Agroforestry for Ecosystem Services and Environmental Benefits

Shibu Jose

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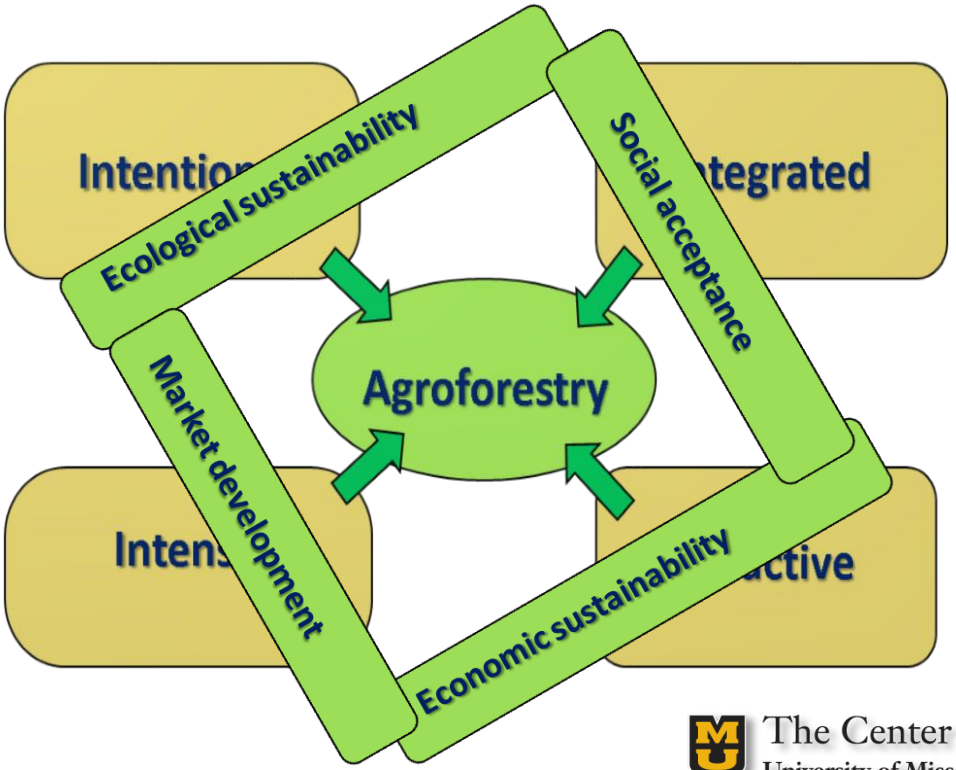
Agroforestry: Age-old Practice with a New Name?

Intentional integration of trees and crops/livestock where interactions are intensively managed



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Claims Galore!!

Agroforestry can be developed for: poverty alleviation; food security; carbon sequestration; combating deforestation and desertification; fodder and fuel-wood supply; and environmental protection (Nair, IUFRO Congress, 2010)

We support agroforestry as a land management approach because it helps landowners achieve certain natural resource goals, such as clean water and productive soils…America's economic success is directly linked to a continous and abundant supply of clean water (Sec. Vilsack, April 17, 2012)

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Science is Now Supporting the Claims!

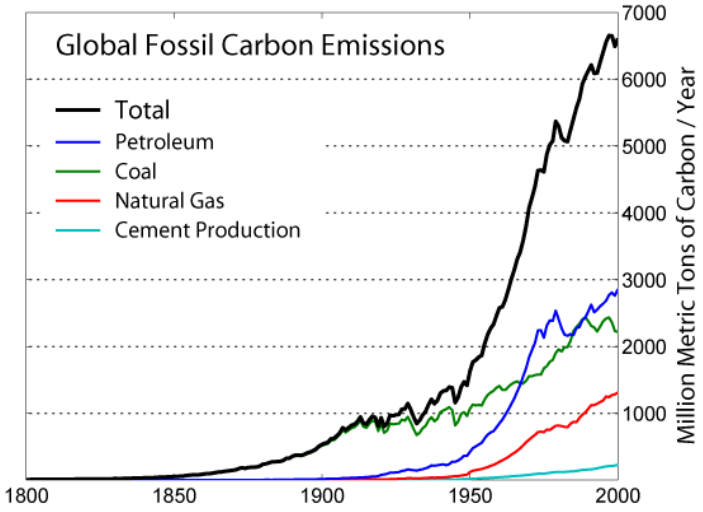
Data to support the claims of ecosystem services and environmental benefits provided by AF

(1) Carbon sequestration,
(2) Biodiversity conservation
(3) Soil enrichment
(4) Air and water quality

Ecosystem Services	Spatial Scale		
	Farm/Local	Landscape/Regional	Global
Net Primary Production	■		
Pest Control	■		
Pollination/Seed Dispersal	■		
Soil Enrichment	■		
Soil Stabilization/Erosion Control	■		
Clean Water	■	■	
Flood Mitigation	■	■	
Clean Air	■	■	
Carbon Sequestration	■	■	■
Biodiversity	■	■	■
Aesthetics/Cultural	■	■	■

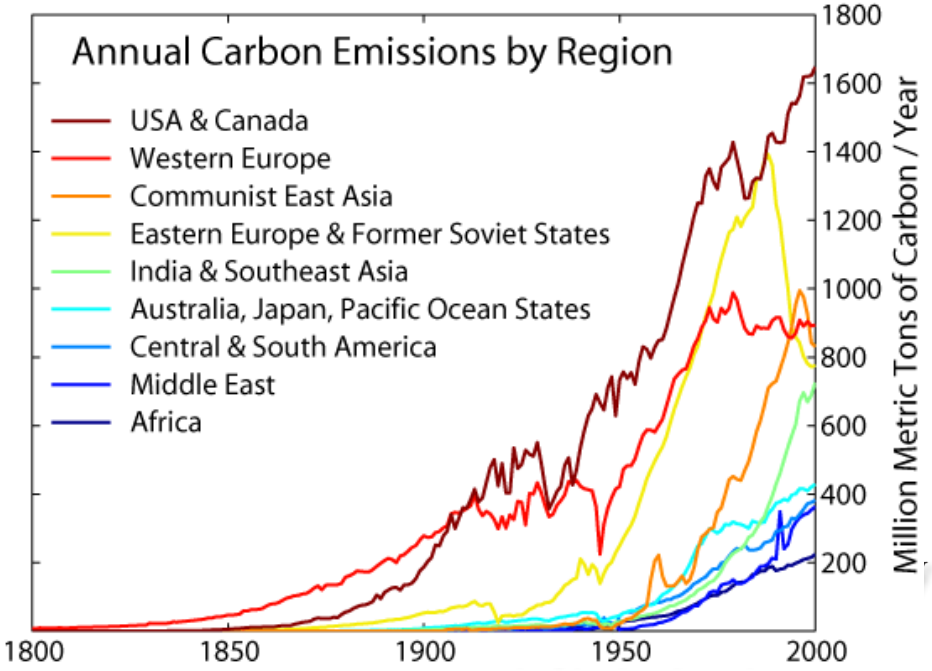
Jose 2009

Agroforestry for C Sequestration

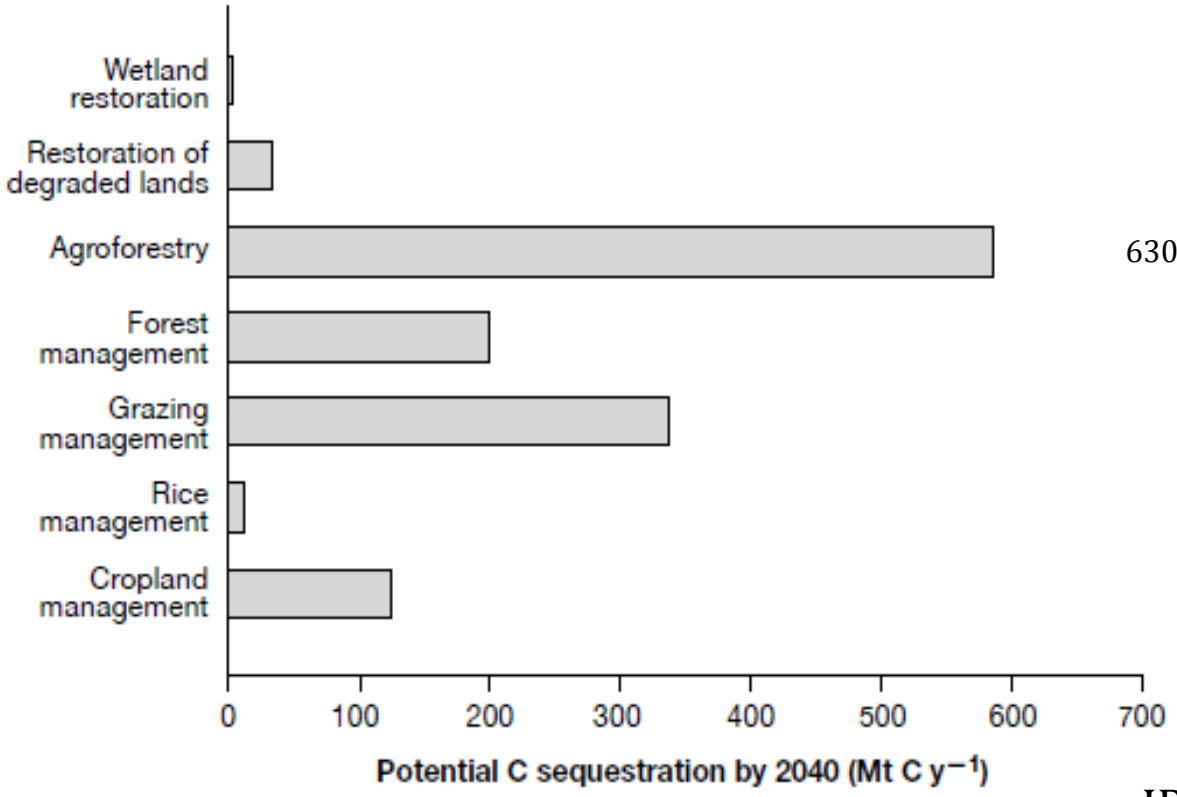


The U.S. produces about 25% of global CO_2 emissions from burning fossil fuels

Data Source:
US DOE, CDIAC



Is Agroforestry a Viable Option for Carbon Sequestration?



630*10^6 ha

IPCC, 2000

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

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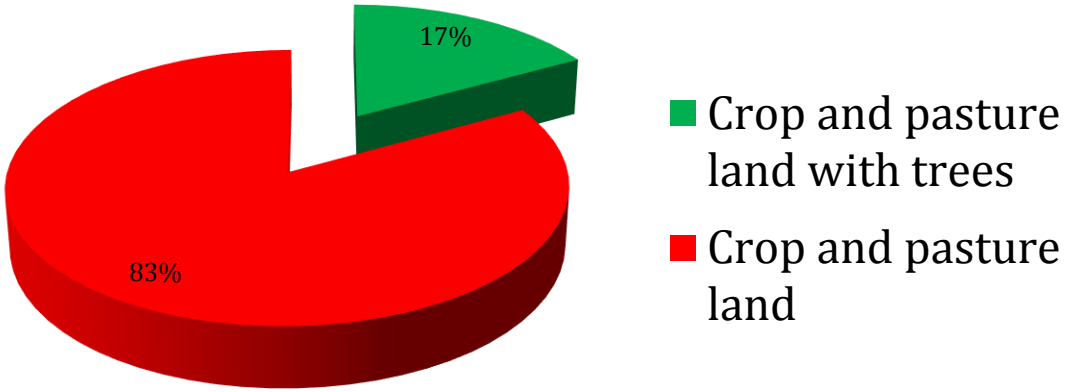
17 % of the World's Arable Land in Agroforestry: What's the U.S. Share?



Dixon, 1995
FAO, 2007
Nair et al., 2009

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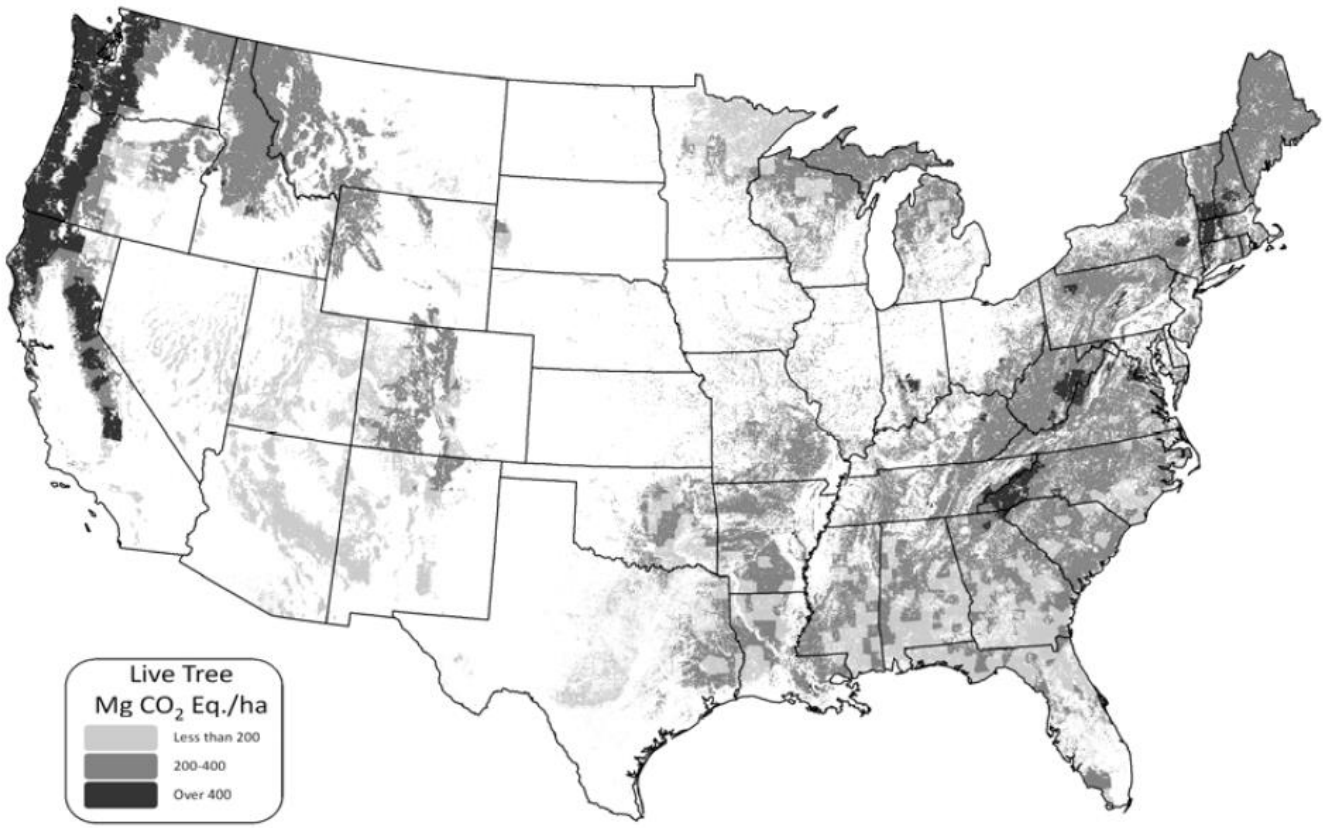
Why Agroforestry Shows Greater Potential?

Average C Density in Live Forest Tree Pool -2009



Source: US EPA, 2011

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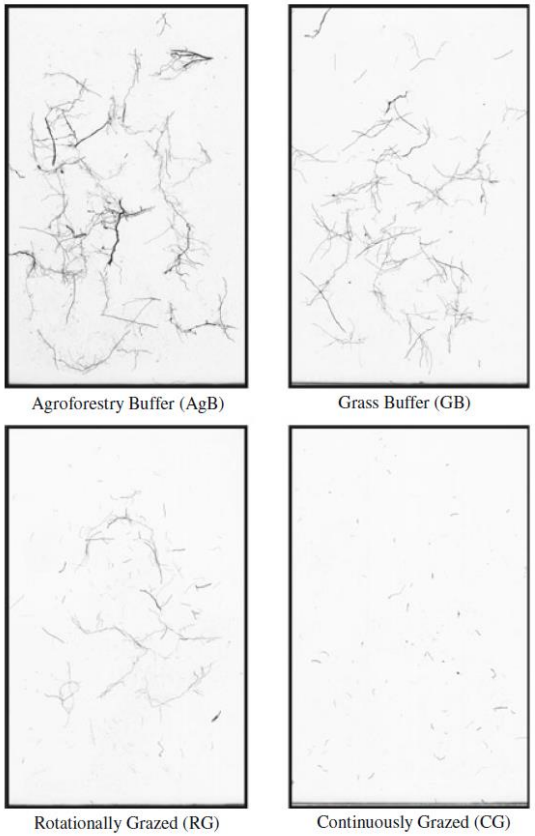
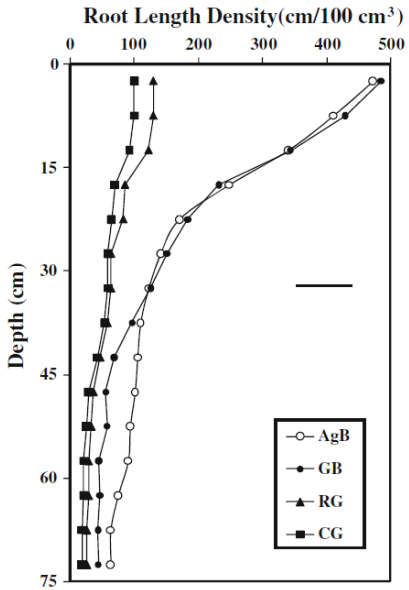
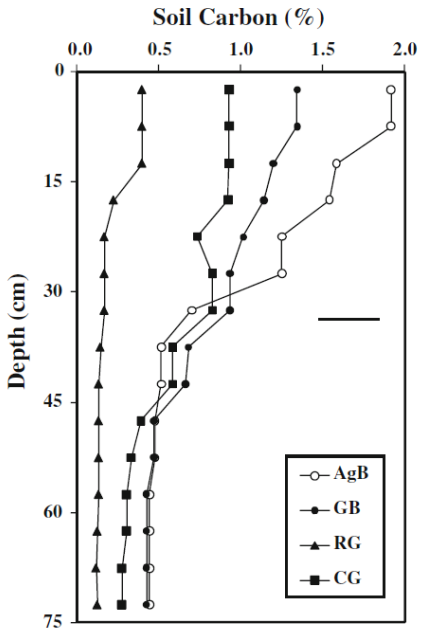
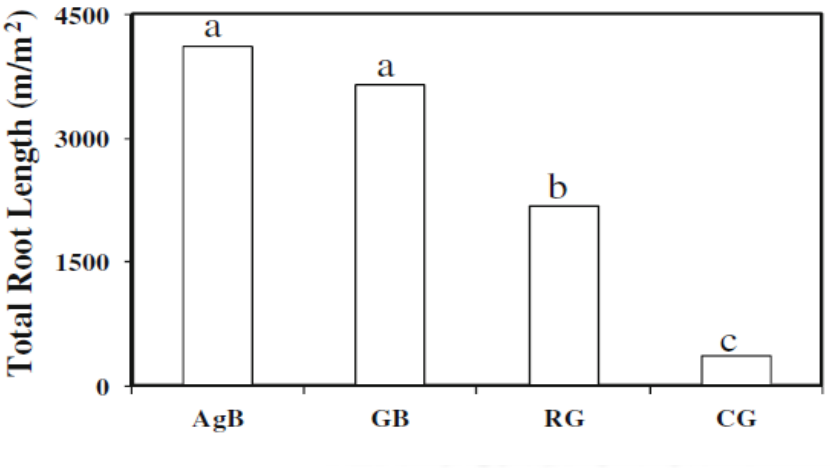
Why Agroforestry Shows Greater Potential?



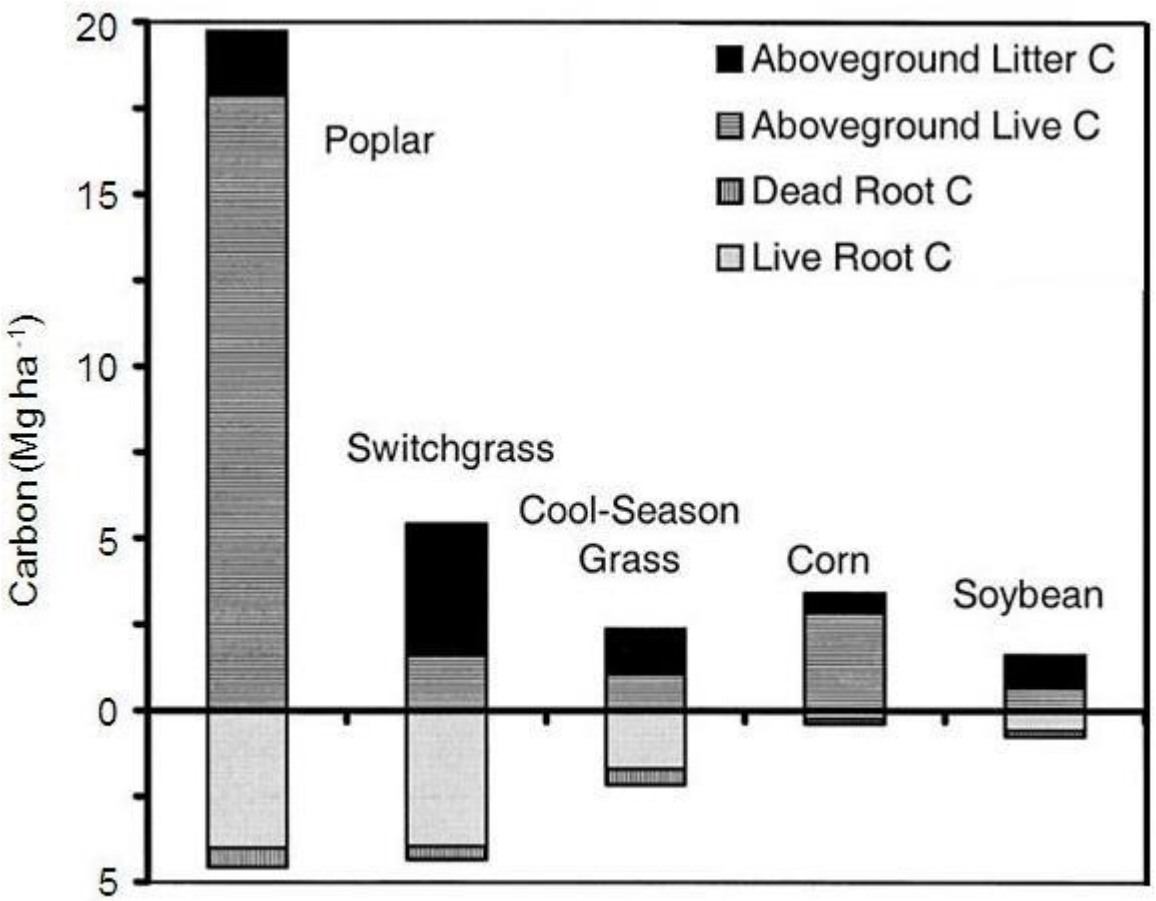






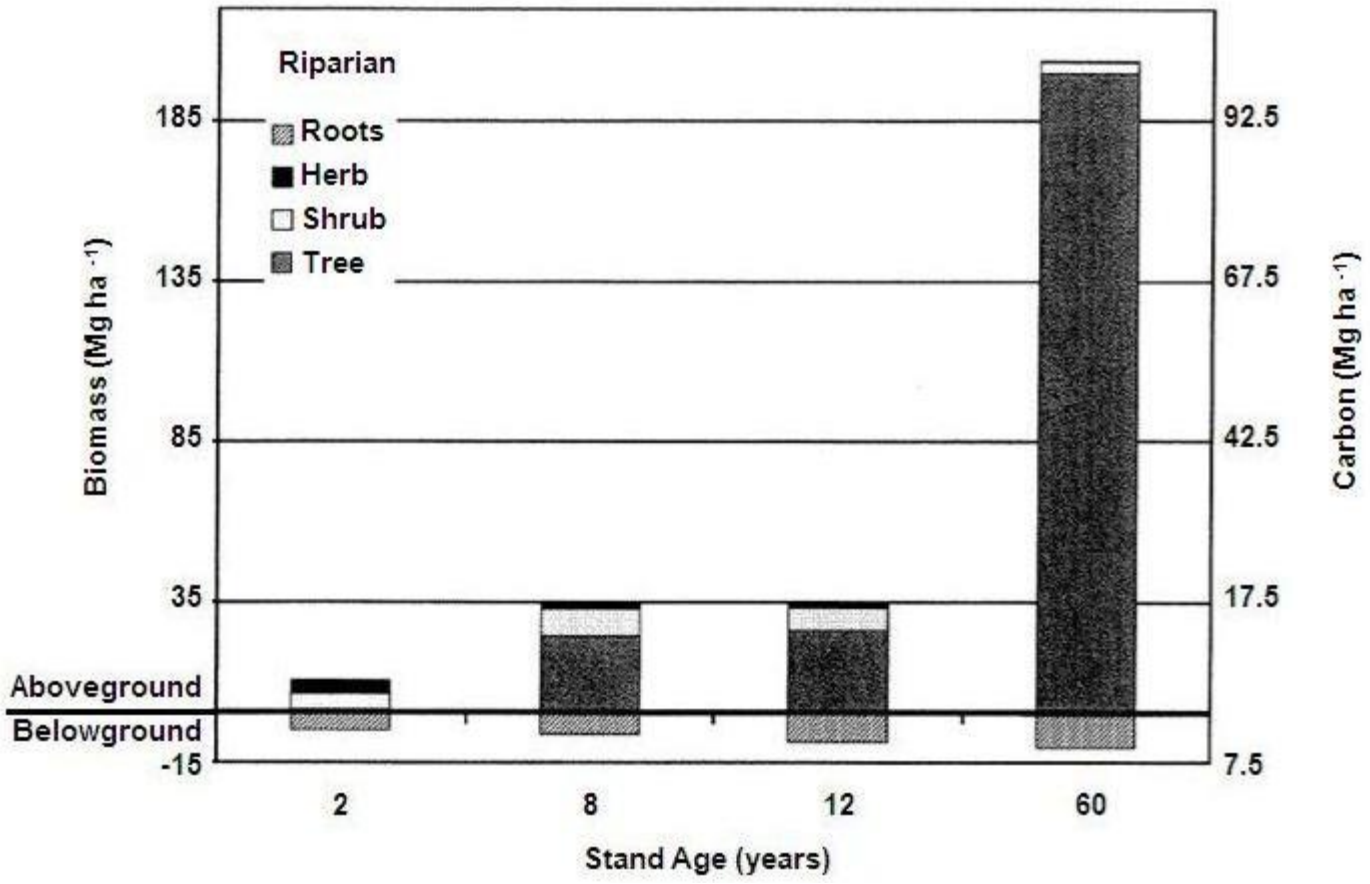
Kumar, Udawatta and Anderson, 2010

Above and Belowground C Addition



Tufekcioglu et al., 2003

Long-term Storage of C



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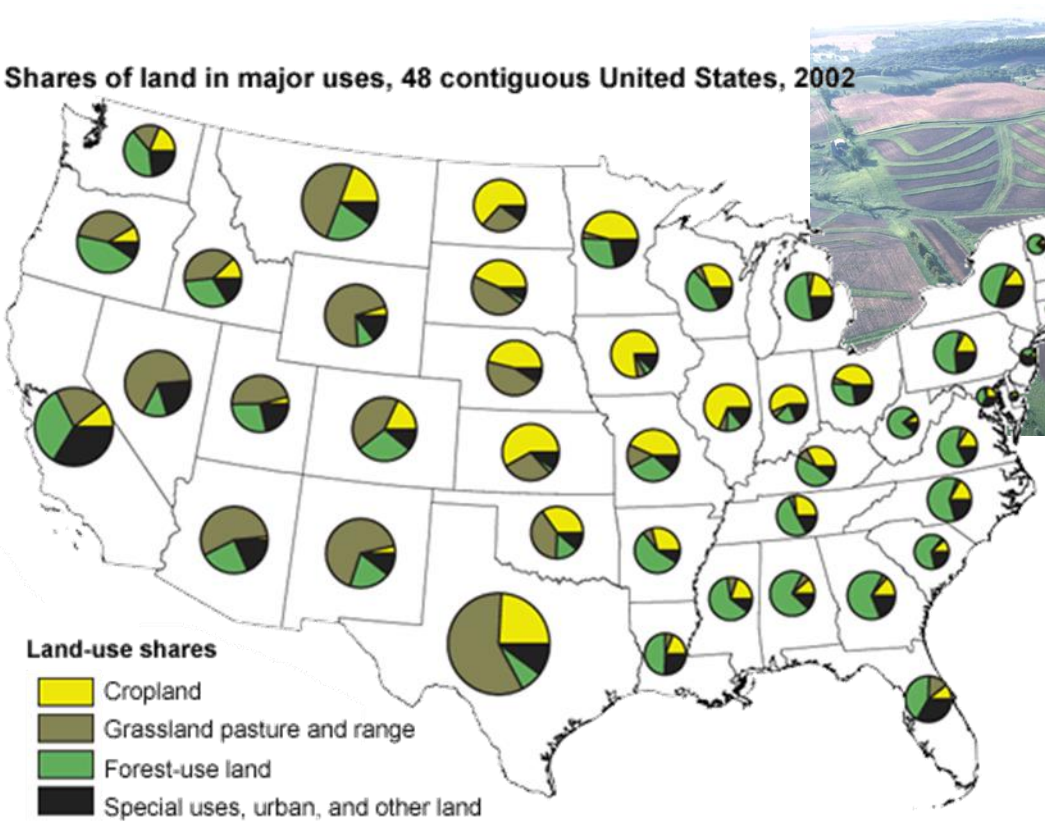
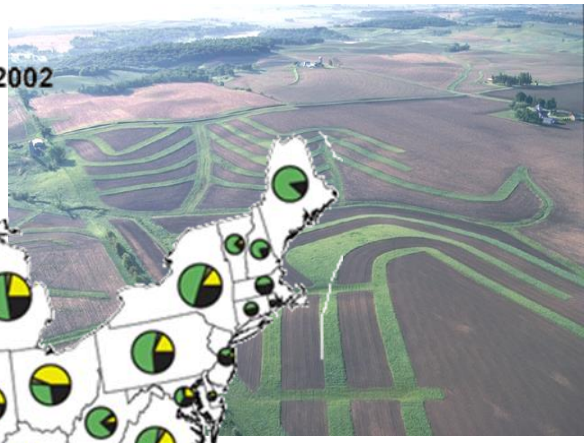
Agroforestry can help increase C Density on 23.7 million marginal pasture and 17.9 million marginal cropland





Preliminary Estimates of C Seq.

- Based on the literature from US and Canada (Udawatta and Jose, 2011)
- Guesstimates of potential land area under agroforestry
- Only four of the five temperate agroforestry practices included
  - Silvopasture
  - Alley Cropping
  - Riparian Buffers
  - Windbreaks

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Silvopasture

- **10% of the pasture land (23.7 million ha)**
- **54 million ha of grazed forestland (18% of the U.S. forestland)**
- **6.1 Mg C ha^{-1} yr^{-1} Sequestration Potential**
- **474 Tg C yr^{-1}**

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Alley Cropping

- **10% of the crop land (17.9 million ha)**
- **3.4 Mg C ha^{-1} yr^{-1} Sequestration Potential**
- **60.9 Tg C yr^{-1}**

Windbreaks

- **5% of cropland (8.95 million ha)**
- **20-yr rotation**
- **Poplar and White Spruce**
- **8.79 Tg C yr^{-1}**

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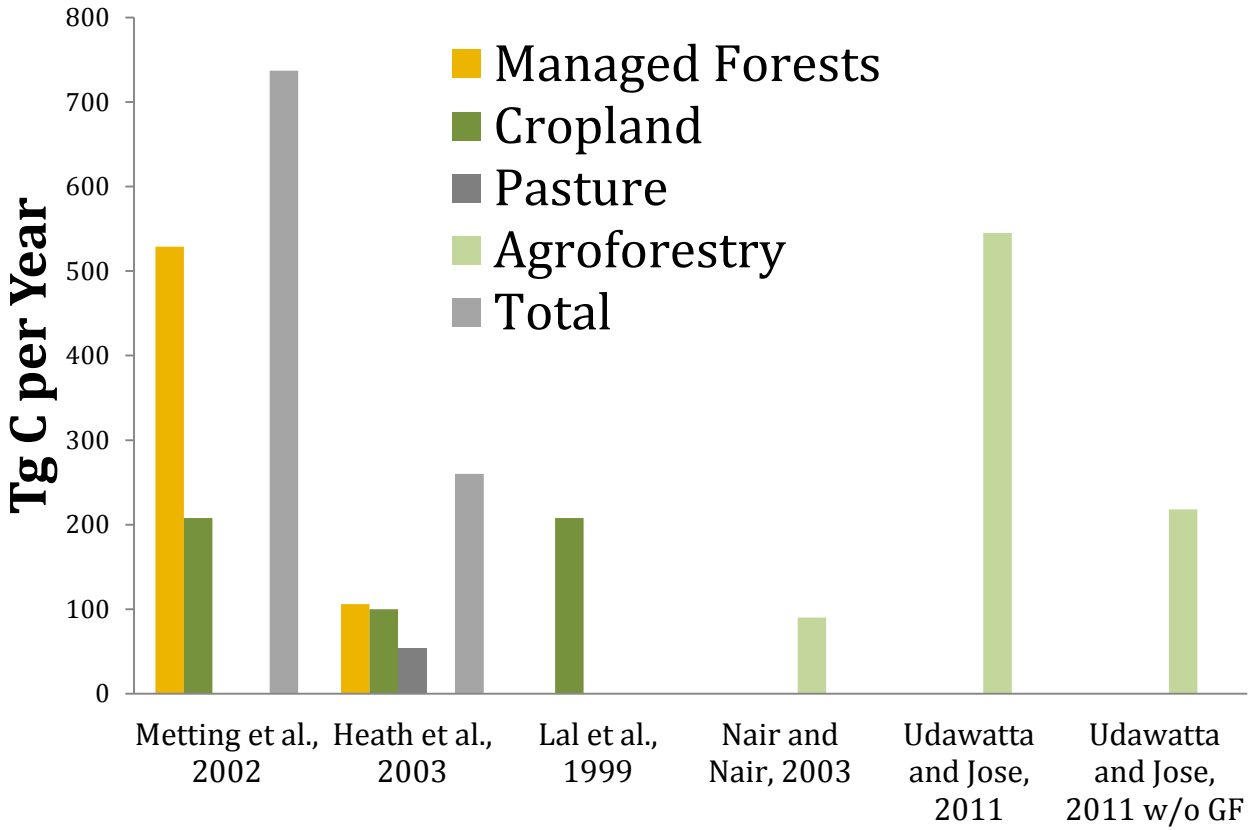
Riparian Buffer

- **If a 30-m wide riparian buffer is established along both sides of 5% of total river length in the U.S., it would occupy 1.69 million ha**
- **2.6 Mg C ha^{-1} yr^{-1} potential C sequestration**
- **4.7 Tg C yr^{-1}**

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



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Agroforestry for Water Quality

Water Body	Total size	Assessed (% of total)	Impaired (% of assessed)
Rivers	3,533,205 miles	16%	**44%**
Lakes	41.7 million acres	39%	**64%**
Estuaries	87,791 square miles	29%	**30%**

EPA, 2009

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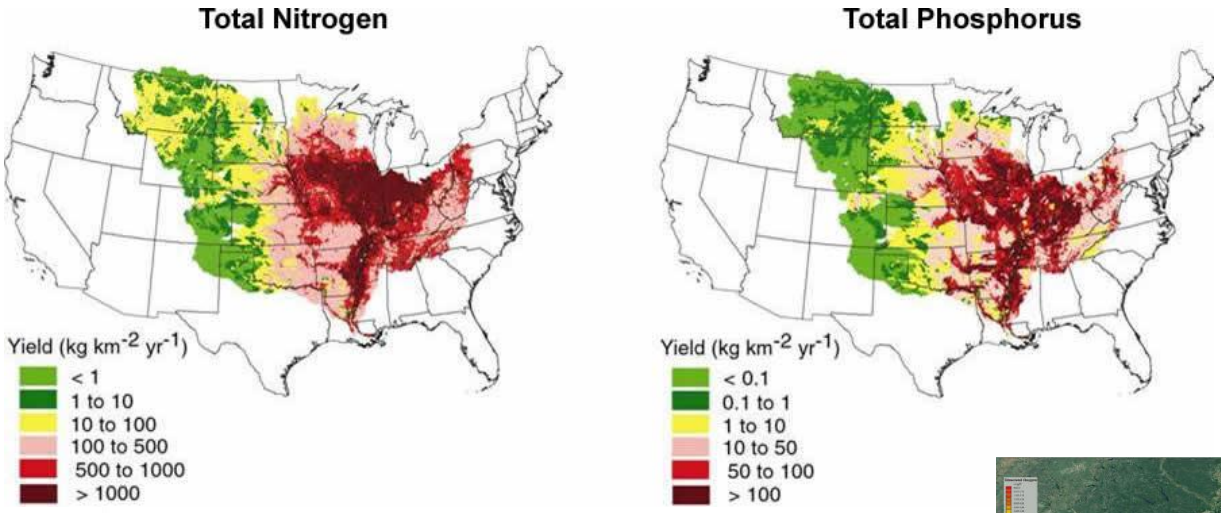
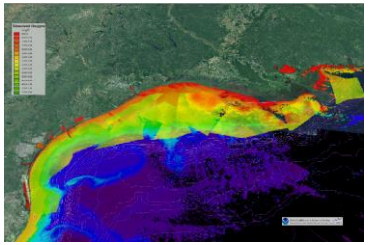
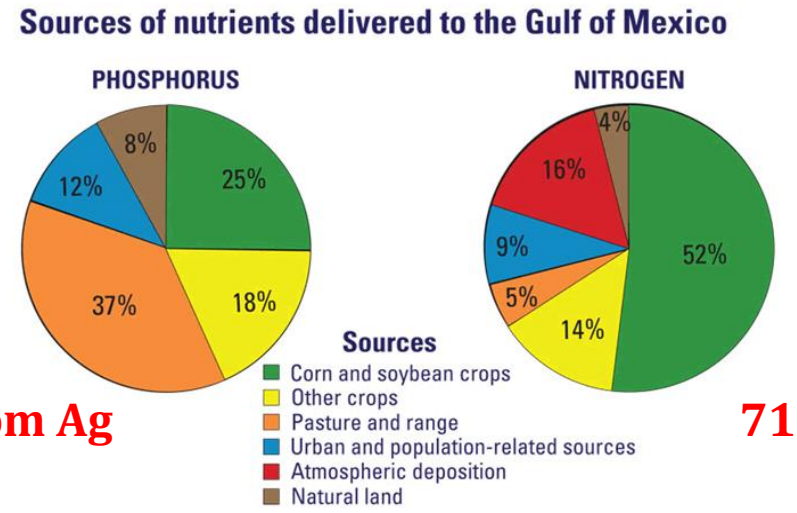
Agroforestry for Water Quality







80% of P from Ag

71% of N from Ag

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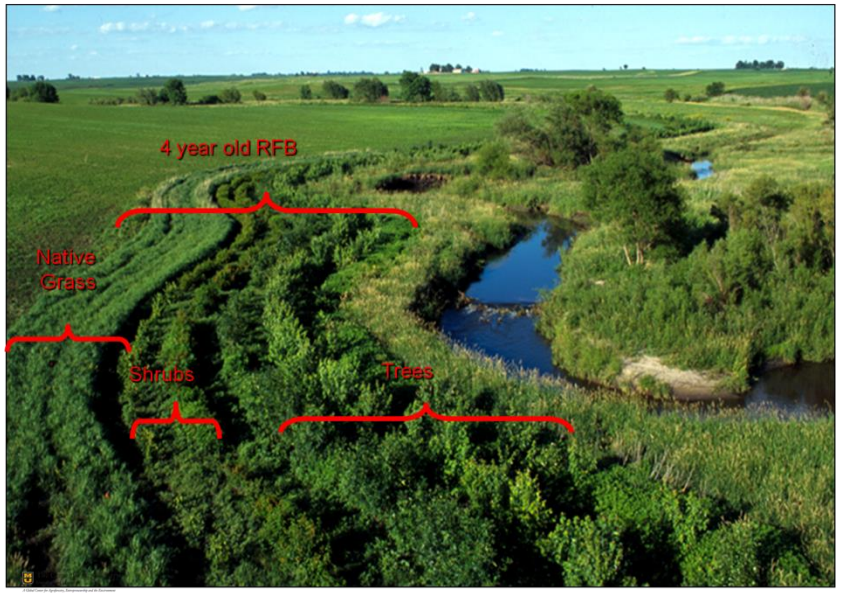
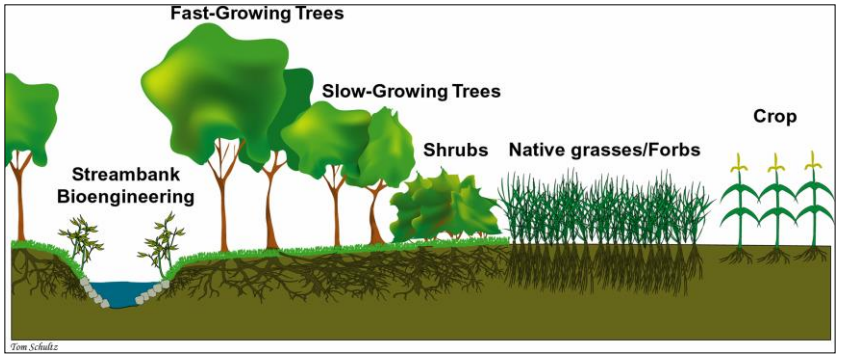
Agroforestry Can Reduce Nutrient Loading!



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

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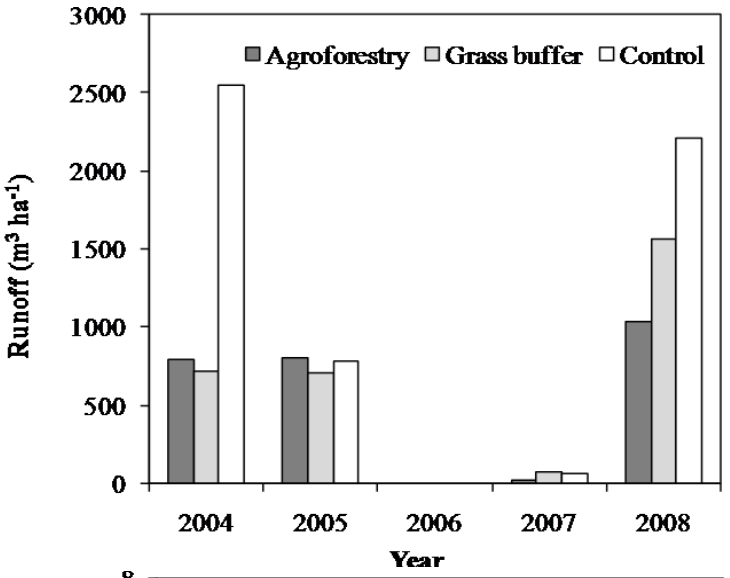
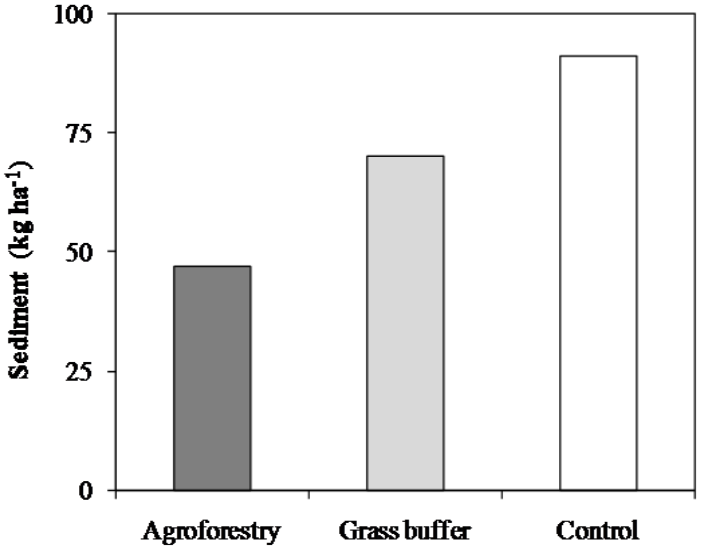
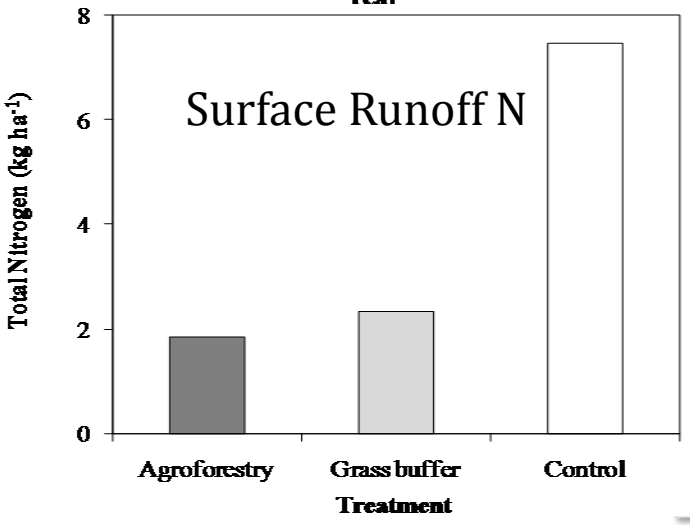
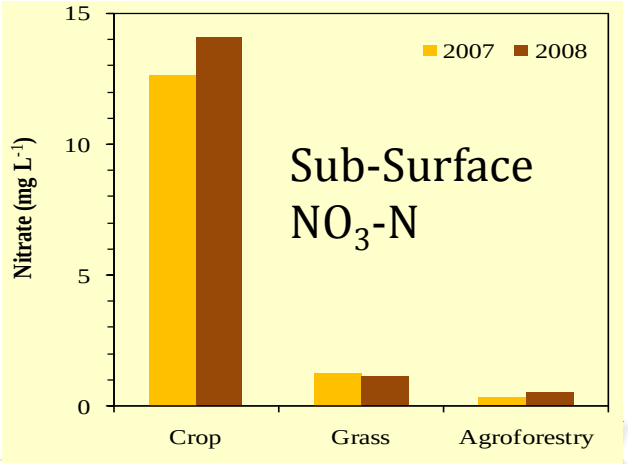
Agroforestry Reduces Runoff and Sediments









Udawatta et al., 2002; 2007; 2009; 2011

Silvopasture Offers the Same Benefit!

Variable	Silvopasture	Pasture
	%	
Runoff	23	15
Sediment	30	28
TP	26	22
TN	11	13
Nitrate-N	11	11

Udawatta et al., 2007; 2009

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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!!

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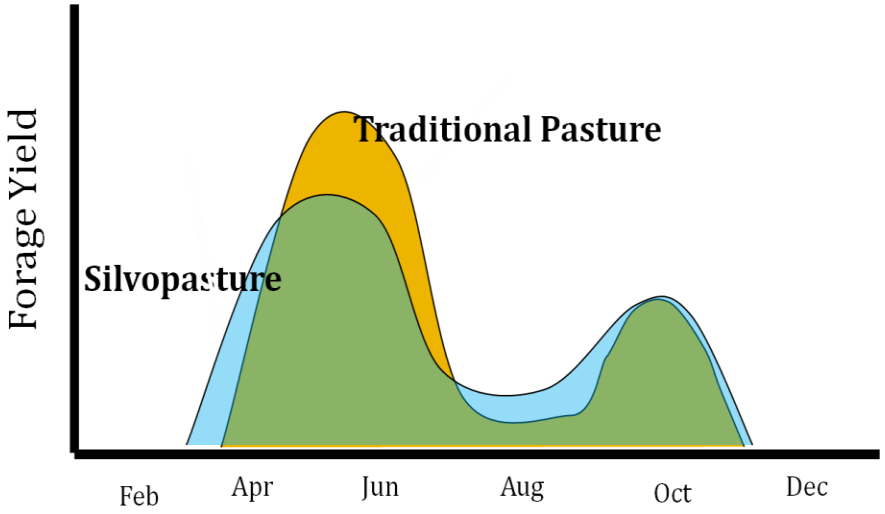
Can Agroforestry Help?

$43 more per head in a silvopasture compared to traditional pasture, i.e. $4300 per year for a small farmer with 100 head



Kallenbach et al. 2009

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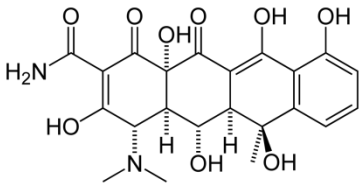
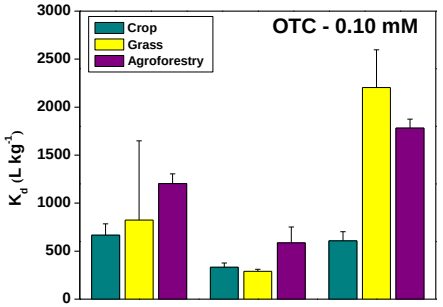
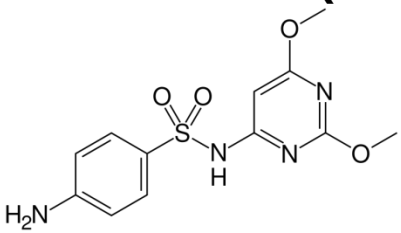
Veterinary Antibiotics –Sorption

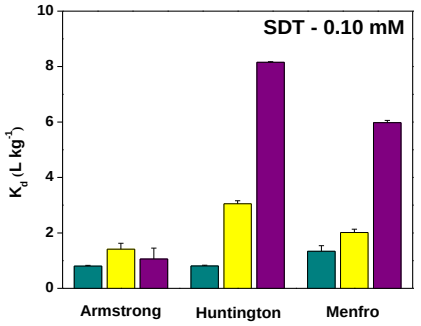
Oxytetracycline (OTC)



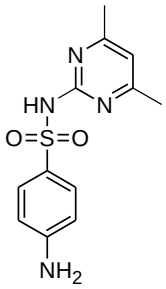


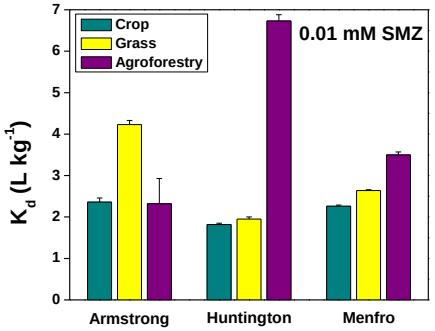
Sulfadimethoxine (SDT)





Sulfamethazine (SMZ)





Lin and Goyne, Lin et al. 2010

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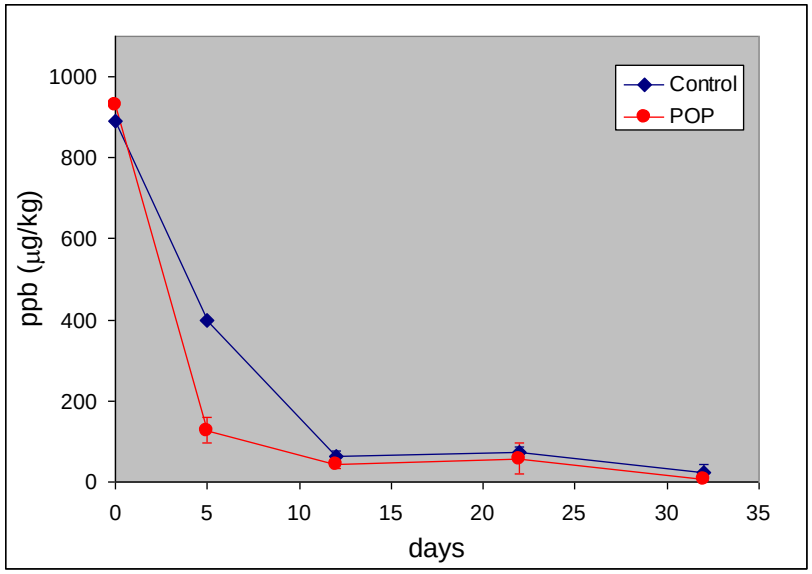
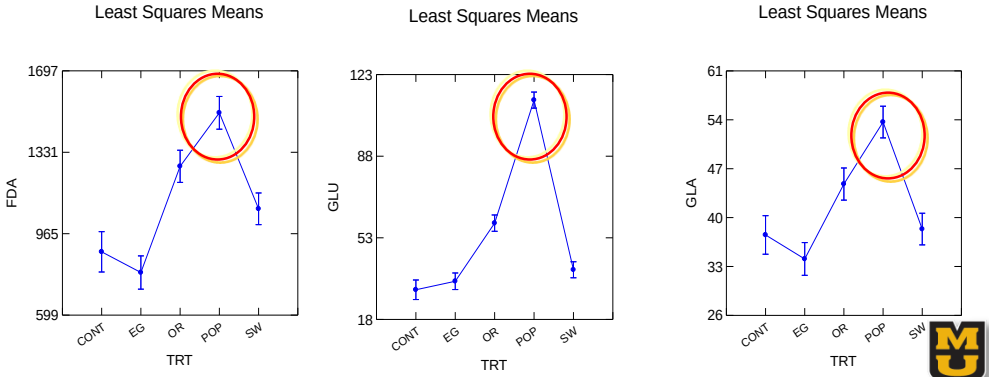
Veterinary Antibiotics – Microbial Degradation



Enhanced Rhizodegradation of Antibiotic (Sulfamethazine) by Poplar

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



Lin and Goyne, Lin et al. 2010

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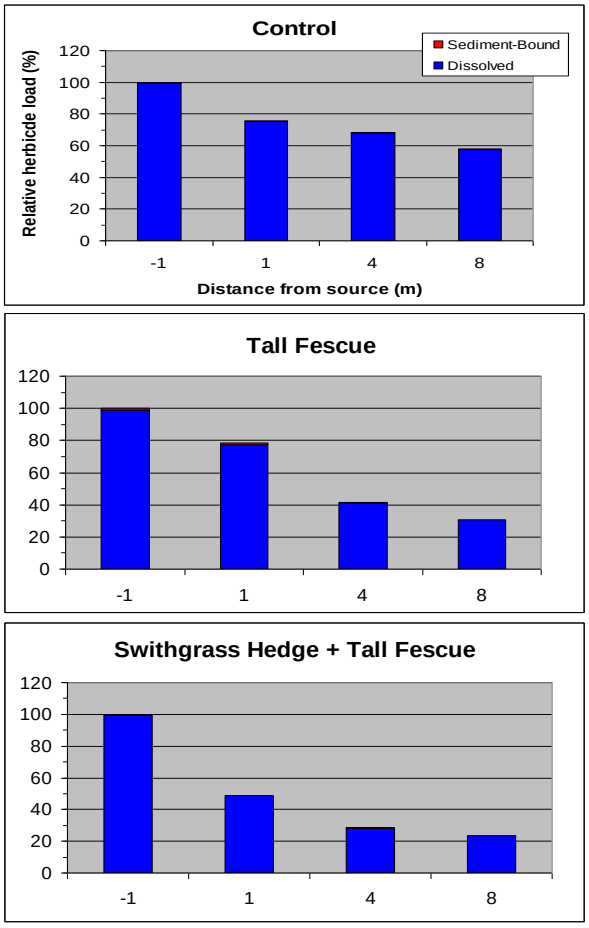
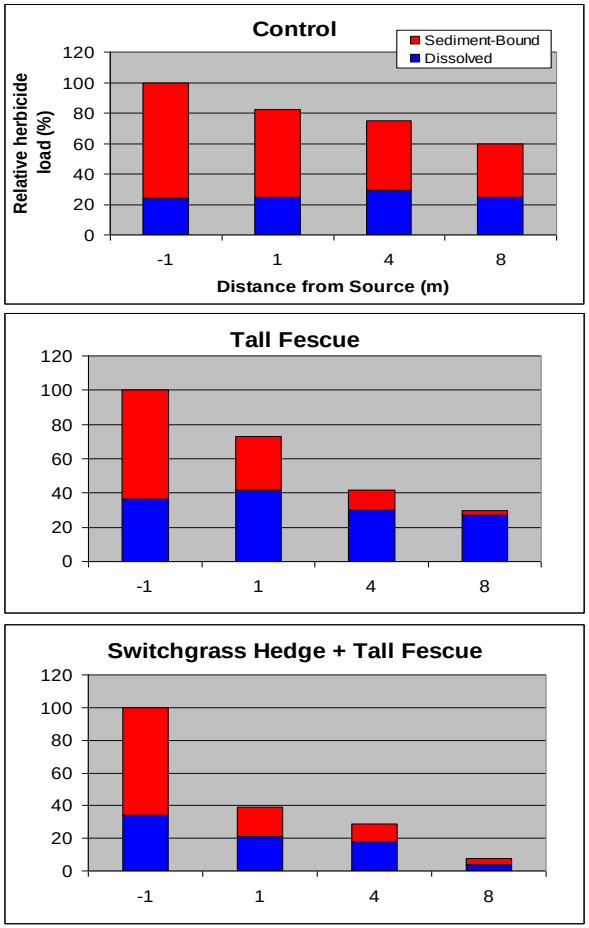
AF Can Reduce Herbicides in Water too!

Atrazine



Glyphosate



Lin et al. 2010

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Agroforestry for Air Quality

Confined Animal Feeding Operations (CAFO) are increasing in numbers

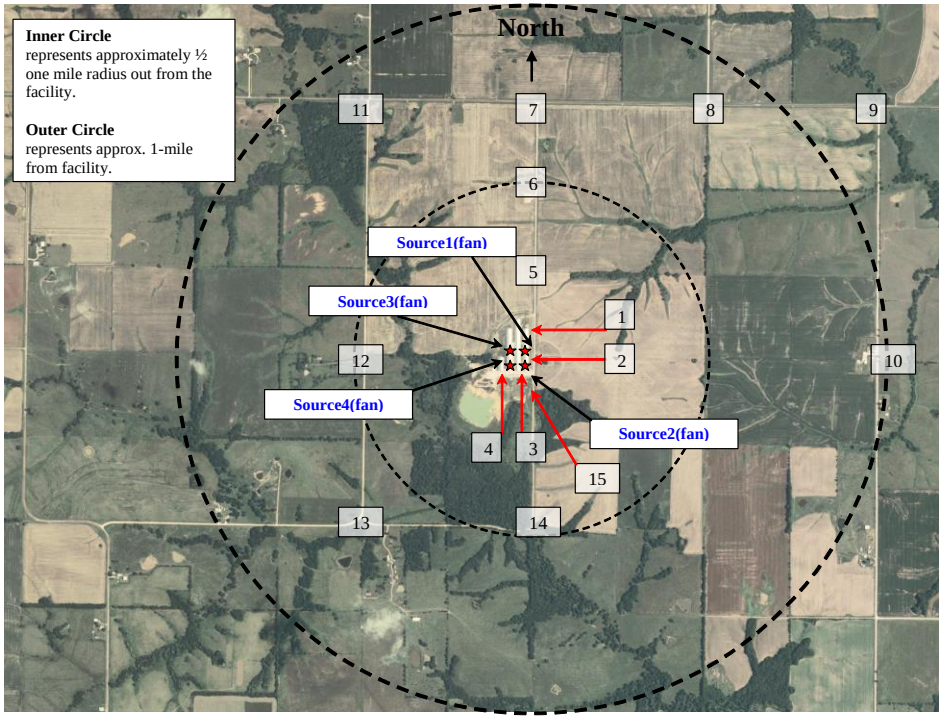
Odors from CAFOs is a major environmental concern

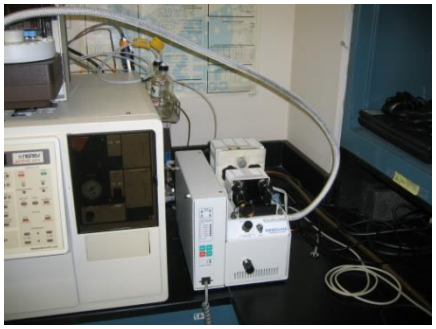
Vegetative environmental buffers (VEBs) for odor abatement is an option

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





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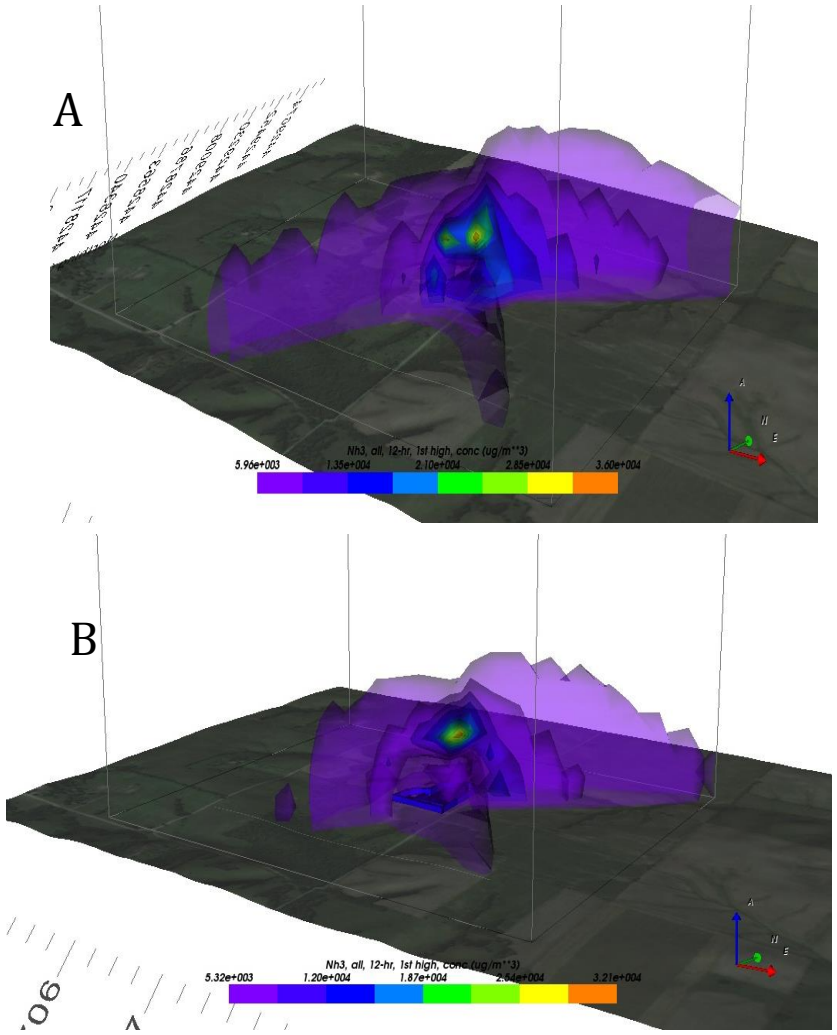
VEB: 27% Reduction in NH_3



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

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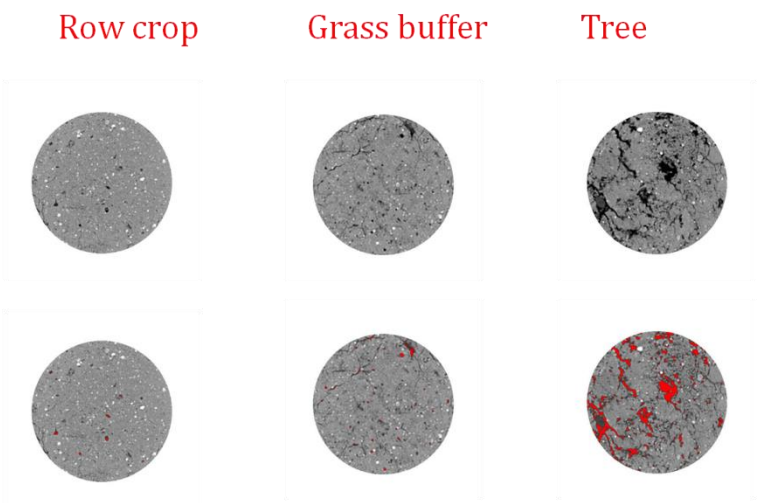
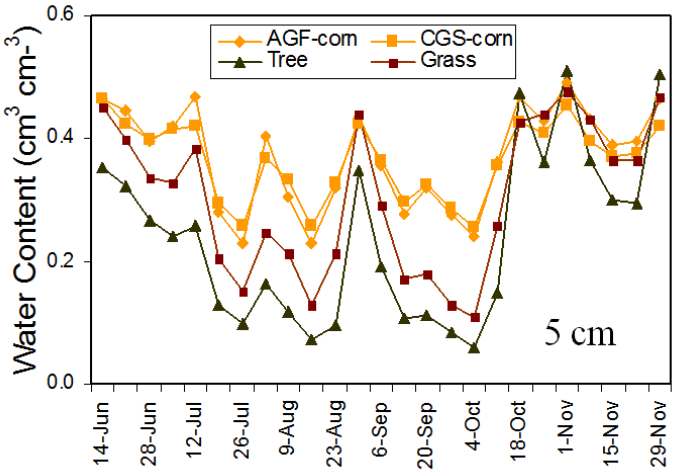
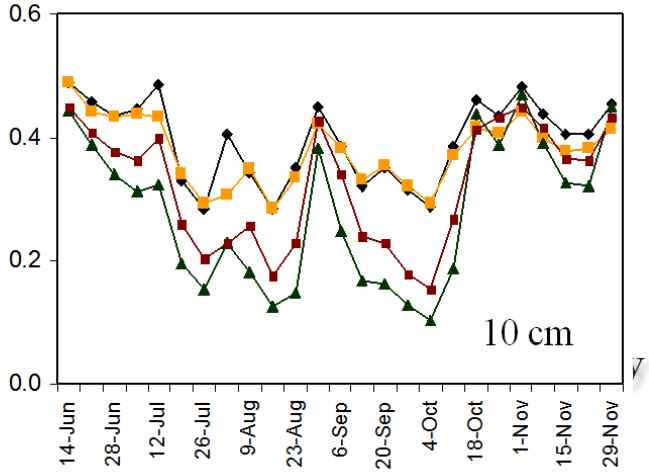
Agroforestry for Soil Enrichment: Soil Physical, Chemical, and Biological Properties

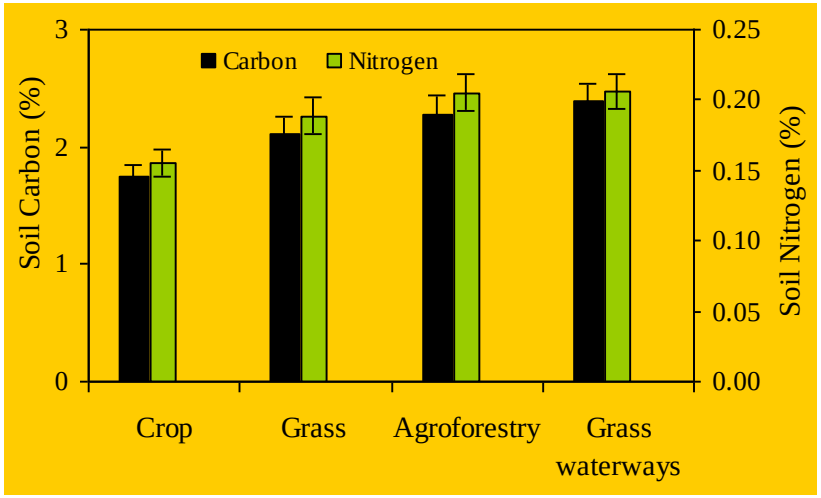


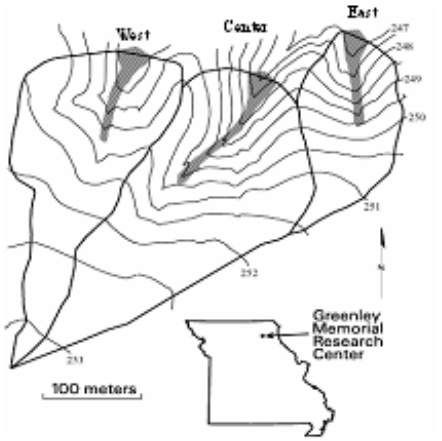
Udawatta et al., 2005; 2006



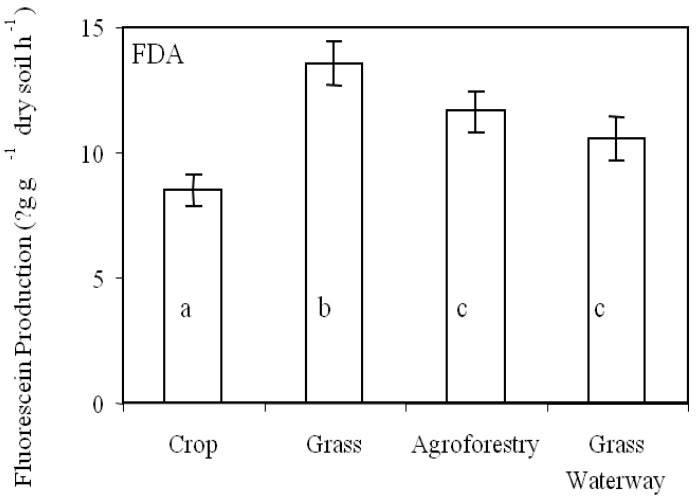


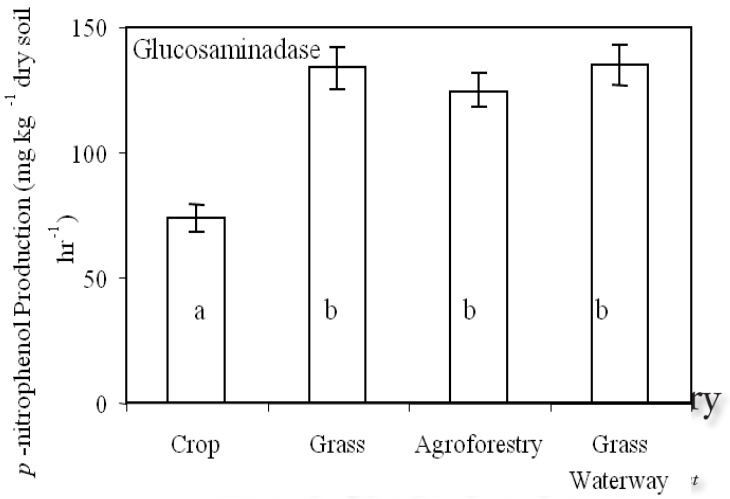
Agroforestry for Soil Enrichment: Soil Physical, Chemical, and Biological Properties





Udawatta et al 2008; 2009





Agroforestry for Biodiversity Conservation

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

(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

(5) Provides Other Ecosystem Services such as Erosion Control, Water Recharge, Water Quality thereby preventing the degradation of Habitats

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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 nation

Much work still remains……..

Not only quantifying the ecosystem services at larger scales, but also quantifying the economic value associated with them

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