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Agricultural Research Service

Agroforestry systems for bioenergy in the southeastern USA

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DEPARTMENT OF
FORESTRY AND ENVIRONMENTAL RESOURCES

FOREST SERVICE U S DEPARTMENT OF AGRICULTURE

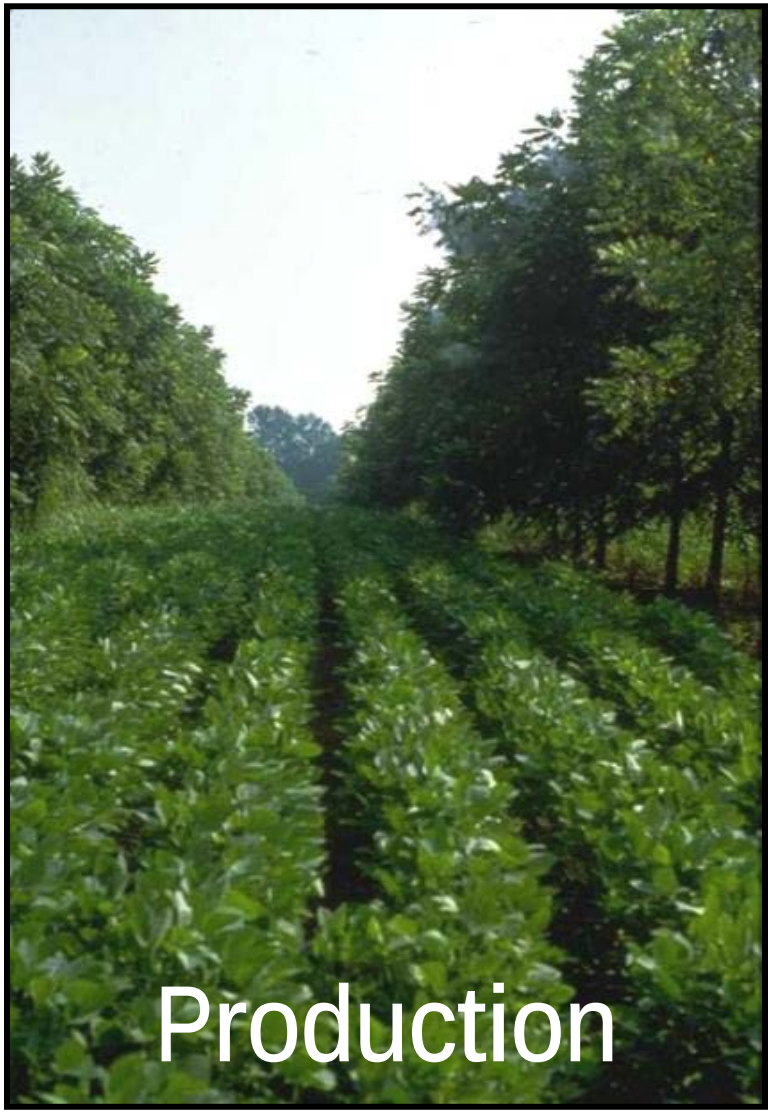
Agroforestry…

WORKING TREES

…Putting the right tree,
in the right location,
for the right reason.

USDA NATIONAL AGROFORESTRY CENTER

Agroforestry



the intentional mixing of trees and/or shrubs into crop/animal production systems to create environmental, economic and social benefits

Agroforestry systems

- ✓ Interest expanding around the globe
- ✓ Advantages
  - o Diversification of products and economic returns
  - o Lower risk than monoculture crops on marginal cropland – when susceptible to floods, drought, fire, pests, diseases
  - o Workable alleys for short-term cropping gains and/or maneuvering of forestry harvest equipment
  - o Shade for livestock
  - o Enhanced wildlife habitat – linkages to natural areas

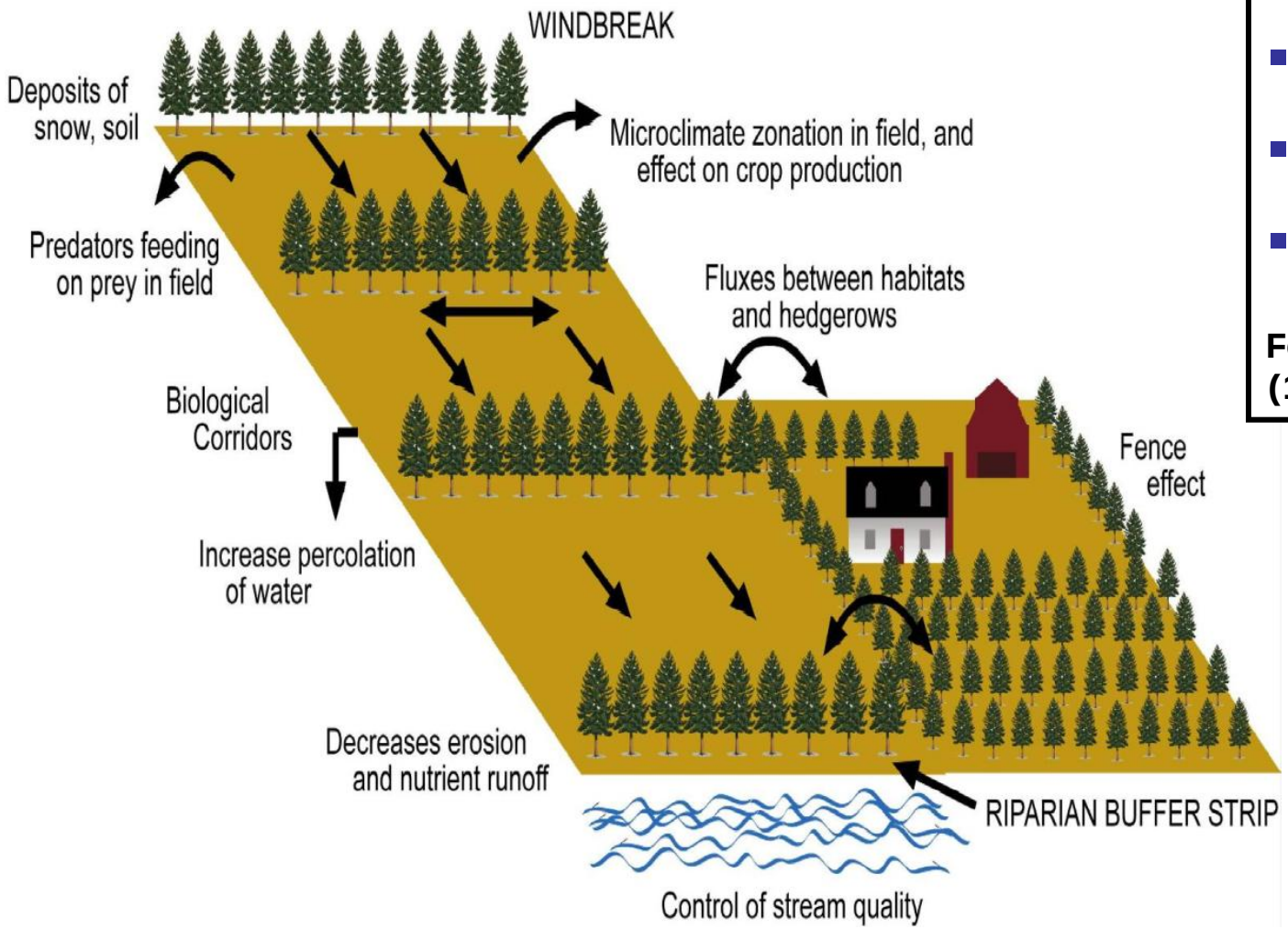
Agroforestry systems

- ✓ Disadvantages
  - On good cropland, returns not as immediately profitable
  - More intensive management than either monoculture
  - Initial labor input high
  - Not mainstream – limited temperate research/extension

Ecological functions

- habitat
- conduit
- filter/barrier
- sink
- source

Forman & Gordon (1986)



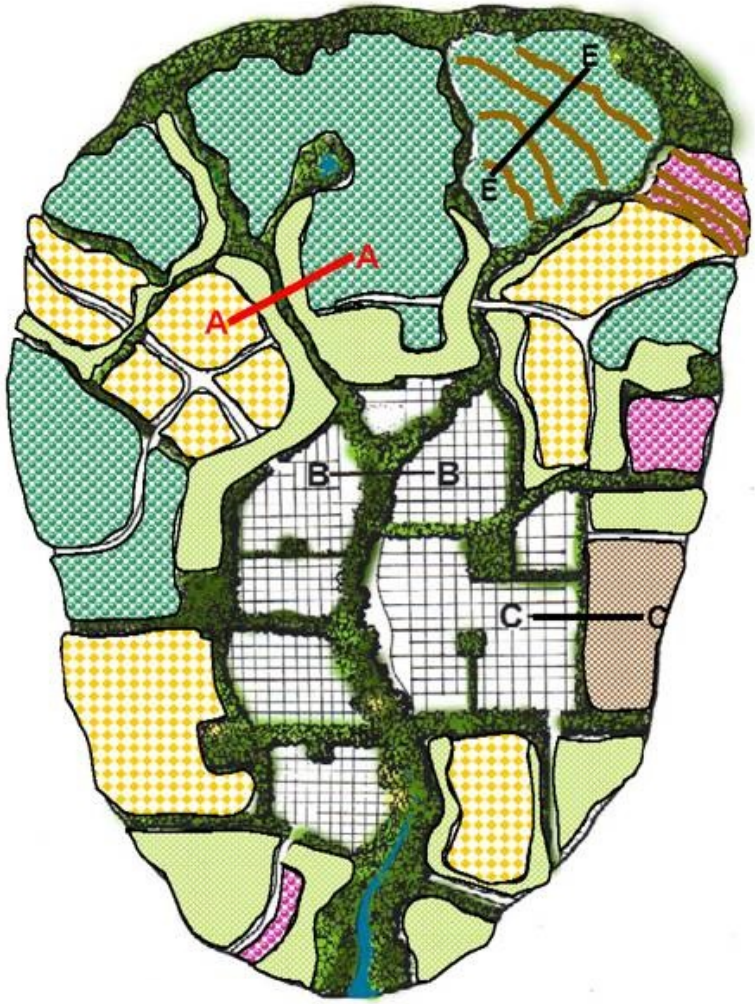
Multiple functions ~ Multiple services

Agroforestry is used for…

- crop and livestock production
- building and road protection
- water/air/soil quality
- economic diversification
- storm-water management
- rural/urban interface
- waste management
- wildlife habitat
- recreation
- greenhouse gas mitigation
- bioenergy

Multiple functions ~ Multiple services

Creating an integrated agricultural/forest bioenergy platform across the landscape



GUIDING PRINCIPLE

✓ **Using productive/conservation systems,**

such as ***agroforestry***

to restore and augment key agricultural and forest ecosystem services to support multiple objectives and a sustainable energy future

Corn/ethanol

Urban

Switchgrass/herb. Perennials

Food crops

Specialty Crops

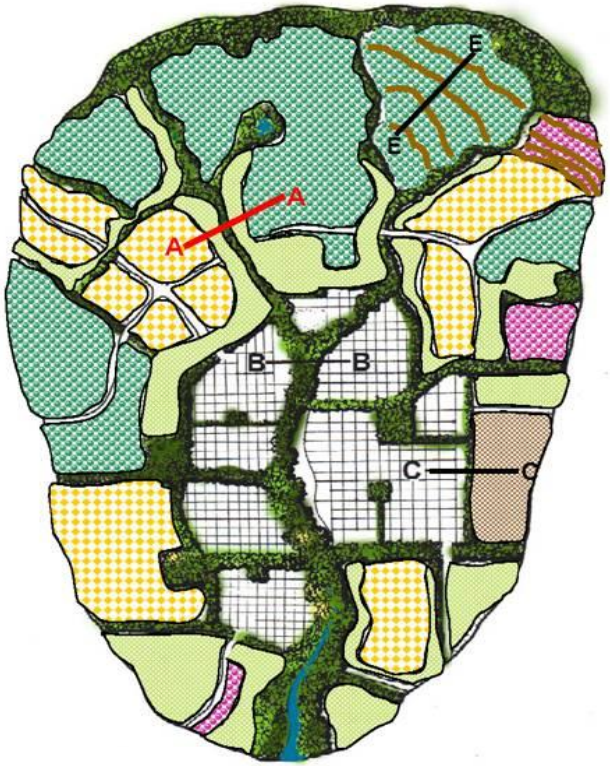
SRWC/Waste Treatment

Agroforestry: Working trees for energy

Additional conservation to support crop production and cellulosic operations, especially if crop residue harvested

- WATER QUALITY
- CARBON SEQUESTRATION
- INCREASING DIVERSITY
  - Wildlife habitat
  - Landscape connectivity
  - Species refugia (*esp. pollinators*)
  - Alternative products/incomes

Multiple roles along an energy continuum



Corn/ethanol | Urban | Switchgrass/herb. Perennials
Food crops | Specialty Crops | SRWC/Waste Treatment

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Agroforestry / timberbelts as a bioenergy feedstock source

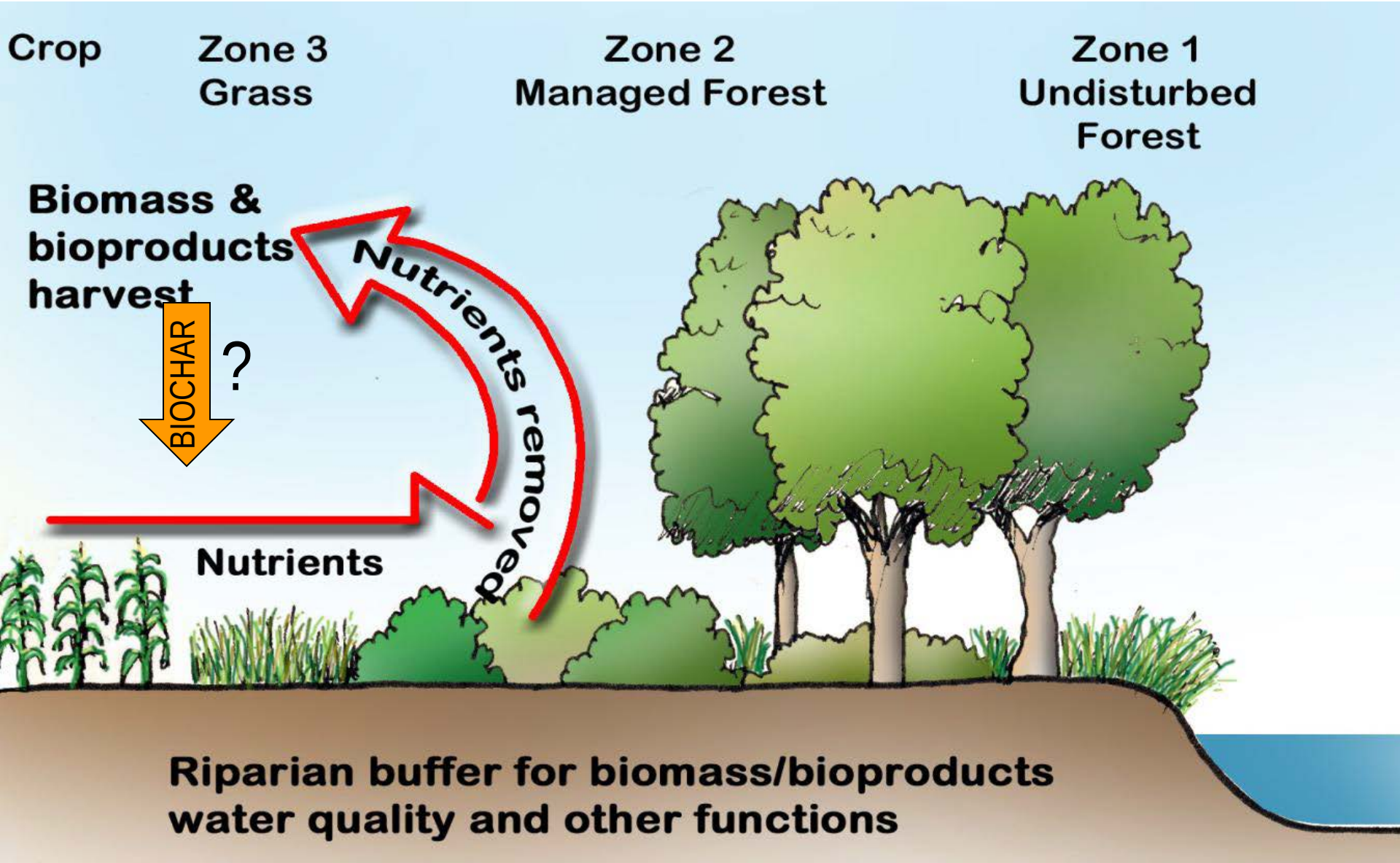
- ✓ Multiple-row windbreaks
- ✓ Commercially valuable, fast-growing trees (e.g., hybrid poplar, willow)
- ✓ Microclimate control – protect/ enhance crop/livestock production
- ✓ Sequential harvesting for biomass feedstock

Agroforestry systems to supply multiple-source bioenergy feedstocks

<u>Alley cropping</u>

- ✓ **Tree rows with herbaceous biomass feedstock alleys (e.g. sorghum, switchgrass)**
- ✓ **High value saw-timber with herbaceous feedstock alley-crop or vice versa**

Riparian buffers



Perennial grasslands enhance biodiversity and multiple ecosystem services in bioenergy landscapes

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Significance

Science-based polices are needed to inform sustainable bioenergy landscape design. Our key finding is that the linkage between biodiversity and ecosystem services is dependent not only on the choice of bioenergy crop but also on its location relative to other habitats. The implication is that careful design of bioenergy landscapes has the potential to enhance multiple services in food and energy crops, leading to important synergies that have not yet informed the ongoing bioenergy debate. This study is especially timely as high commodity prices are driving conversion of marginal lands to annual crop production, reducing future flexibility.

www.pnas.org/cgi/doi/10.1073/pnas.1309492111

Forest thinning to encourage understory forage

Conversion to silvopasture
(e.g. Buron Lanier Farm, Burgaw NC)

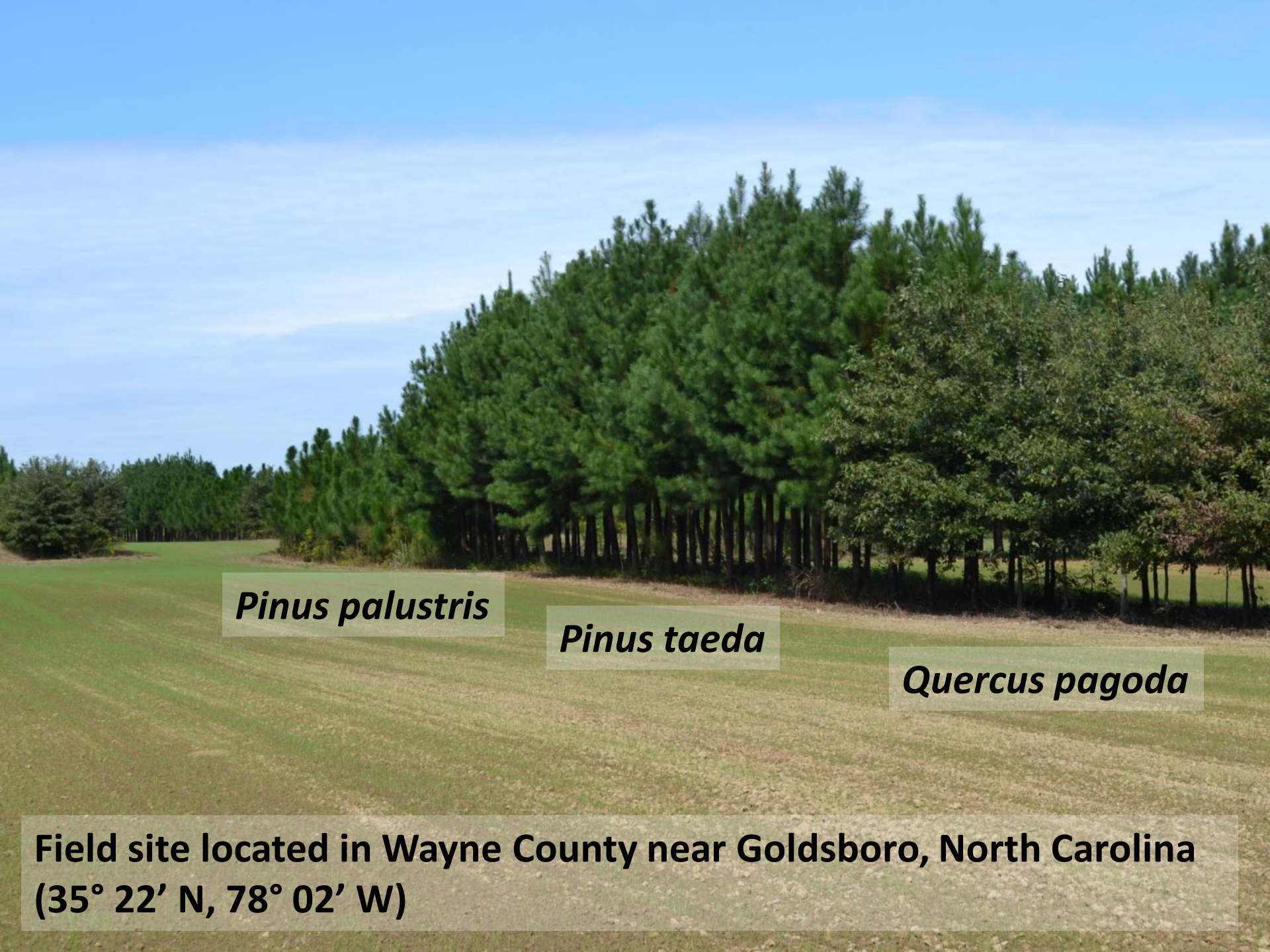
(Photo courtesy Randy Browning, U.S. Fish and Wildlife Service).

Example of trees planted onto pasture

17-year-old slash pine, bahiagrass, crimson clover, and cattle silvopasture. Trees were planted in double-row 4x8 ft spacing with 40 ft pasture alleys between the double-rows. Bahiagrass dominates alleys during summer and crimson clover during winter months. http://edis.ifas.ufl.edu/

Example of trees planted onto cropland

Center for Environmental Farming Systems
– Goldsboro NC



Field site located in Wayne County near Goldsboro, North Carolina (35° 22’ N, 78° 02’ W)

Objectives

1) NC agroforestry demonstration for landowners, farmers, and professionals
2) Long-term research of alley cropping and transition to silvopasture
3) Measure production tradeoffs of trees and crops / silvopasture
4) Research site for graduate students and professors with interests in agroforestry systems

- Site characteristics
  - 17 acre alley system initiated in 2007
  - Cropped field, Neuse River bottom, susceptible to floods / droughts
  - Mixture of soil types
- Tree species
  - Loblolly pine, longleaf pine, cherrybark oak
  - Planted in 3 row sets, 5’ x 5’ diamond spacing
- Tree planting
  - Drop tube – pottapookie for longleaf in sandy soils, or dibble in organic soil
  - Dibble for loblolly
  - Modified KBC 6” bar for cherrybark oak
- Weed control (1st and 2nd years)
  - Oust before bud break
  - Hand hoe to remove morning glory and sicklepod
- Crops
  - soybeans / corn rotation

Scientific leader – Paul Mueller, NCSU

Weather and crops

Year / crop	2007 Soybeans	2008 Corn	2009 Soybeans	2010 Corn
Growing season rainfall (in)	15	22	19	14
Crop yield, all replicates (bu/a)	12	51	12	20
Crop yield, Rep 5 bottomland (bu/a)	30	112	30	52

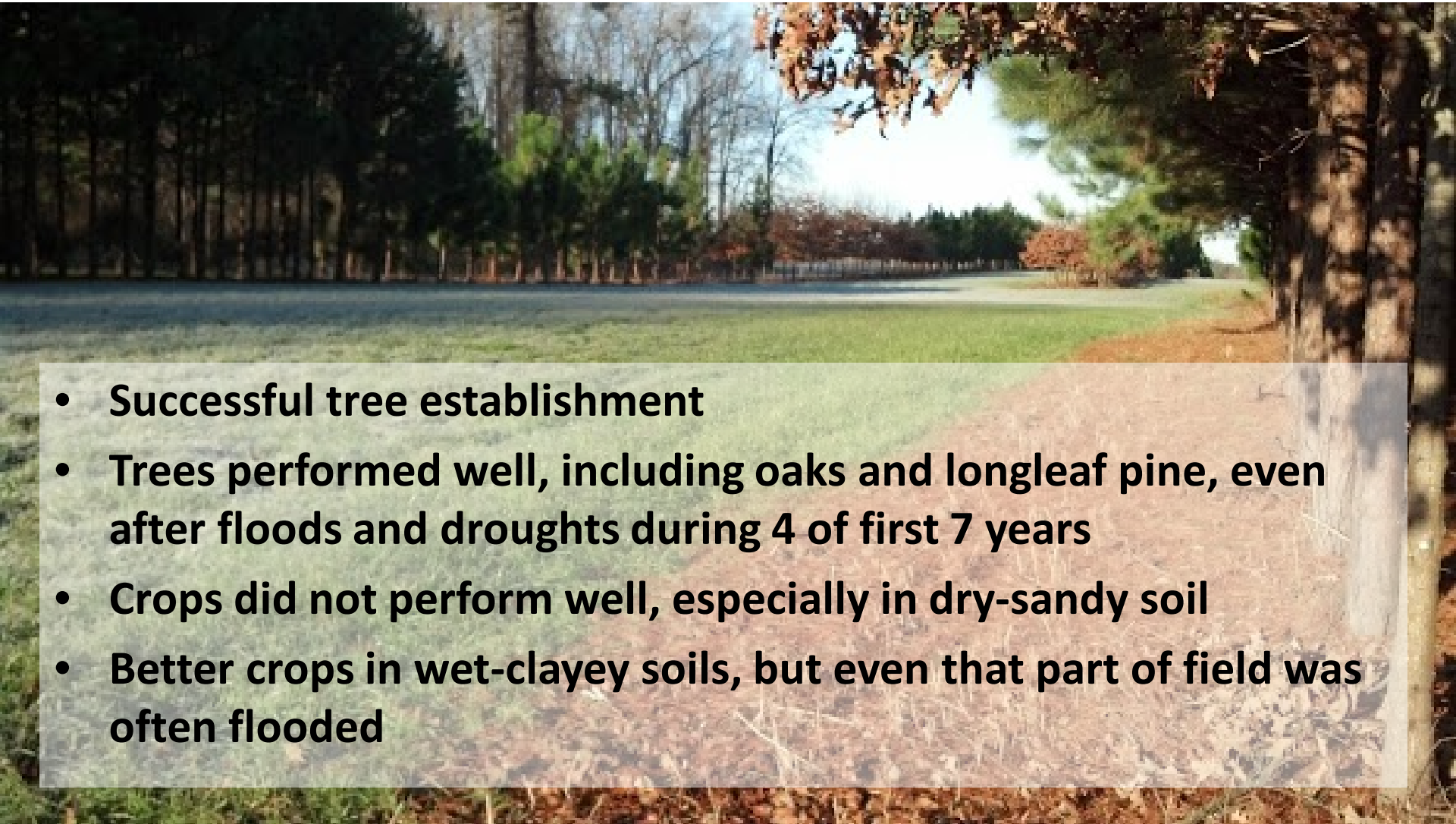
	2007	2008	2009	2010	2011	2012	2013
Yield (bu/a)	12	51	12	20	31	49	0
Net return ($/a)	-107	-120	-113	-324	97	-79	0

Soybean in alleys – August 2011

Corn in alleys – June 2012 – best site

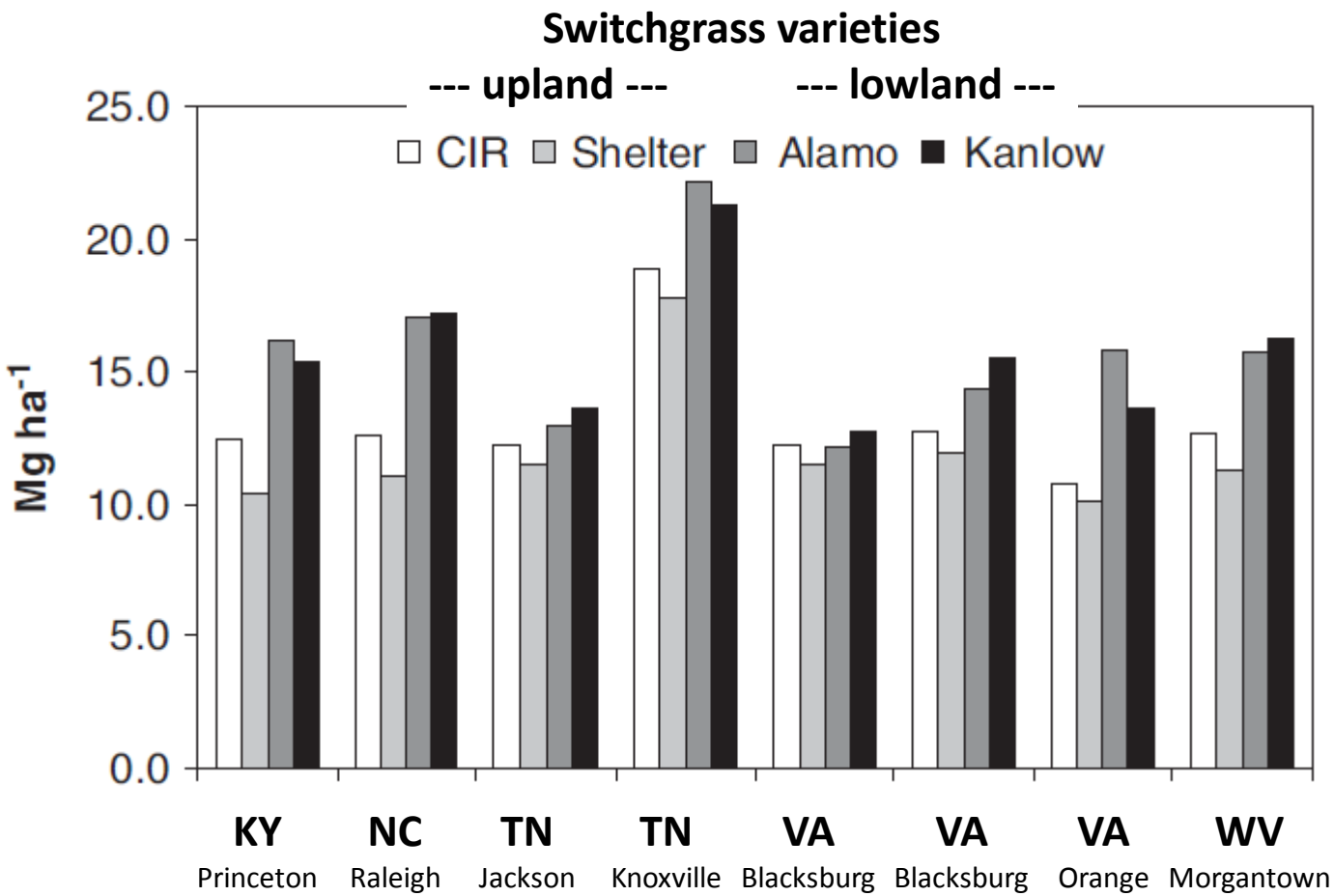
Corn in alleys – June 2012 – poor site

Conclusions from alley cropping



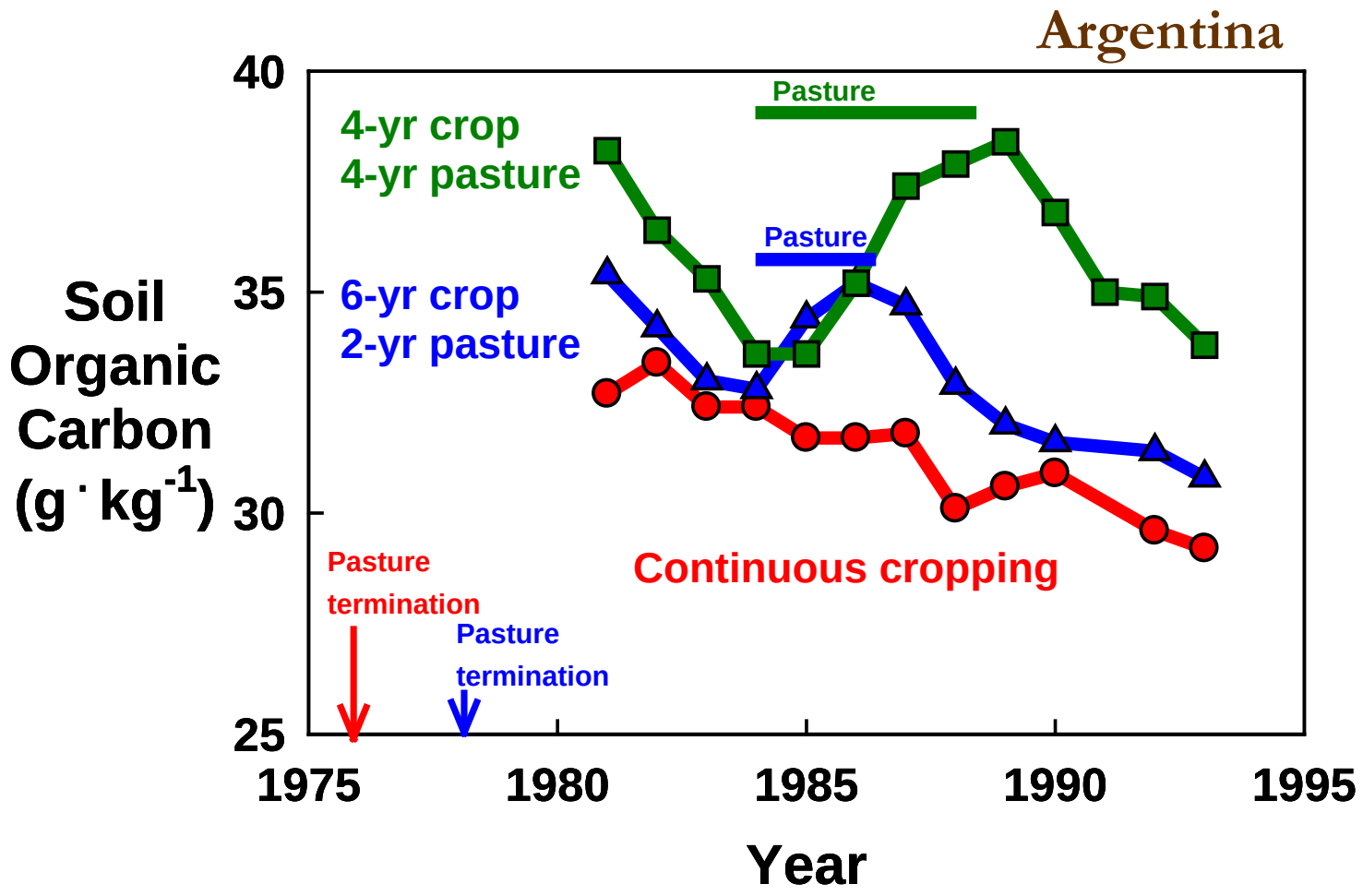
- Successful tree establishment
- Trees performed well, including oaks and longleaf pine, even after floods and droughts during 4 of first 7 years
- Crops did not perform well, especially in dry-sandy soil
- Better crops in wet-clayey soils, but even that part of field was often flooded

Opportunities with perennial forages



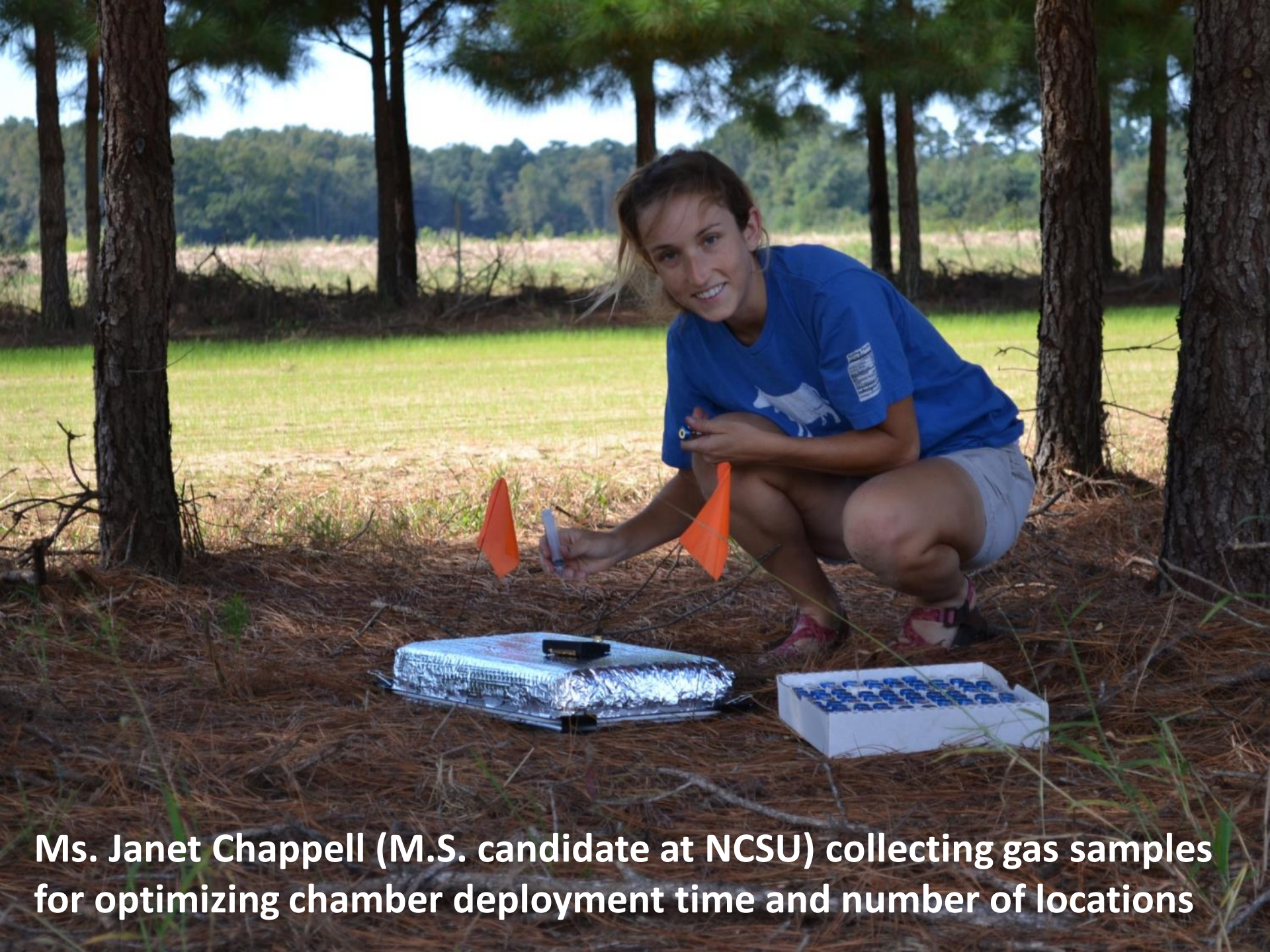
From Fike JH, Parrish DJ, Wolf DD, Balasko JA, Green JT, Rasnake M, Reynolds JH (2006) Biomass and Bioenergy 30:207-213

Perennial forages and soil organic C



Data from Studdert GA, Echeverria HE, Casanovas EM (1997) Soil Sci. Soc. Am. J. 61:1466-1472

Greenhouse gas sampling chamber under *Pinus taeda*



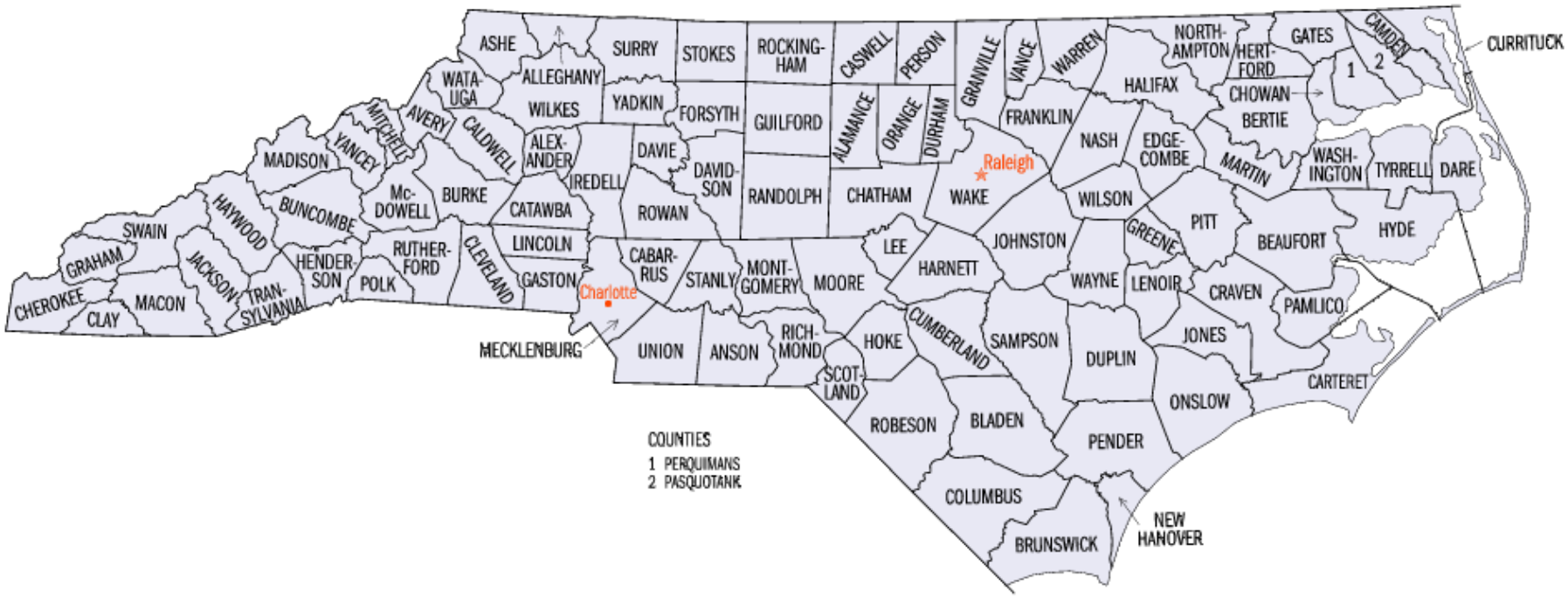
Ms. Janet Chappell (M.S. candidate at NCSU) collecting gas samples for optimizing chamber deployment time and number of locations

Collection of soil samples for determining soil organic C and N fractions, bulk density, and soil texture

Significant areas of marginal croplands in the southeastern USA

- **Unpredictable crop yields due to coarse texture that causes susceptibility to drought**
- **Ill-suited lands that must be drained for better aeration**
- **Susceptible to flooding**
- **Narrow corridors that limit equipment movements**
- **Poor access to favorable markets**

Marginal cropland in North Carolina



Realistic yield expectation for corn (http://nutrients.soil.ncsu.edu/yields/)

- **0.4 million acres (1%) <50 bu/a**
- **5.3 million acres (15%) <75 bu/a**
- **14.1 million acres (41%) <100 bu/a**

Thanks to David Crouse, NCSU Soil Science

2007 US Census of Agriculture

- **0.9 million acres of corn – mean yield of 101 bu/a**

Flexible opportunities

Silvopasture systems combine the ecological and production strengths of long-term woody biomass with similar strengths of short-term production food crops or herbaceous forages – flexibility maintained

Initial establishment costs may include:

- Herbicides and/or Labor for removal of competition and weed management = $50 to $250 per acre depending on mechanical or chemical application used and condition of site
- Prescribed burning = $20-25 per acre
- Tractor/equipment work for site preparation. On old agricultural fields disking/subsoiling = $25-50 per acre. On cutover forestland = $100-150
- Costs of seedlings: $40-75 per thousand bare-root; $100-125 per thousand containerized
- Labor for planting - $35-45 per acre for southern pines

Annual costs may include:

- Herbicides for continued management of competition
- Tree pruning (beginning around year 5 after establishment)
- Fencing and maintenance
- Fertilizer applications
- Watering facilities for cattle
- Forage or other annual crop seed
- Pre-commercial thinning

Cost estimates for forage management may include approximately:

- Establishment (seed+ planting costs + labor and equipment) = $275
- Annual nutrient costs - $85
- Annual Hay Harvesting Costs $20/ton = $60
- Periodic lime cost every 5 years = $24

Important points to consider:

Stress on cattle can decrease feed efficiency by as much as 20%. Therefore, if the average feed bill on open pasture is $150 per animal unit, a silvopasture system can save the farmer about $30 per animal unit annually due to reduced stress

The increased grazing period resulting from a well-managed forage rotation less affected by early fall/late spring frosts can reduce feed costs by as much as $25 per animal unit per year

Reduction in fertilizer and herbicides can save as much as $15 per acre

Nutrient cycling can save up to $5 per acre

Grazing can eliminate the cost of mechanical or chemical competition control in mid-rotation pine plantations