



Temperate Agroforestry in the 21st Century: A North American Perspective

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Challenges of the 21st Century

Food
+50%

Energy
+50%



Water
+50%

GHG emission
+37%

Biodiversity Loss
-68% forest loss in SA
-26% in China
-24% in Africa
-20% in EE,AU, NZ

Diseases, invasives
+50%



Food-Energy-Environment Trilemma

Tilman et al. 2009, Science 325

The World is Looking for Sustainable Solutions



Food-Energy-Environment Trilemma



Can Agroforestry Be Part of the Solution?





BTW, What is Agroforestry?

Trees/Shrubs on a Farm

Meet the 4 "I" Criteria

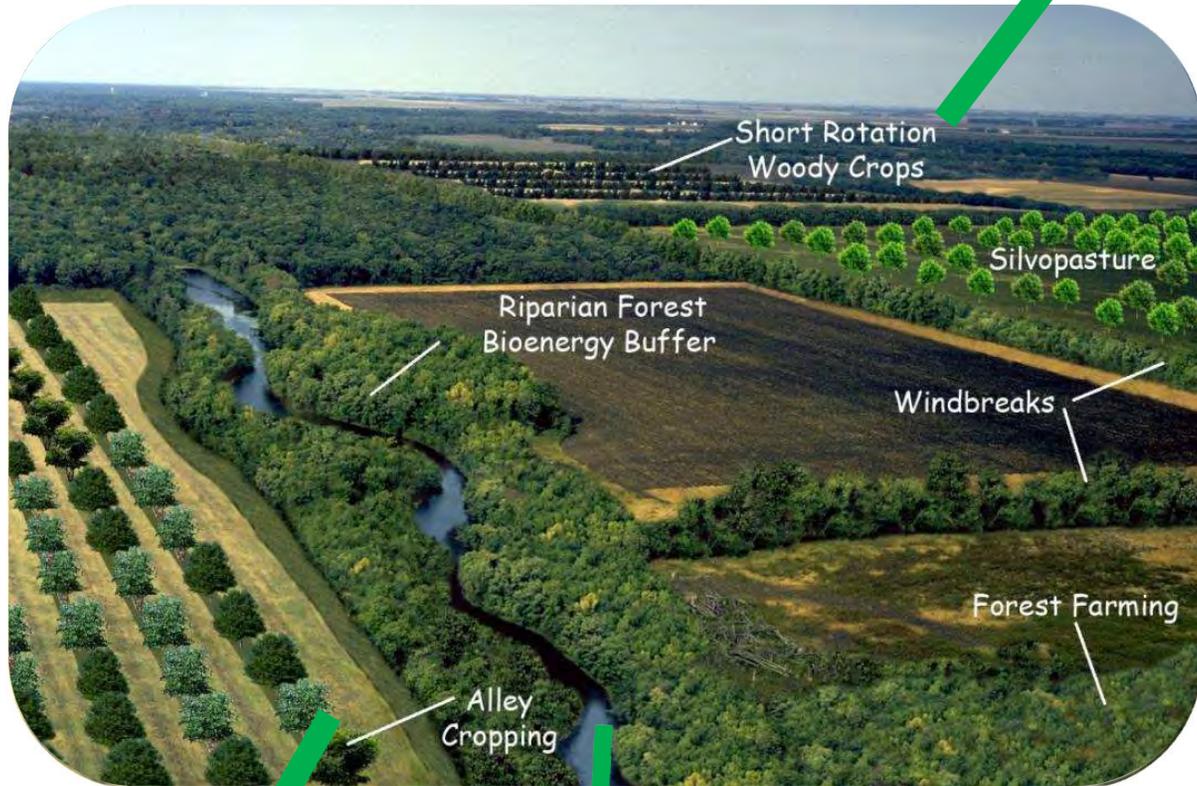
Intentional
Integrated
Interactive
Intensive

Windbreaks/Shelterbelts
Alley Cropping/Intercropping
Riparian Buffer
Silvopasture
Forest Farming



Can Agroforestry Be Part of the Solution?

Yes, We Know; Time to Make it Mainstream



So, Where is Agroforestry Headed?

National Agroforestry Center (origin in the 1990 Farm Bill; started in 1992; as a partnership between Forest Service and NRCS in 1995)

University programs (Several; MU, VA Tech, UMN, UF, Illinois, Oregon, Penn State, New Mexico State Univ., Auburn, Tuskegee, Cornell, Northern Arizona, Iowa State)

AFTA

University of Missouri Center for Agroforestry

USDA Policy for Agroforestry (The Framework, 2011)

Regional Working Groups

Training Programs (Online, Agroforestry Academy, Agroforestry Institute)

Savanna Institute

Certified Agroforester – Andy Mason





So, Where is Agroforestry Headed?



Top 10 USDA Science Efforts (Office of the Chief Scientist) (2014)

1. Genetics and Genomics
2. Climate Change
3. The Human Microbiome
4. Behavioral Economics
5. Open Data for Agriculture
- 6. Agroforestry**
7. Food Safety
8. Bioproducts and Bioenergy
9. Nutrition and Epigenetics
10. Grand Challenges in Biology

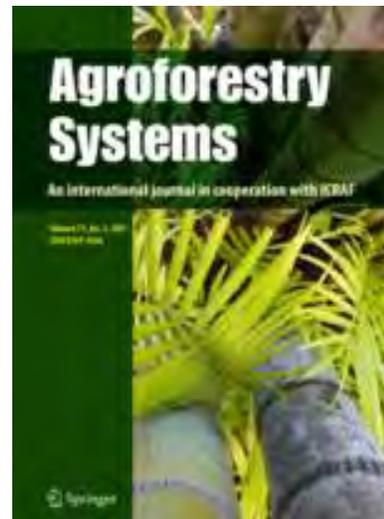


Agroforestry as a Science

Not an “age-old practice with a new name” anymore!

A strong scientific foundation has been laid, particularly during the last two decades

Biophysical and Socioeconomic dimensions have been explored in detail



Springer-Nature

Nearly 400 submissions from 79 countries!

A rejection rate of 66% in 2018

Shibu Jose, Editor-In-Chief

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Agroforestry As a Practice

USA

Forests = 300 million ha

Farmland = 179 million ha

Pasture – 237 million ha

Total = 716 million ha

Agroforestry = 61 million ha (~8%)

**Or 7 million ha (~1%)
(if you remove grazed forests)**



Can Agroforestry Provide Food Security?

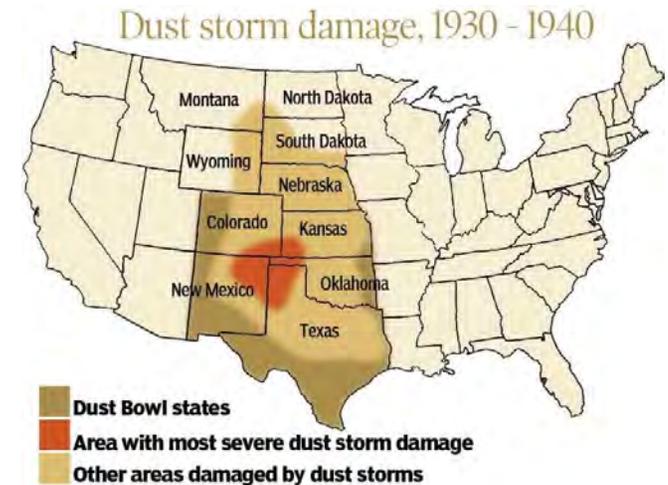


Dust bowl of the 1930s

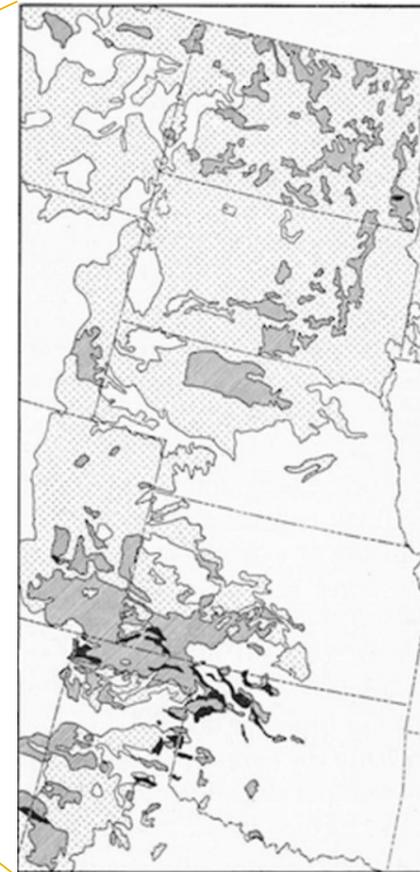
Prolonged drought

Severe soil erosion

Famine and great depression



Severity of Soil Erosion from Dust Bowl



0 2 3 4

1 Most Severe, 2 Moderate, 3 Mild and 4 None

Windbreaks Transformed the Great Plains from a Desert to Productive Agricultural Land



Great Plains produce wheat, cotton, corn (maize), sorghum, and hay and cattle and sheep.

Known as the Wheat Belt of the United States

How Did We Do It?

220 million tree seedlings and
~19,000 miles planted in the 30s

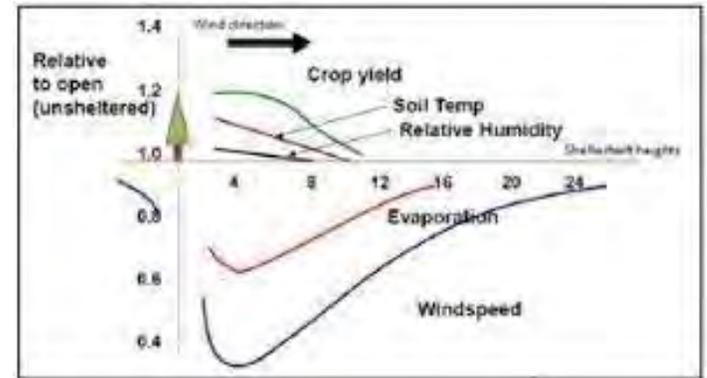
86,000 miles of field windbreaks
today

Protect about 4 million acres of
agricultural land in the Great Plains

Nebraska:

- 15,300 miles of field windbreaks protect 1 million acres of crops
- \$72 million/year in increased crop yields

A major effort underway to map crop yield in
relation to windbreaks in the Great Plains;
Number of papers from USA, Canada, China



Trees Can Generate Income Too!

Farm Diversification – Global Competitiveness

- ◆ Chinese Chestnut - \$6000 /acre/year
beginning 7th yr

Castanea mollissima

(Fagaceae)



- ◆ Pecan - \$3000 /acre/yr
beginning 8th yr

Carya illinoensis

(Juglandaceae)



- ◆ Elderberry - \$6000 – 12,000 /acre/yr

Sambucus Spp.

(Adoxaceae)



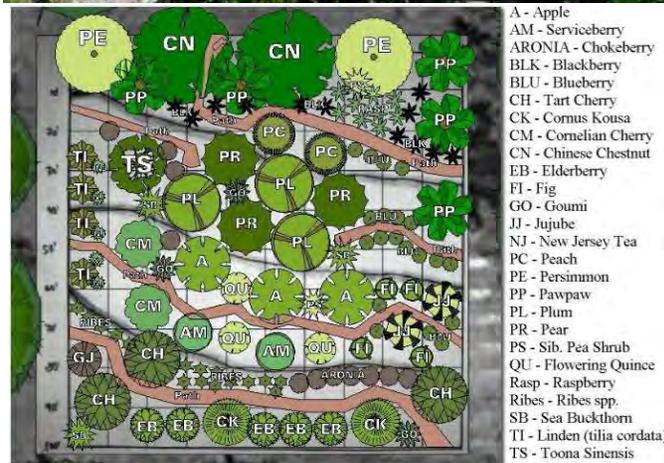
Even Trees in Cities Can Provide Food and Protection

Urban Agroforests/Food Forests



Seattle

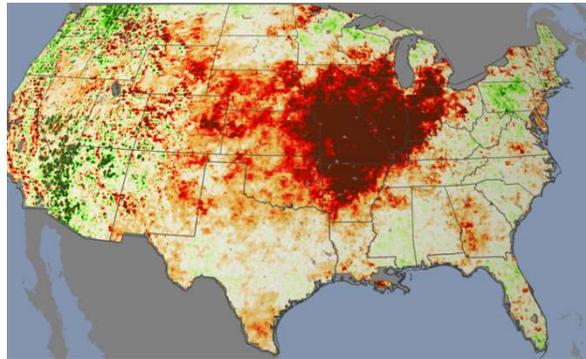
Pittsburgh



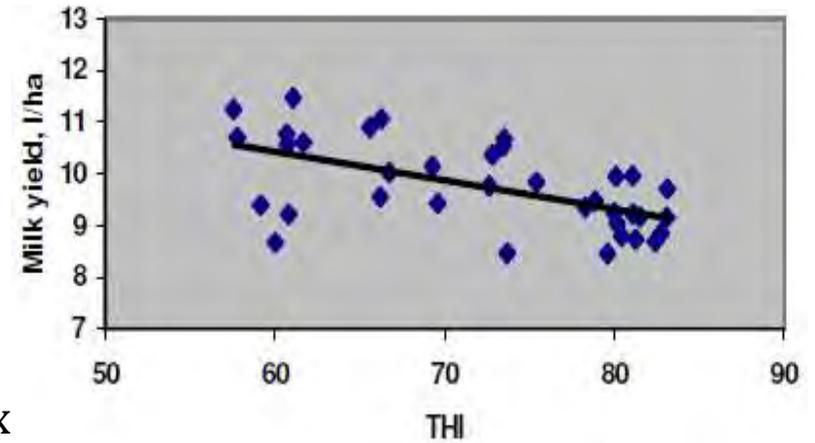
The canopy and shrub layers of our planned food forest.

Kansas City

Planting Trees on Pastures Can Help Livestock Industry



2012 August- Heat Stress Index



\$2 billion lost annually!!

Planting Trees = Less Stress = \$\$\$\$\$\$

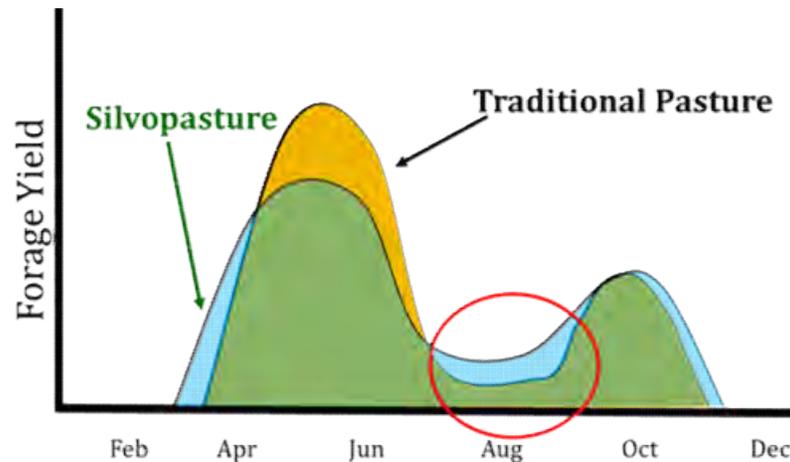
- Dairy cows provided with shade produced 10-19% more milk than non-shaded cows (University of Florida)
- When temperatures exceeded 90°F, milk production decreased by 20 to 30% (Virginia Tech. University)
- Cattle provided with shade had conception rates of 44%, compared to conception rates of 25% without shade (University of Florida)
- Shade increased overall pregnancy rates of cattle by 40% (87.5% with shade compared to 50% without shade)(University of Missouri)





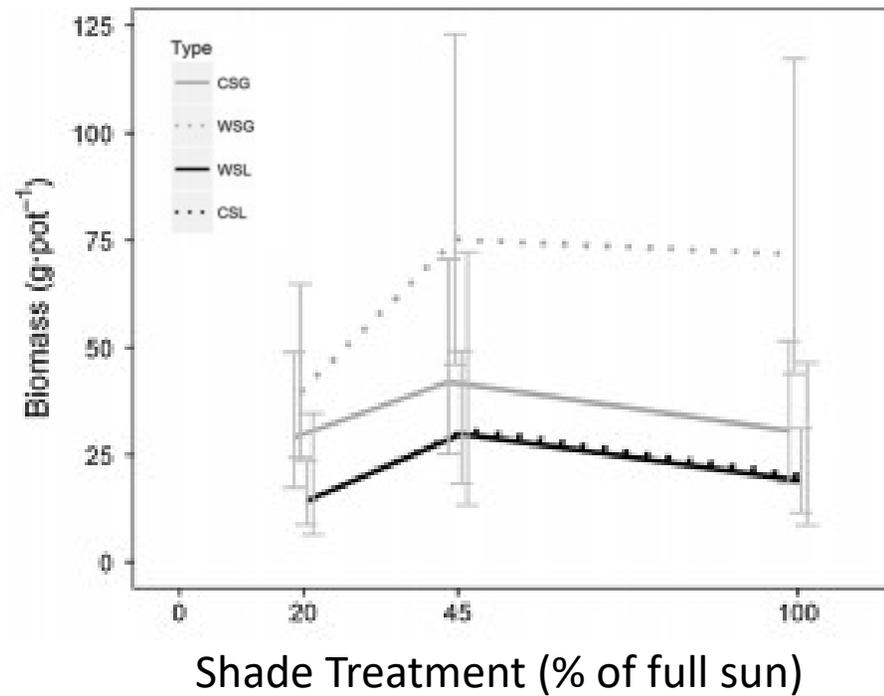
Data from Silvopasture

- Lost approximately 10% less weight over winter
 - Had less stress at calving
 - Heavier calves
-
- Overall returns in the *Silvopastoral* system were about **\$110 per pair** greater than in the *Traditional* pasture





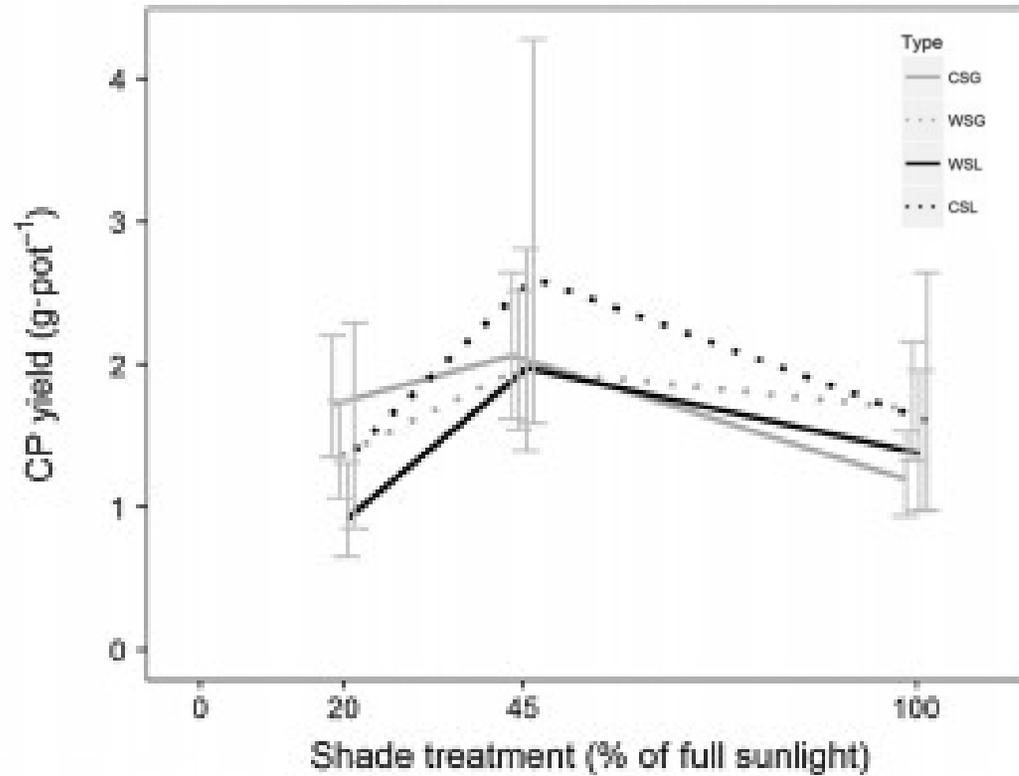
Shade and Forage Quantity



Pang et al. 2019

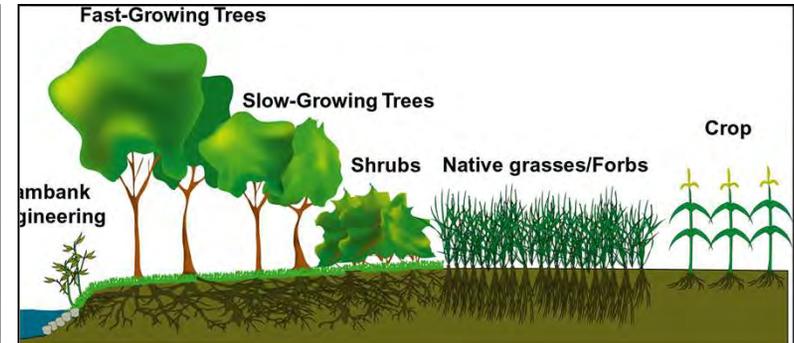


Shade and Forage Quality



Pang et al. 2019

Riparian Buffer: Another Agroforestry Practice



Water Quality Is A Major Concern

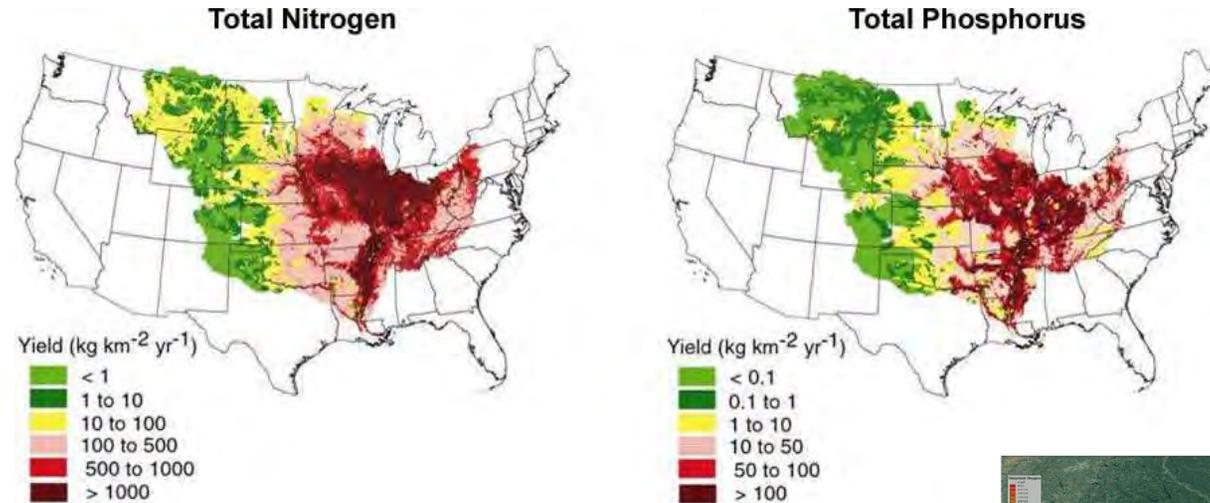
| Water Body | Total size | Assessed (% of total) | Impaired (% of assessed) |
|------------|---------------------|-----------------------|--------------------------|
| Rivers | 3,533,205 miles | 19% | 39% |
| Lakes | 41.7 million acres | 43% | 45% |
| Estuaries | 87,791 square miles | 36% | 51% |

EPA, 2012

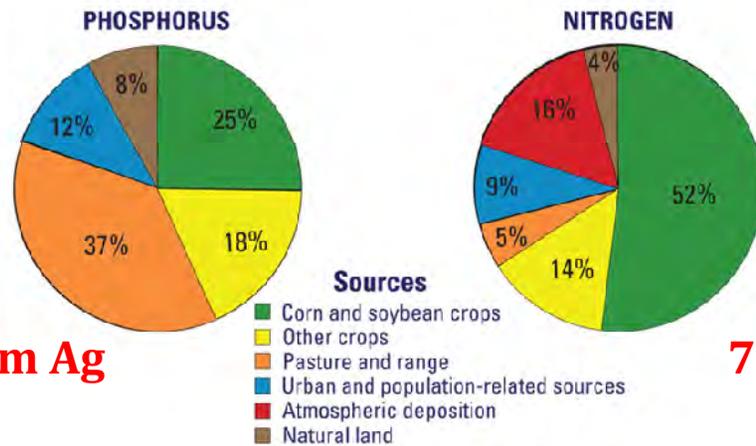




Hypoxia in the Gulf of Mexico

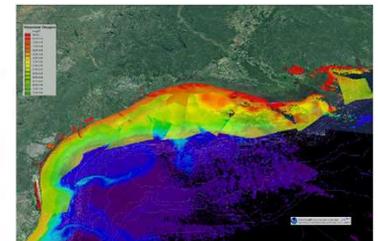


Sources of nutrients delivered to the Gulf of Mexico



80% of P from Ag

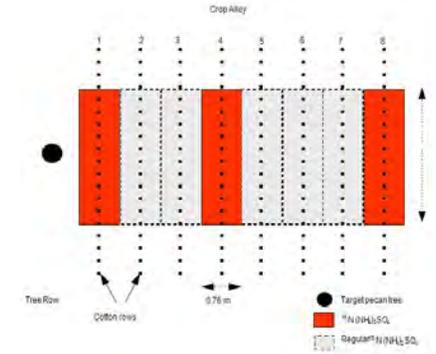
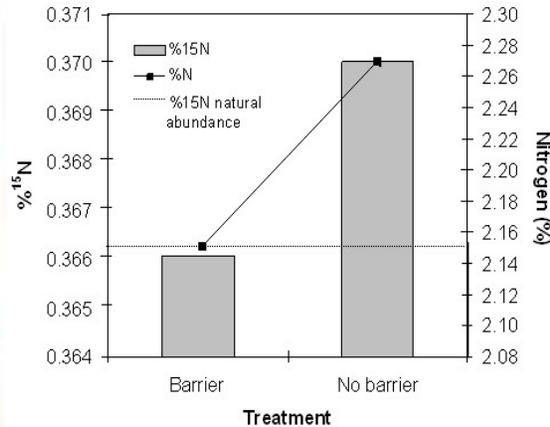
71% of N from Ag



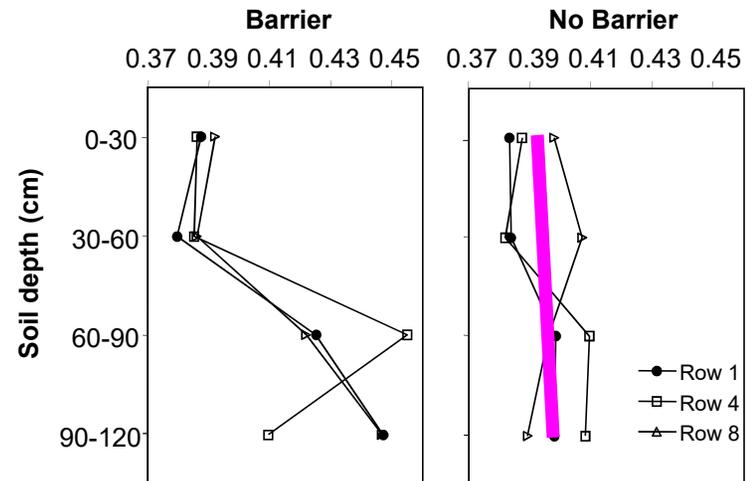
Safety net Role of Tree Roots



Pecan N% and 15N

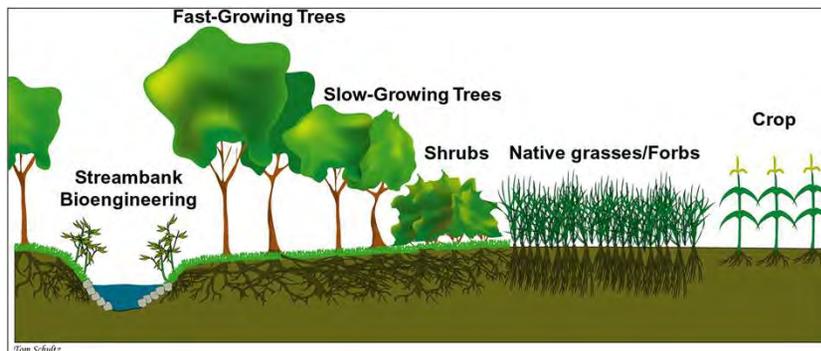
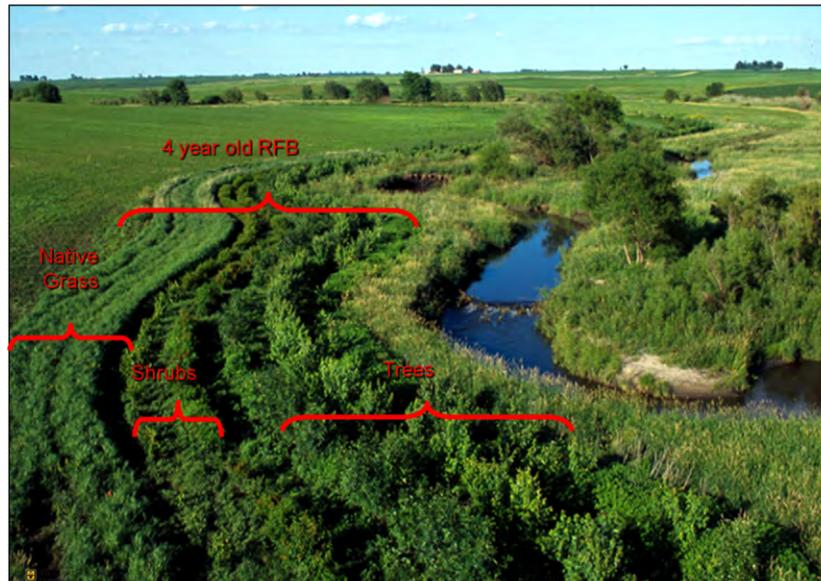


Soil ¹⁵N



Allen et al. 2004. Forest Ecology and Management, 192:395-407

Agroforestry/Riparian Buffers Can Reduce Nutrient Loading!



50 to 80% total N
41 to 92% NO₃-N

46 to 93% total P
28 to 85% dissolved P

Lin et al., 2000; 2003;
Schultz et al., 2009

Iowa State Univ.

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AF Can Reduce Veterinary Antibiotics in Surface and Ground Water!

11 to 16 million kg of Veterinary Antibiotics (VA) used annually in U.S. (Levy, 1998; Mellon et al., 2001)

Therapeutic, prophylactic, and growth promotion purposes

30 to 80% of a VA dose passes through the GI tract

VA concentrations in manure range from trace to 200 mg L⁻¹ or kg⁻¹ (Kumar et al., 2005)

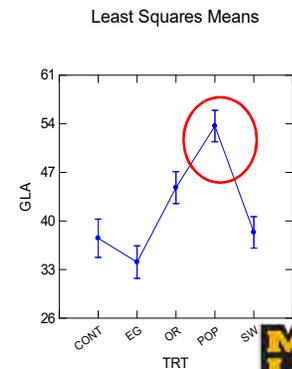
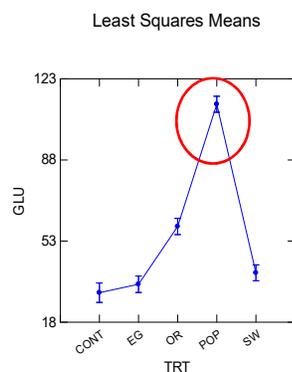
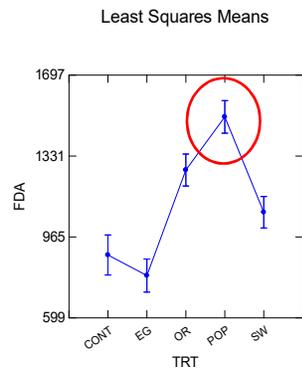
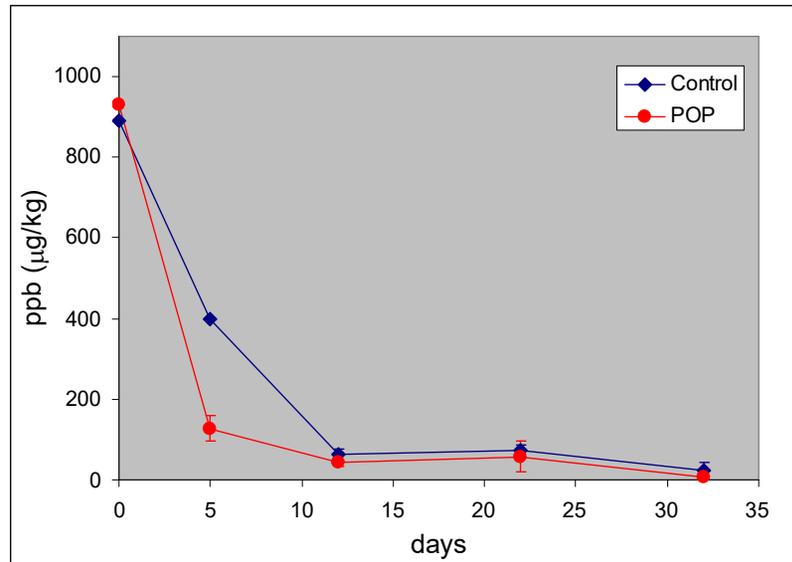
VAs in water resources – **Major Water Quality Concern!!**



Veterinary Antibiotics – Microbial Degradation

Enhanced Rhizodegradation of Antibiotic (Sulfamethazine) by Poplar

Via Increased Microbial Enzyme Activities (FDA, fluorescein diacetate hydrolytic; GLA, glucosaminidase, GLU, β -glucosidase)



Lin and Goyné, Lin et al. 2010

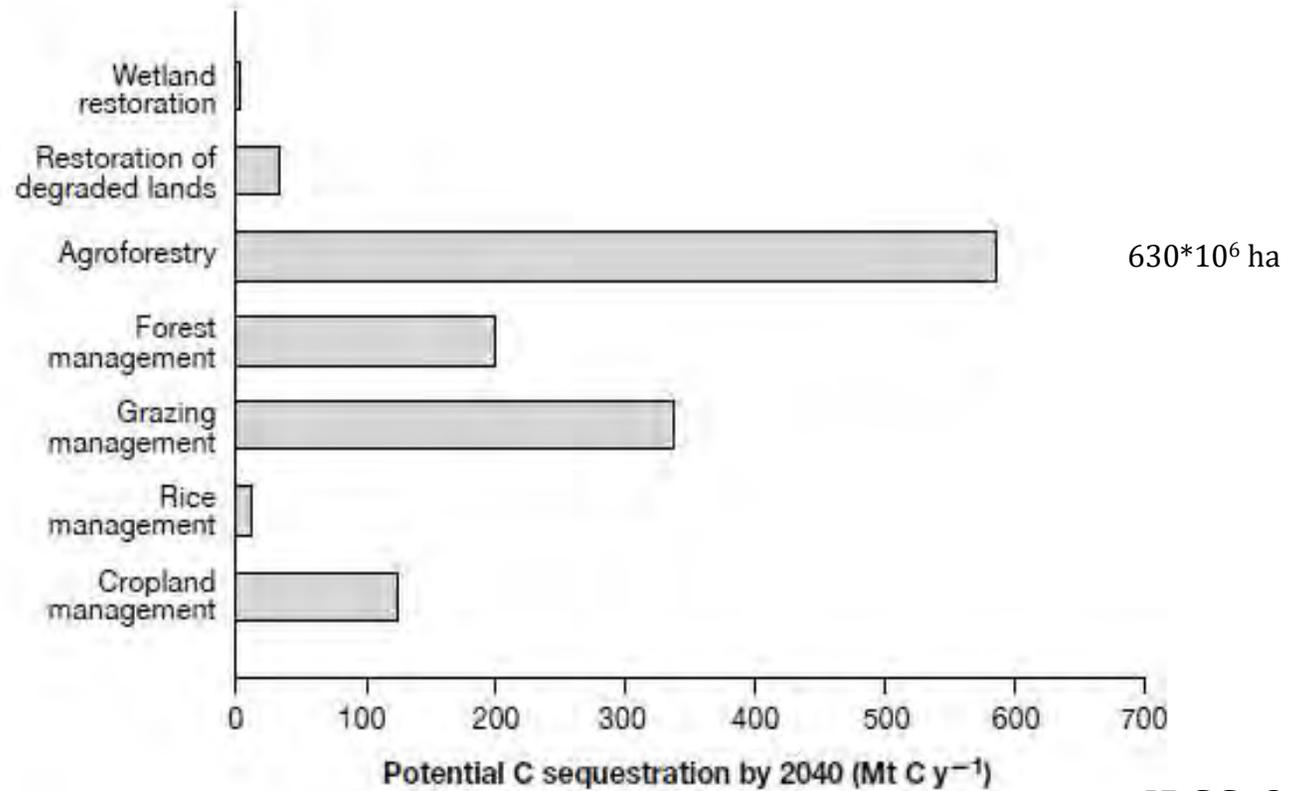


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Agroforestry for C Sequestration



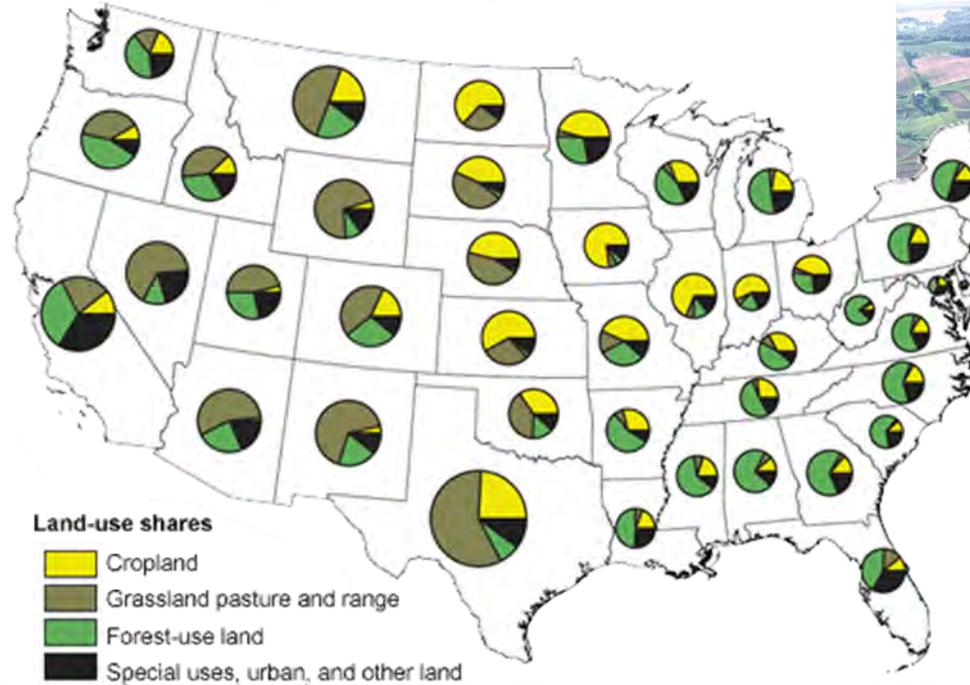
IPCC, 2000

Estimated C sequestration = 1.1-2.2 PgC/yr
(Dixon, 1995)

Planting Trees On Farms

Can help increase C Density on 23.7 million marginal pasture and 17.9 million marginal cropland in the US

Shares of land in major uses, 48 contiguous United States, 2002



Estimates of C Sequestration

10% of the pasture land (23.7 million ha);
54 million ha of grazed forestland (18% of
the U.S. forestland); 474 Tg C yr⁻¹

10% of the crop land (17.9
million ha); 61 Tg C yr⁻¹ (**Actual
Area =< 0.5 million ha**)

5% of cropland (8.95 million ha);
Poplar and White Spruce; 20-yr
rotation; 9 Tg C yr⁻¹; (**Actual Area
=1.21 million ha**)

30-m wide riparian buffer along both
sides of 5% of total river length - 1.69
million ha; 5 Tg C yr⁻¹ (**Actual Area
=1.15 million ha of upland and riparian
buffer, NRCS**)



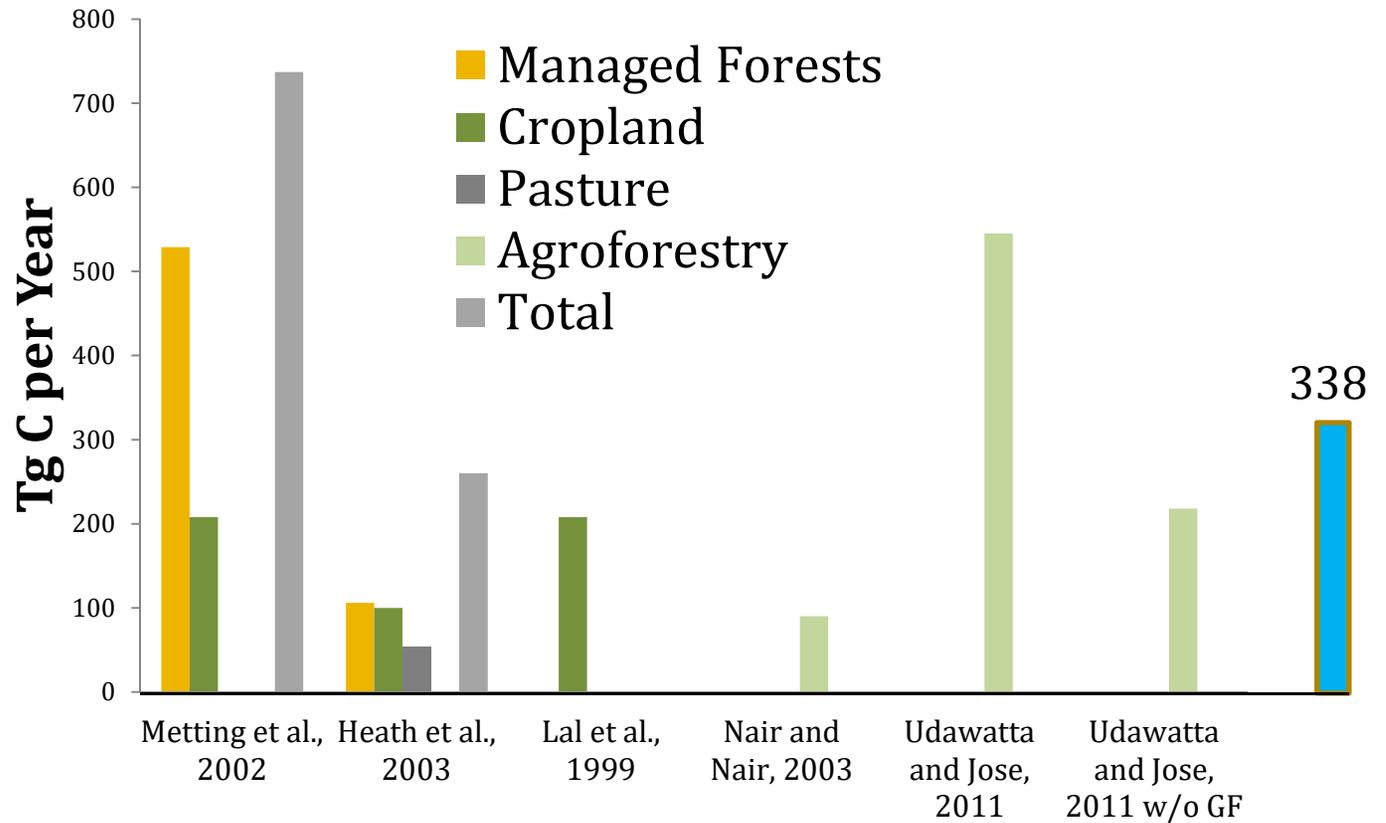
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- (Udawatta and Jose, 2011)



Agroforestry Could Offset Current C Emission Rate by 13 - 34%





Agroforestry/Windbreaks for Air Quality

Confined Animal Feeding Operations (CAFO) are increasing in numbers

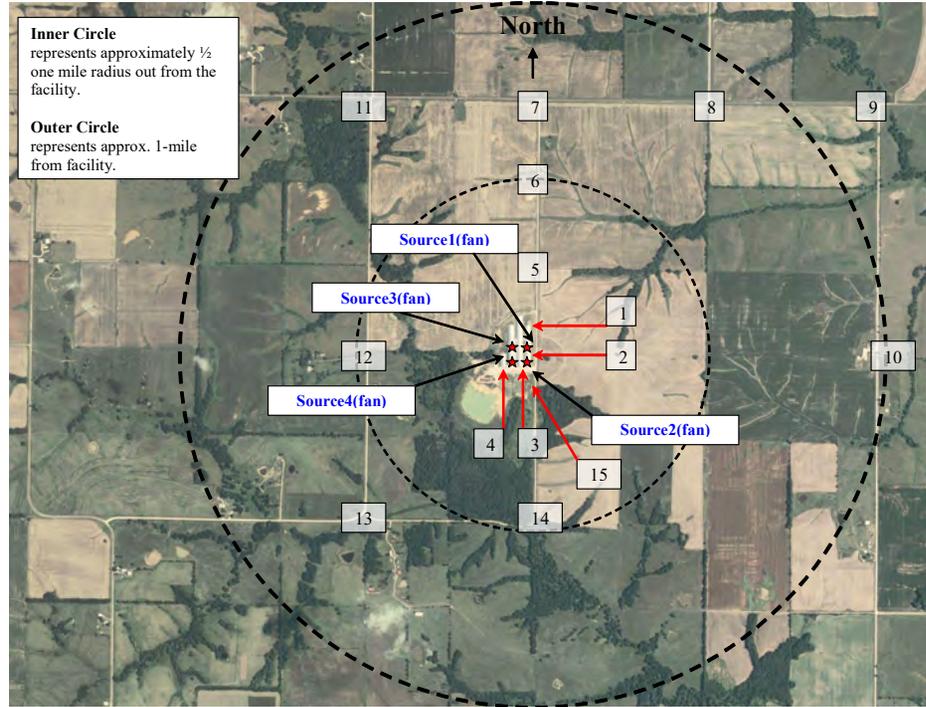
Odors from CAFOs is a major environmental concern

Vegetative environmental buffers (VEBs) for odor abatement is an option

Significant quantities of compounds known to correlate highly with odor can be removed through the use of windbreak technology

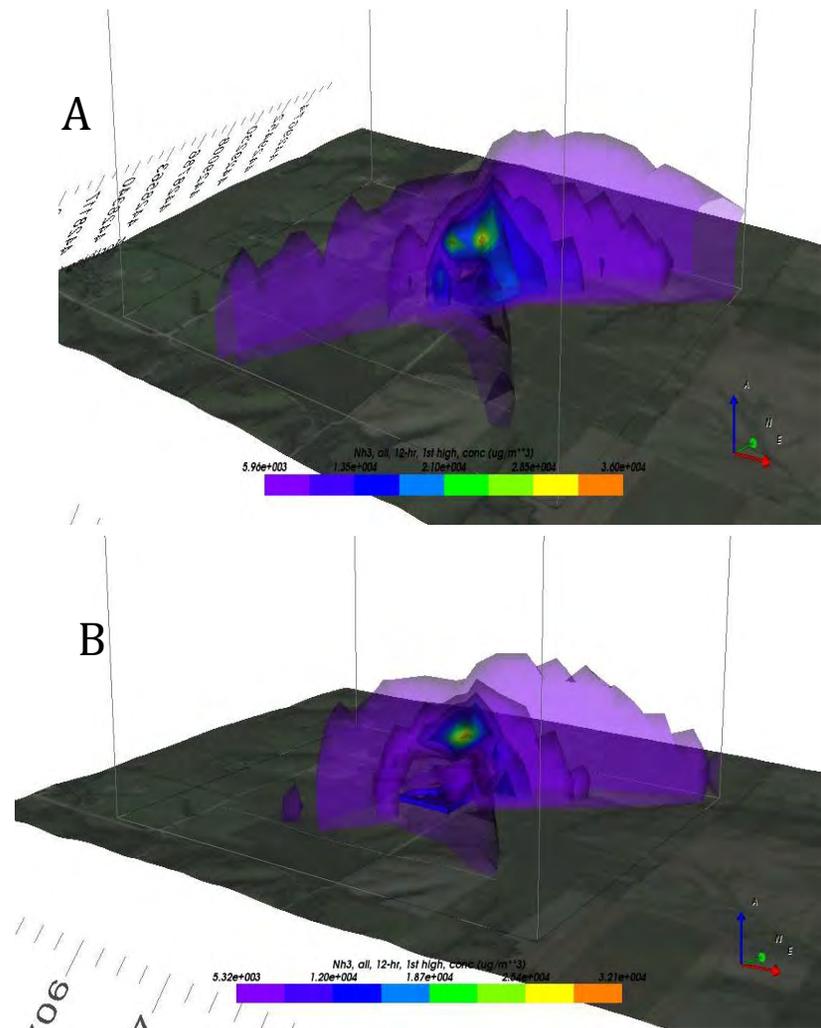
e.g., ammonia 47%;
dust emissions 50%

Agroforestry for Air Quality: VEBs





VEB: 27% Reduction in NH_3



12 hr AERMOD model simulation showing 3-D dispersion of NH_3 without VEB (A), and with a fully developed VEB (B) – 27% Reduction

Lin et al. 2012



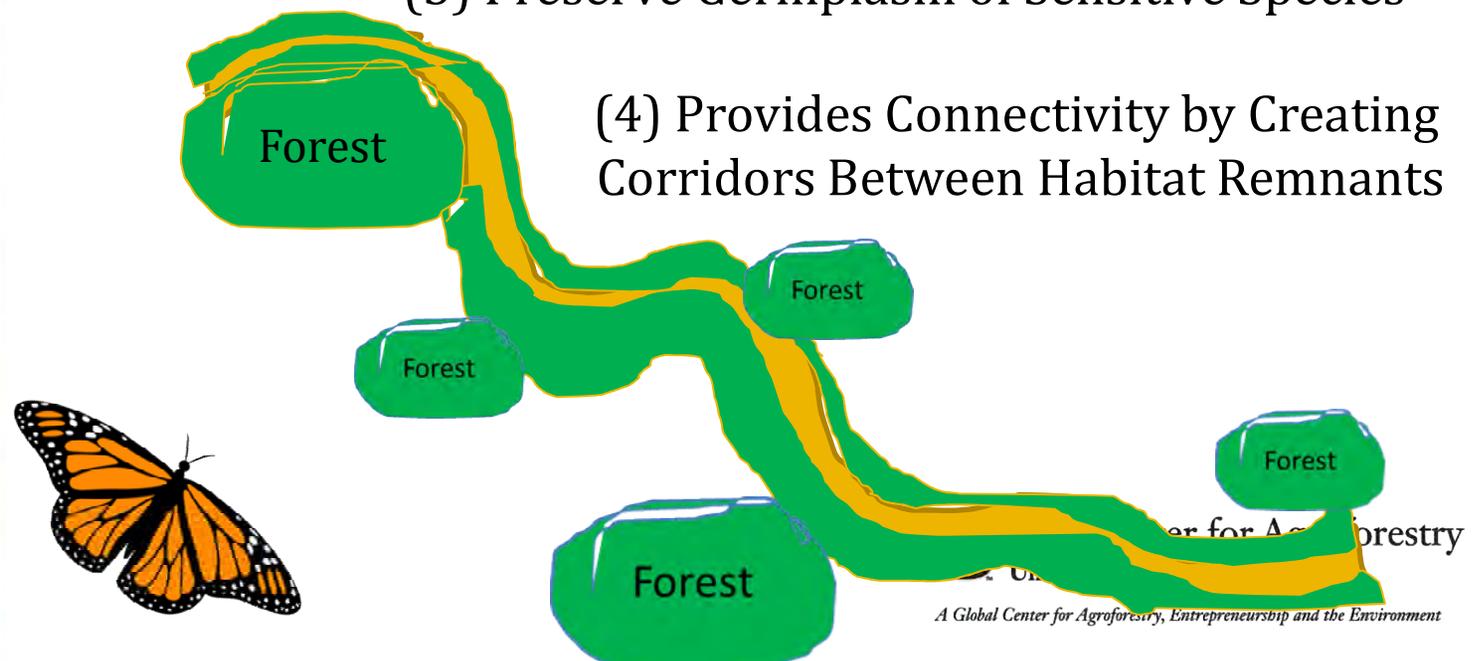
Agroforestry for Biodiversity Conservation: Habitat/Pollinators

(1) Reducing Pressure on Natural Habitats by Providing a More Productive, Sustainable Alternative to Traditional Agriculture

(2) Providing Habitat for Native Plant and Animals that Can Tolerate Certain Level of Disturbance

(3) Preserve Germplasm of Sensitive Species

(4) Provides Connectivity by Creating Corridors Between Habitat Remnants





Well, the Momentum Is Building in the US and Canada

- Young farmers are interested in diversifying their farms
- Older farmers are looking for perennial crops so that they don't have to do all the annual disking, planting etc.
- Revival of carbon markets for climate change mitigation
- Agroforestry's role in conservation – soil health, pollinators, corridors
- Growing interest in specialty crop production and emphasis on local food, organic food, and urban food forests
- Agroforestry as an economic engine for rural revitalization



In Conclusion.....

We **should** support agroforestry as a land management approach because it helps landowners achieve certain natural resource goals, such as clean water and productive soils... (Sec. Vilsack, April 17, 2012)

...which will lead to economic and environmental prosperity of our nations

Much work still remains.....



Not only in research.....



....but in making agroforestry a mainstream land use practice, as part of a multifunctional working landscape, for the right reasons