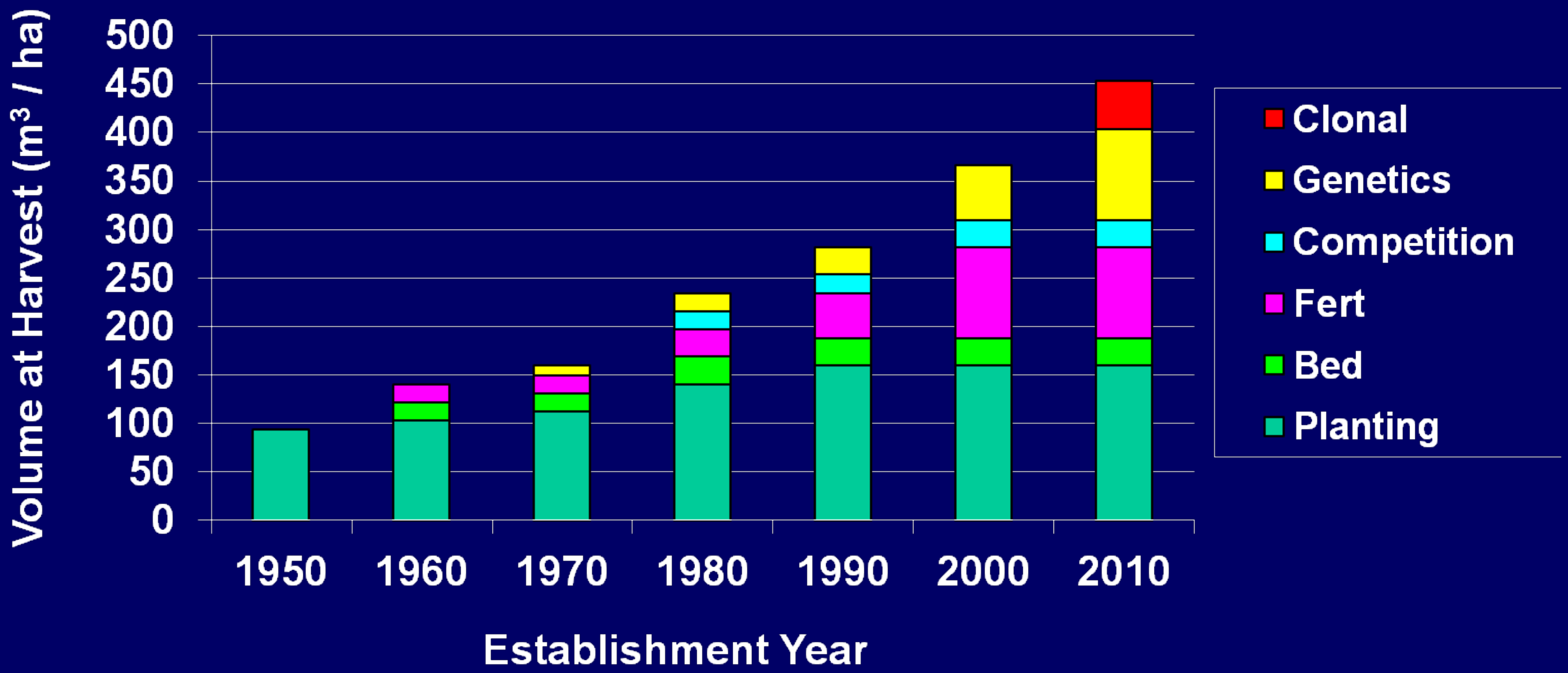
Southern Pine Forests in the US

- 24 million ha of pine forests with 14 million ha of pine plantations
- Produce about 16% of global industrial wood
- Forestry is in top 3 industries in all 12 southern states –
- More than $200 billion in direct revenue annually



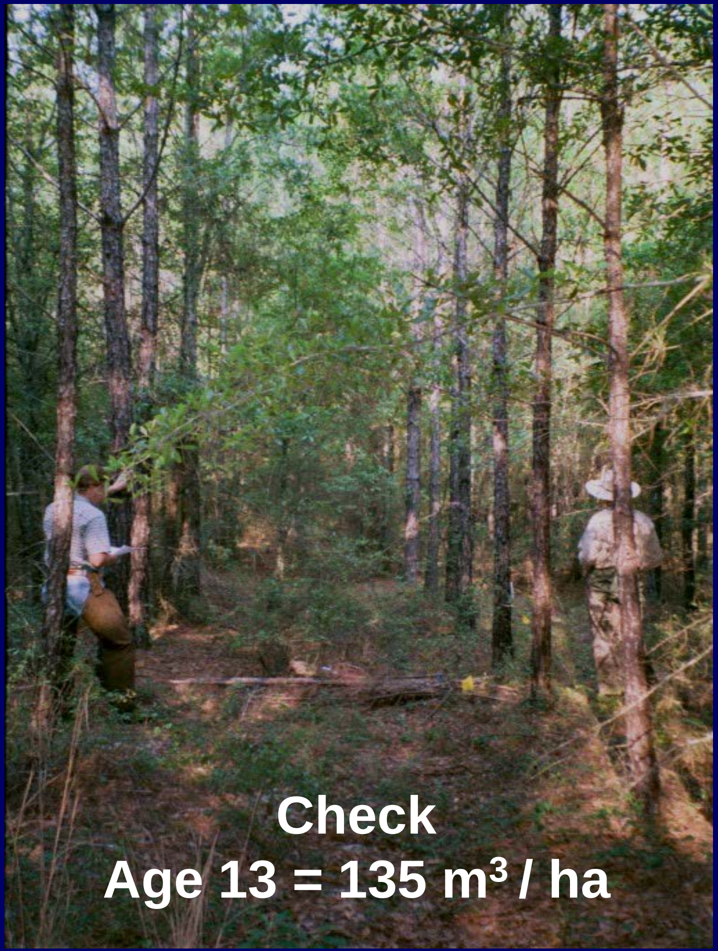
Natural Range of *Pinus taeda* L.

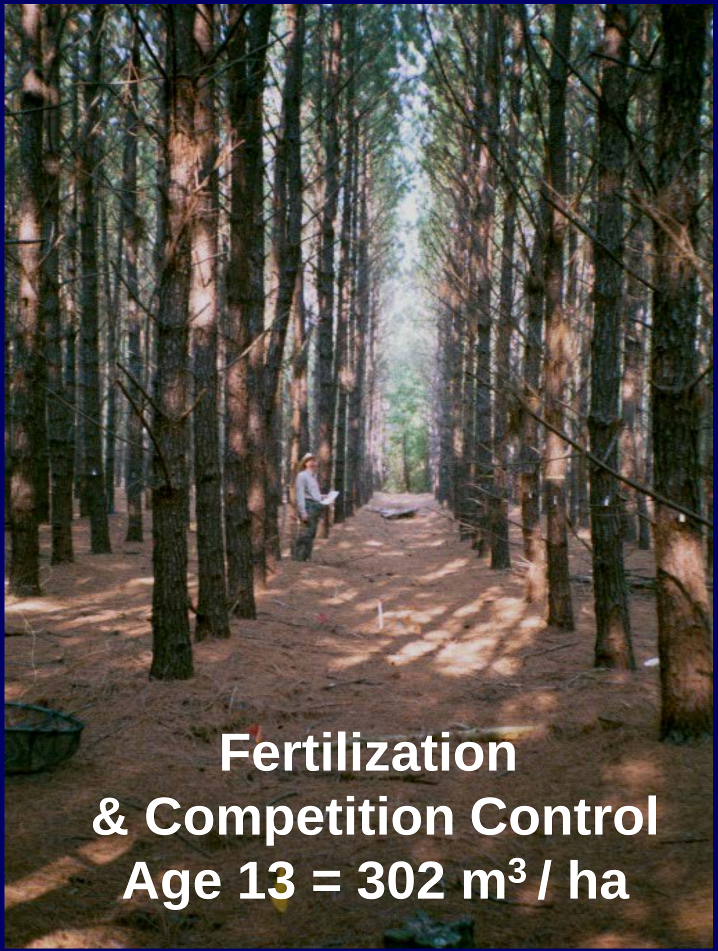
Contribution of Forest Management Practices to Productivity Improvements in Loblolly Pine in the Southeastern United States



Fox et al. 2007

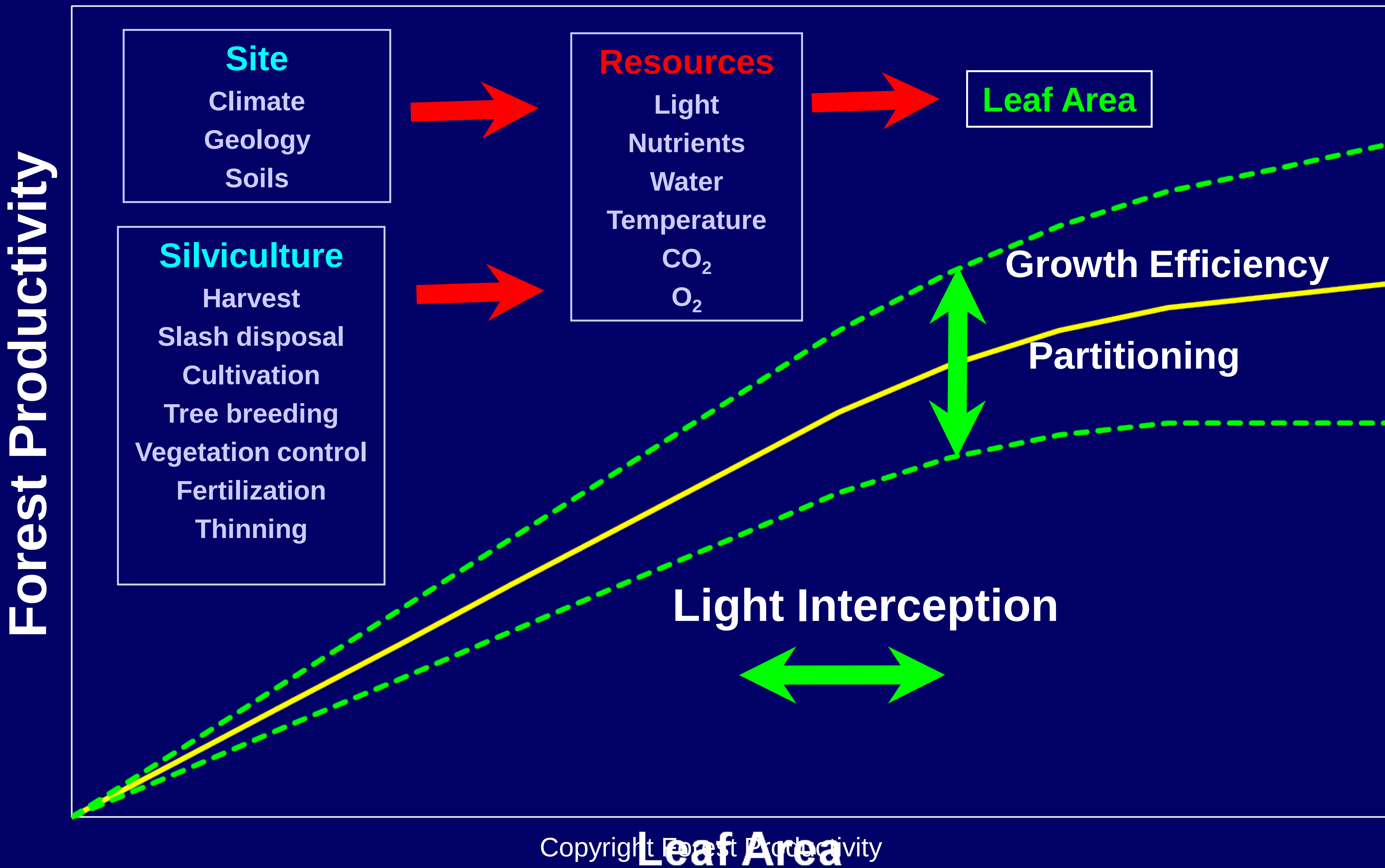
Impacts of Intensive Management on Growth of Loblolly Pine in Southeast Georgia





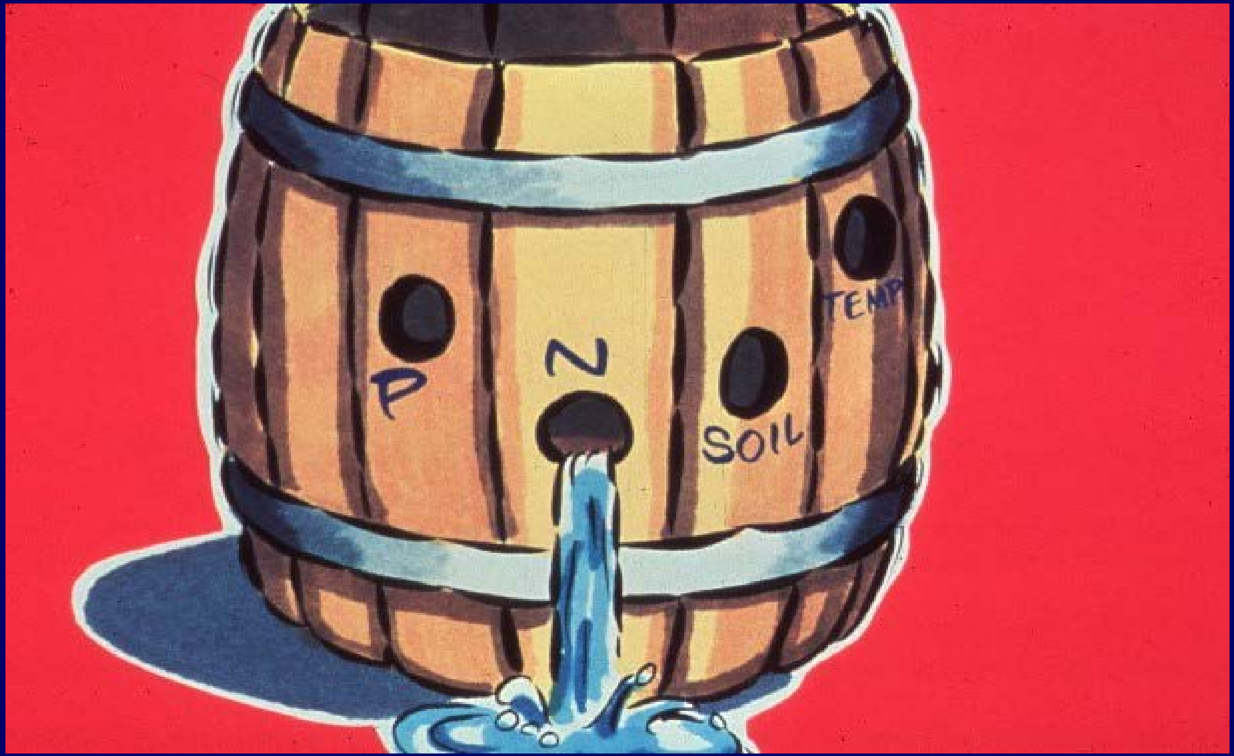
Fertilization of Southern Pine

Silviculture - Site Resources - Leaf Area



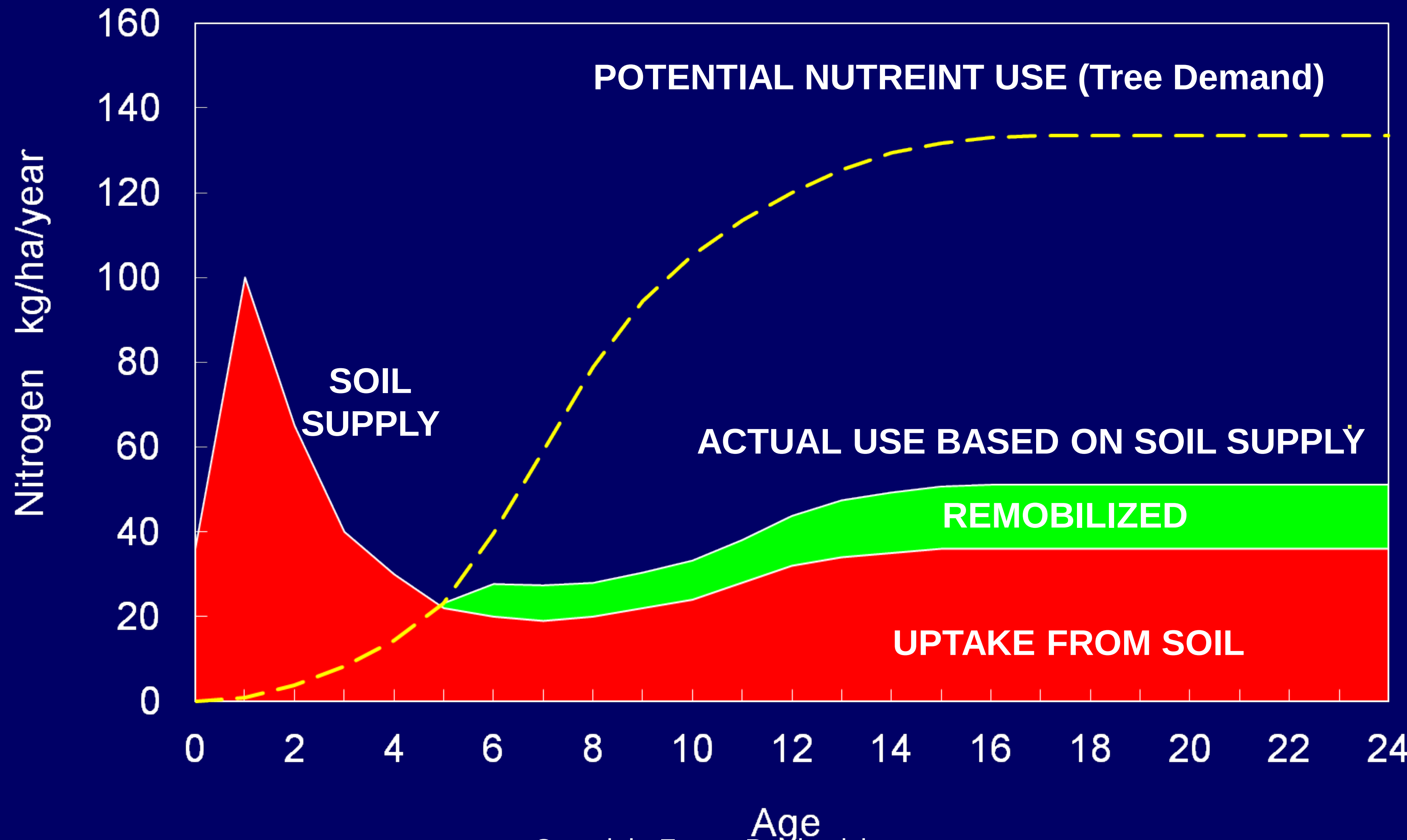
Five-Year-Old Loblolly Pine in Virginia

Liebig's Law of the Minimum
Resource Deficiencies



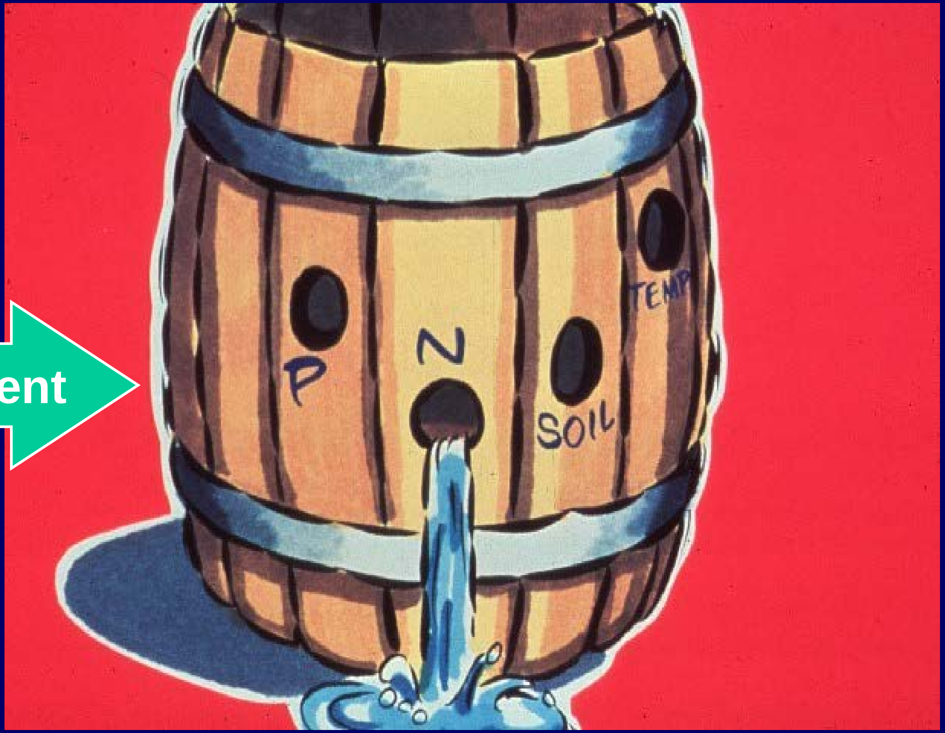
Multiple Deficiencies Often Limit Tree Growth
(N and P are Deficient on Most Soils in the South)

Model for Soil Nutrient Supply and Tree Nutrient Demand



Genetics Determines the Potential Nutrient Demand of the Tree

Tree Improvement

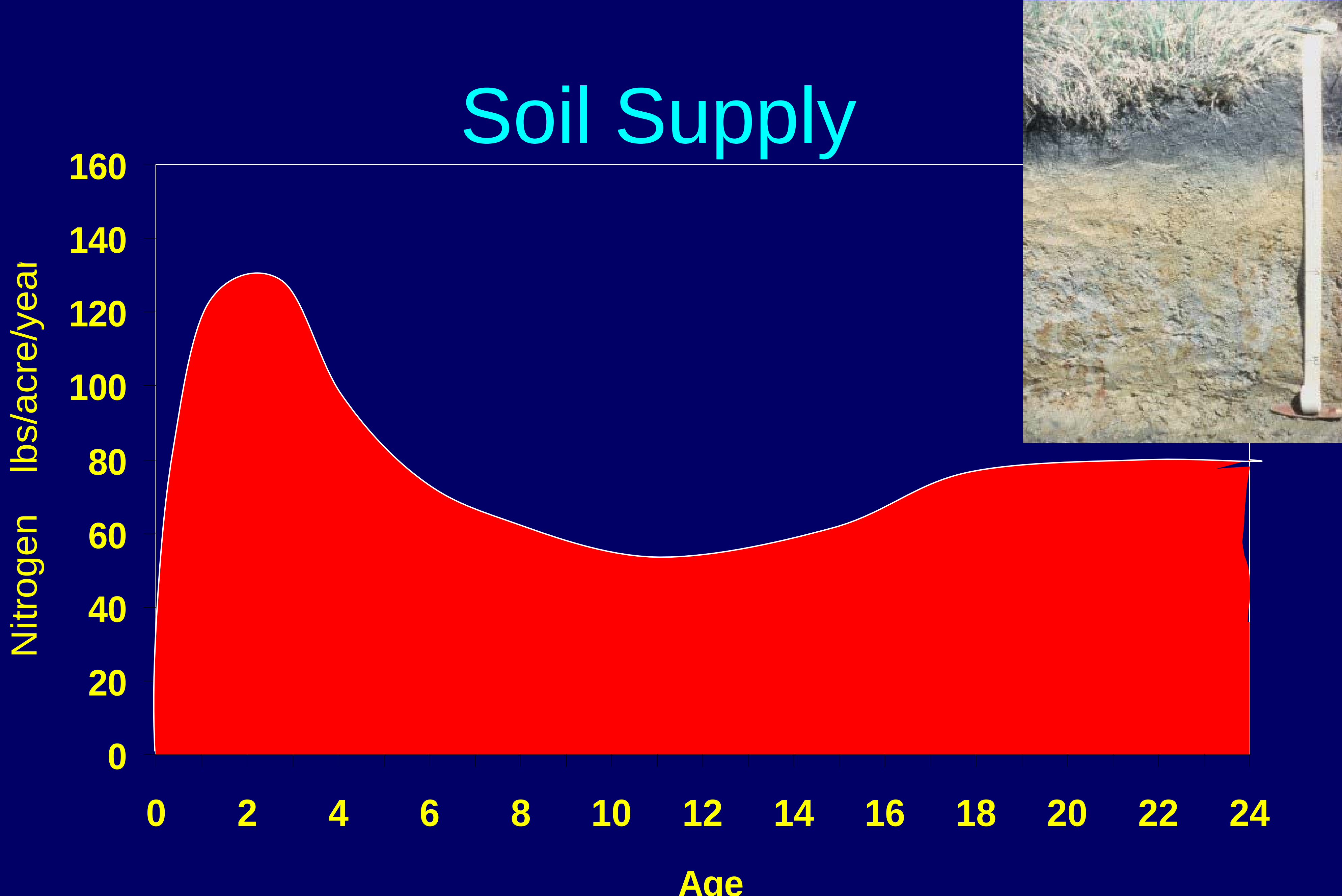


Poor Genotype

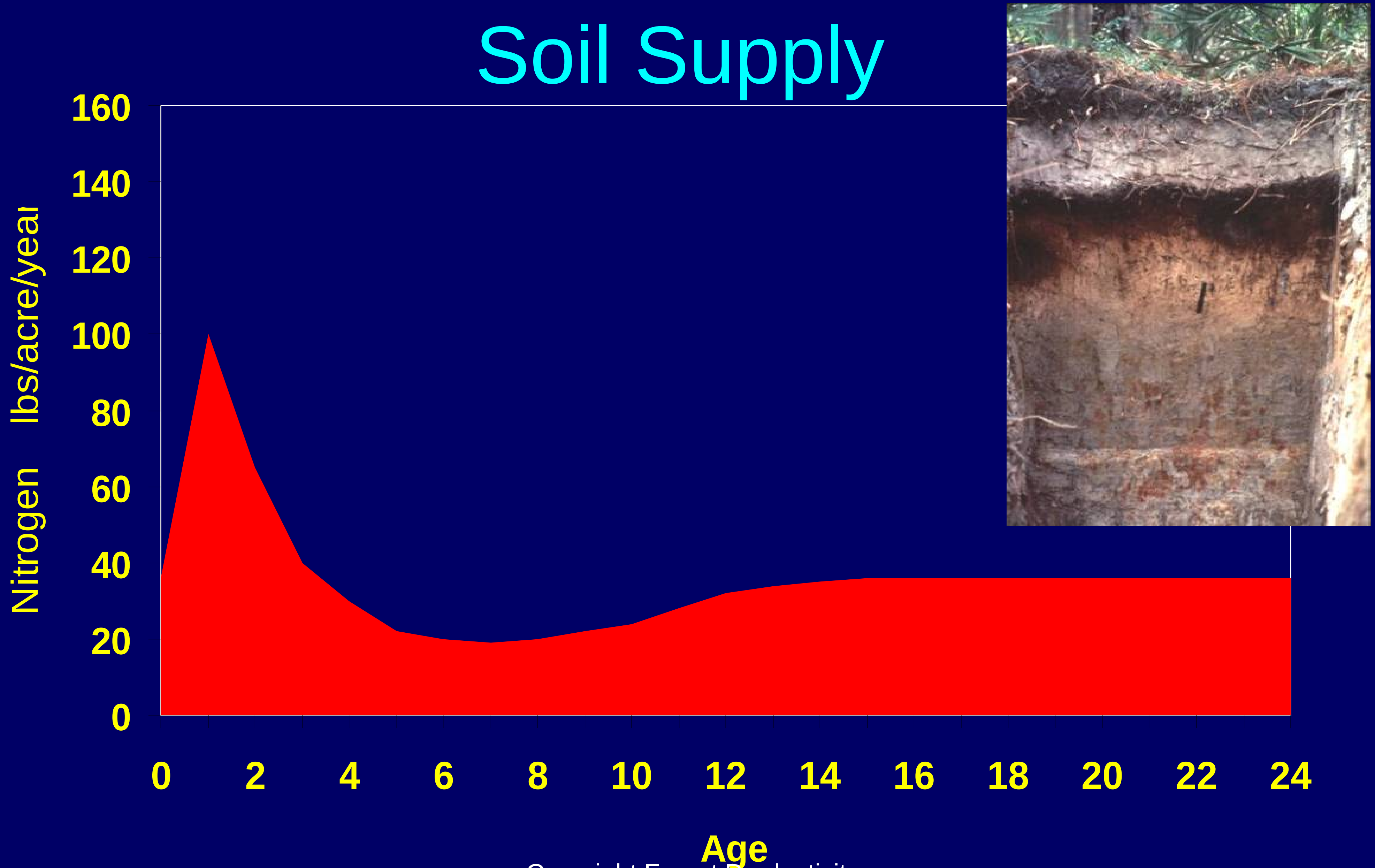
Good Genotype

But Resource Availability
Will Still Limit Growth of Even the Best Genotypes

Soil Supply

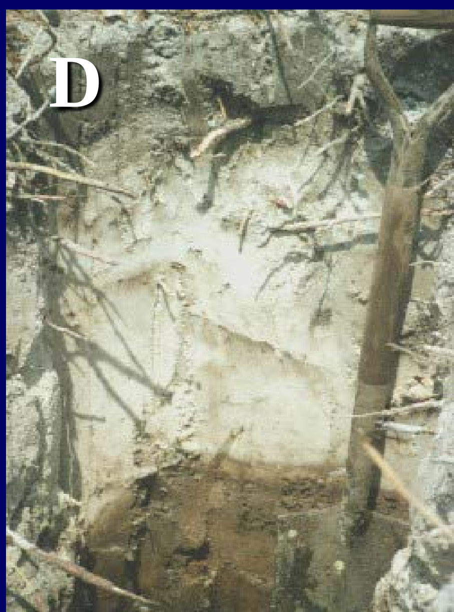

Nitrogen lbs/acre/year
0
20
40
60
80
100
120
140
160
0
2
4
6
8
10
12
14
16
18
20
22
24
Age

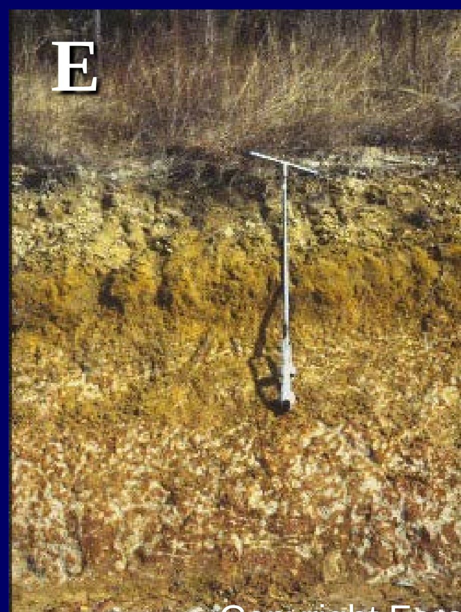
Soil Supply

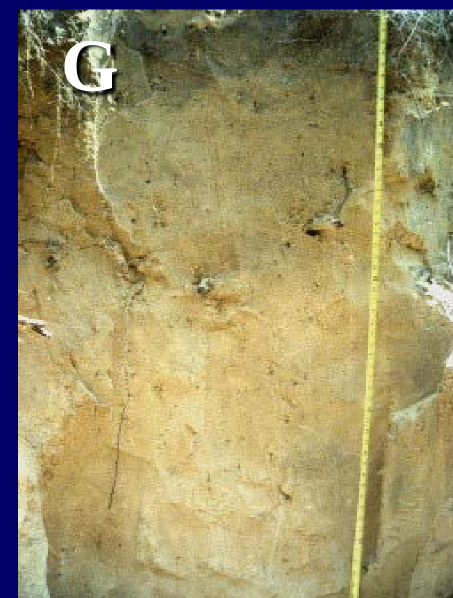


Nitrogen lbs/acre/year
160
140
120
100
80
60
40
20
0
0 2 4 6 8 10 12 14 16 18 20 22 24
Age

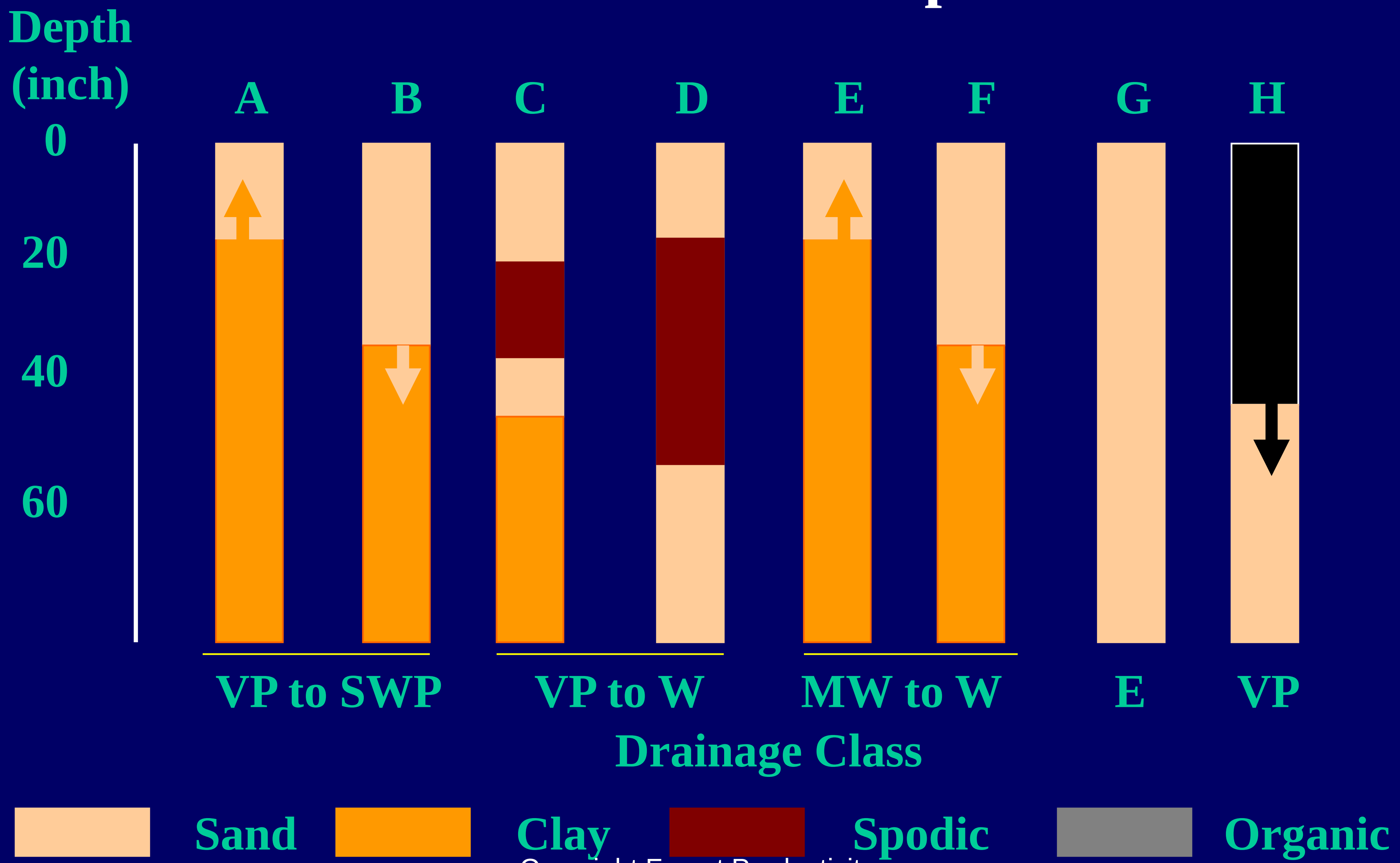
CRIFF Soil Groups



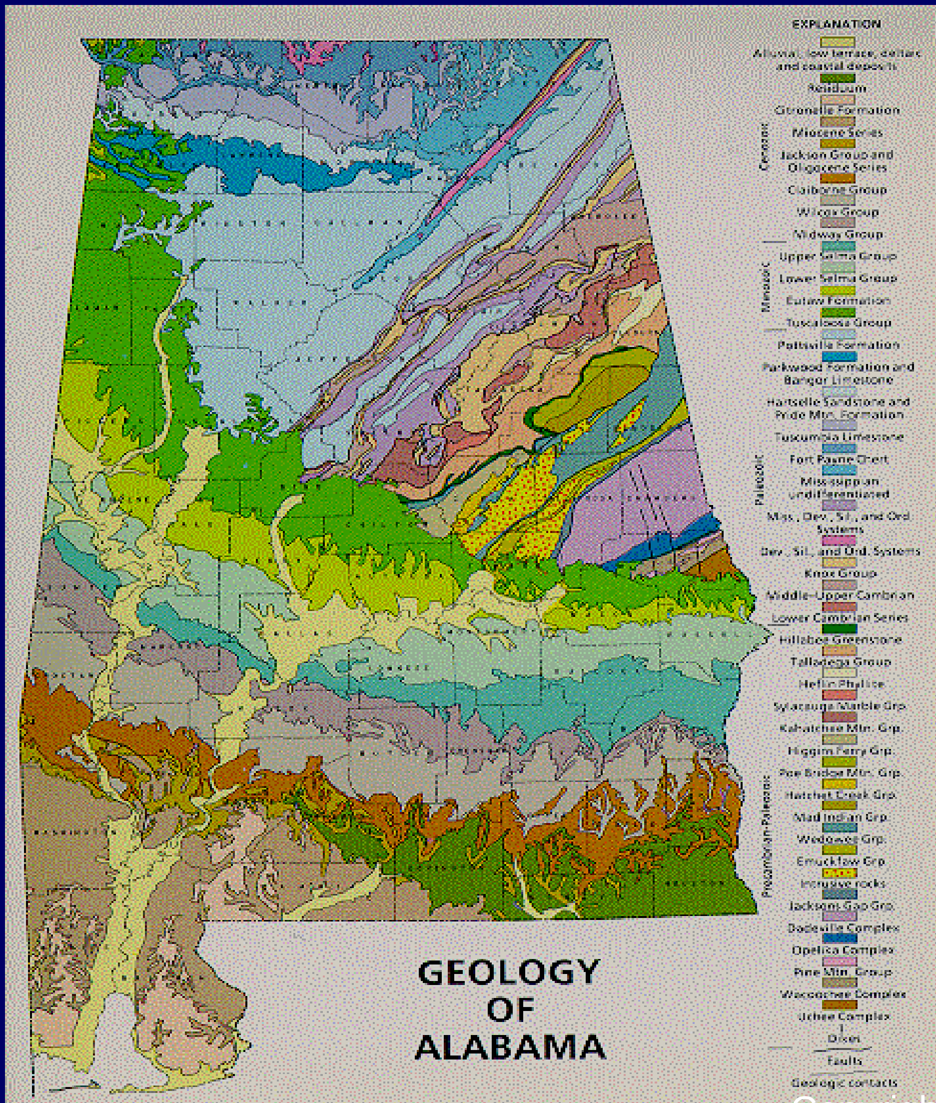


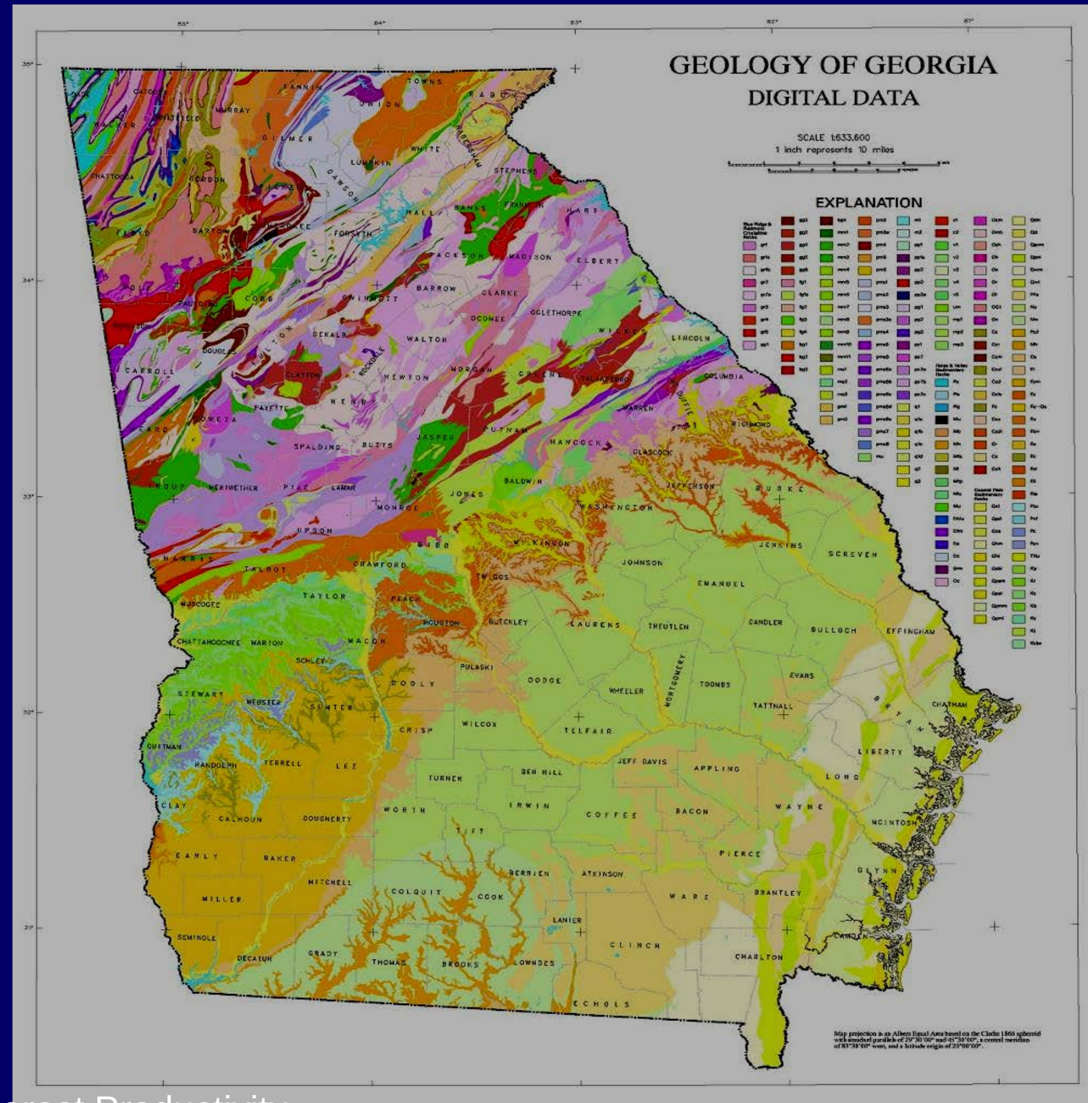


CRIFF Soil Groups



Geology (Parent Material) Impacts Soil Nutrient Supply





Establishment P Fertilization

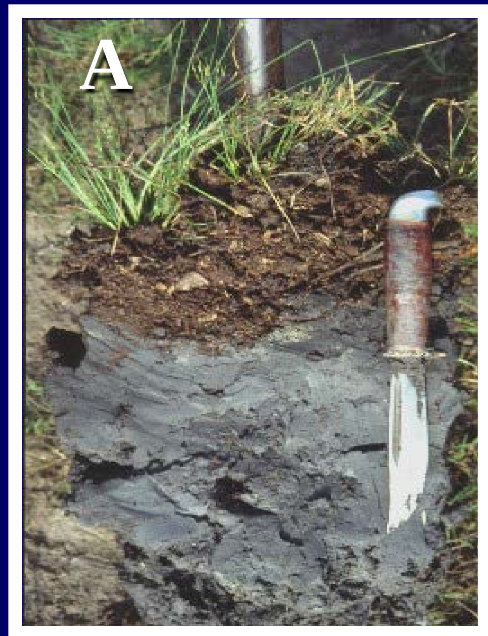
Growth Response to P Fertilization on CRIFF A Group Soils

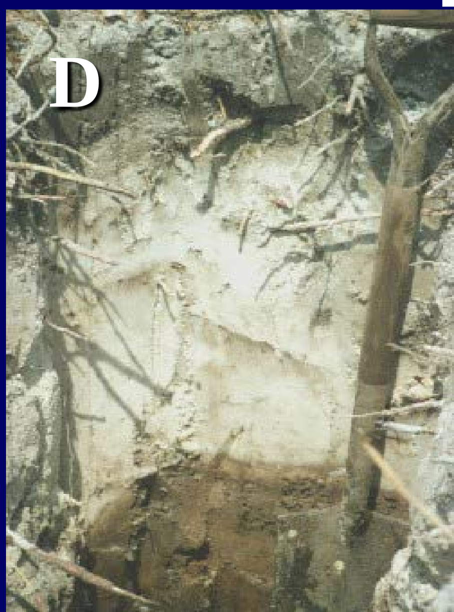
Age 20 Loblolly Pine Plantations in Coastal Georgia

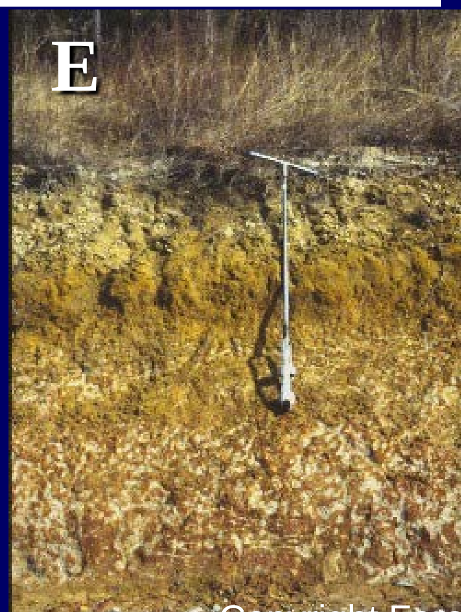
0 kg/ha P at Planting
Poorly Drained Clay Soil

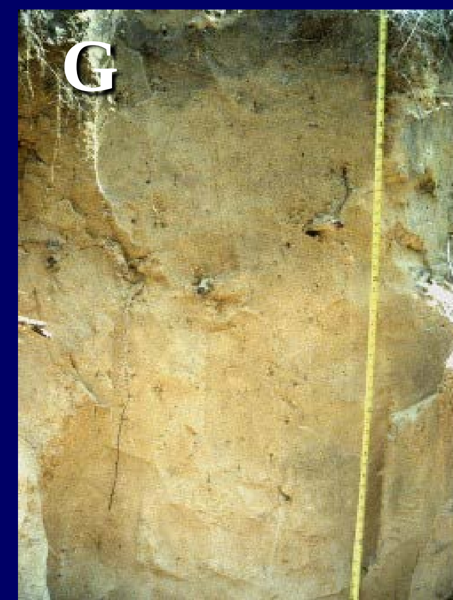
50 kg/ha P at Planting
Poorly Drained Clay Soil

CRIFF Soil Groups

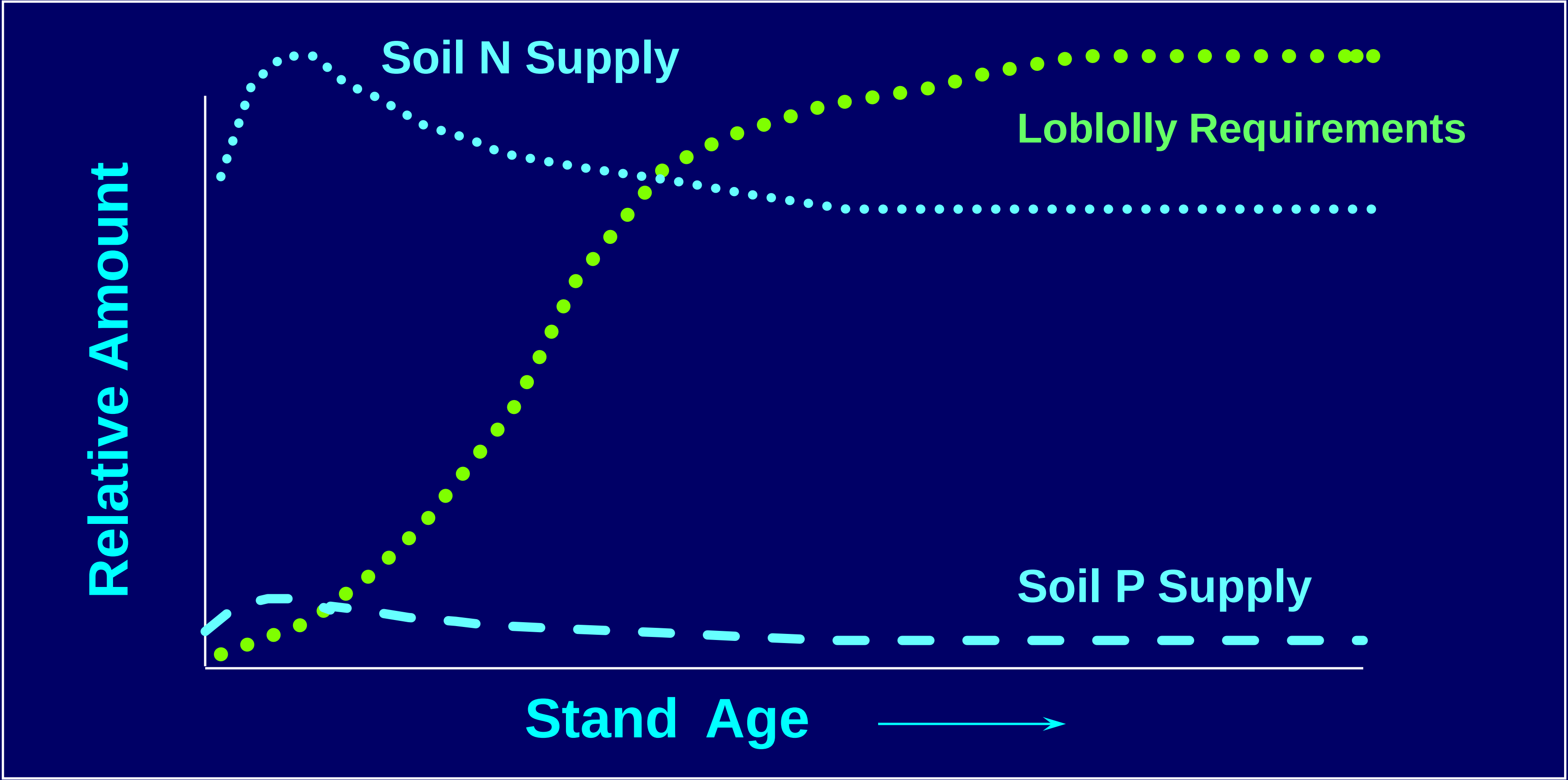








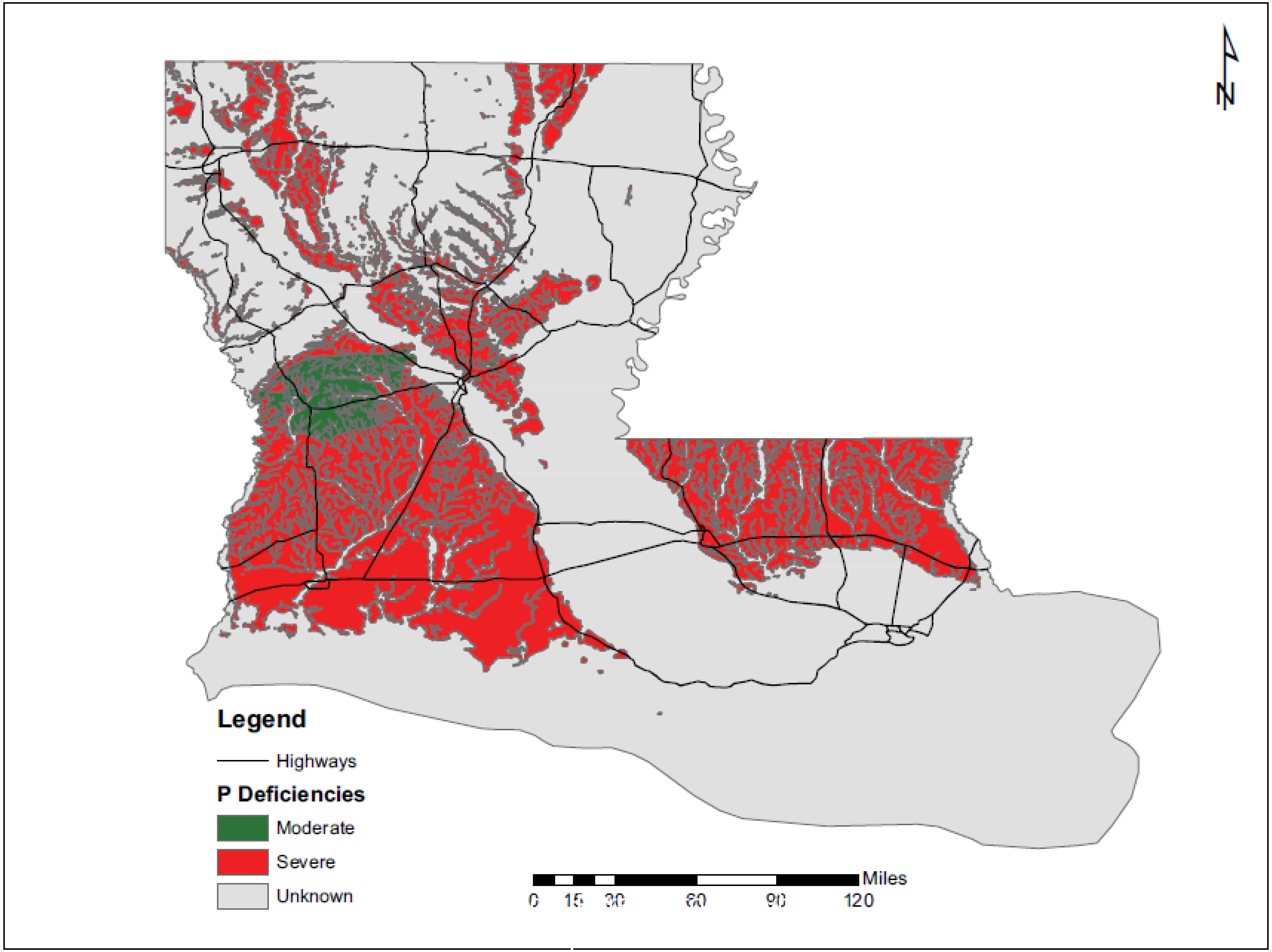
Soil Nutrient Dynamics in Coastal Plain
CRIFF A - Clayey, Poorly Drained Ultisols



P Deficient Terraces of the Atlantic Coastal Plain (ACP) and Gulf Coastal Plain (GPC) of the South

Province	Geologic Series	Terrace	Deficiency
ACP	Pleistocene	Silver Bluff	Severe P
		Princess Anne	Severe P
		Pamilico	Severe P
GCP	Pleistocene	Montgomery	Severe P
		Bentley	Severe P

Louisiana Potential P Deficiencies



Well Drained Clay
Greenville

Regionwide 14

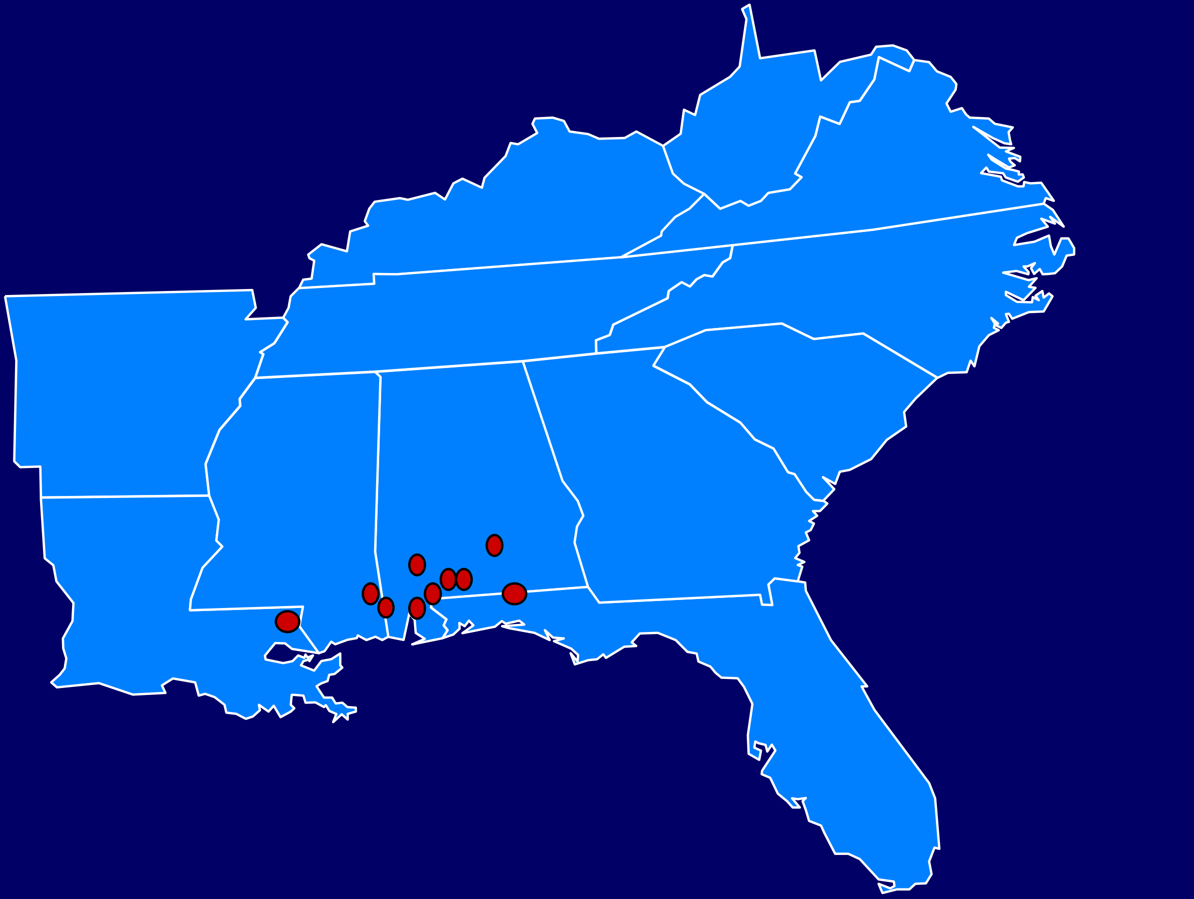
Treatments

Control

P

NP

NPK

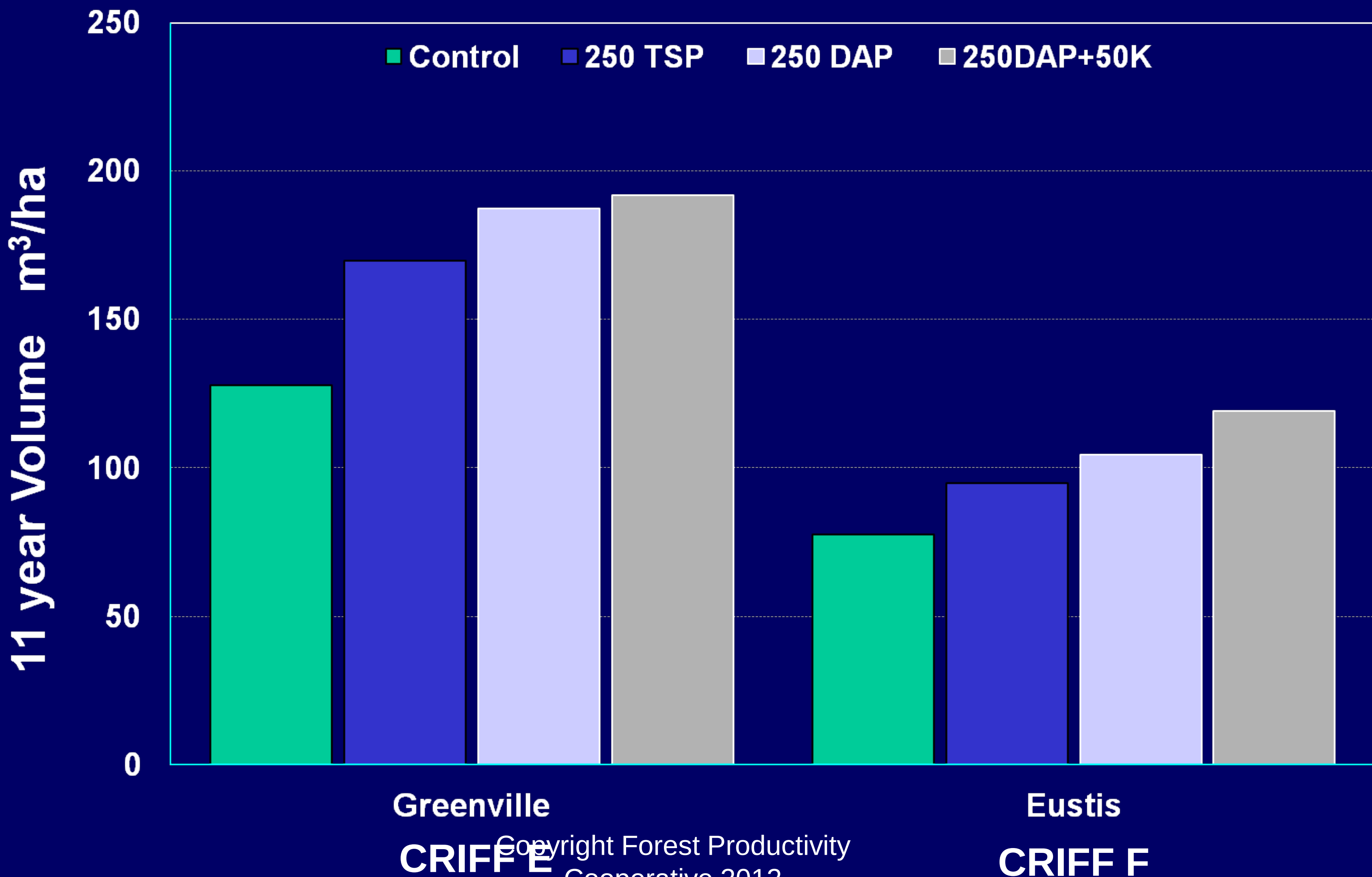


Growth Response of Loblolly Pine at Age 5 Following NP Fertilization at Planting in Alabama on Citronelle Terrace

Check

Fertilized

P DEFICIENT SITES – Citronelle Terrace

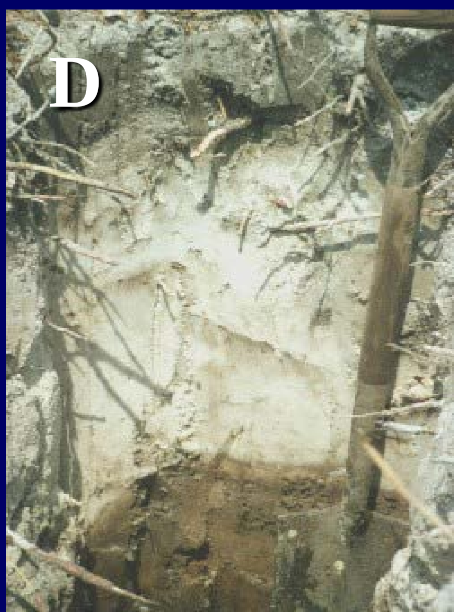


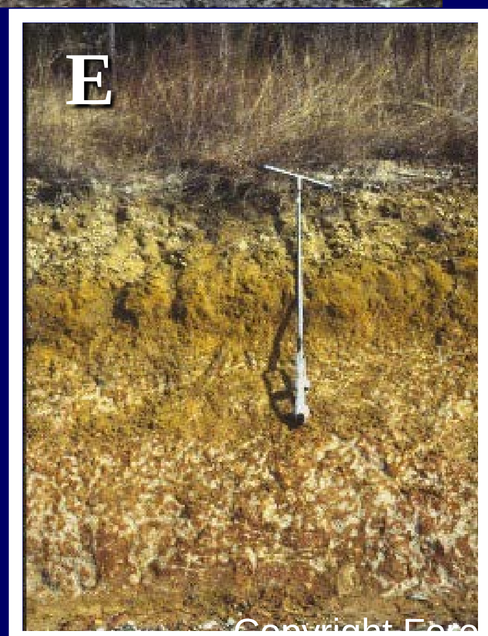
Loblolly Pine at Age 20 Following NP Fertilization at Planting On Citronelle Terrace in Alabama

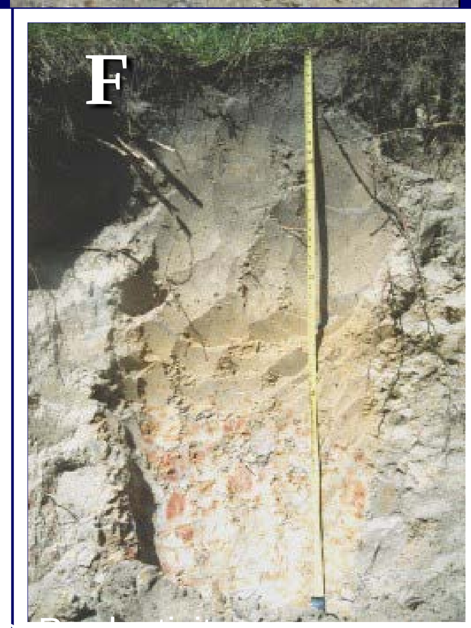
Check

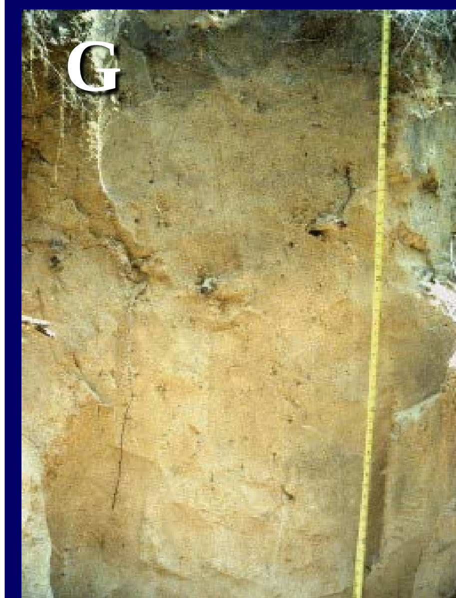
Fertilized

CRIFF Soil Groups

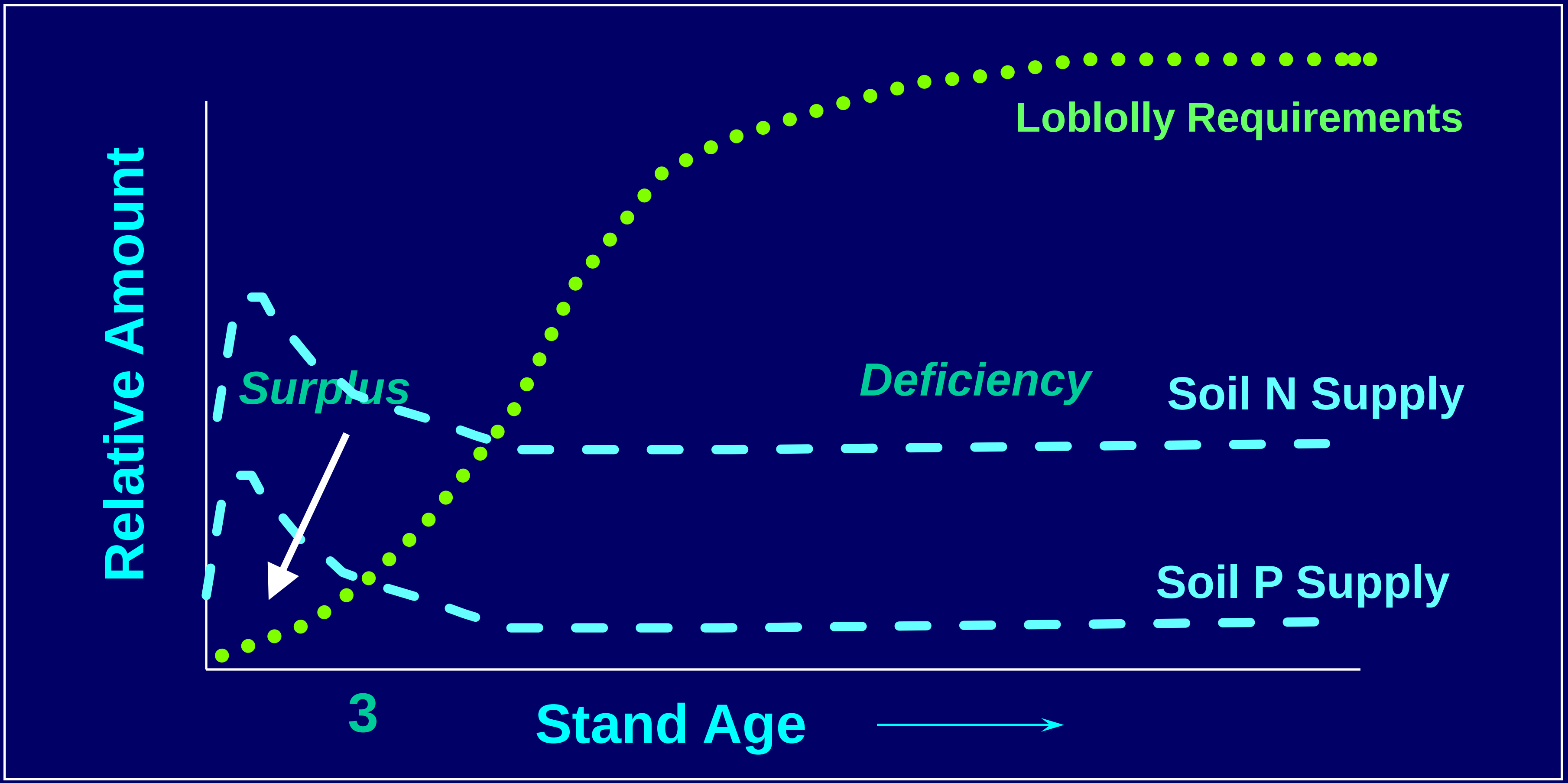








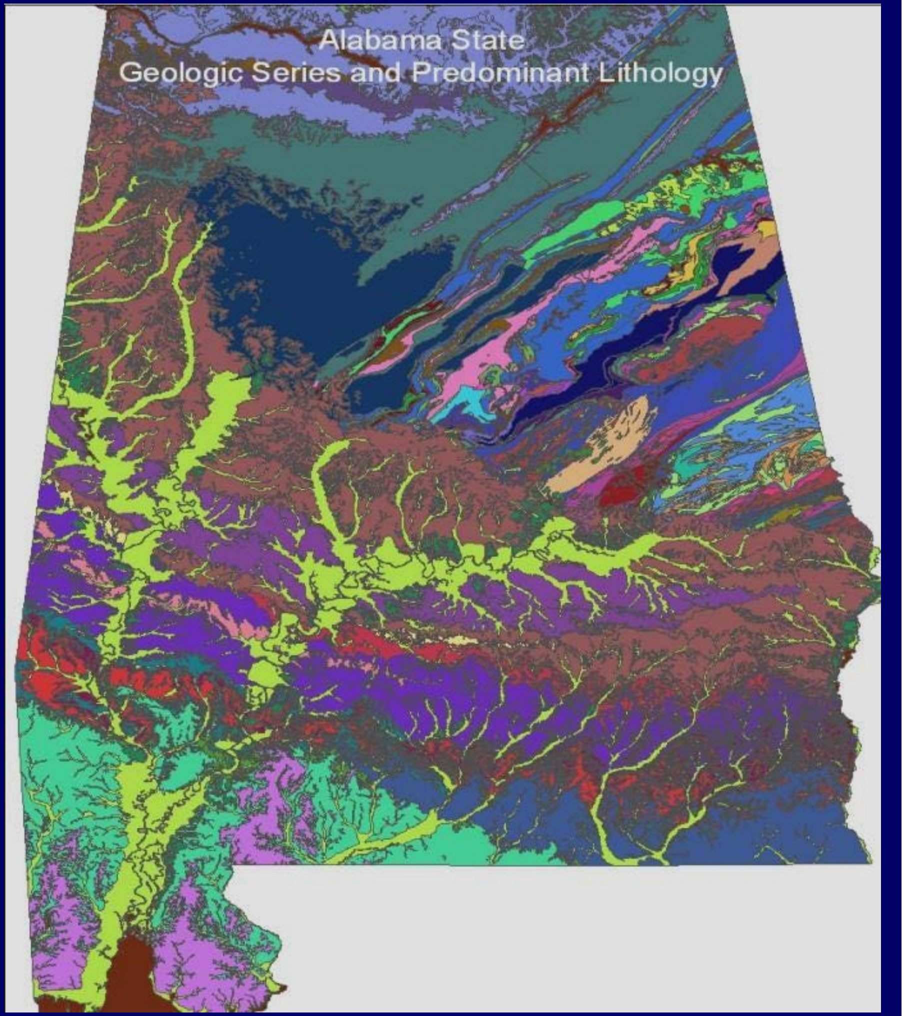
Soil Nutrient Dynamics on Citronelle Terrace
CRIFF E, F Soils (Citronelle Terrace)

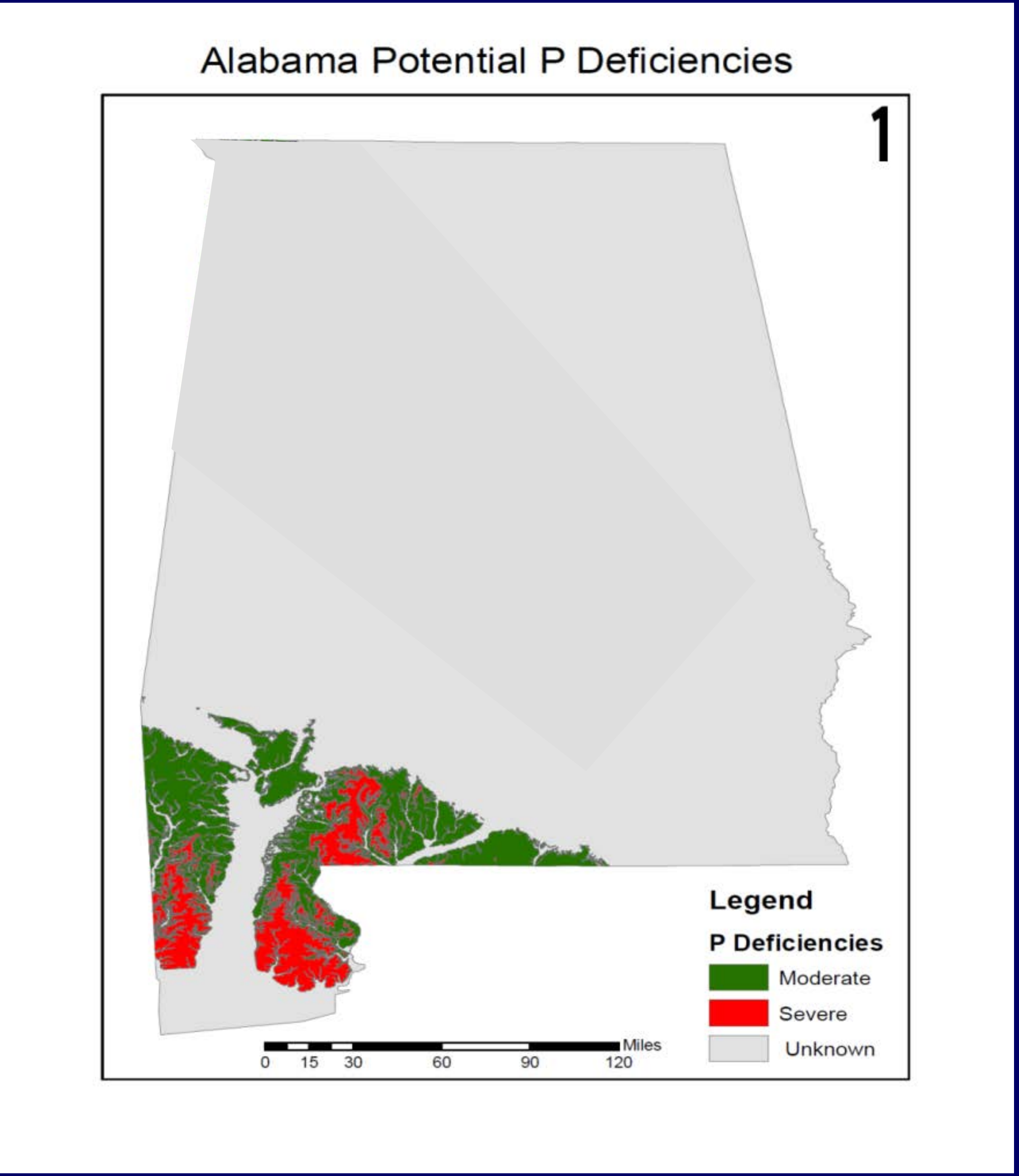


Nutrient Deficiencies on Terraces of the Alabama and Mississippi Coastal Plain

Province	Geologic Series	Terrace	Deficiency
LGCP	Pleistocene	Montgomery	Severe P
		Bentley	Severe P
UGCP	Pleistocene/Pliocene	Citronnelle	Severe P

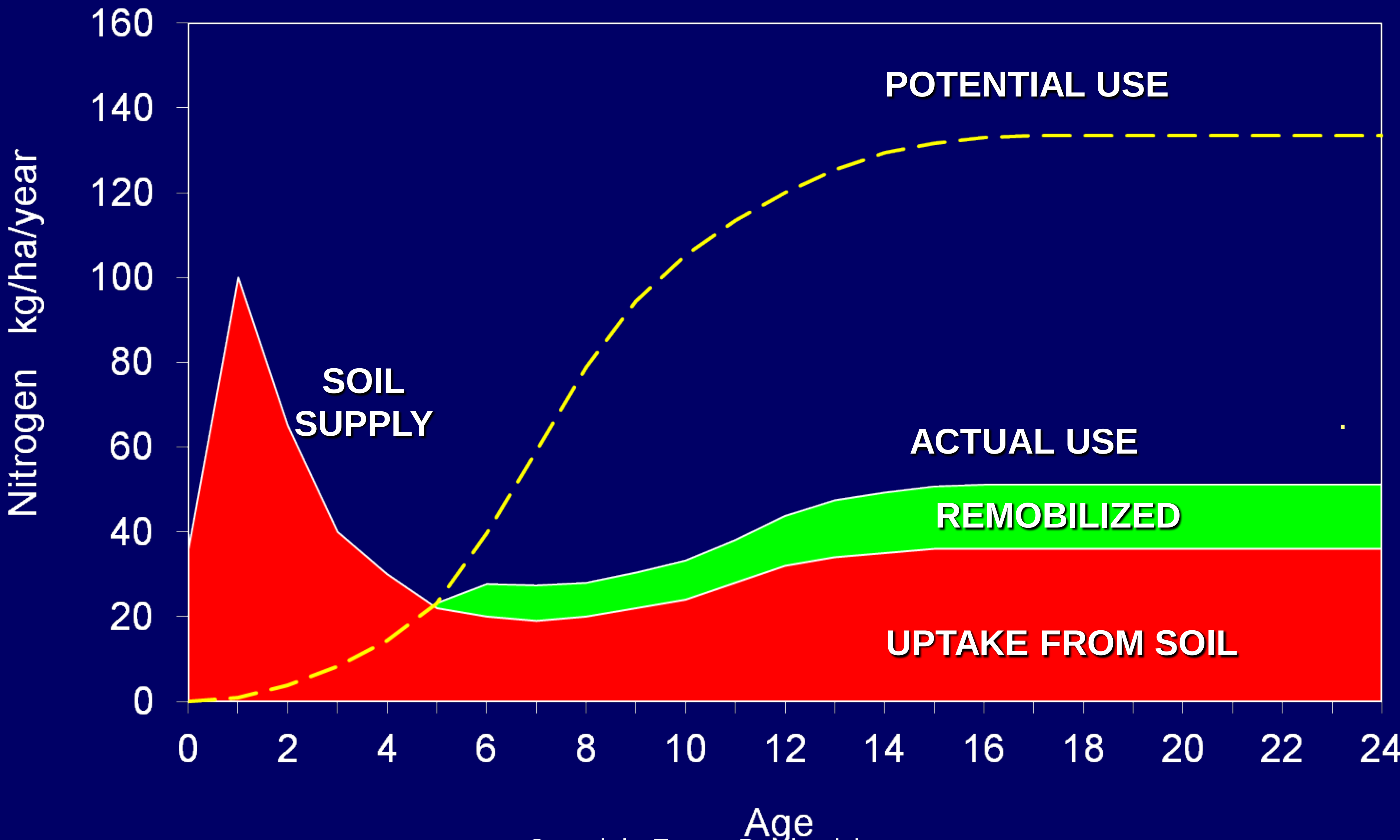
Alabama Geology





Midrotation Fertilization

Nitrogen Deficiency



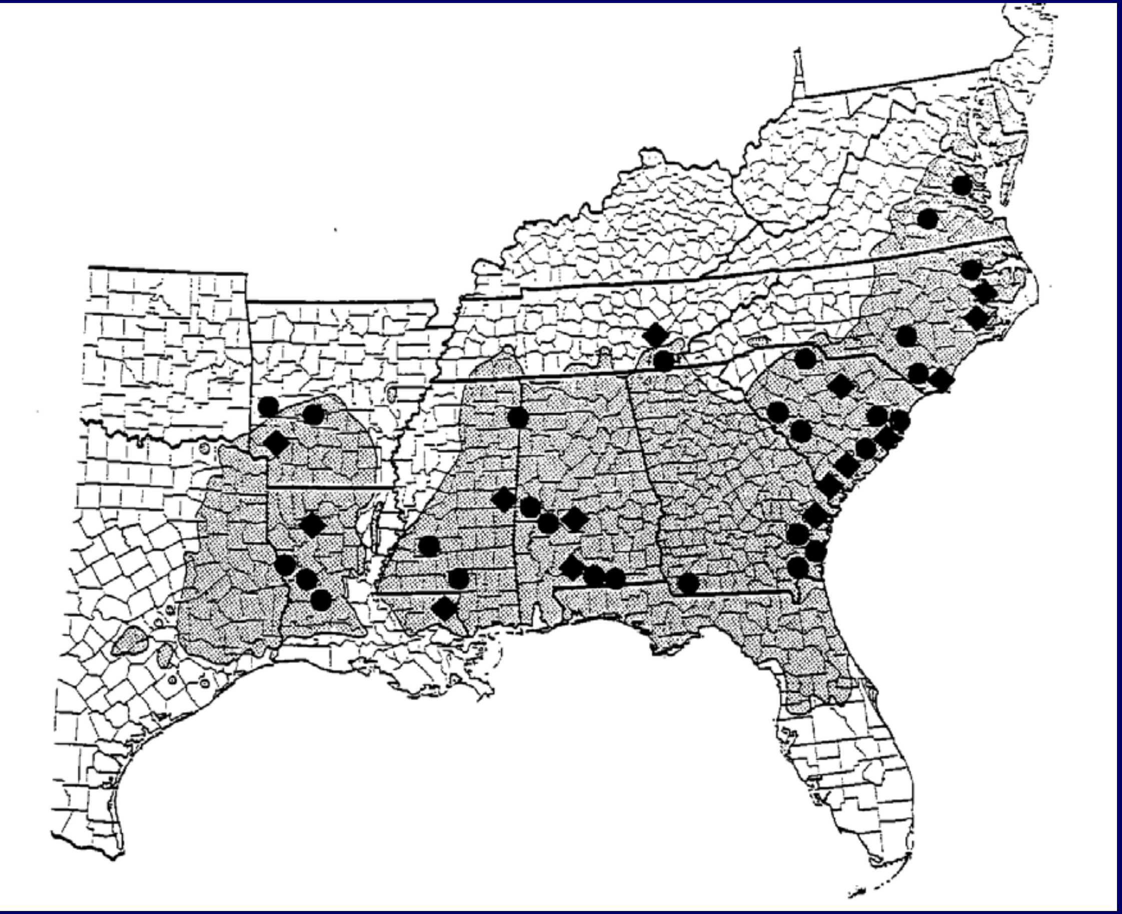
Regionwide 13
Midrotation Fertilization Study

<u>Treatments</u>

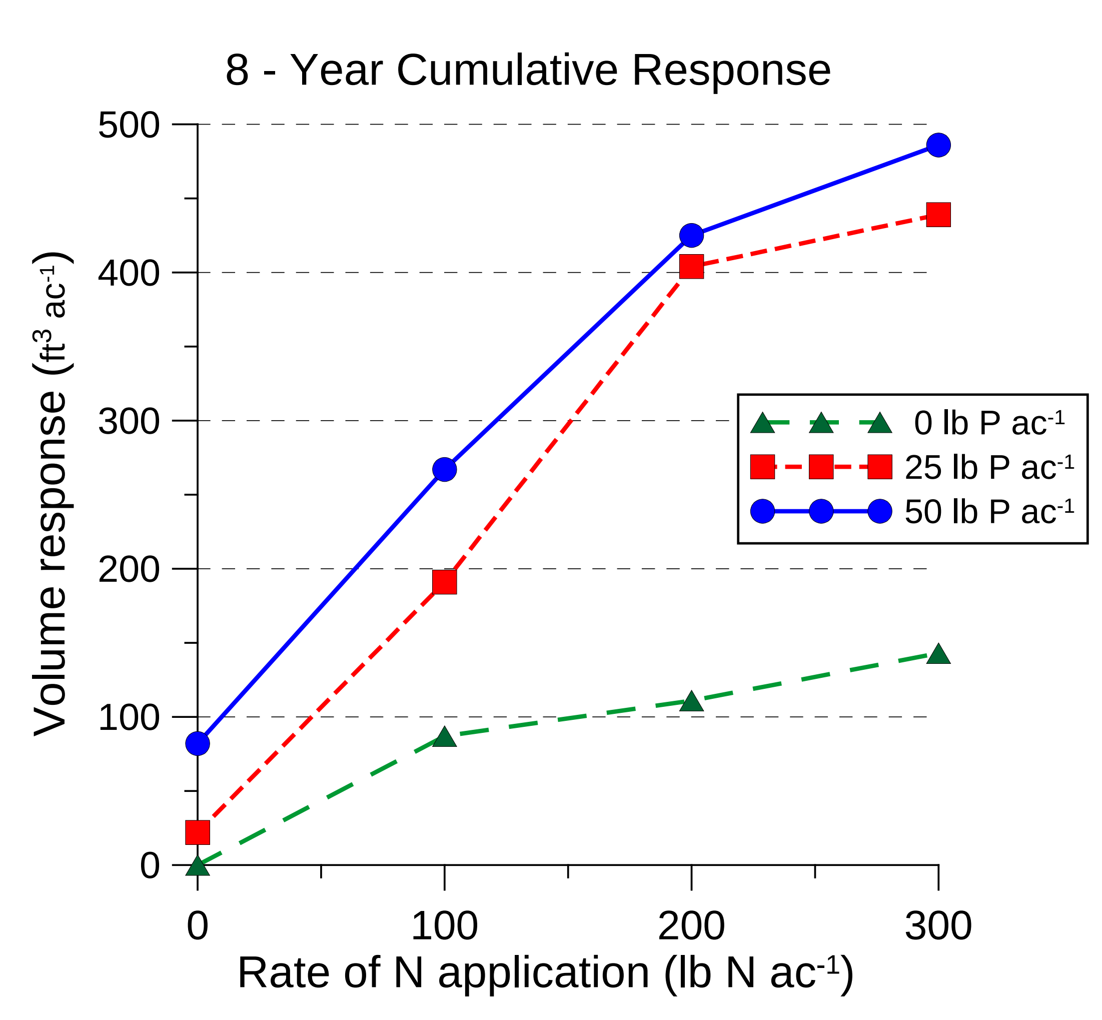
Factorial N + P

N @ 0,100,200,300 kg/ha

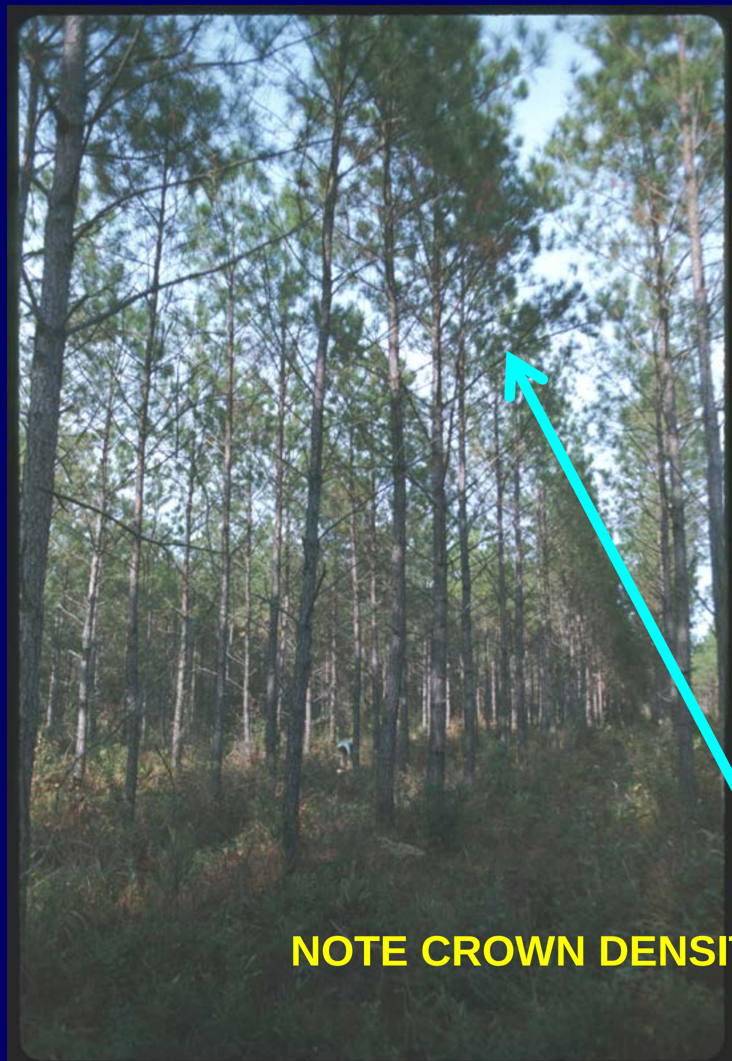
P @ 0, 25, 50 kg/ha



Growth Response of Loblolly Pine to Midrotation Fertilization



RW130802
2-Year Response

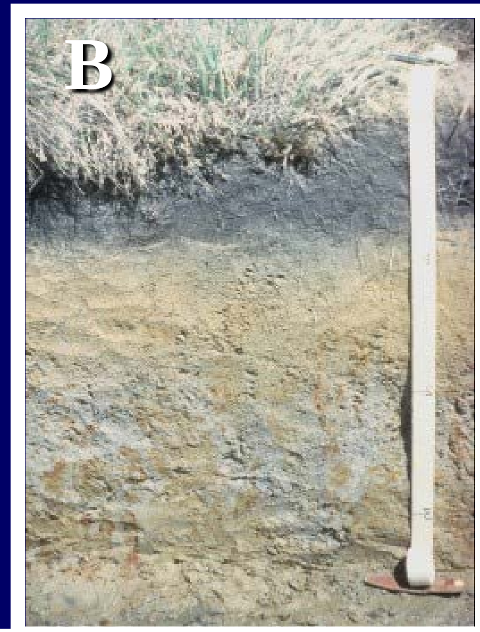


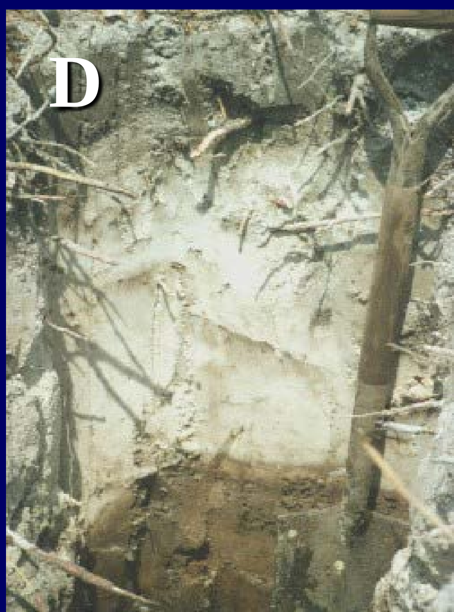
NOTE CROWN DENSITY AND LEAF AREA DIFFERENCES

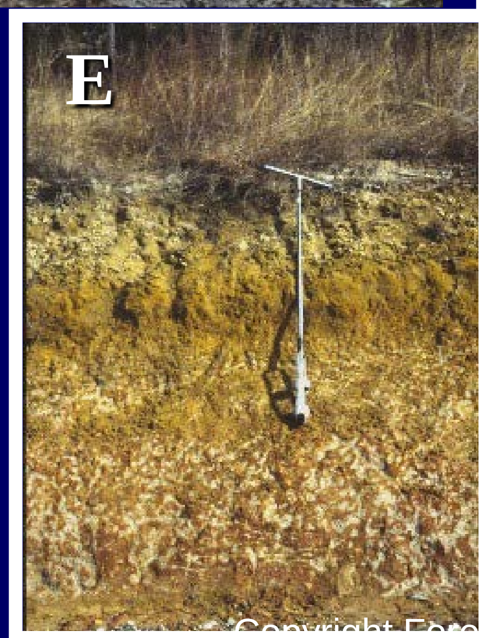
Check

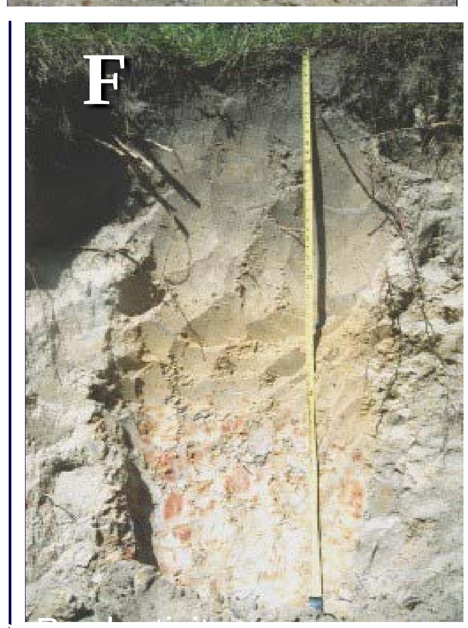
200N + 25 P

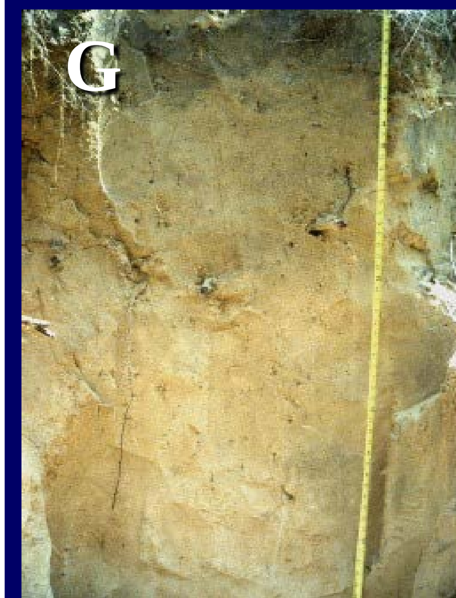
CRIFF Soil Groups



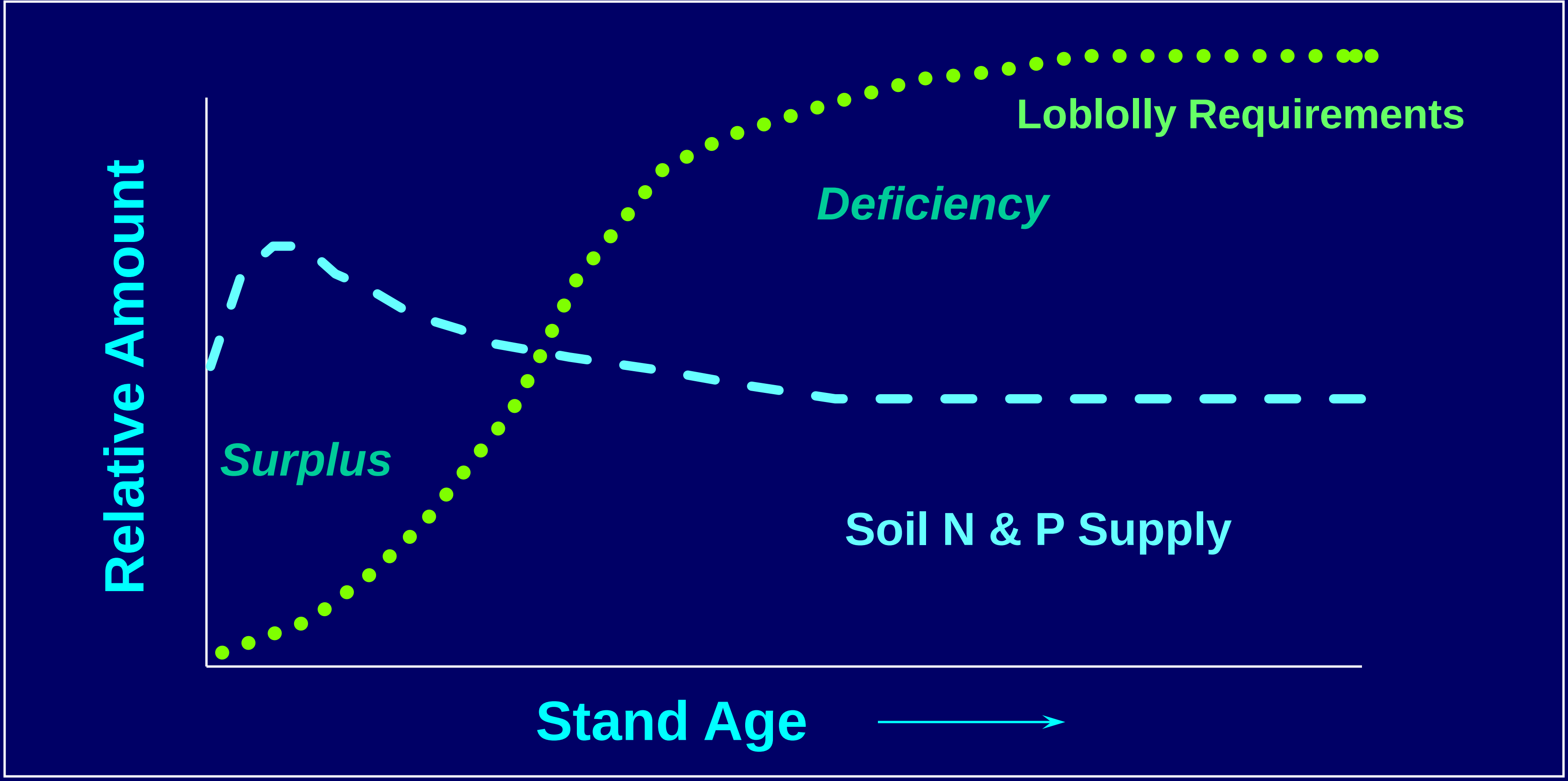




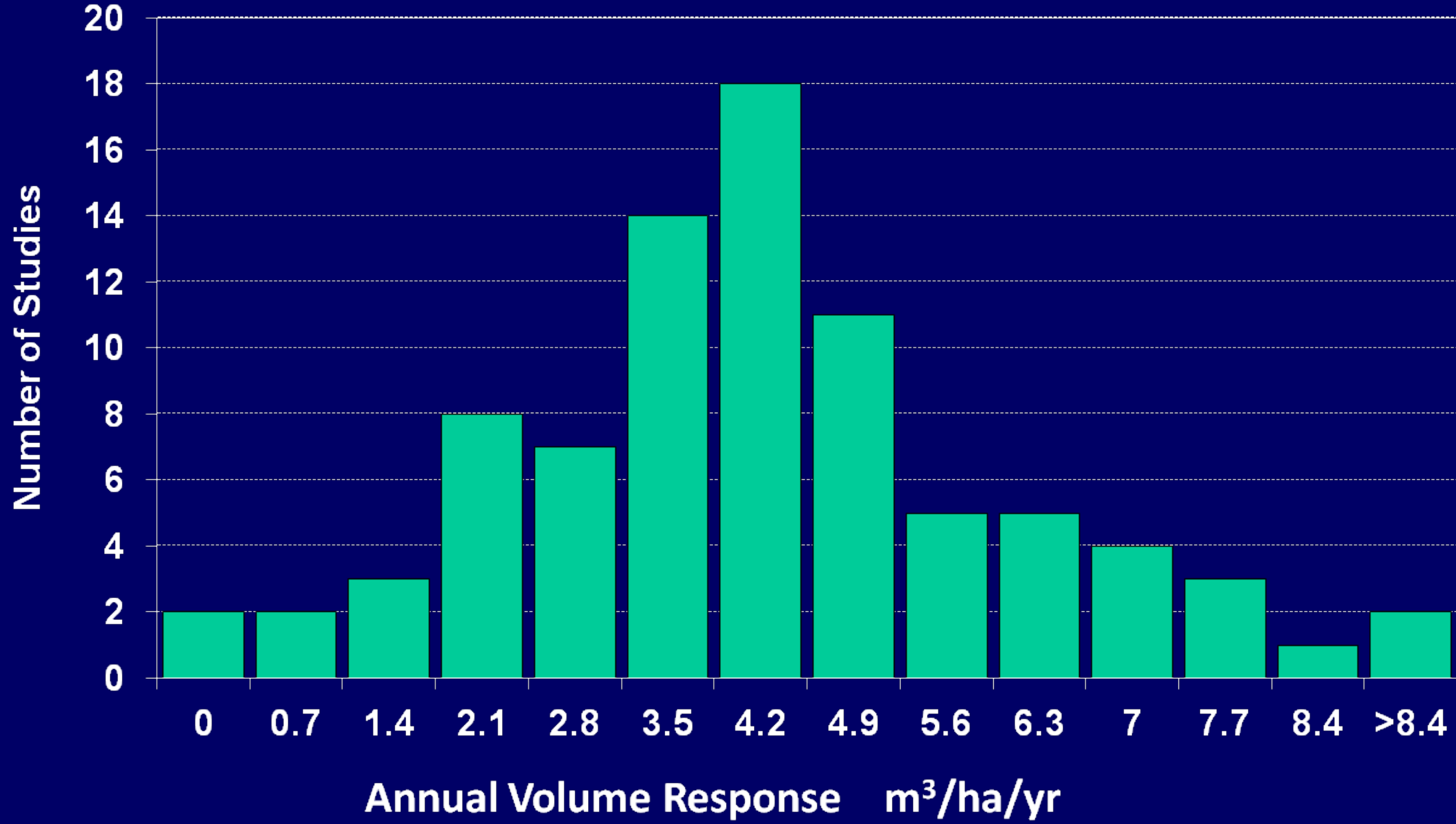




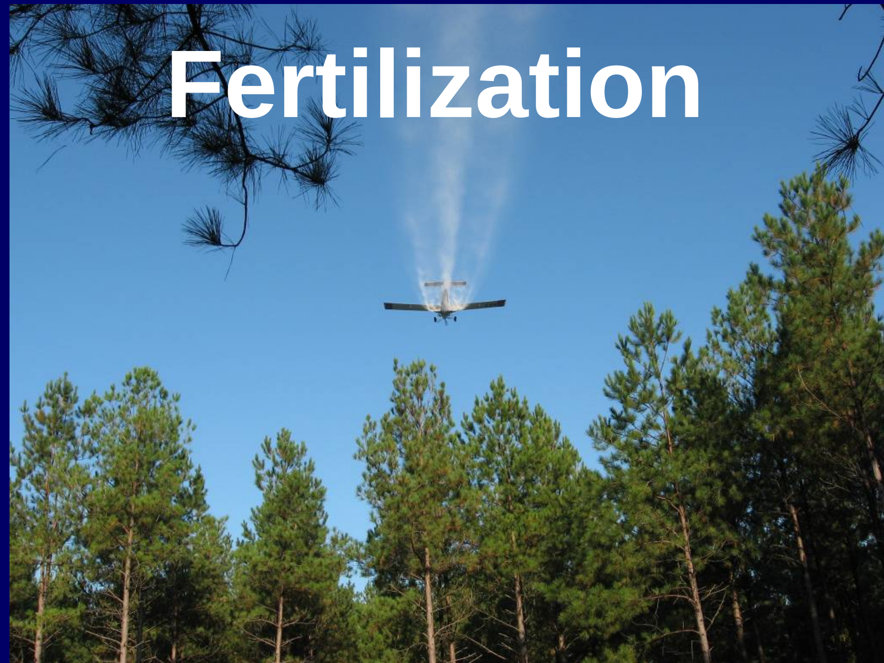
Soil Nutrient Dynamics Coastal Plain and Piedmont Ultisols - CRIFF B, E, F



Frequency Distribution of Four-Year Response 200N+25P in Established Loblolly Pine Stands



Fertilization

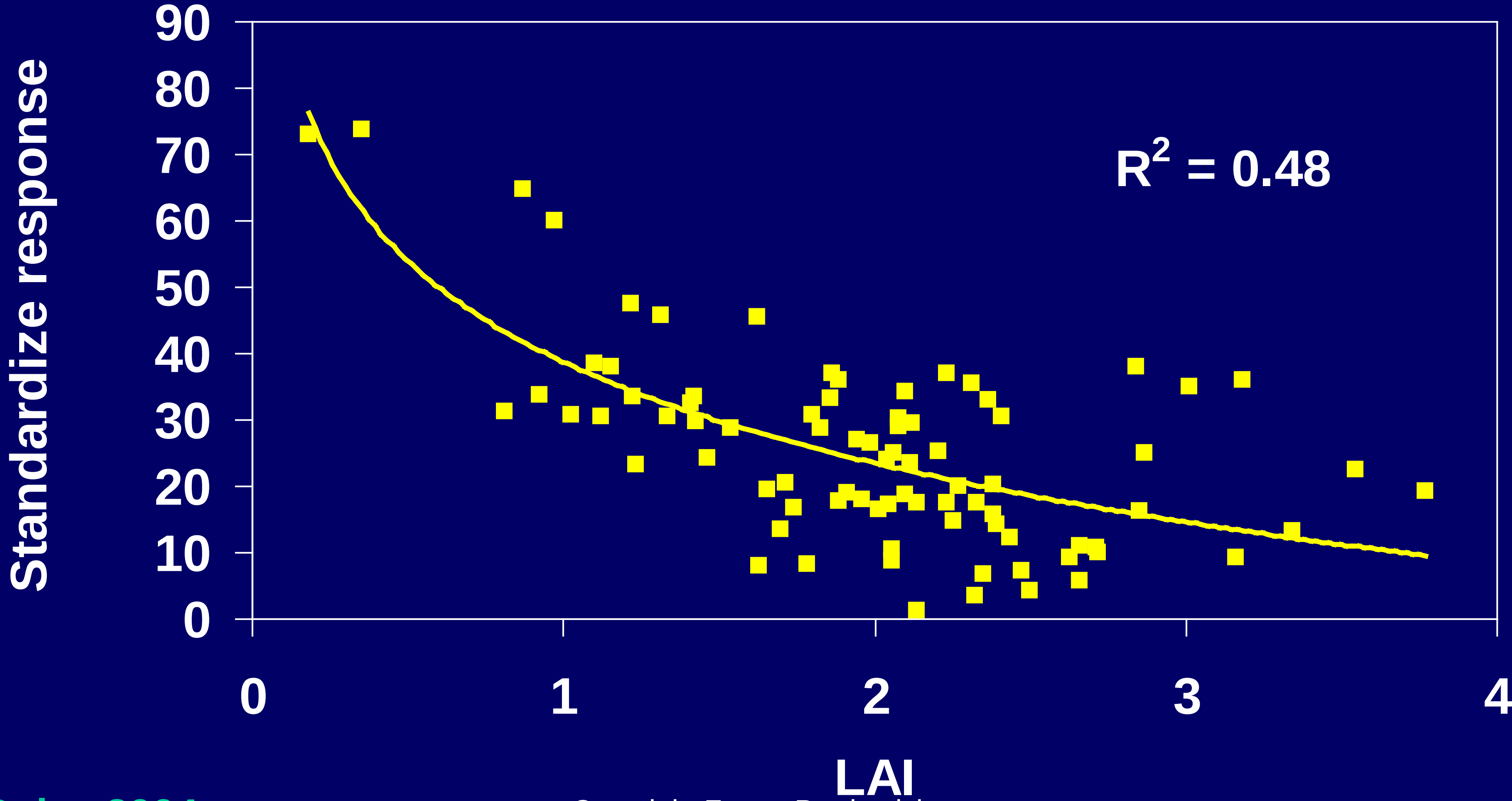


Low LAI

High LAI

LAI effects on Growth Response to Fertilizer

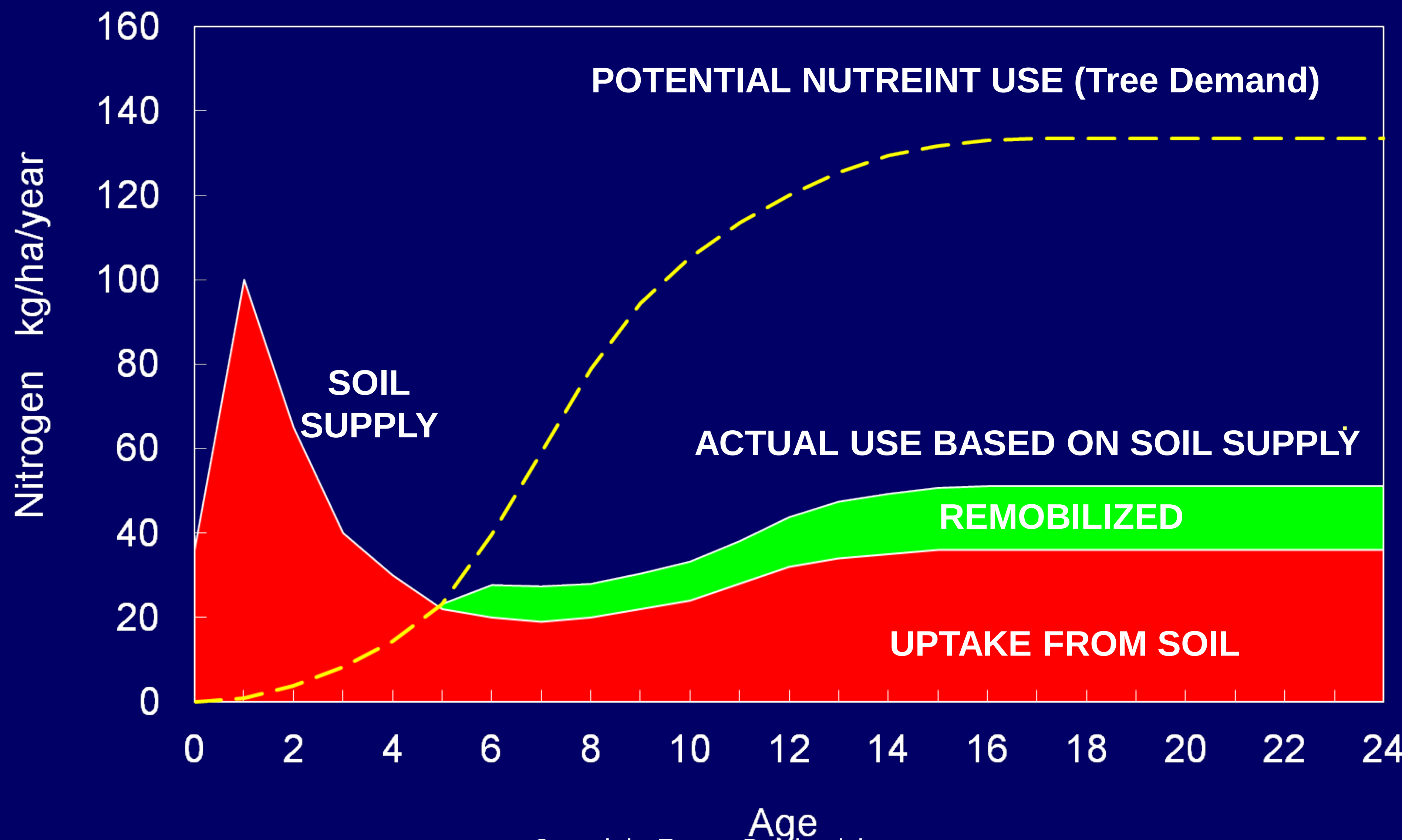
SR = ((Treatment Growth - Stand Average Growth) / std dev) x (cv + 100)



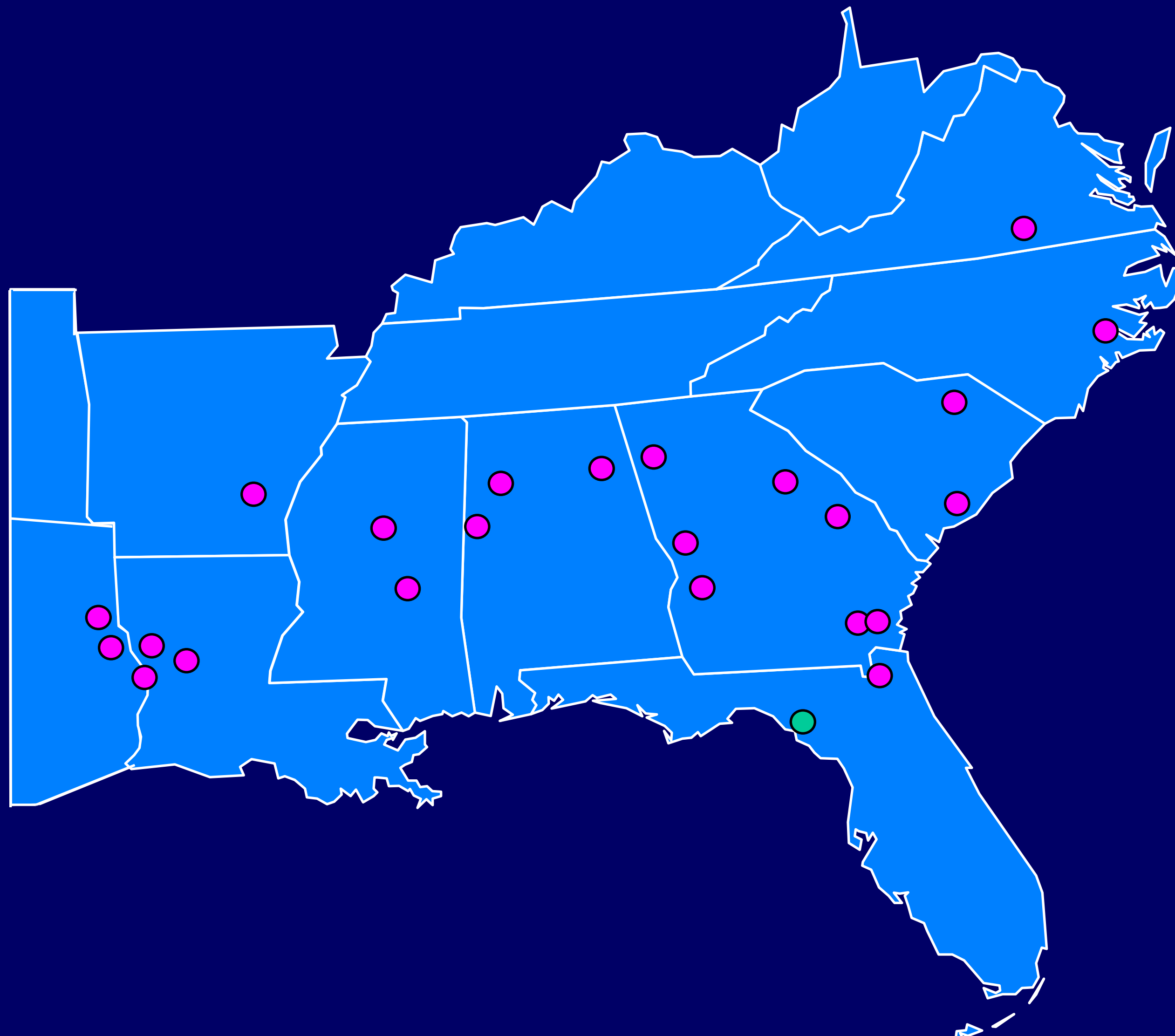
Rojas 2004

Juvenile Stand Fertilization

Model for Soil Nutrient Supply and Tree Nutrient Demand



Juvenile Stand Fertilization Regionwide 18 - Trial Locations



Regionwide 18 Treatments

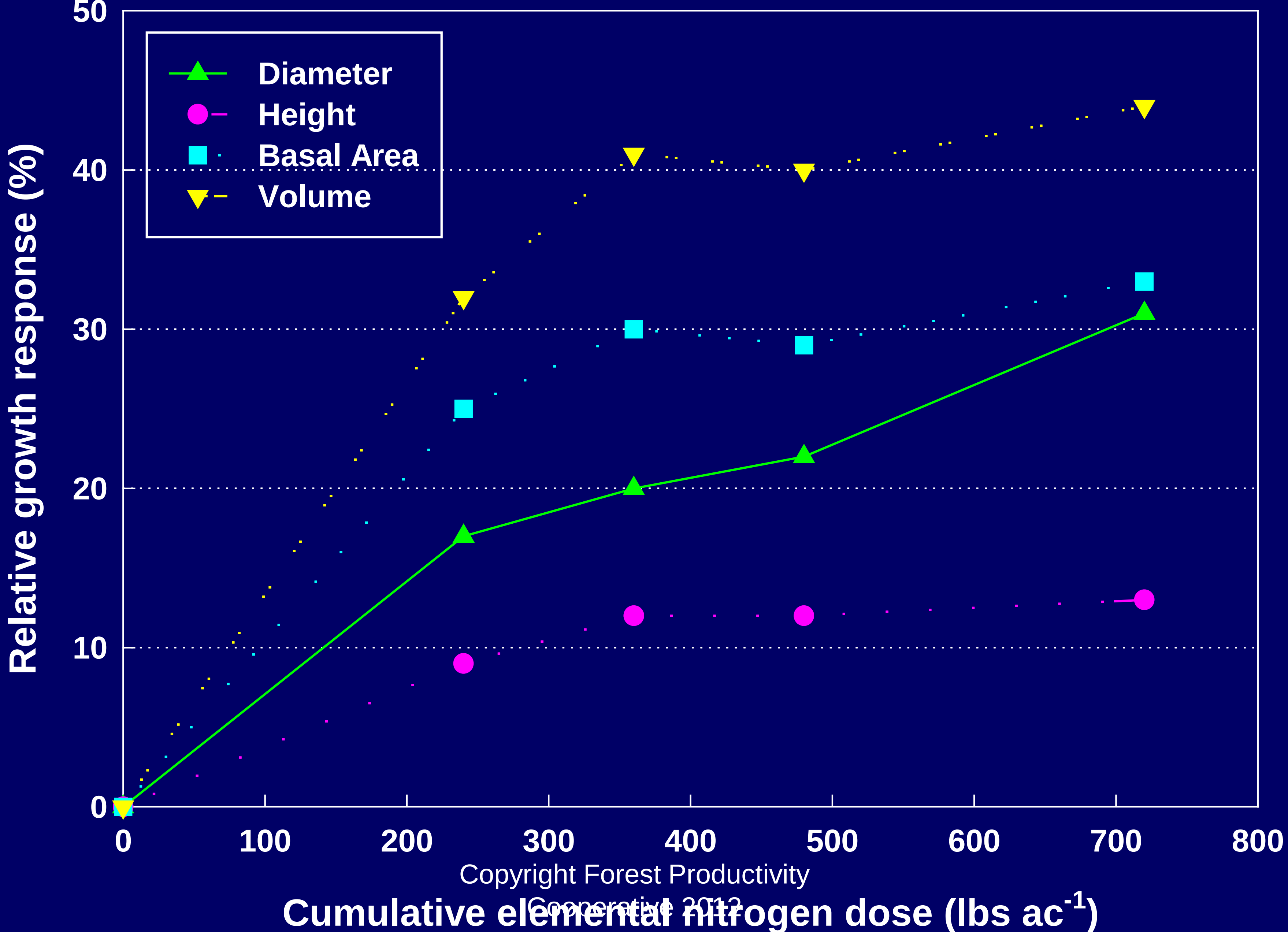
Treatment Code	Rate kg/ha	Frequency Years	Cumulative N at Years in Study			
			2	4	6	8
Control	0	None	0	0	0	0
206	60	2 yrs	60	120	180	240
212	120	2 yrs	120	240	360	480
218	180	2 yrs	180	360	540	720
412	120	4 yrs	120	120	240	240
418	180	4 yrs	180	180	360	360
424	240	4 yrs	240	240	480	480
624	240	6 yrs	240	240	240	480

Growth Response of Juvenile Loblolly Pine to N + P Fertilization 2 Years After Treatment

Control

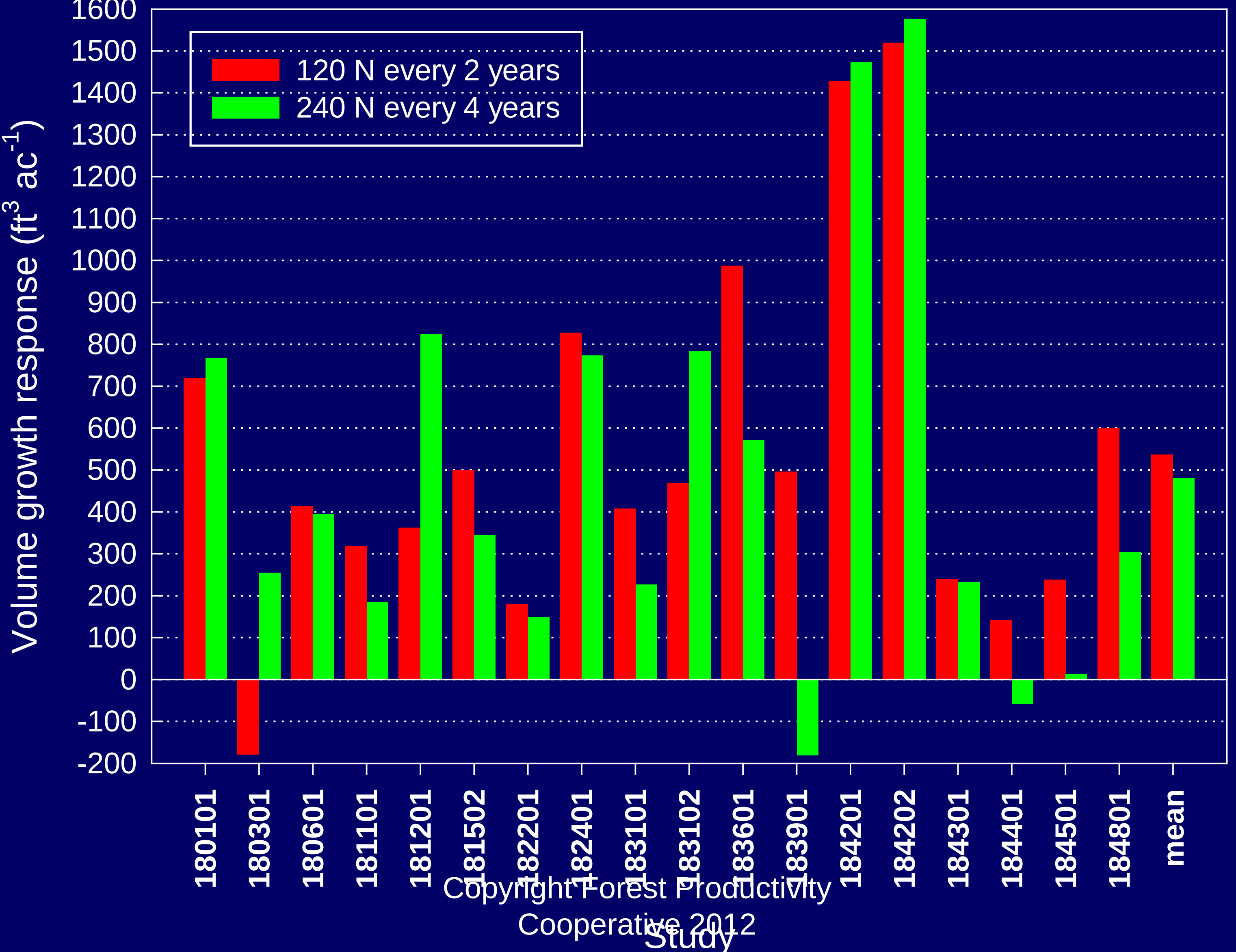
Fertilized

RW18 average treatment response

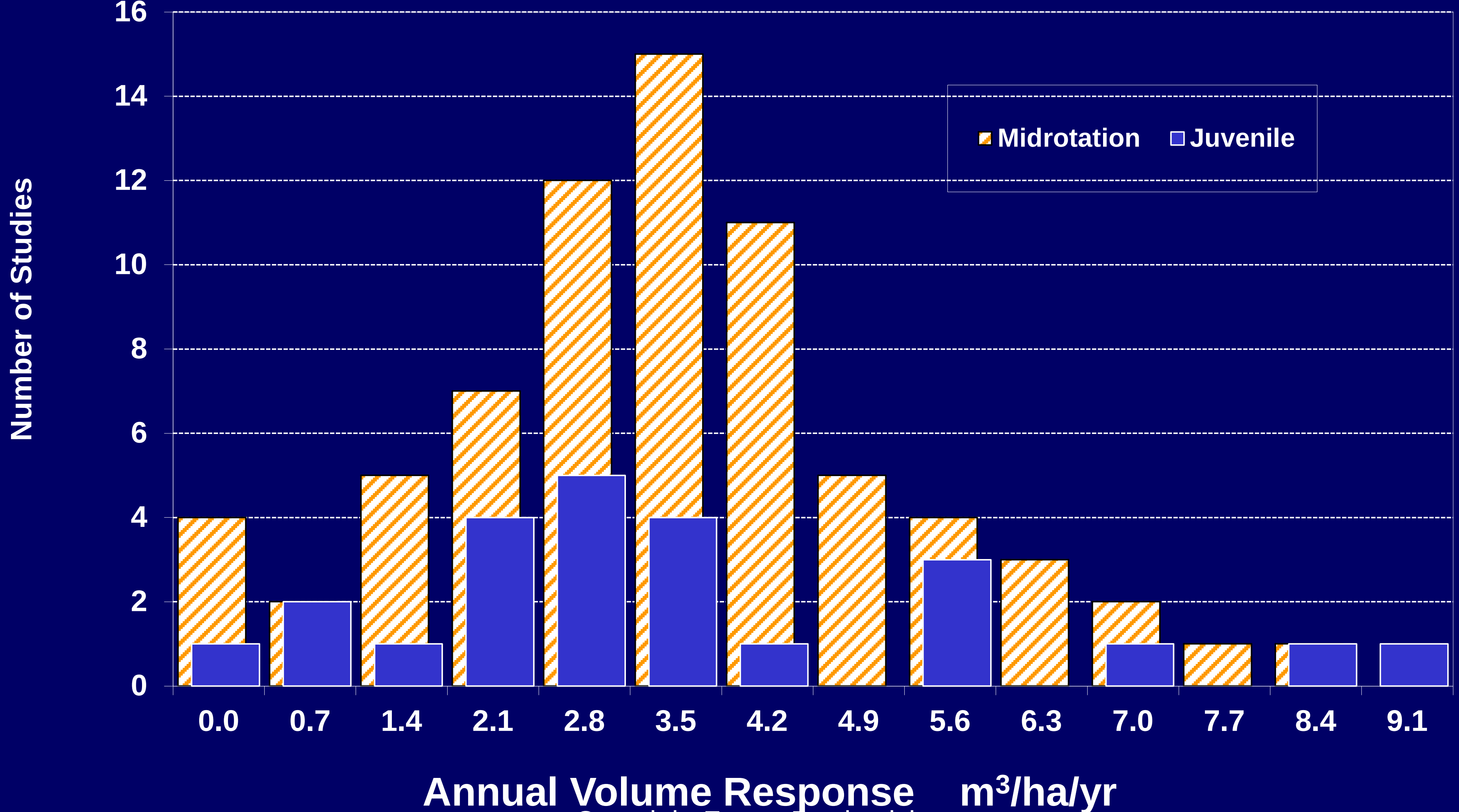


Frequency effect at 8 years

Cumulative dose 480 lbs ac^{-1} elemental N

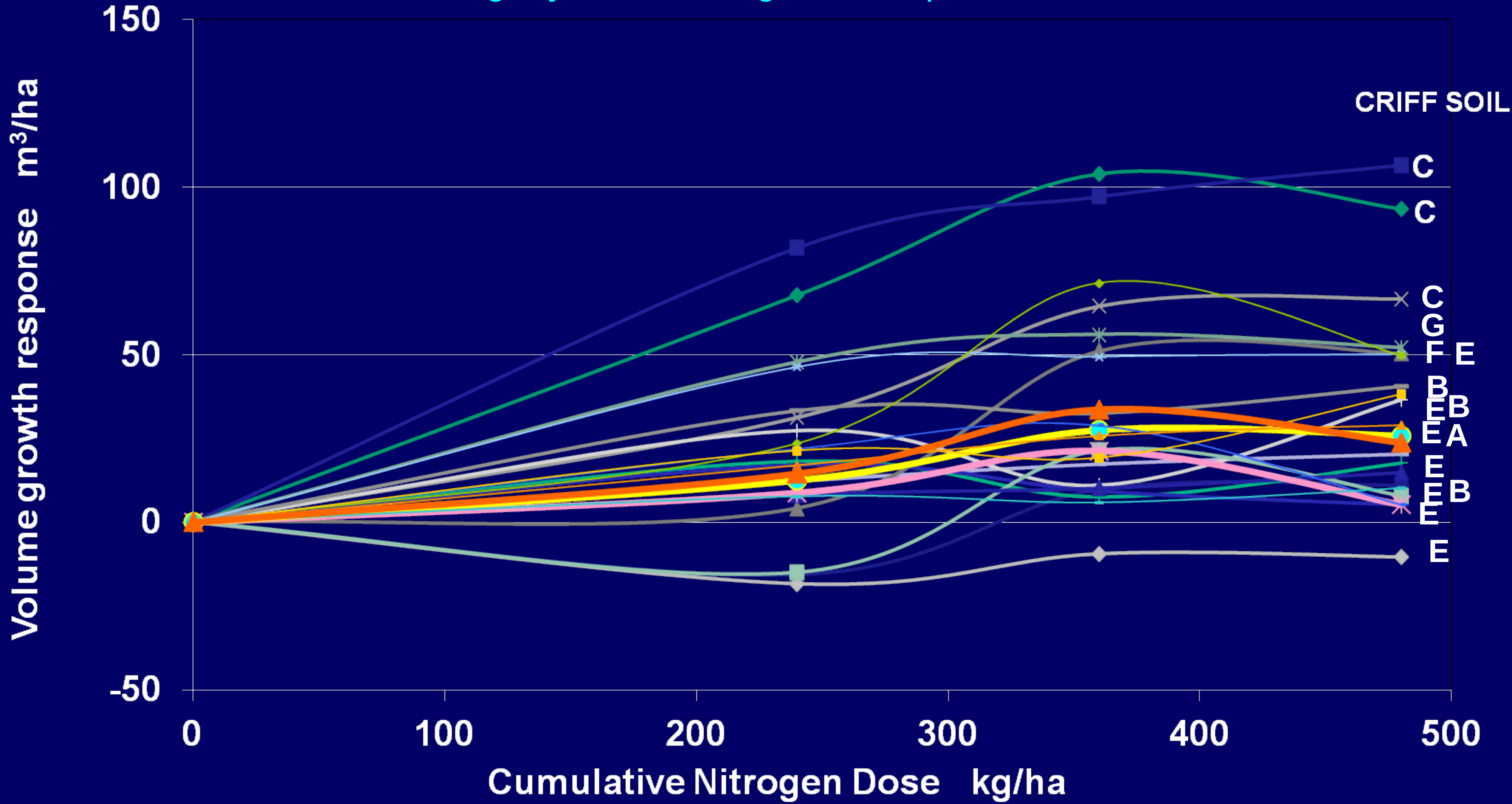


Frequency Distribution of Growth Response Following N+P Fertilization in Loblolly Pine



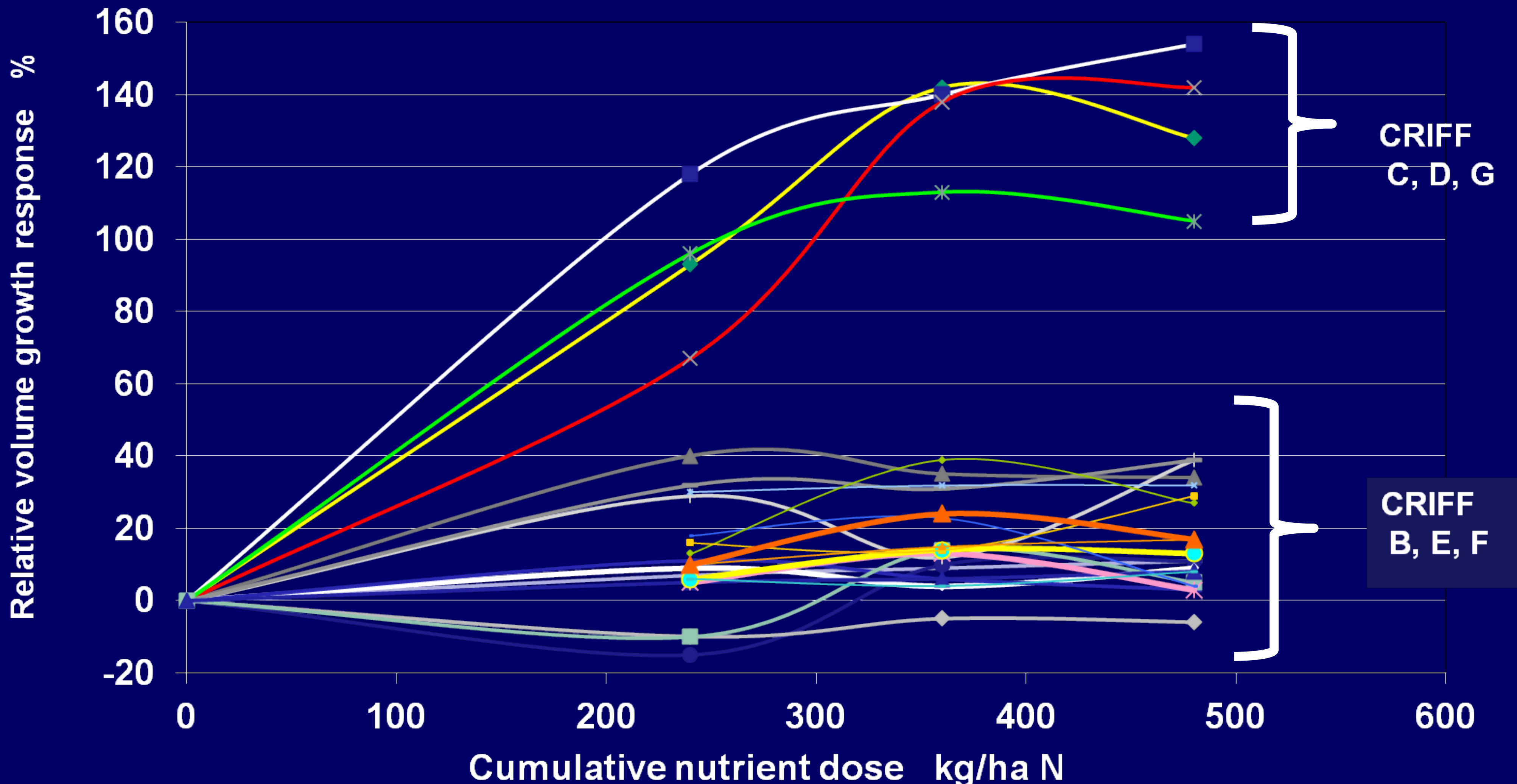
Regionwide 18

Eight-year volume growth responses

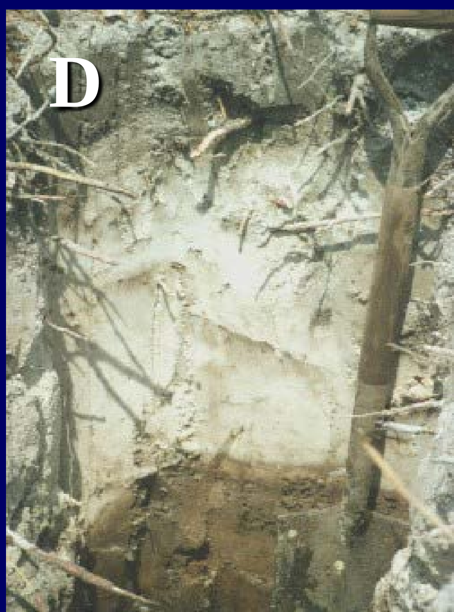


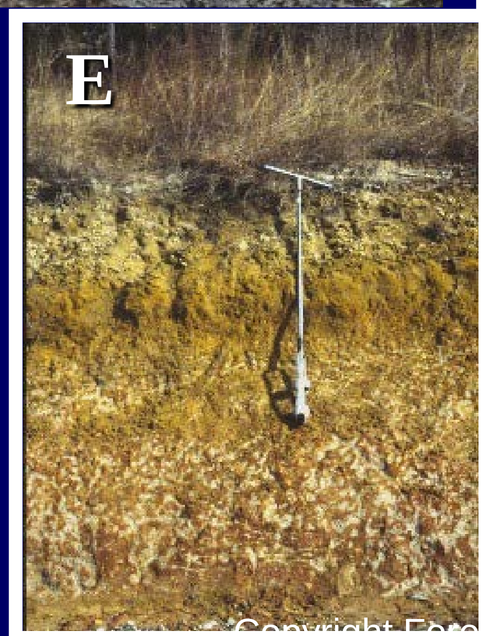
Regionwide 18

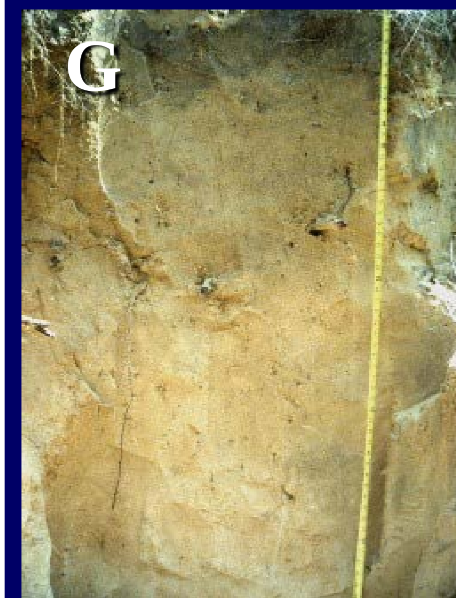
Eight-year volume growth responses



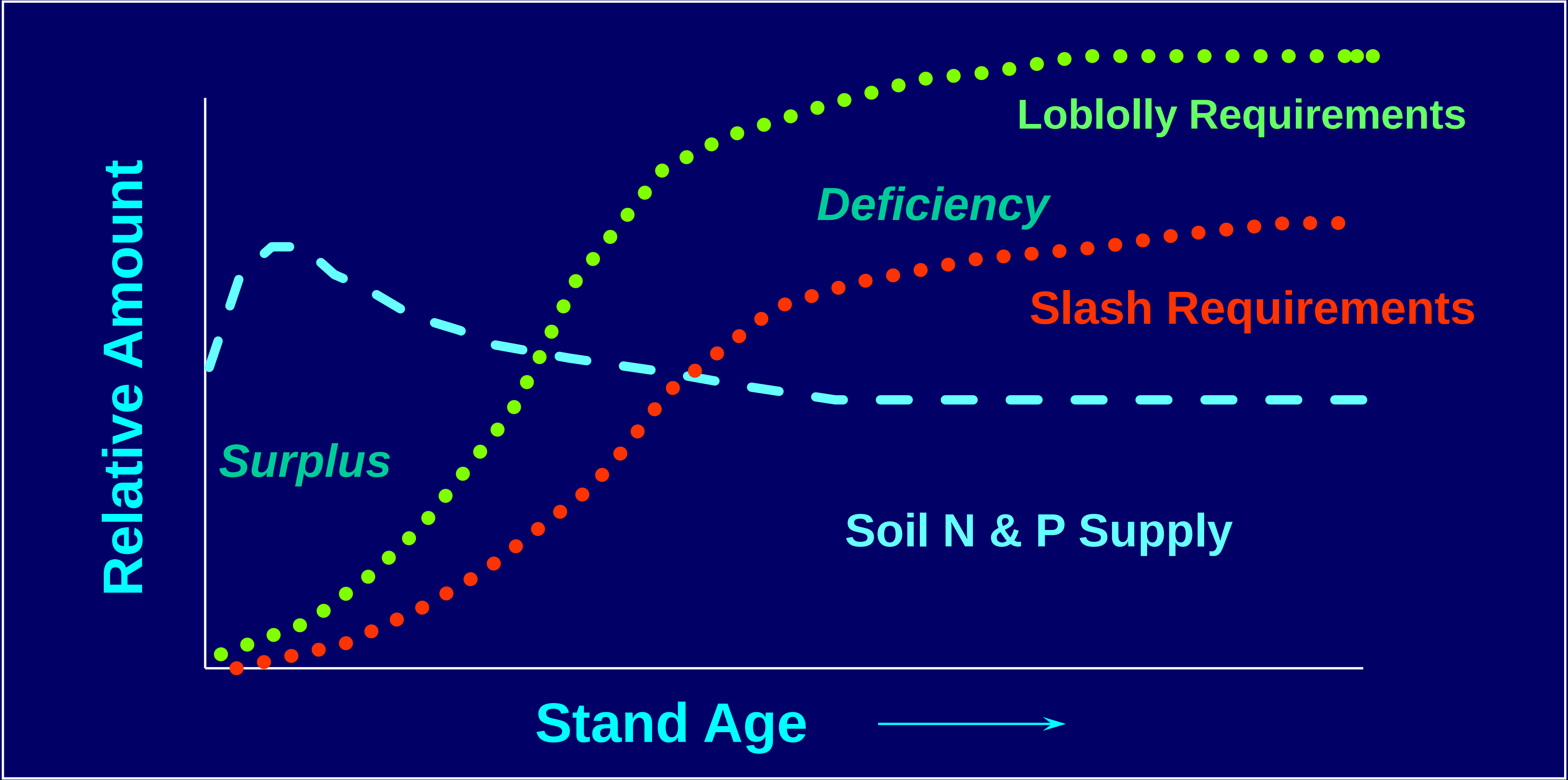
CRIFF Soil Groups



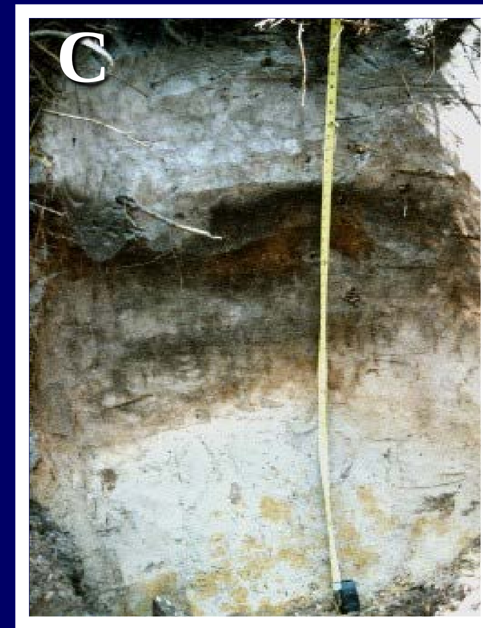


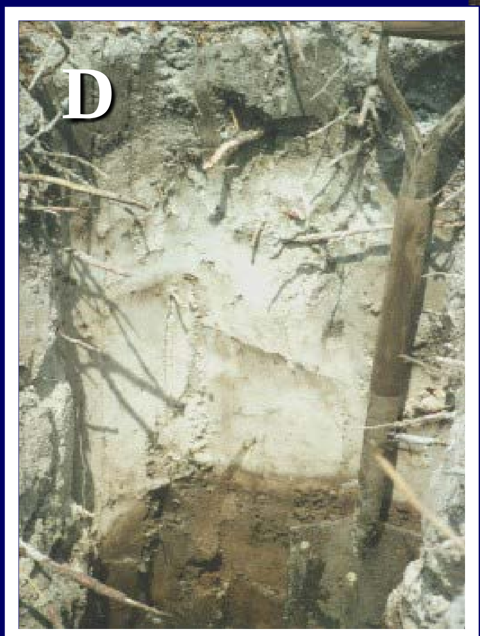


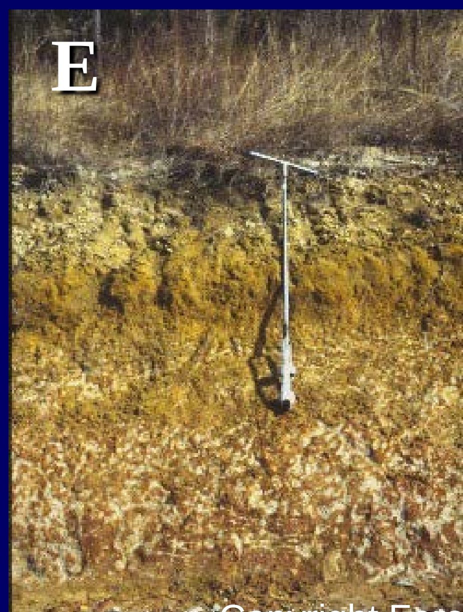
Soil Nutrient Dynamics Coastal Plain and Piedmont Ultisols - CRIFF B, E, F

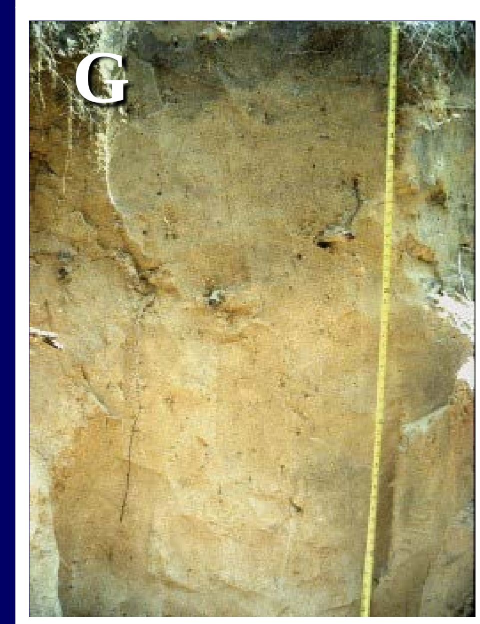


CRIFF Soil Groups







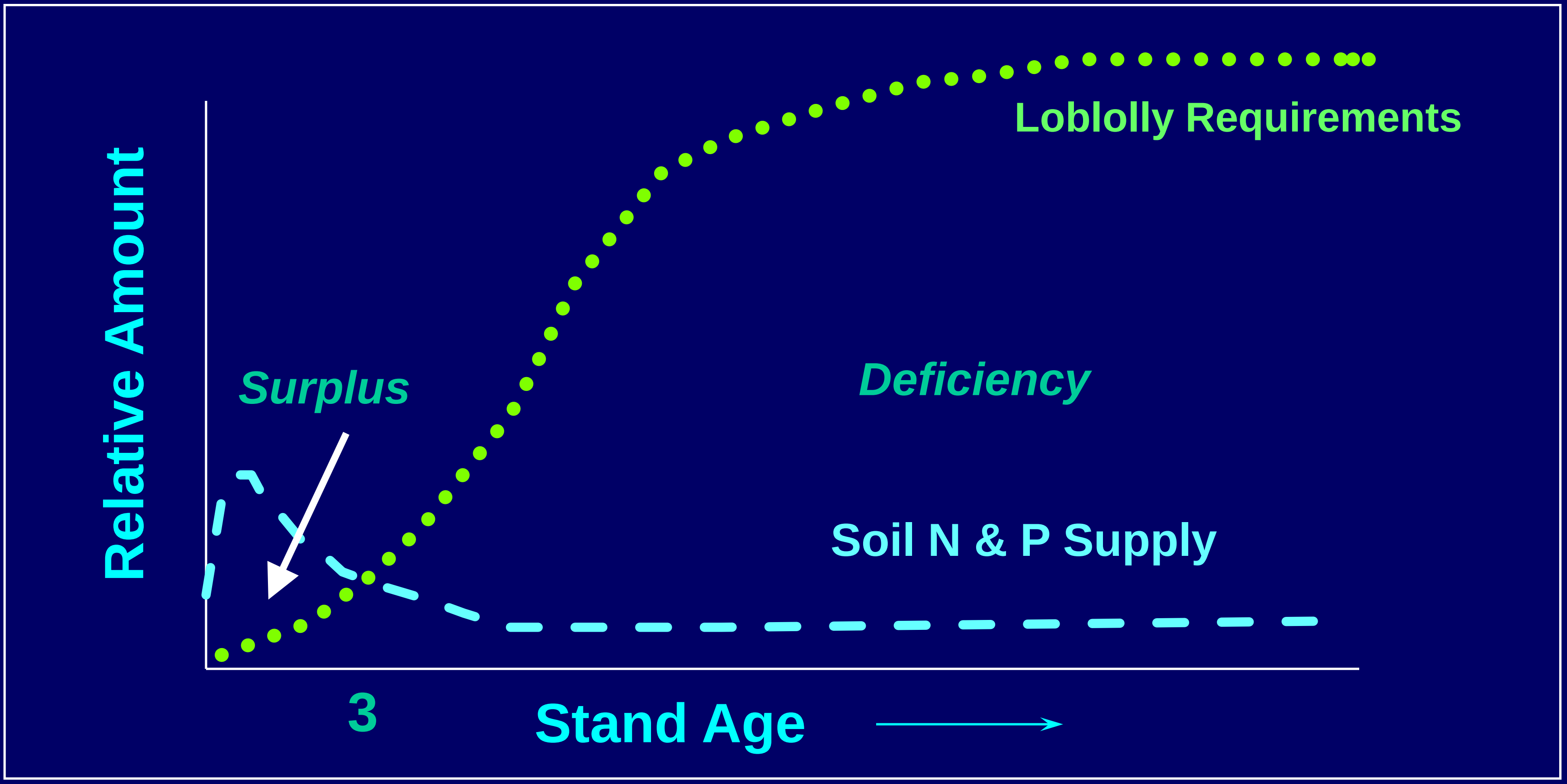


11 Year Fertilizer Response at 184202 in Southeast Georgia

Control

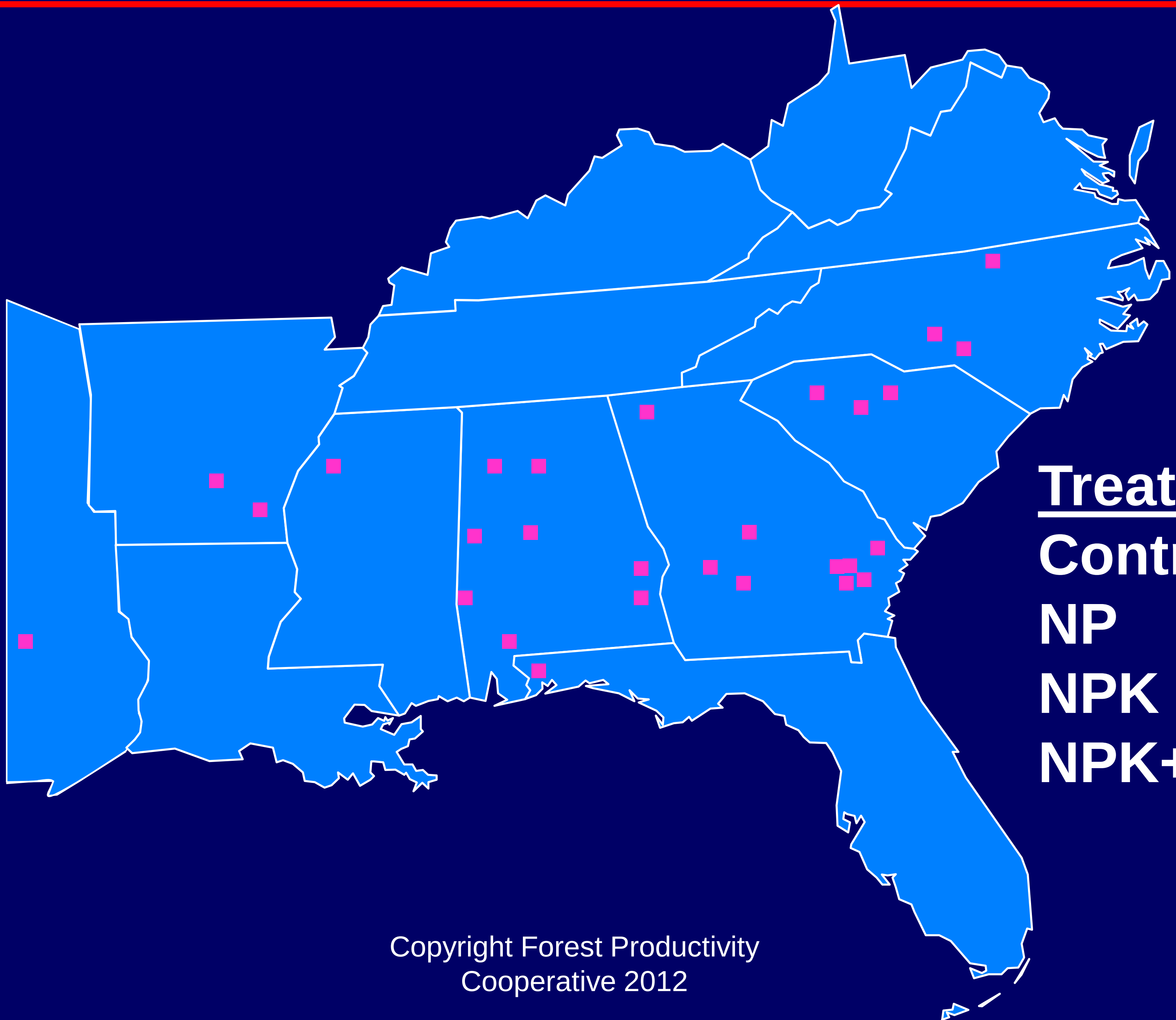
Fertilized (2 180 Treatment)

Soil Nutrient Dynamics in the Flatwoods
CRIFF C,D,G



Potassium and Micronutrients

RW15 Study Locations



Treatments

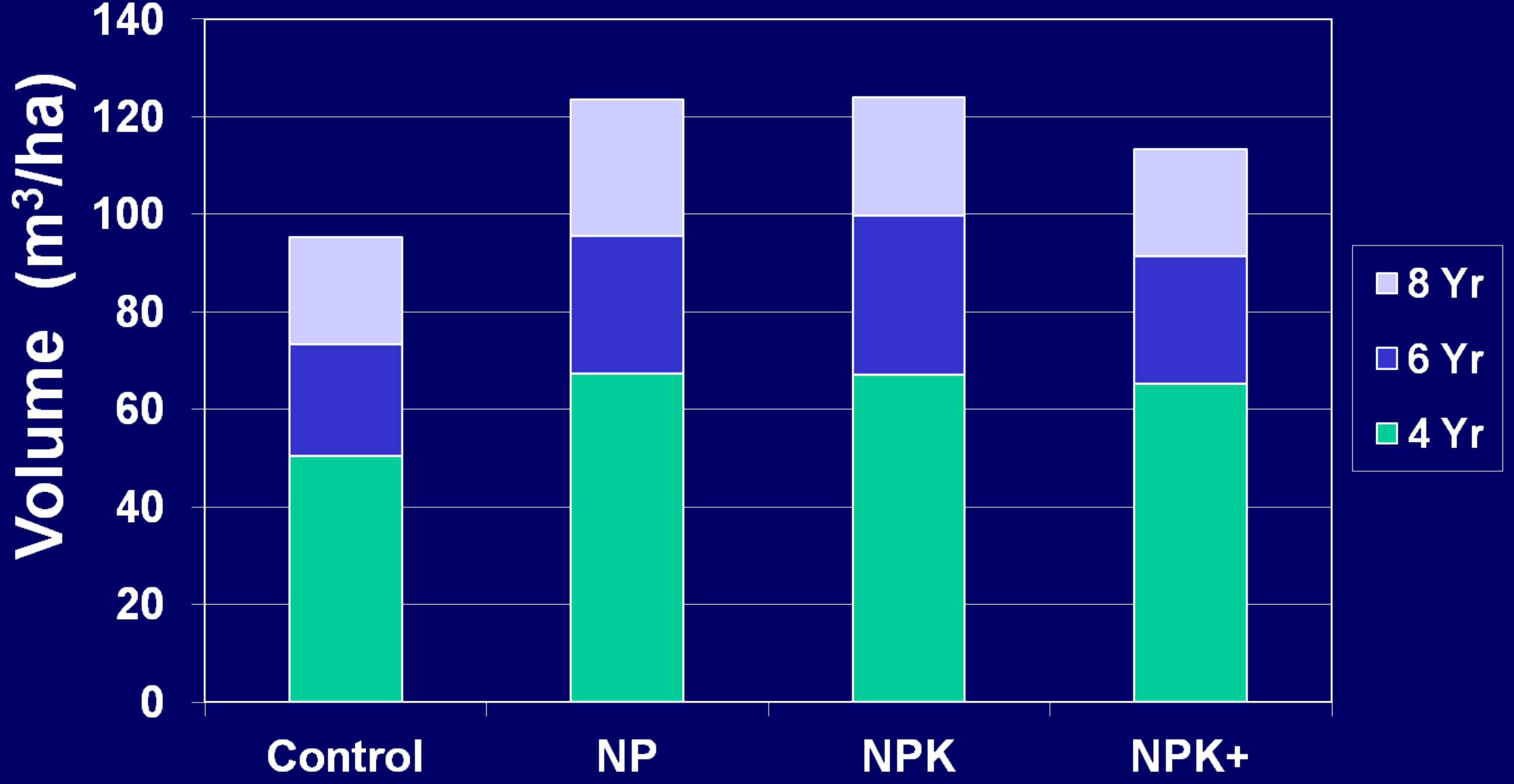
Control

NP

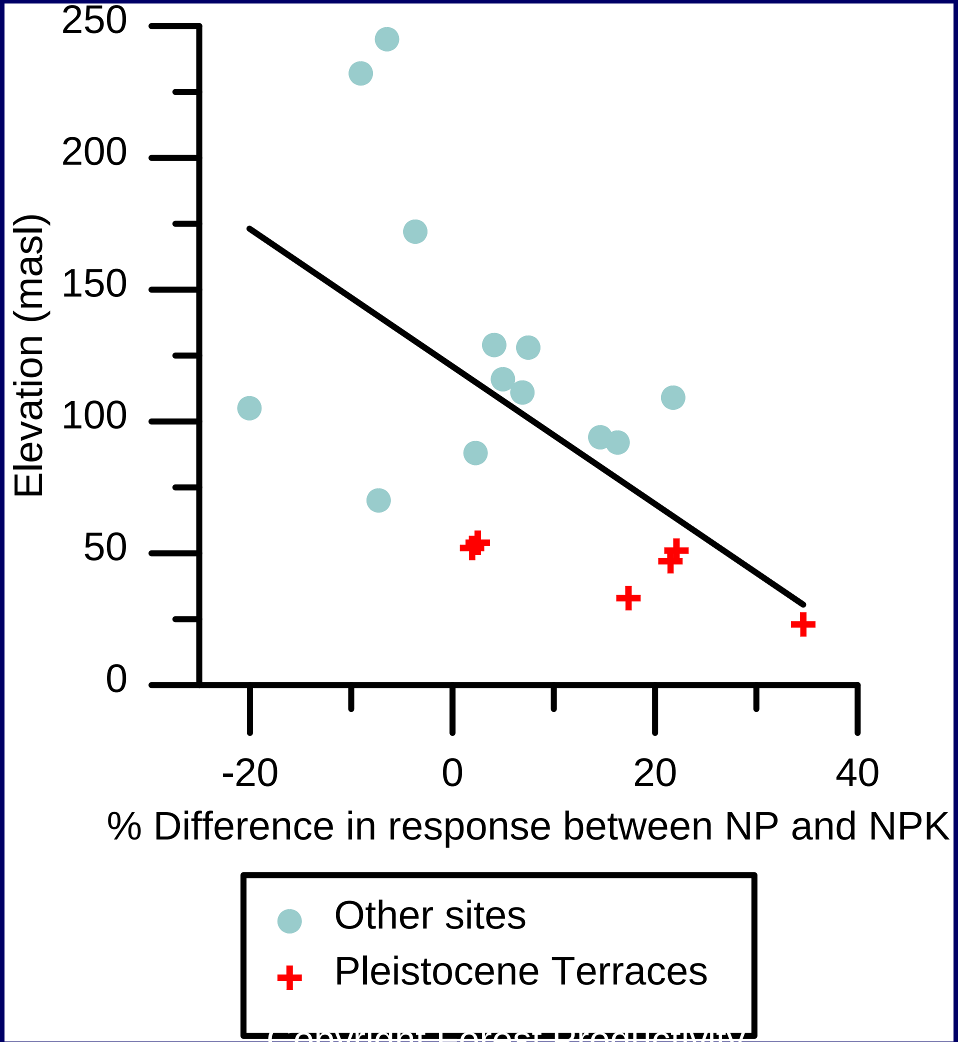
NPK

NPK+Micro

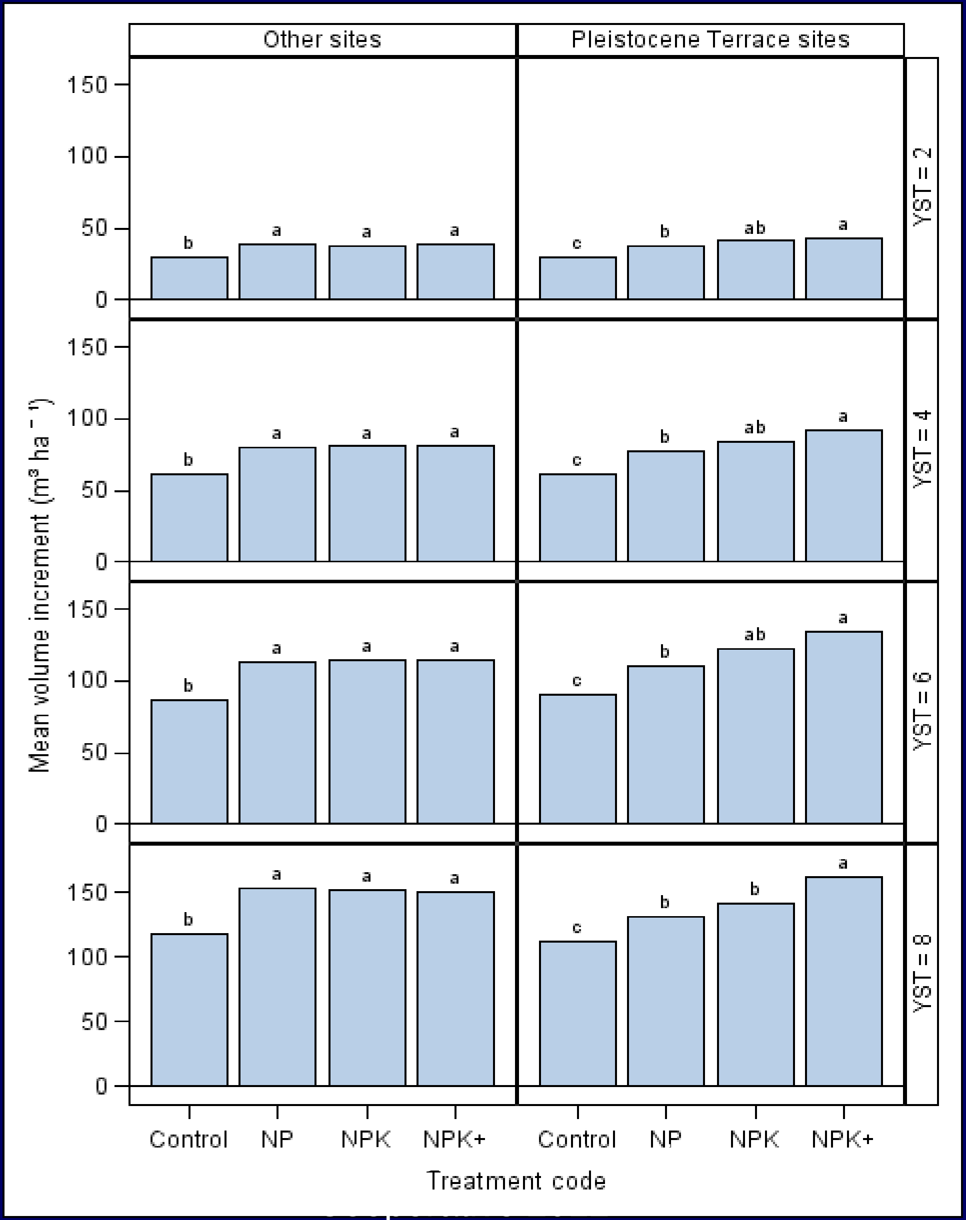
Cumulative Volume Growth in RW15



Response to Potassium Fertilization and Elevation

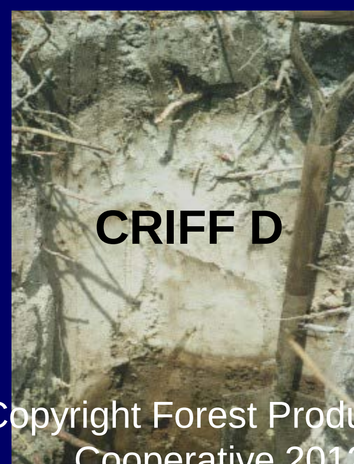


Loblolly Pine Response to K and Micronutrient Fertilization



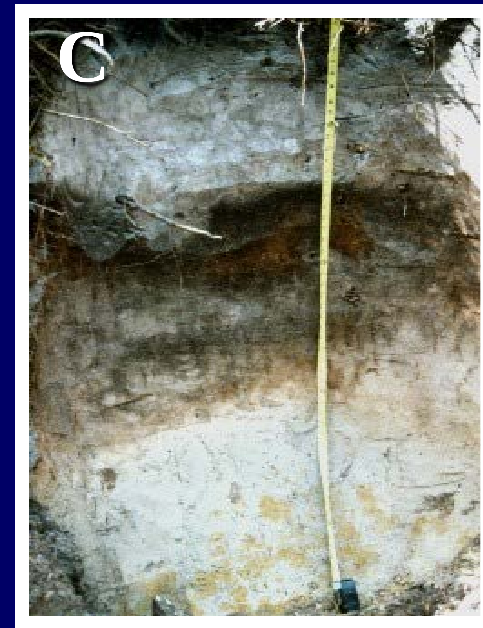
Pinus elliottii at age 10 years in north Florida, USA

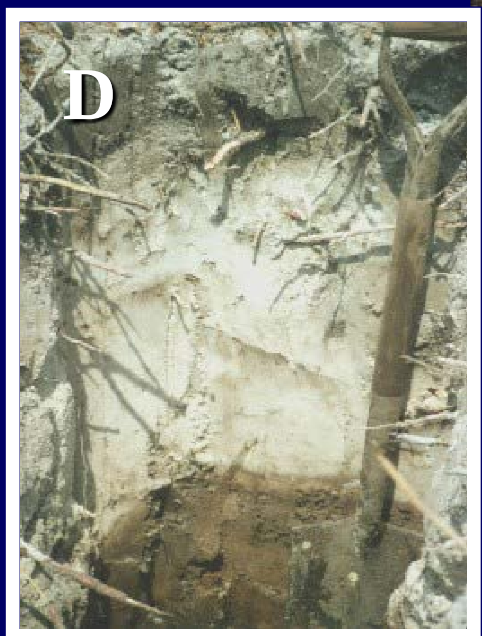
Non Fertilized

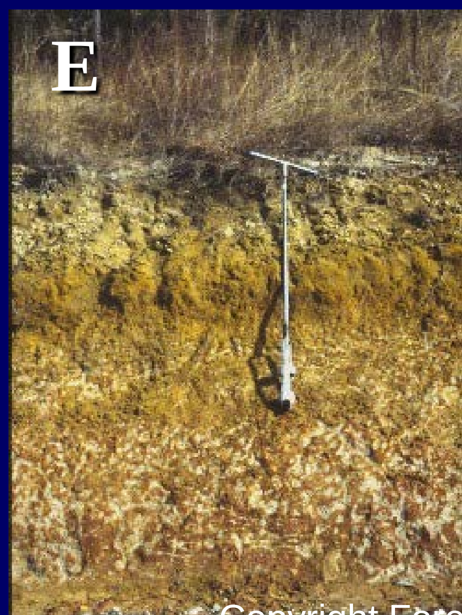


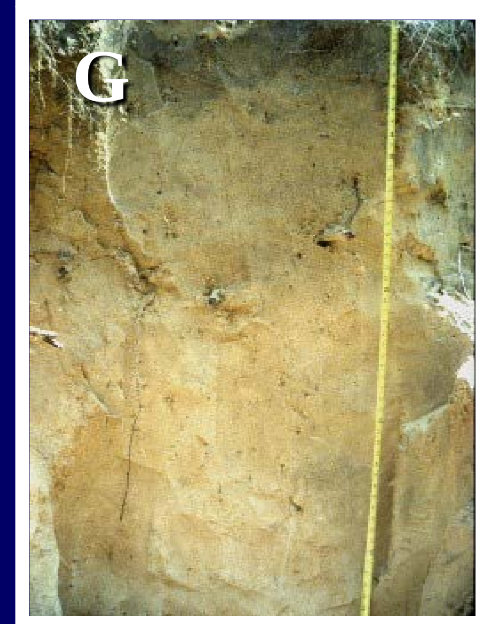
N + P + K + Mico
@ Age 3

CRIFF Soil Groups

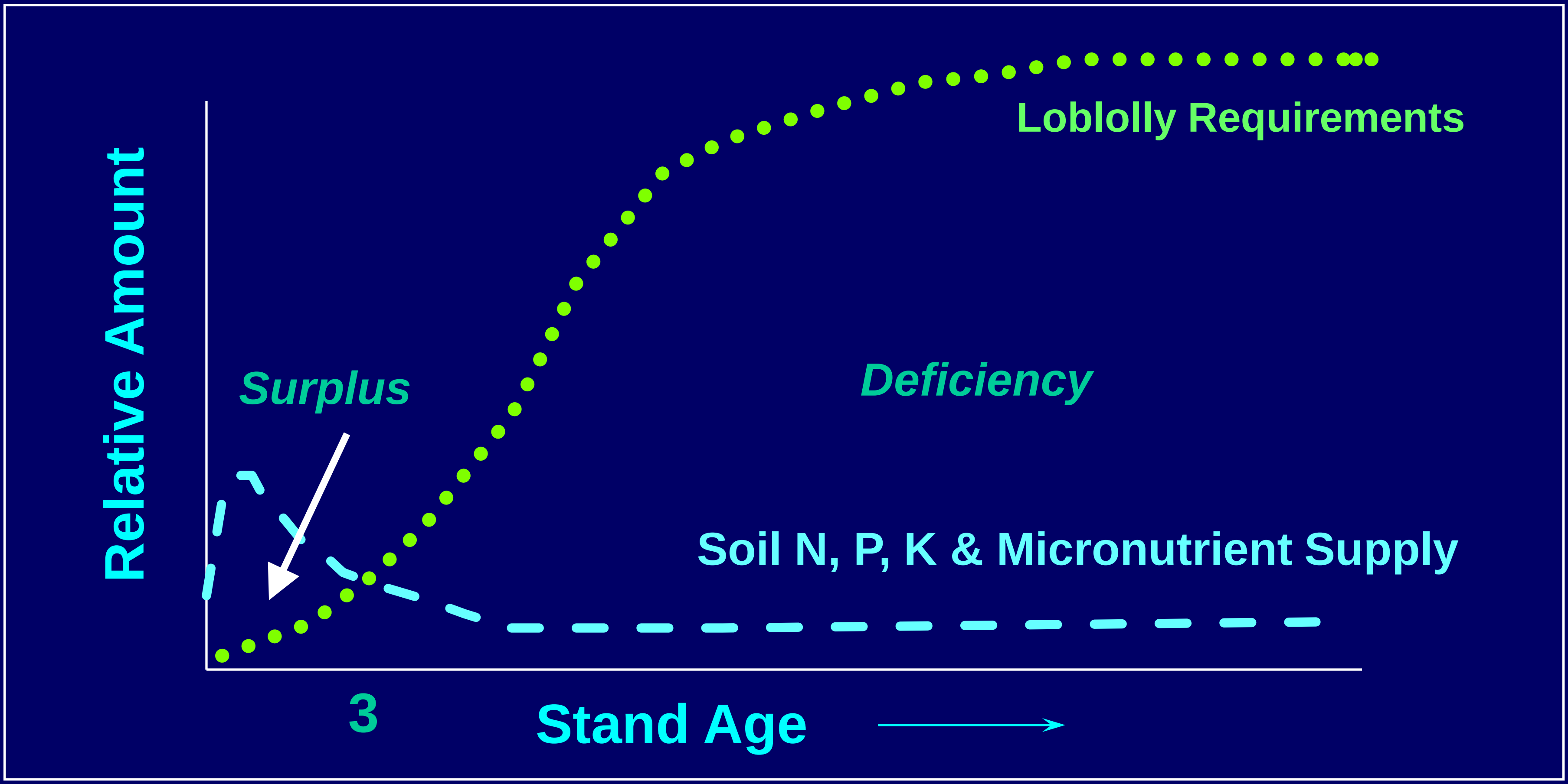






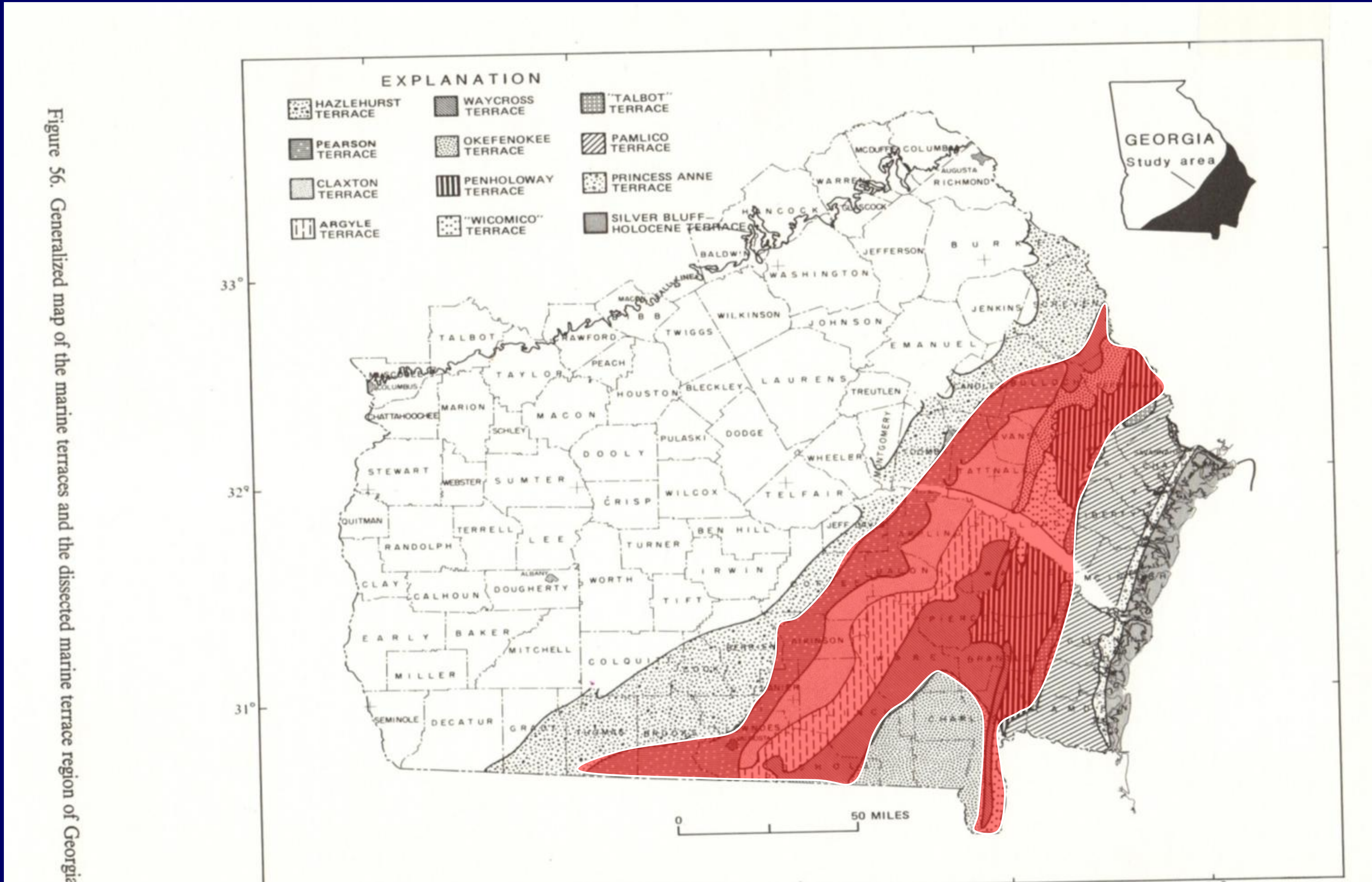


Soil Nutrient Dynamics in the Flatwoods
CRIFF C,D,G



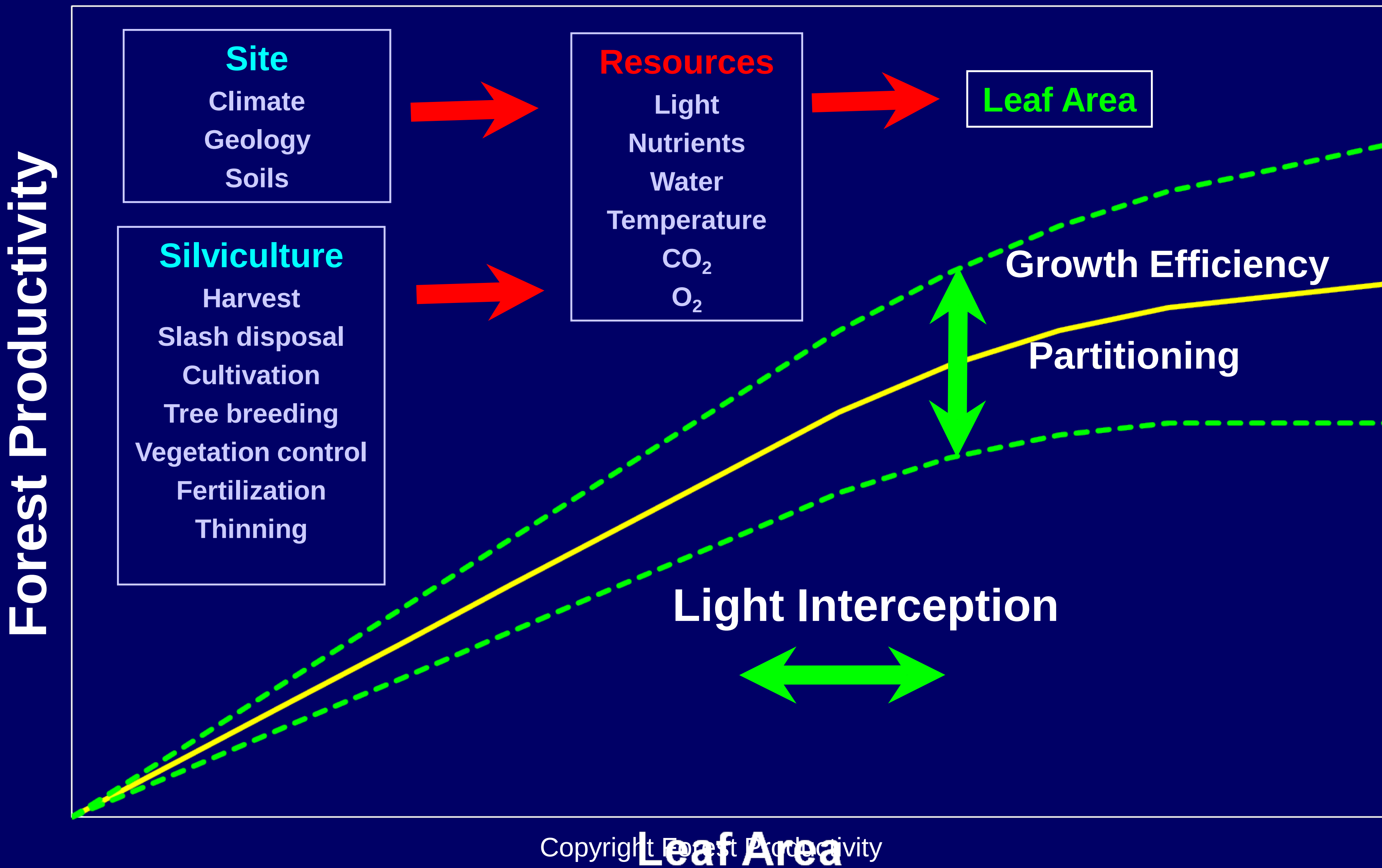
Nutrient Deficient Terraces of the Florida, Georgia and the Carolina's Coastal Plain

Province	Geologic Series	Terrace	Deficiency
LACP	Pleistocene	Silver Bluff	Severe P
		Princess Anne	Severe P
		Pamilico	Severe P
		Talbut	P, K, B
		Penholoway	P, K, B
		Wicomico	P, K, B
UACP	Pliocene	Coharie	P, K, B
Sandhills	Upper Cretaceous	Peedee	P, K, B
		Black Creek	P, K, B
		Middledorf	P, K, B

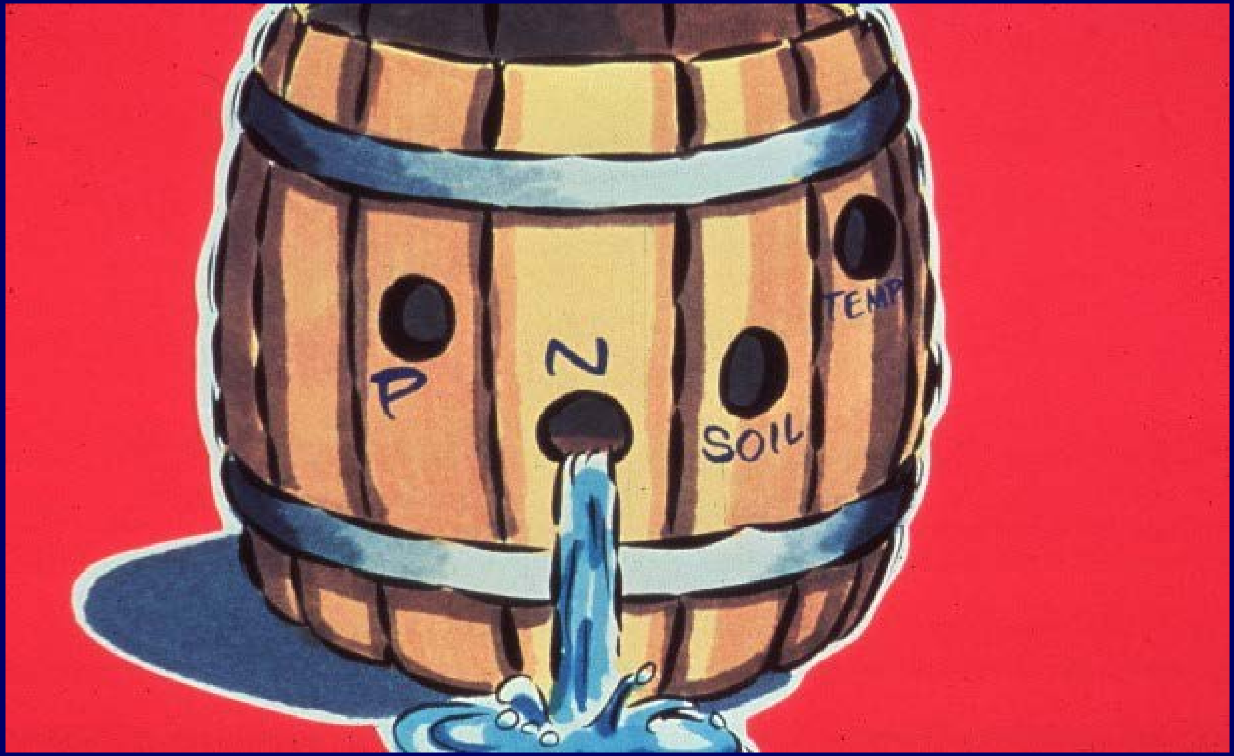


Location of K Deficiencies on Pliestocene Terraces in Georgia

Silviculture - Site Resources - Leaf Area

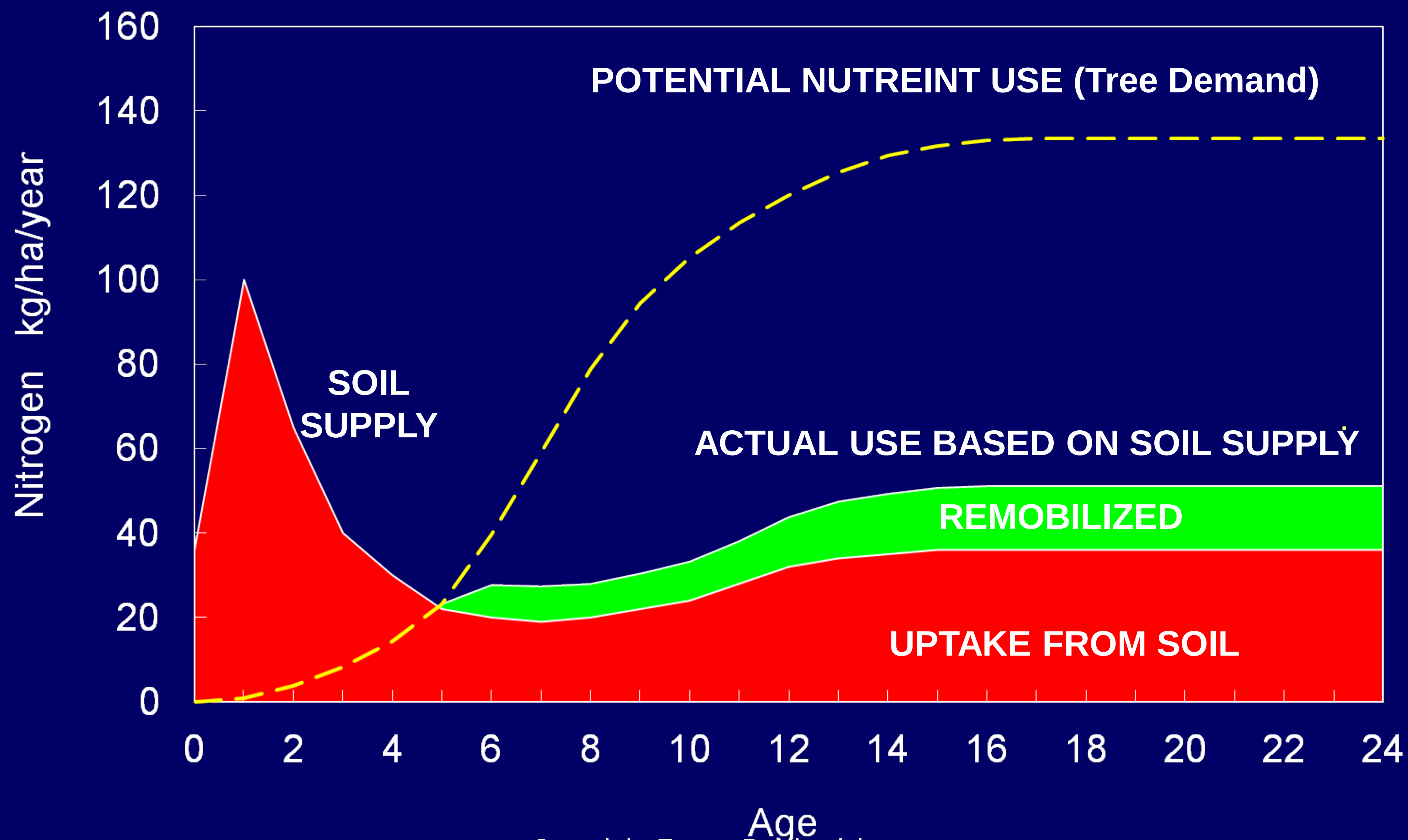


Liebig's Law of the Minimum
Nutrient Deficiencies

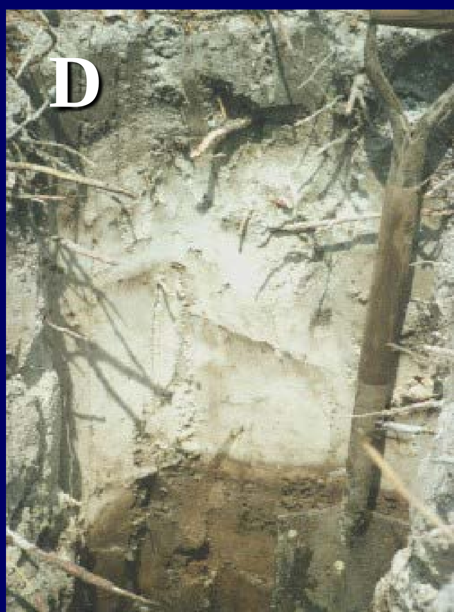


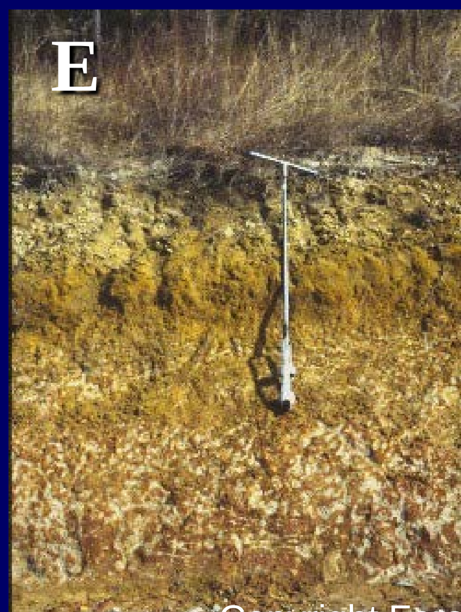
Multiple Deficiencies Often Limit Tree Growth
(N and P are Deficient on Most Soils in the South)

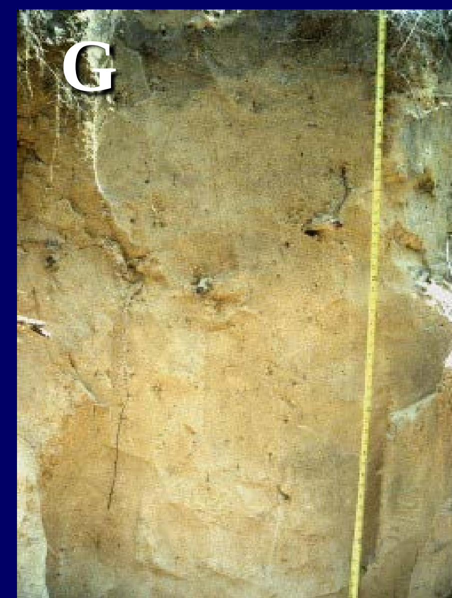
Model for Soil Nutrient Supply and Tree Nutrient Demand

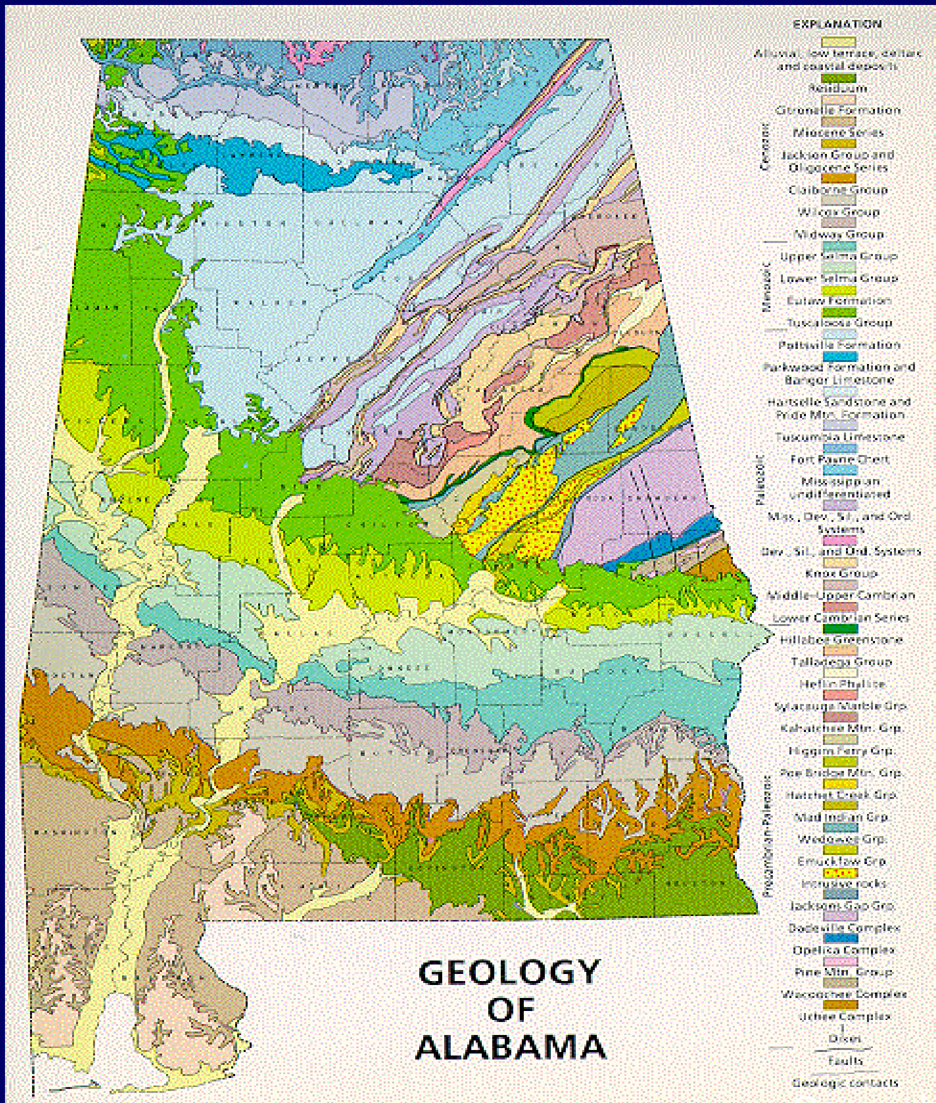


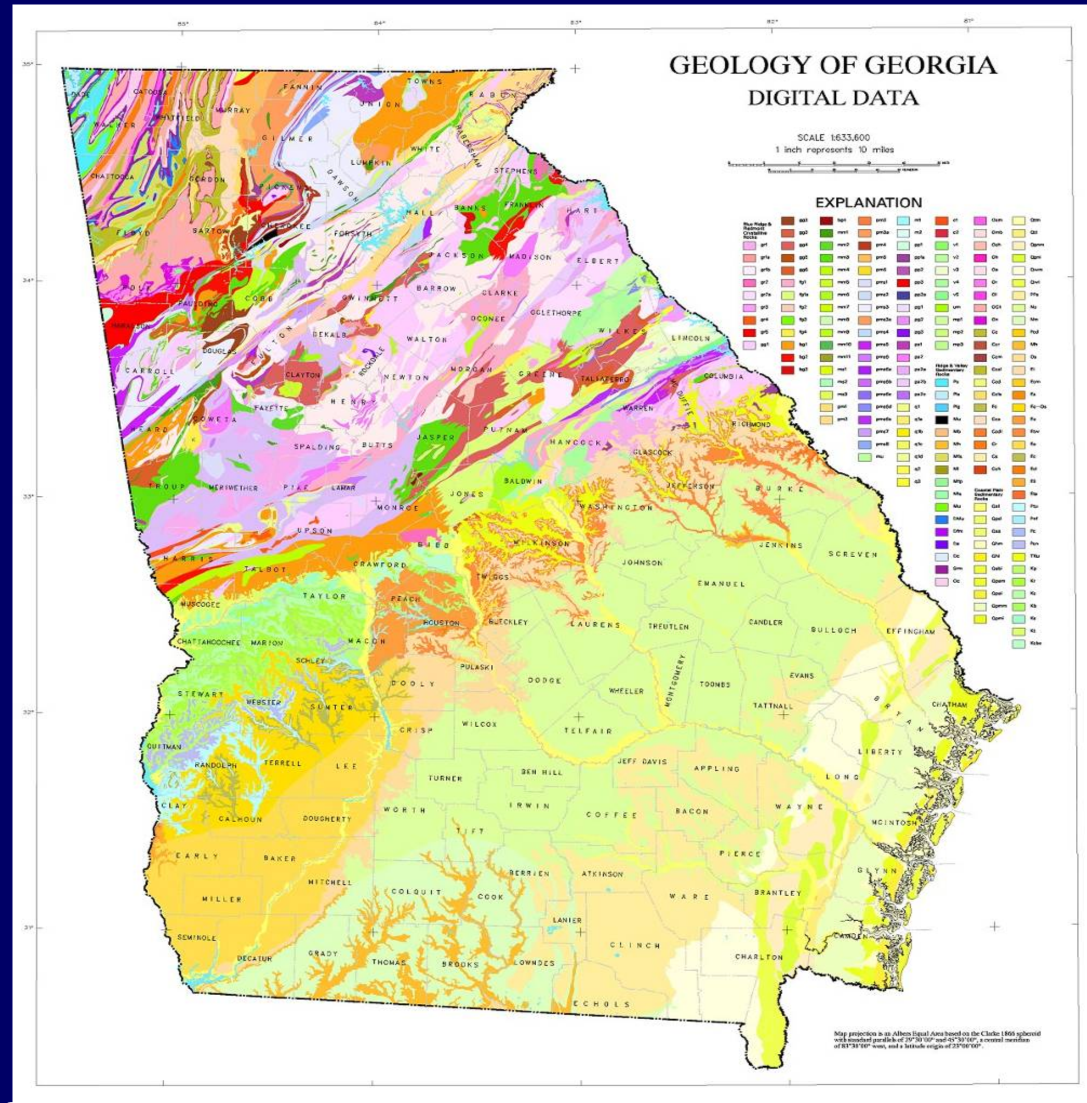
CRIFF Soil Groups







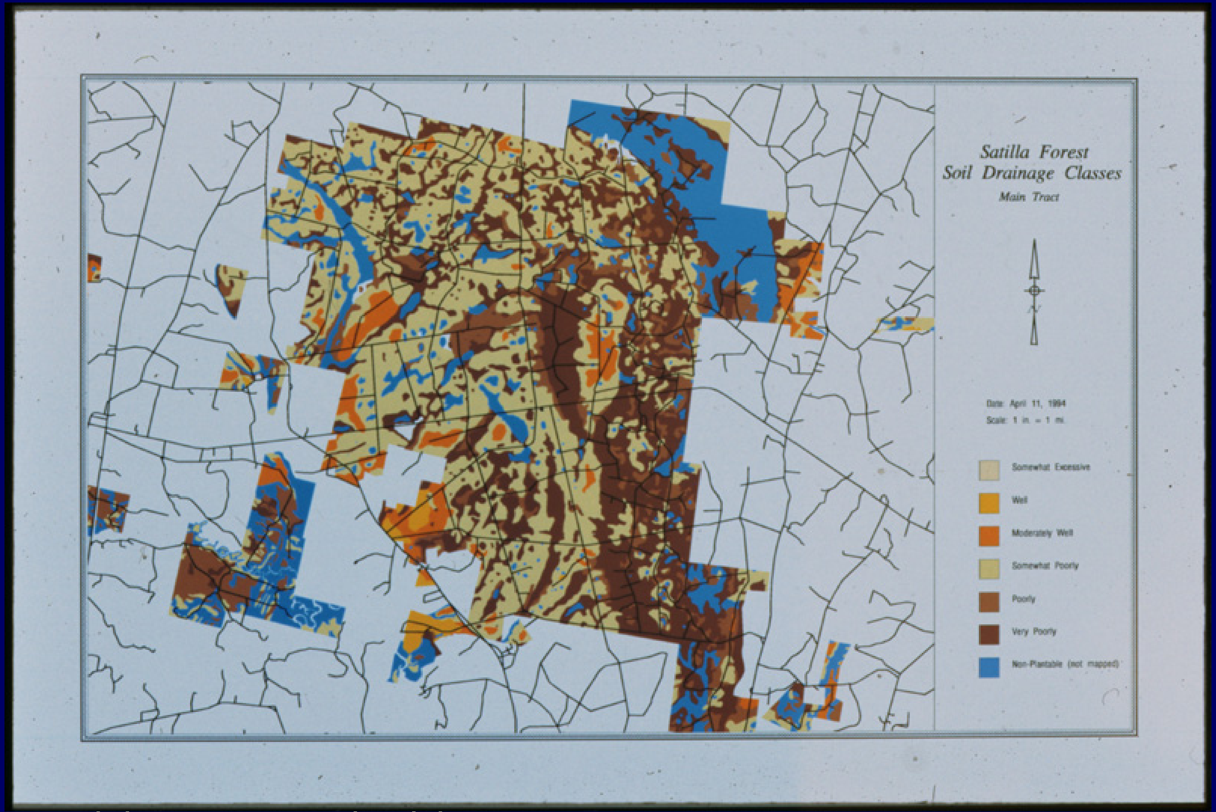

EXPLANATION
Alluvial, low terrace, deltaic and coastal deposits
Residuum
Citronelle Formation
Miocene Series
Jackson Group and Oligocene Series
Claiborne Group
Wilcox Group
Midway Group
Upper Selma Group
Lower Selma Group
Eutaw Formation
Tuscaloosa Group
Pottsville Formation
Parkwood Formation and Bangor Limestone
Hartselle Sandstone and Pride Mtn. Formation
Tuscumbia Limestone
Fort Payne Chert
Mississippian undifferentiated
Miss., Dev., Sil., and Ord. Systems
Dev., Sil., and Ord. Systems
Knox Group
Middle-Upper Cambrian
Lower Cambrian Series
Hillabee Greenstone
Talladega Group
Heflin Phyllite
Sylacauga Marble Grp.
Kahatchee Mtn. Grp.
Higgins Ferry Grp.
Poe Bridge Mtn. Grp.
Hatchet Creek Grp.
Mad Indian Grp.
Wedowee Grp.
Emuckfaw Grp.
Intrusive rocks
Jacksons Gap Grp.
Dadeville Complex
Opelika Complex
Pine Mtn. Group
Waccochee Complex
Uchee Complex
Dikes
Faults
Geologic contacts
Cenozoic
Mesozoic
Paleozoic
Precambrian-Paleozoic
GEOLOGY OF ALABAMA


GEOLOGY OF GEORGIA
DIGITAL DATA
SCALE 1:633,600
1 inch represents 10 miles
EXPLANATION

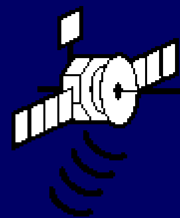
Site Specific Silvicultural Fertilization Prescriptions Based on Soils, Geology and Stand Conditions

Soil Variability

Soil Map as a GIS Layer



Technology for Precision Silviculture Prescriptions



Questions ???