Water Quality Improvement and Agroforestry Practices

Ranjith P. Udawatta
Center for Agroforestry
University of Missouri
www.centerforagroforestry.org

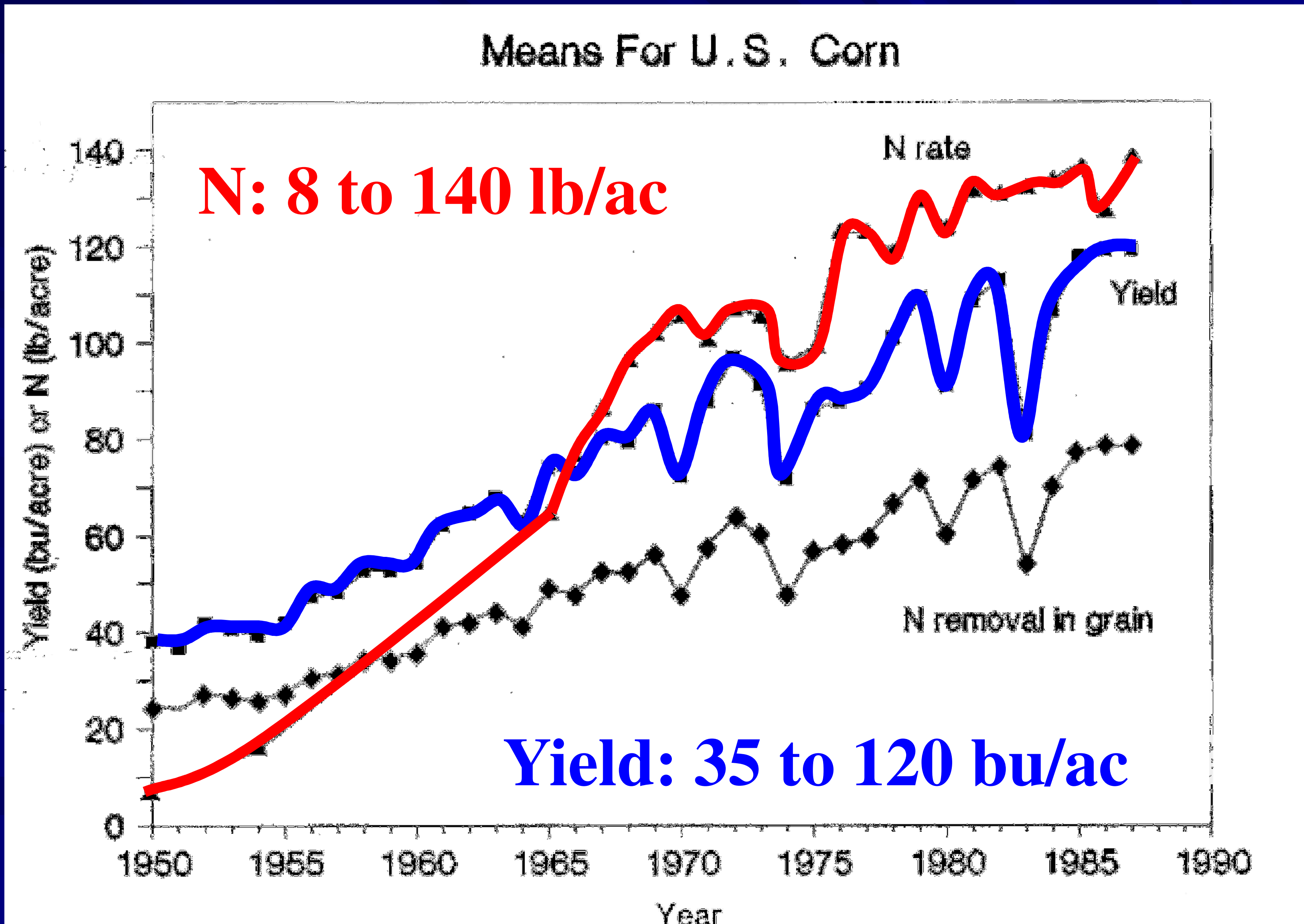
From 1950 to 2000, the number of people fed by a single U.S. farmer increased from 19 to 129.

Globally, food grain production grew from 630 million tons in 1950 to 2000 million tons in 2000.

During the same period fertilizer and agrochemical use also increased with more forest clearing.

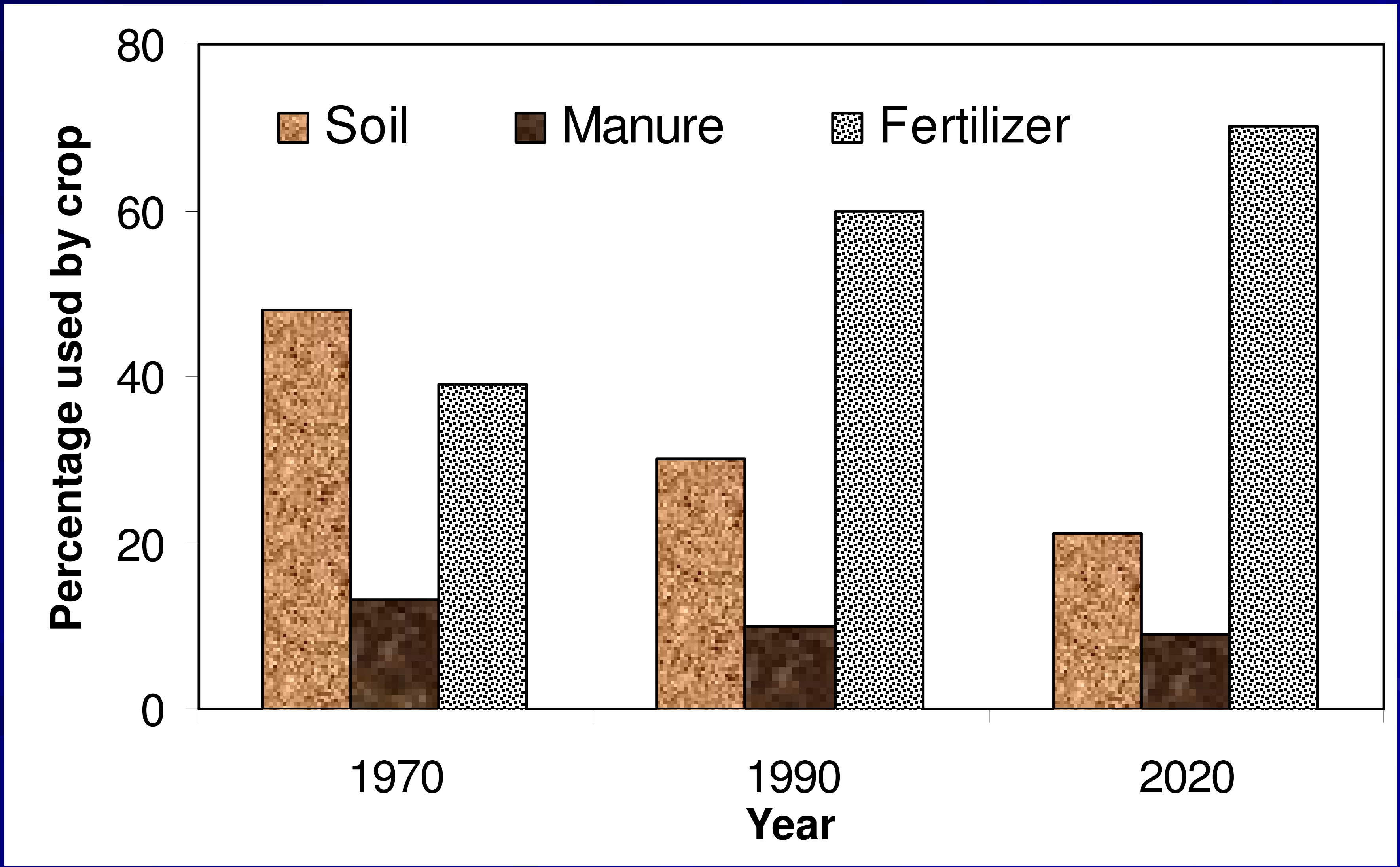
Lal, 2007

US Corn Production and Fertilizer use from 1950 to 1990

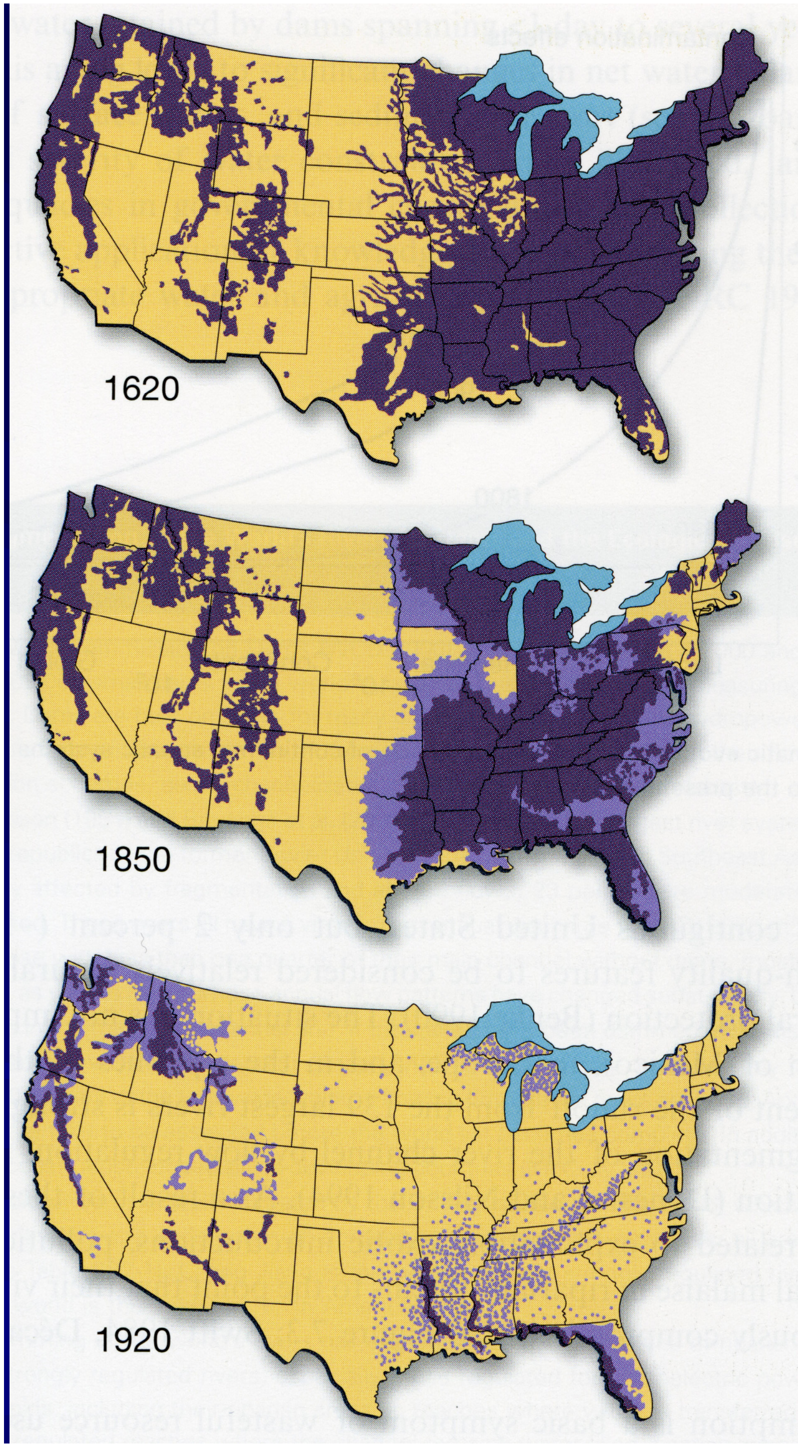


Follett et al., 1990

Percentage of Nutrients Derived from soil, manure, and inorganic fertilizer



Ayoub, 1999; Bockman et al., 1990; Nair and Graetz, 2004



Forest Cover

N and P loss from Agricultural Watersheds in North Missouri

P Loss: Range 0.29 to 3.59 kg ha^{-1} yr^{-1}
Mean 1.36 kg ha^{-1} yr^{-1}

48% or more of the annual loss occurred during crop free period

Runoff volume and sediment loss were highly correlated with P loss

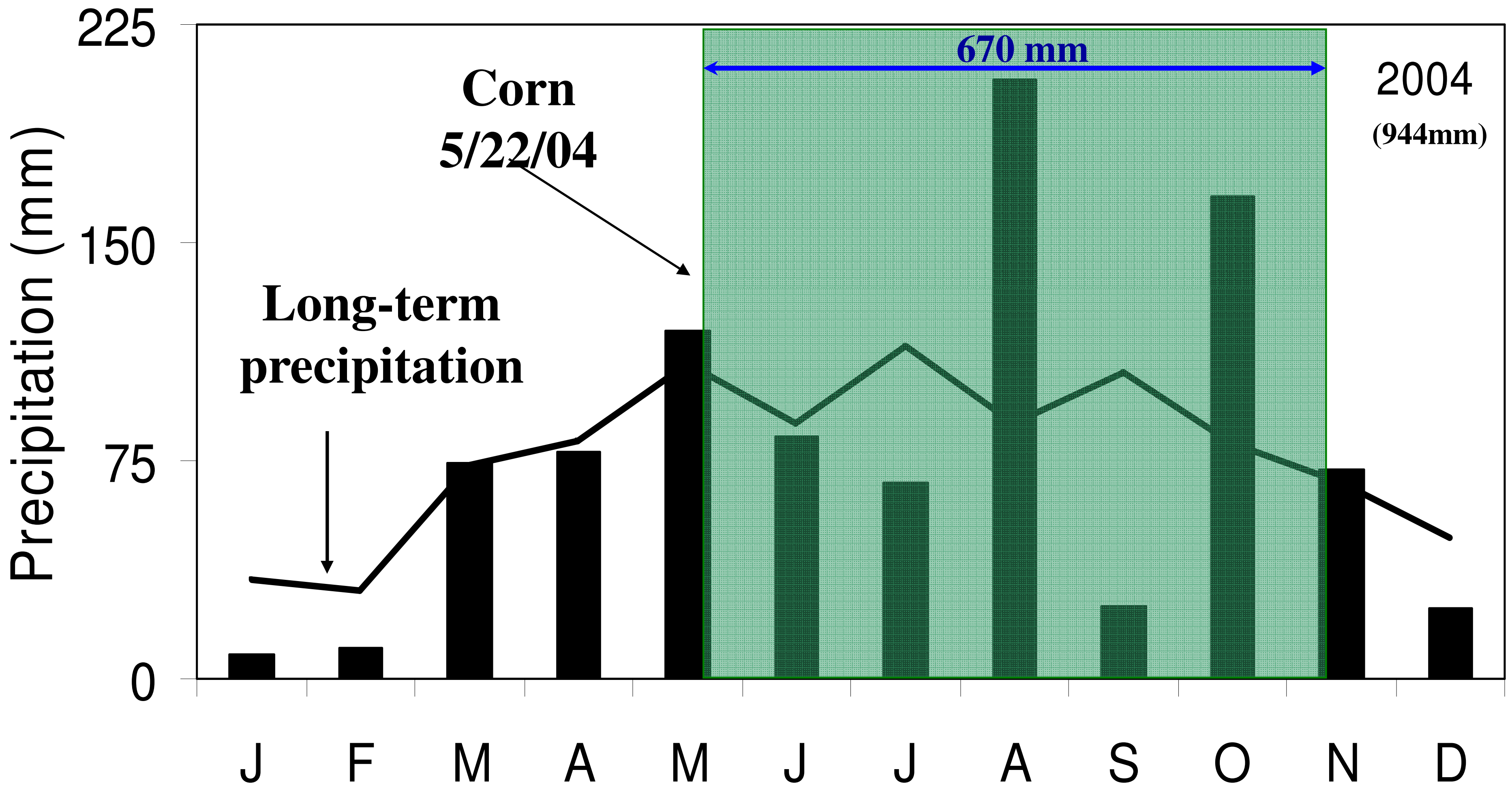
Udawatta et al., 2004

N Loss: Range 13 to 19 kg $ha^{-1}yr^{-1}$
Mean 16 kg $ha^{-1}yr^{-1}$

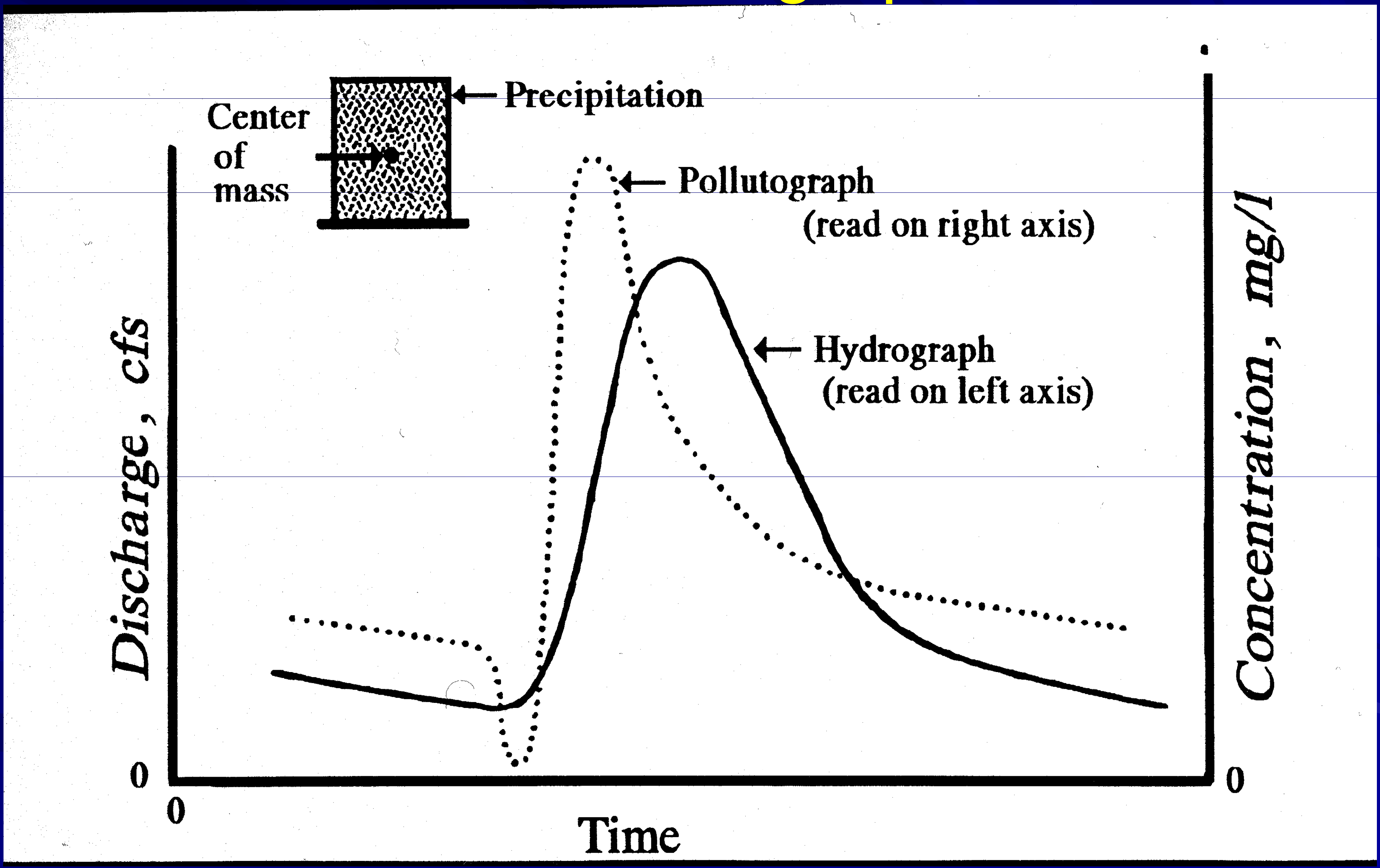
57% of the annual loss occurred during crop free period

Udawatta et al., 2006

2004 Monthly Precipitation and Cropping Period



Relationship Between Storm Hydrograph and Pollutograph



Source: P.E. Black, 1996 Watershed Hydrology, page 129

Water Quality parameters:

Sediment, Conductivity, Turbidity,

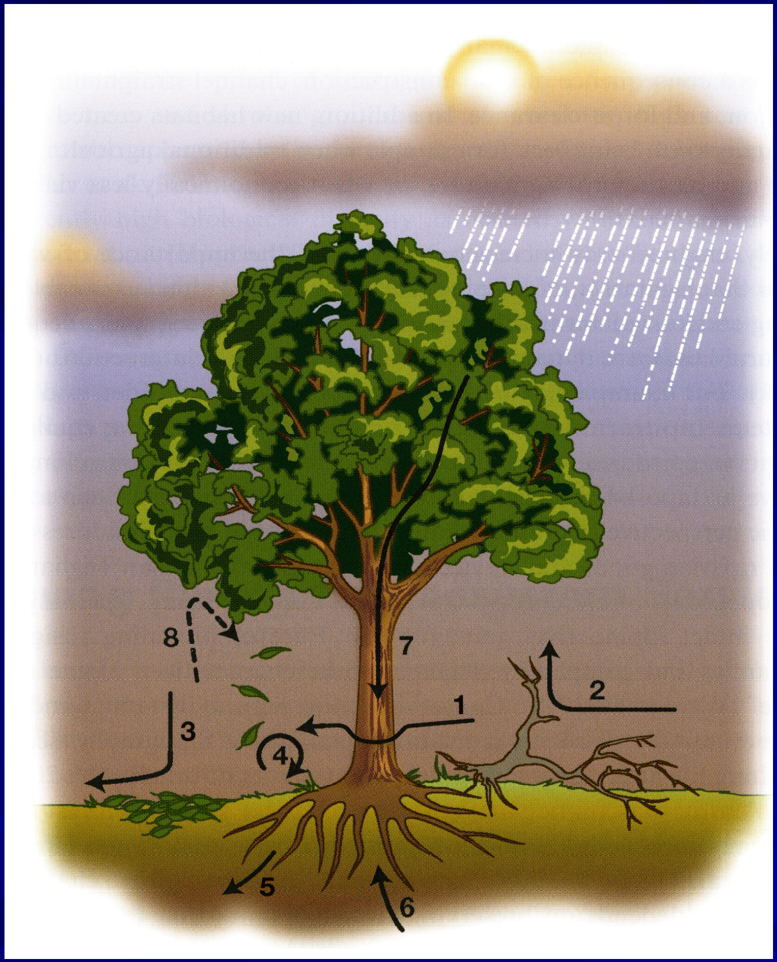
CATIONS	ANIONS
Calcium (Ca^{+2})	**Bicarbonate (HCO_3^-)**
Magnesium (Mg^{+2})	**Carbonate (CO_3^{-2})**
Potassium (K^+)	**Sulfate (SO_4^{-2})**
Sodium (Na^+)	**Chloride (Cl^-)**
Iron (Fe^{+2}, Fe^{+3})	**Nitrate (NO_3^-)**
Manganese (Mn^{+2})	**Silica (SiO_2)**

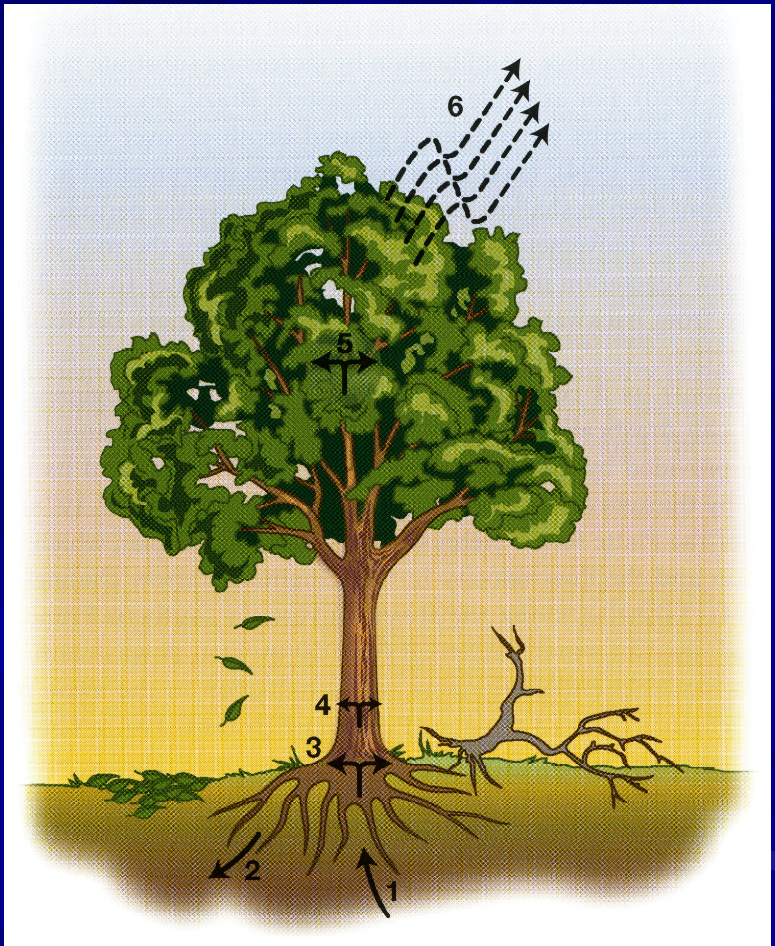
Pesticides
Bacteria

Studies conducted in tropical agroforestry systems have shown that tree roots can enhance levels of nutrient uptake and reduce losses from agroforestry systems, compared to sole crop stands with shallow rooting depths

(Buresh and Tian, 1997; Nair et al., 1999)

Trees Protect Water Resources





Rationale

* Despite improvements in the use of soil conservation practices, crop rotation and nutrient management programs, significant concern still exists regarding soil erosion and nutrient losses in runoff from row crop production.

* Agroforestry and grass buffers are used to reduce nonpoint source pollution from row-crop watersheds (Udawatta et al., 2002).

Rationale

* There is a need to improve our understanding on mechanisms and processes associated with these buffers in relation to water and soil quality improvements which affect sediment, nutrient, and pesticide in runoff.

1. **Agroforestry and Grass Buffer Effects on Non Point Source Pollution Reduction from Row-crop Watersheds**

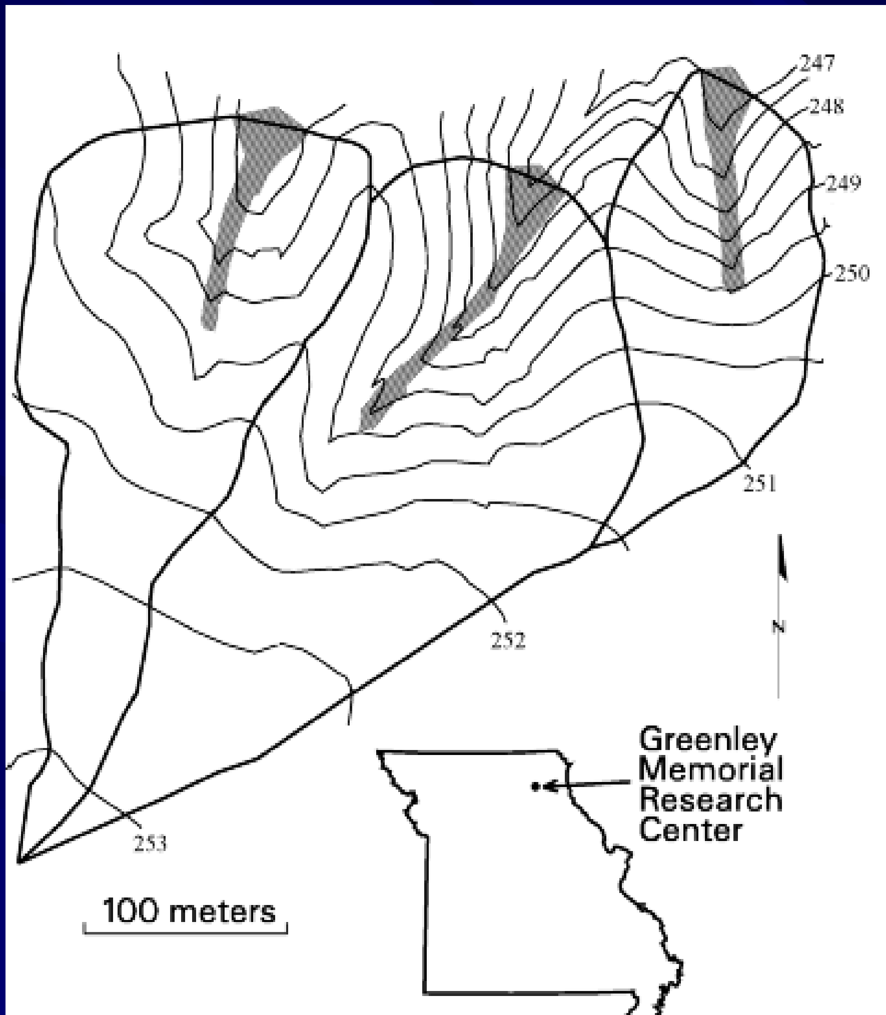
2. **Seasonal Soil Water Differences in Row-crop, Grass buffer and Agroforestry Buffers.**

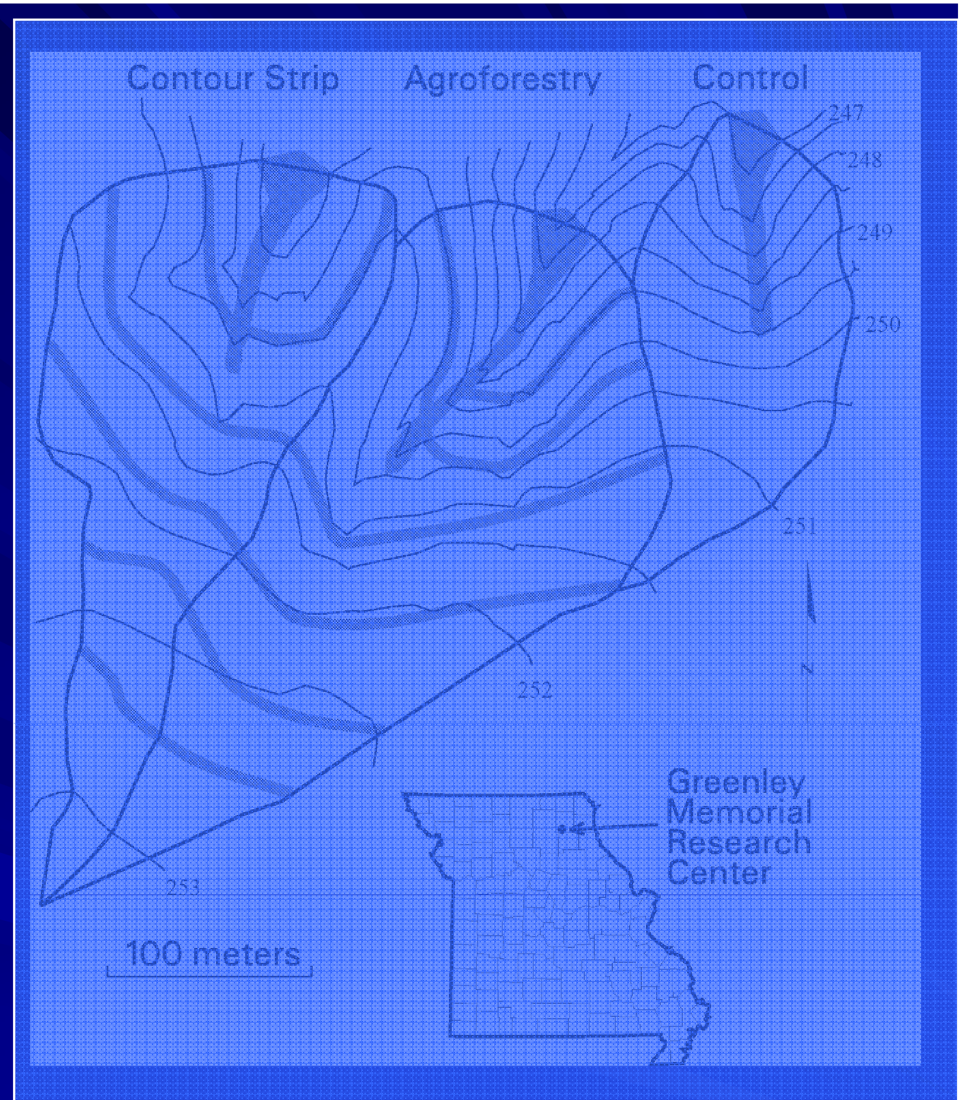
3. **Soil Properties and Pore Characteristics as Influenced by Grass and Agroforestry Buffers**

4. **Root Length Density as Influenced by Grass and Agroforestry Buffers.**

5. **Water Stable Soil Aggregates, Soil carbon, Soil Nitrogen, and Enzyme Activities as Influenced by Agroforestry Buffers**

Agroforestry and Grass Buffer Effects on Non Point Source Pollution Reduction from Row-crop Watersheds





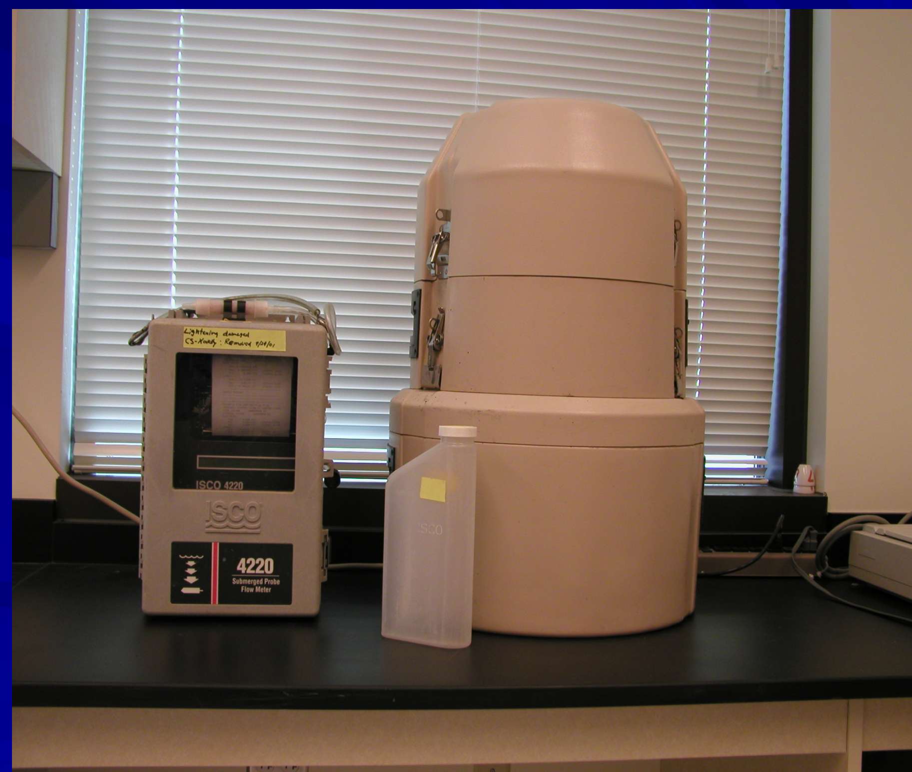
1991-1997

Approximate study site location in Missouri and 0.5 m interval contour lines on watersheds. Gray bands represent location of contour grass buffers on contour strip watershed, agroforestry buffers on agroforestry watershed and grass waterways on all three watersheds.

At 5000 feet Elevation In 2002

Sampler housing, concrete approach section, H-flume, and sample collection assembly

Flow meter and water sampler

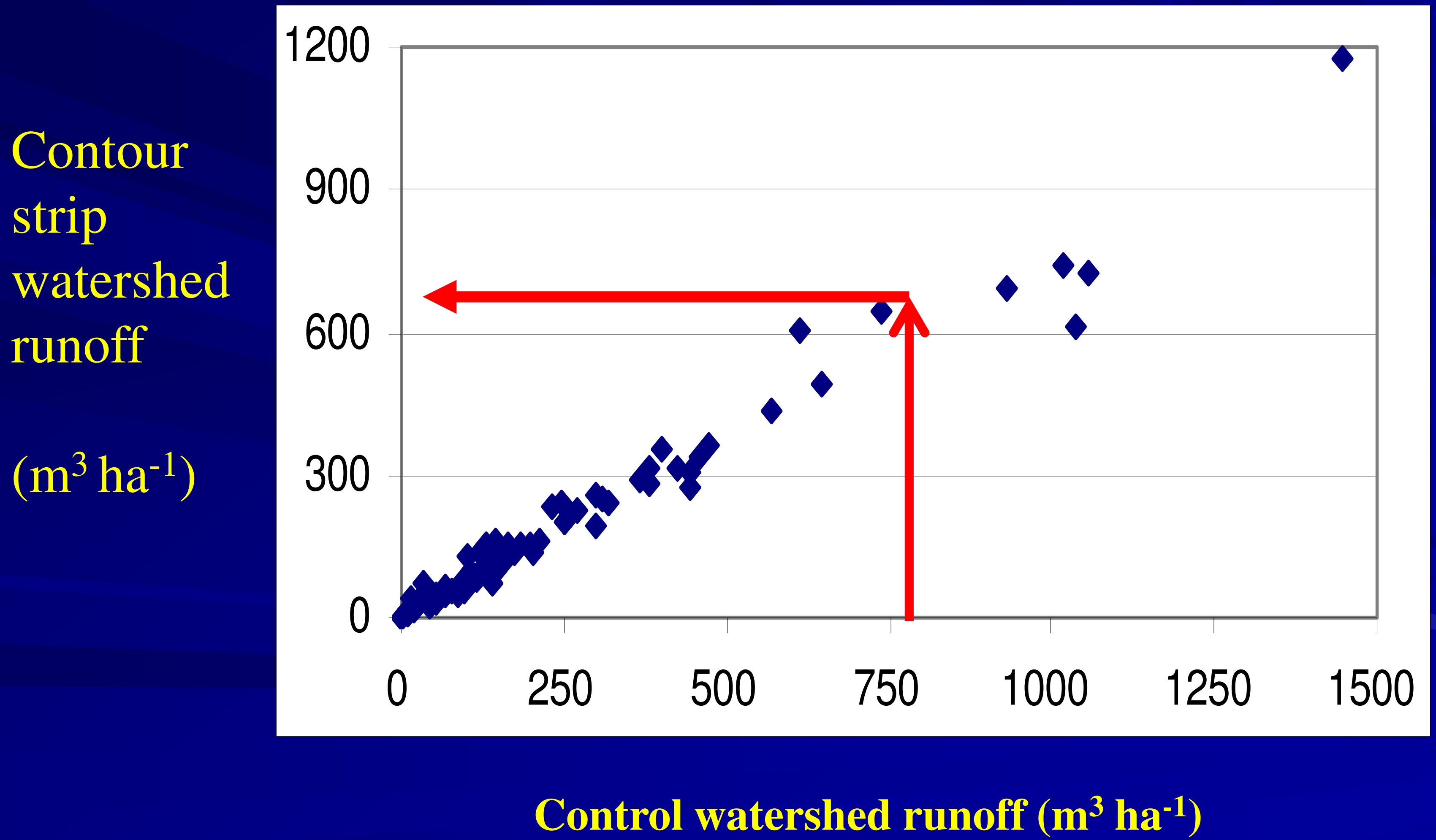



2003


2005

Runoff Relationship Between Agroforestry and Control Watersheds During the Calibration Period

Contour strip = 0.99 * Control, $R^2 = 0.97$

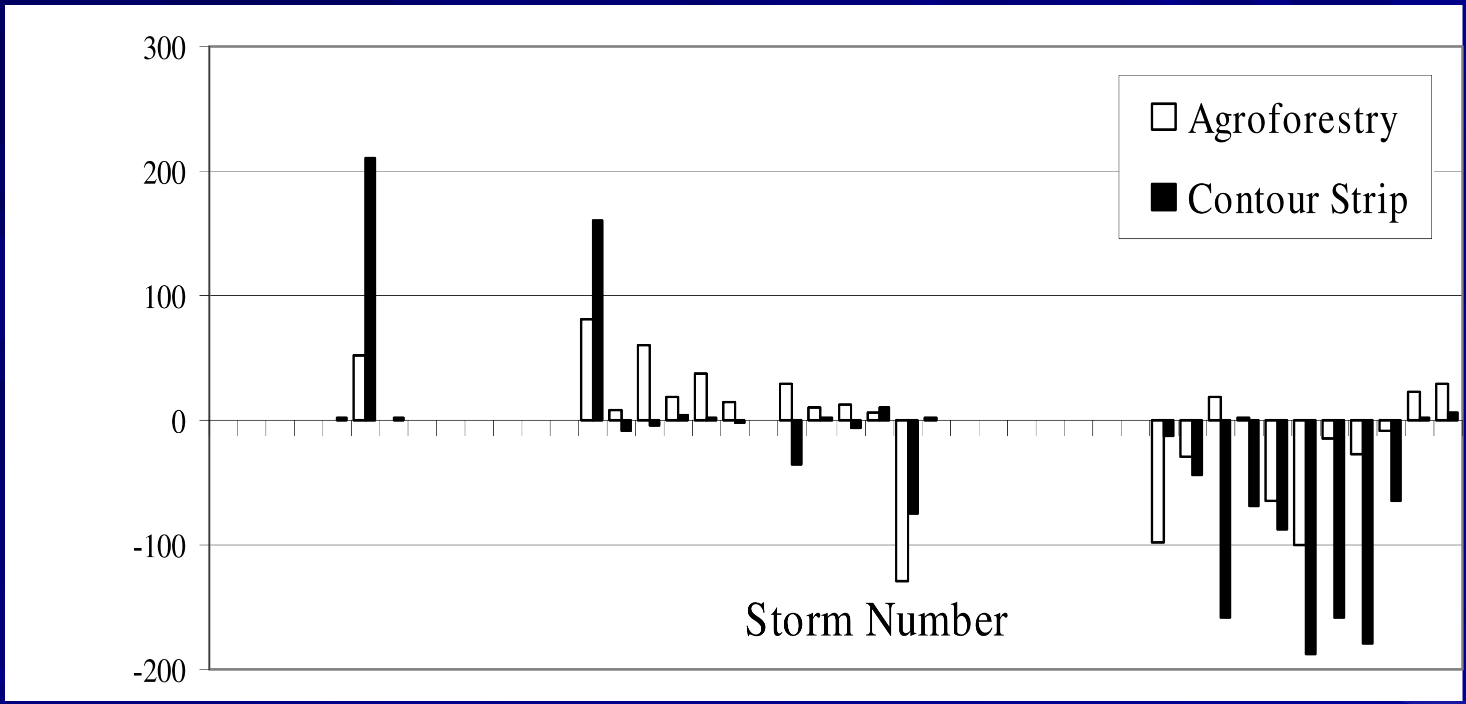


Udawatta et al., 2002

Observed Deviation from Predicted (observed minus predicted) Runoff on Agroforestry and Contour Strip Watersheds During the Treatment Period

Change in runoff

m^3/ha



Storm number and sampling year

Treatment Effects on Runoff and Nutrient Loss from Agroforestry and CGS Watersheds

Variable	Agroforestry	CGS
	---------------%	---------------
Runoff	19	20
Sediment	11	12
TP	16	18
TN	18	19
Nitrate-N	23	21

Summary

1. The agroforestry treatment after only 9 years reduced runoff, sediment, total phosphorus, total nitrogen, and nitrate-N loss by 19, 11, 16, 18 and 23% based on calibration relationships.

2. The contour strip treatment after only 9 years reduced runoff, sediment, total phosphorus, total nitrogen, and nitrate-N loss by 20, 12, 18, 19 and 21% based on calibration relationships.

1. Agroforestry and Grass Buffer Effects on Non Point Source Pollution Reduction from Row-crop Watersheds

2. Seasonal Soil Water Differences in Row-crop, Grass buffer and Agroforestry Buffers.

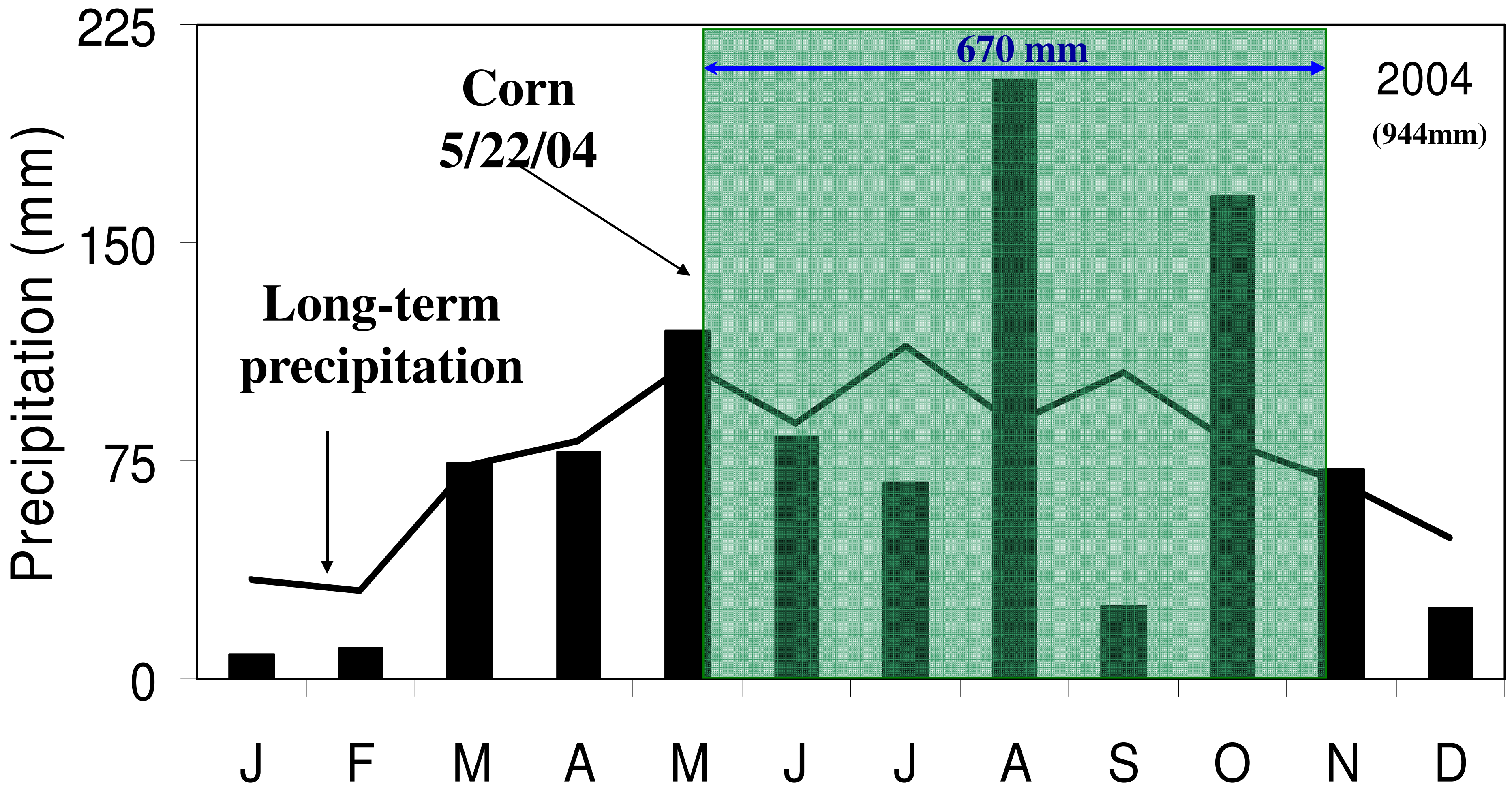
3. Soil Properties and Pore Characteristics as Influenced by Grass and Agroforestry Buffers

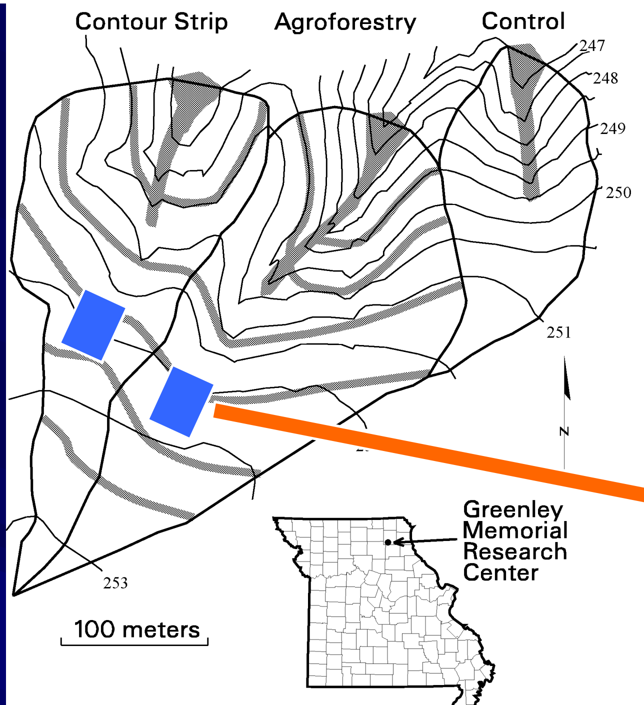
4. Root Length Density as Influenced by Grass and Agroforestry Buffers.

5. Water Stable Soil aggregates, Soil carbon, Soil Nitrogen, and Enzyme Activities as Influenced by Agroforestry Buffers

Seasonal Soil Water Differences in Row-crop, Grass buffer and Agroforestry Buffers

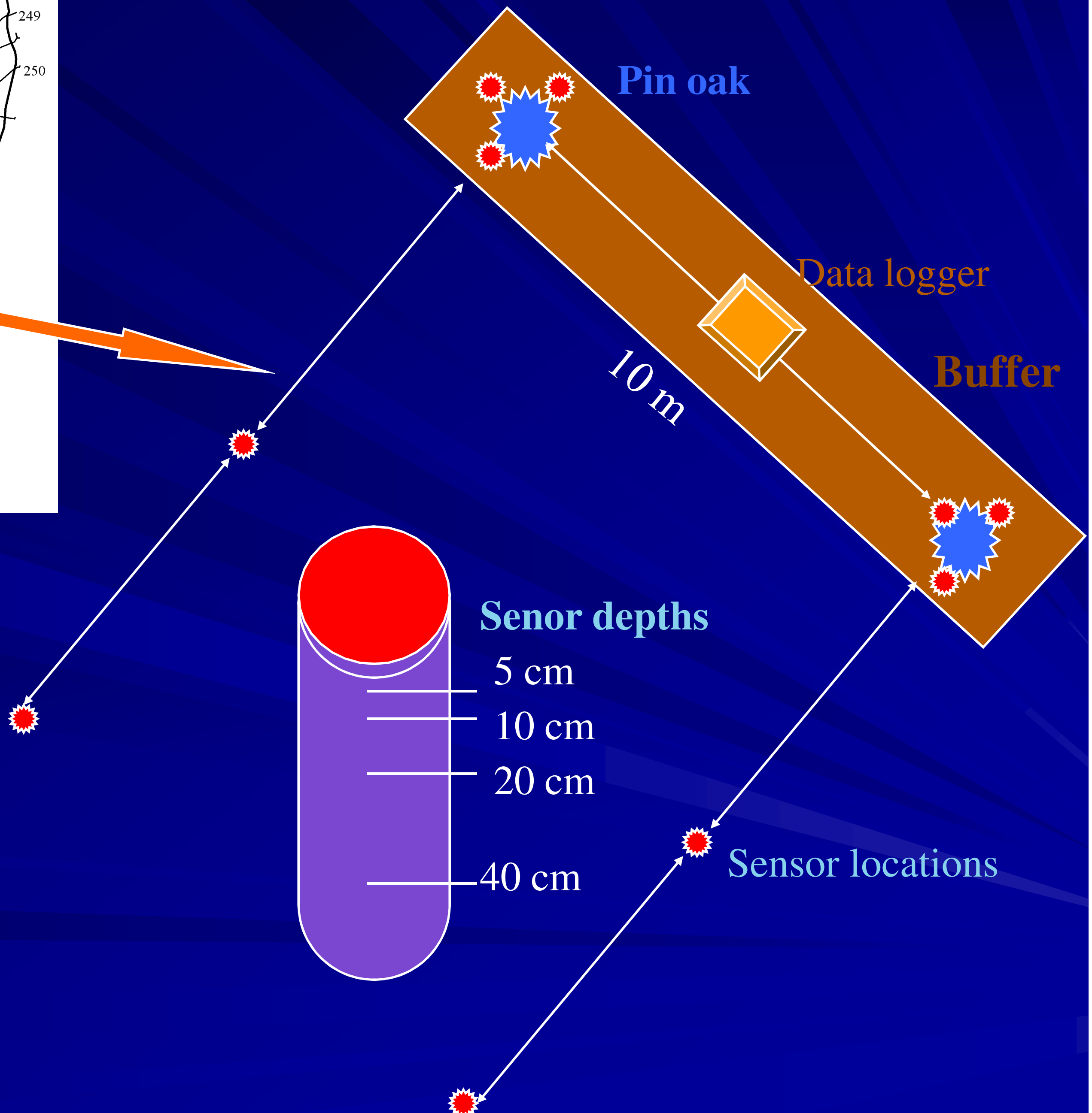
2004 Monthly Precipitation and Cropping Period

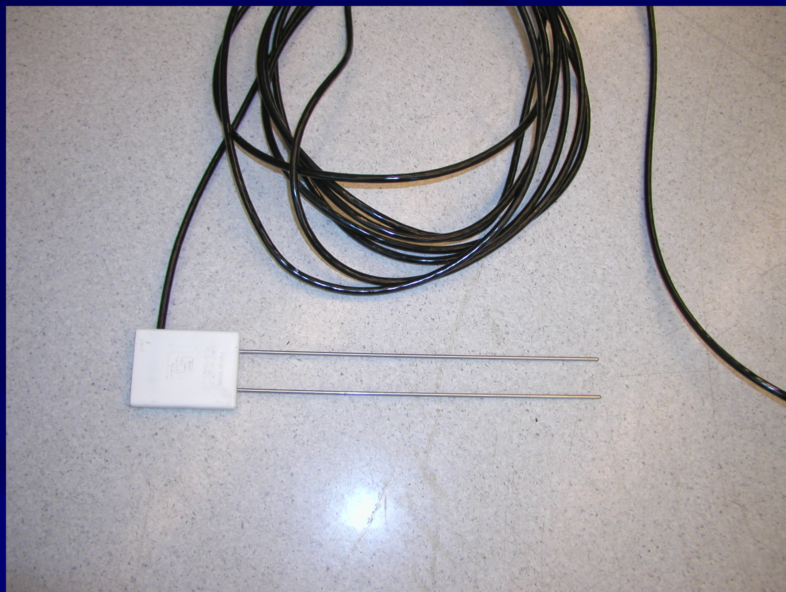




Study Design

Campbell TDR soil moisture sensors were installed on two transects

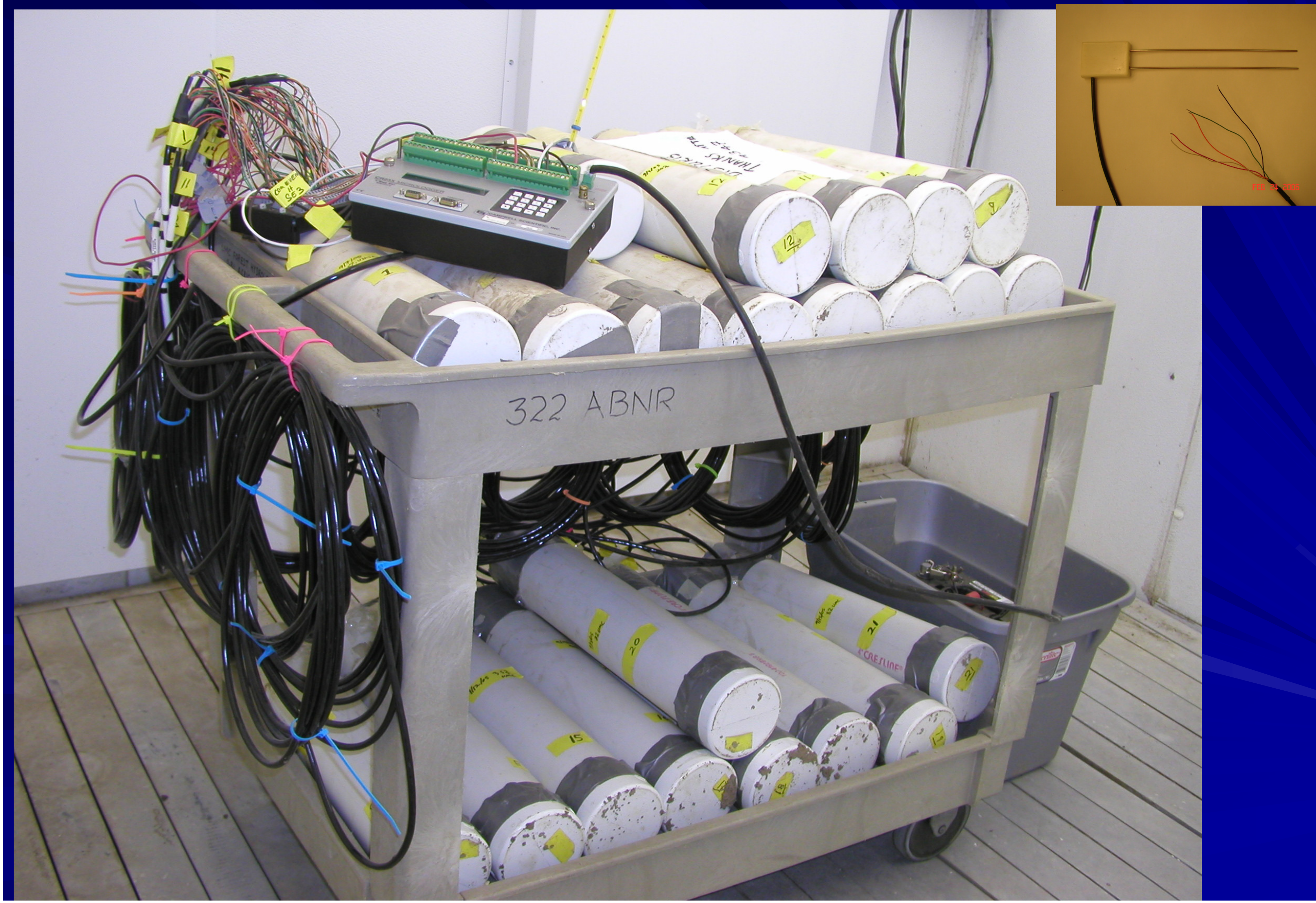




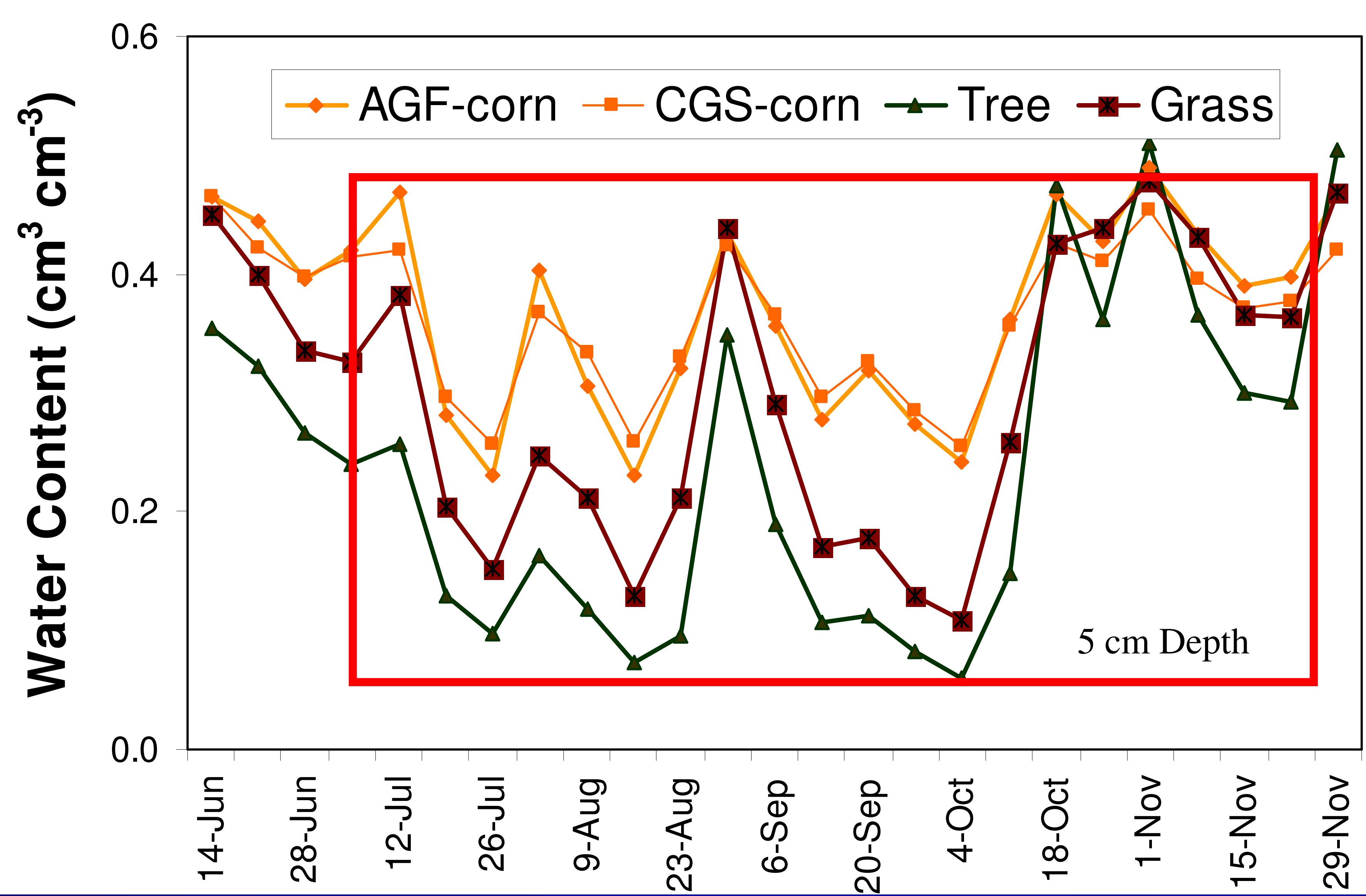
Campbell CS 616
Soil Moisture Sensor

Campbell CR23X
Data Logger

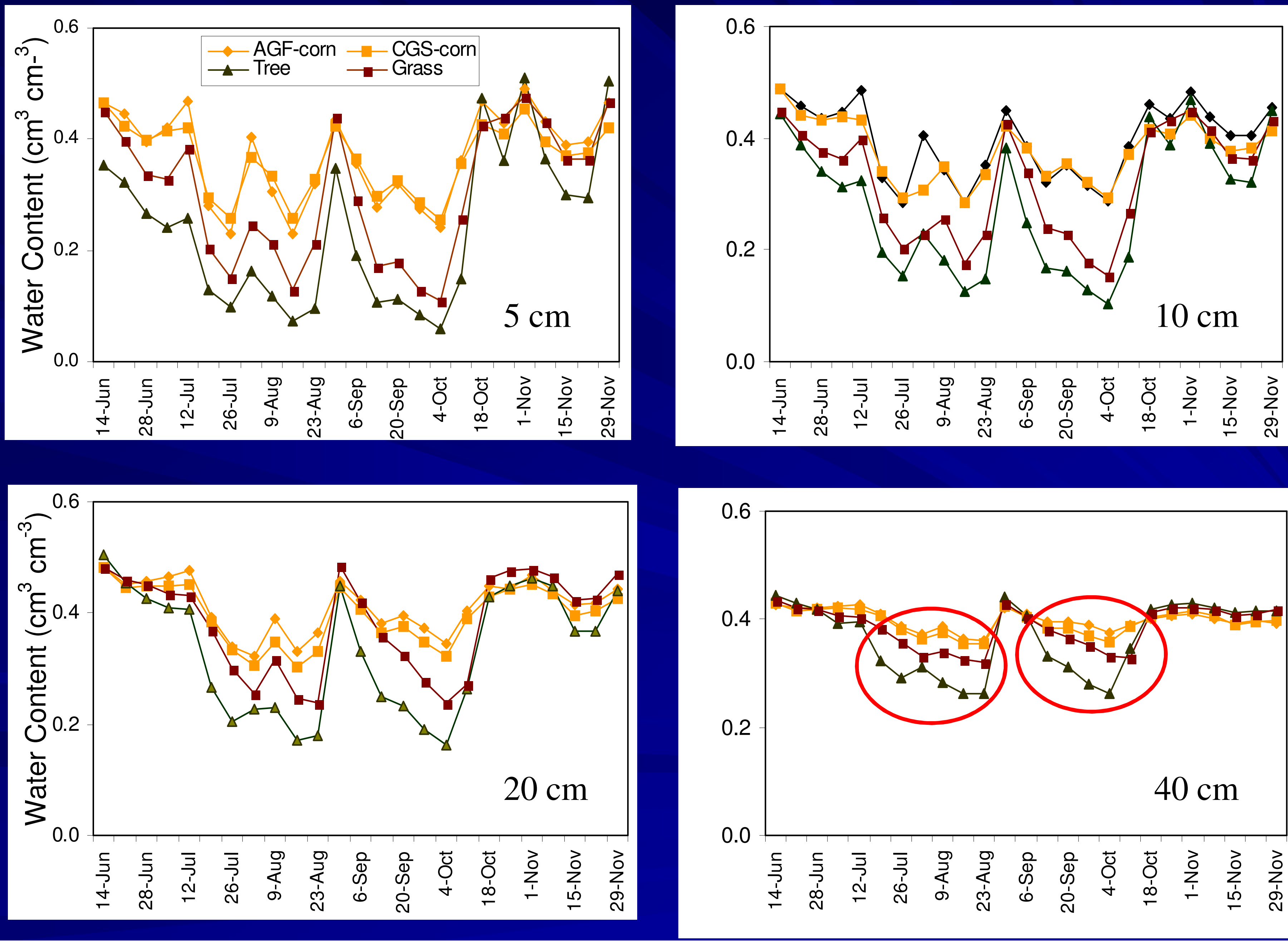
Calibration of Campbell Soil Moisture Sensors



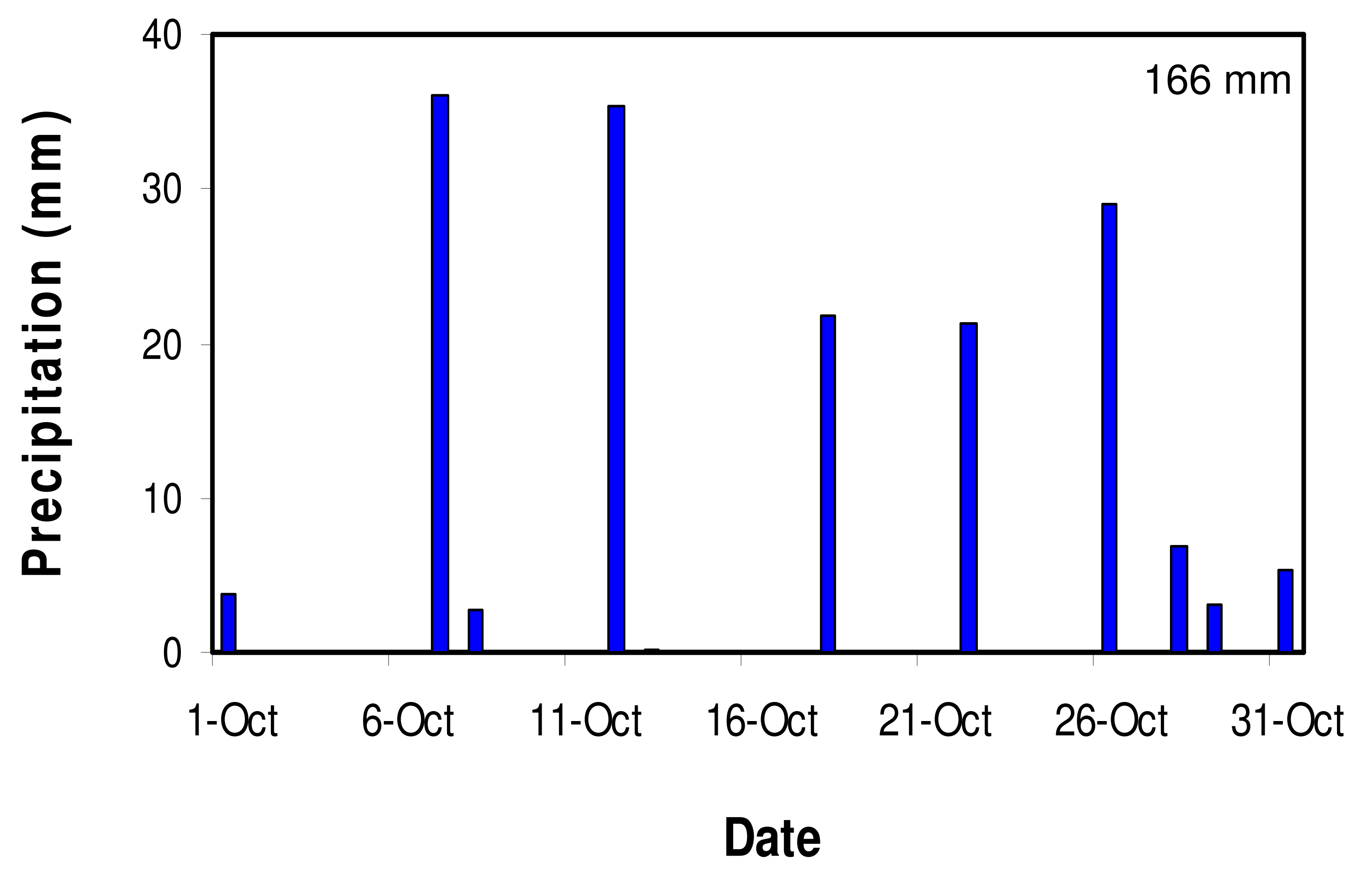
Soil Water Content for Tree, Grass, and Crop Areas from June 14 to November 30, 2004



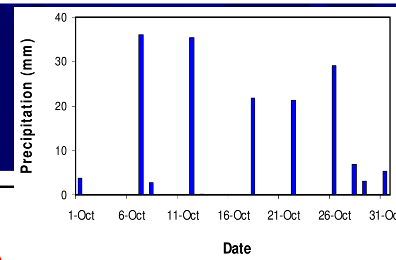
Soil Water Content for Tree, Grass, and Crop Areas 6-14 to 11-30

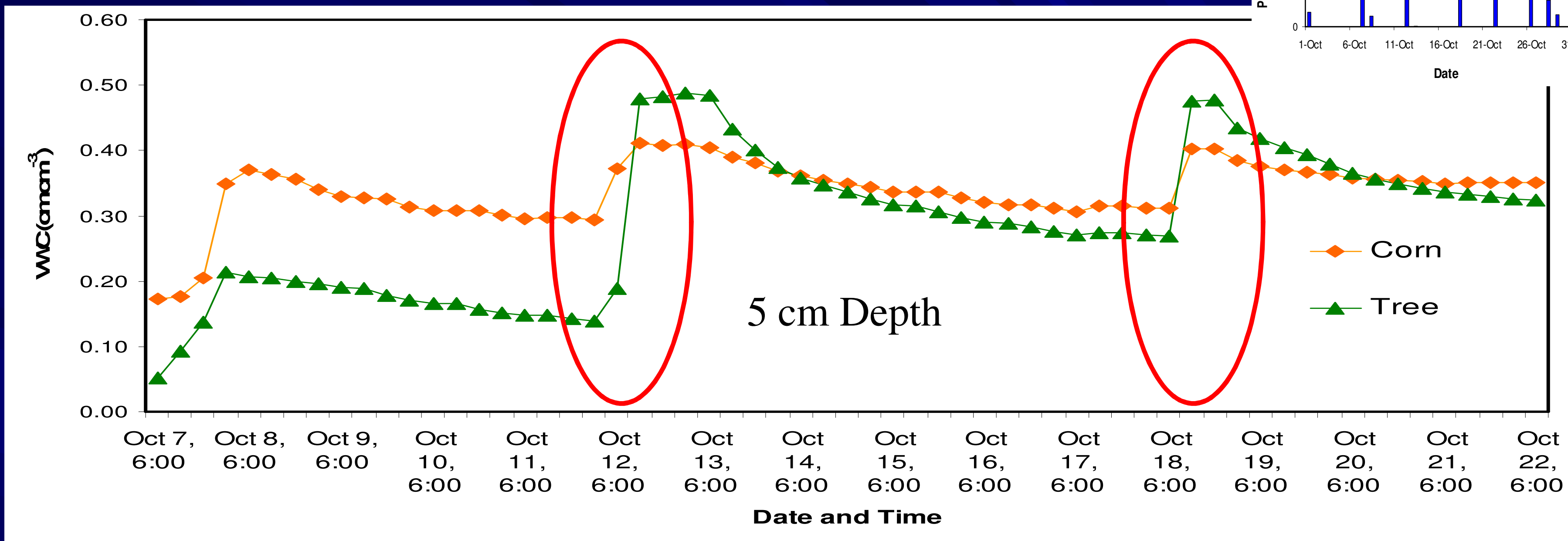


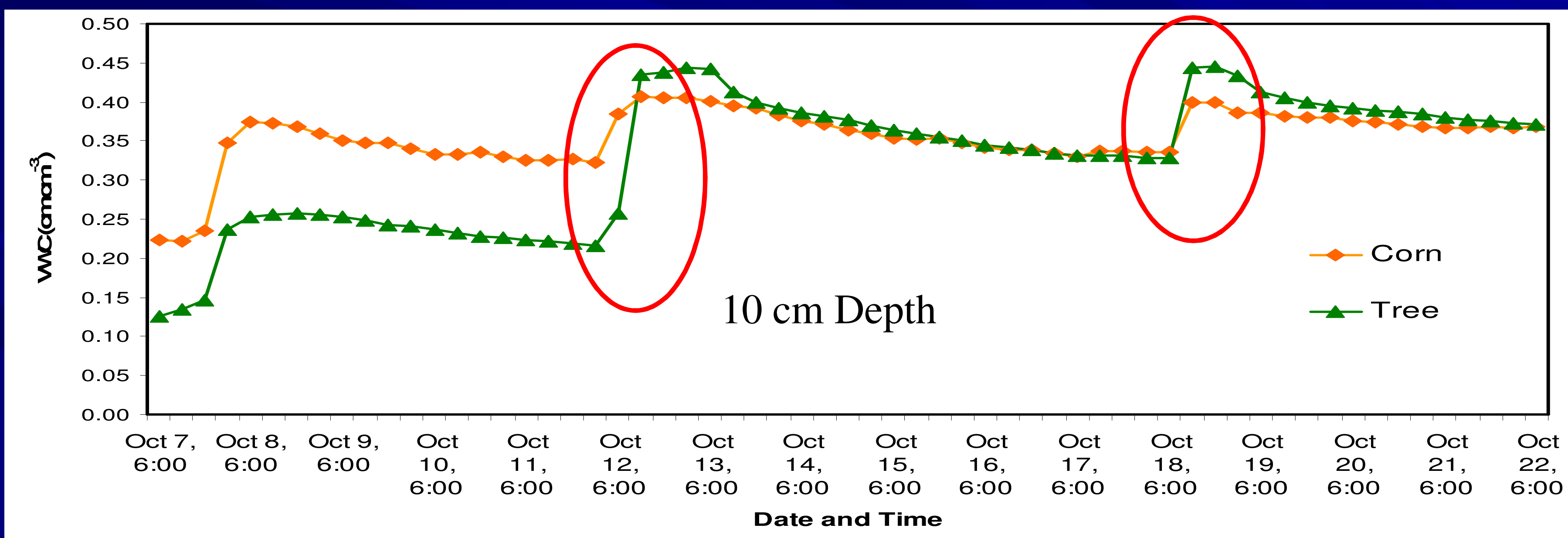
Daily Precipitation During October 2004 Recharge Period



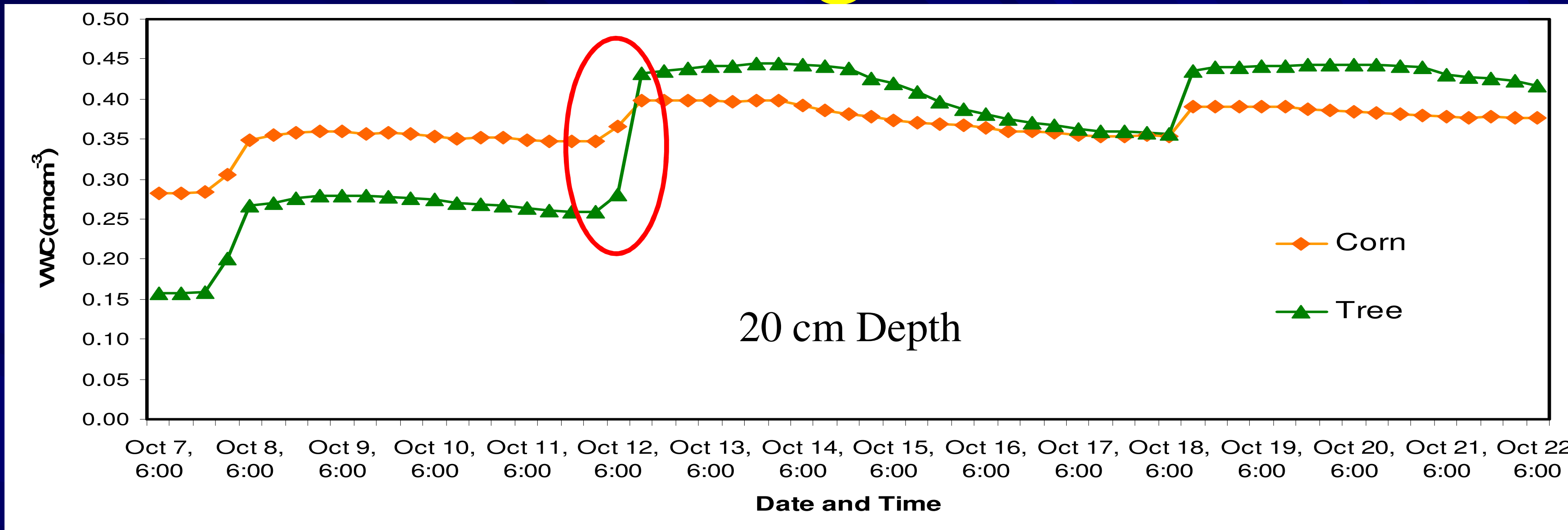
Soil Water Recharge (5 and 10 cm depths)

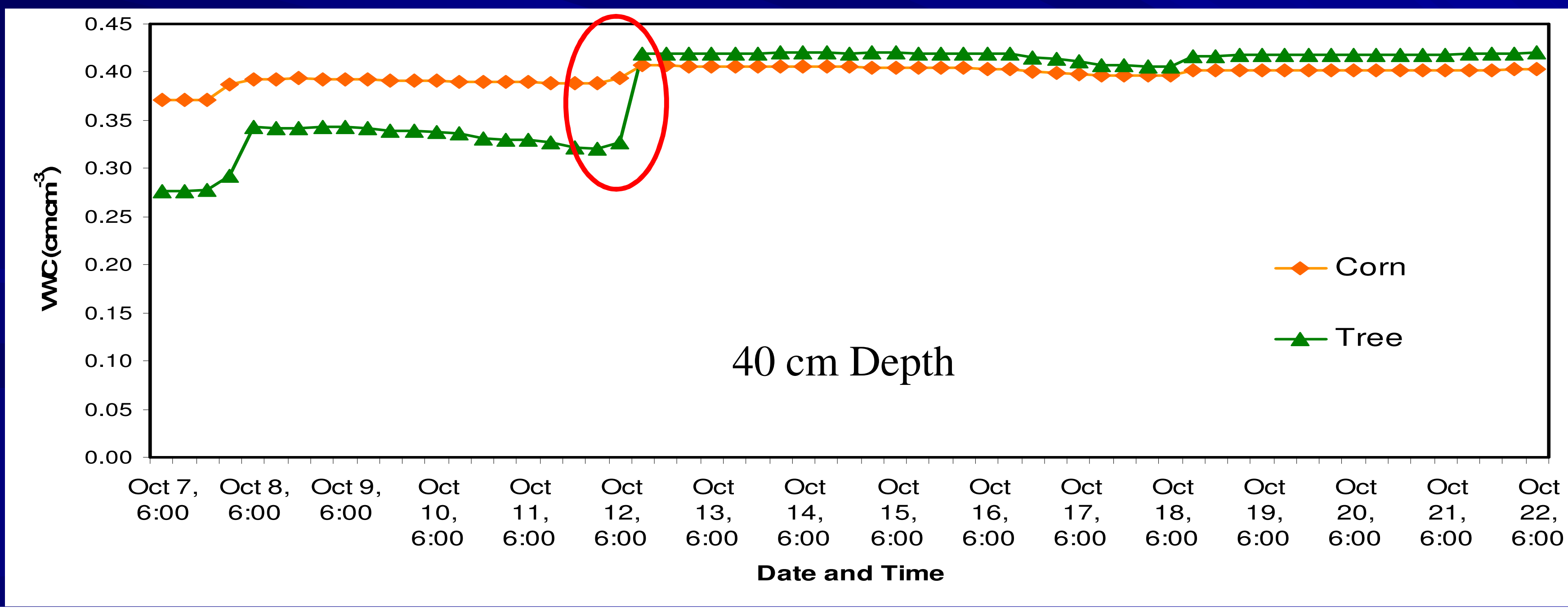






Soil Water Recharge (20 and 40 cm depths)





Summary:

Changes in soil moisture in crop, grass, and agroforestry areas at 5, 10, 20, and 40 cm depths during 2004 growing season shows that agroforestry and grass buffers had less volumetric water than crop areas.

During the recharge periods buffers stored more water than crop areas.

Agroforestry and grass buffers can store more water than crop areas and thereby reduce runoff, sediment, and nutrient losses from row crop watersheds.

Udawatta et al., 2005

1. Agroforestry and Grass Buffer Effects on Non Point Source Pollution Reduction from Row-crop Watersheds

2. Seasonal Soil Water Differences in Row-crop, Grass buffer and Agroforestry Buffers.

3. Soil Properties and Pore Characteristics as Influenced by Grass and Agroforestry Buffers

4. Root Length Density as Influenced by Grass and Agroforestry Buffers.

5. Water Stable Soil aggregates, Soil carbon, Soil Nitrogen, and Enzyme Activities as Influenced by Agroforestry Buffers

Soil Properties and Pore Characteristics as Influenced by Grass and and Agroforestry Buffers

Cores taken at 5 depths:

0-10, 10-20, 20-30, 30-40, and 40-50 cm depths

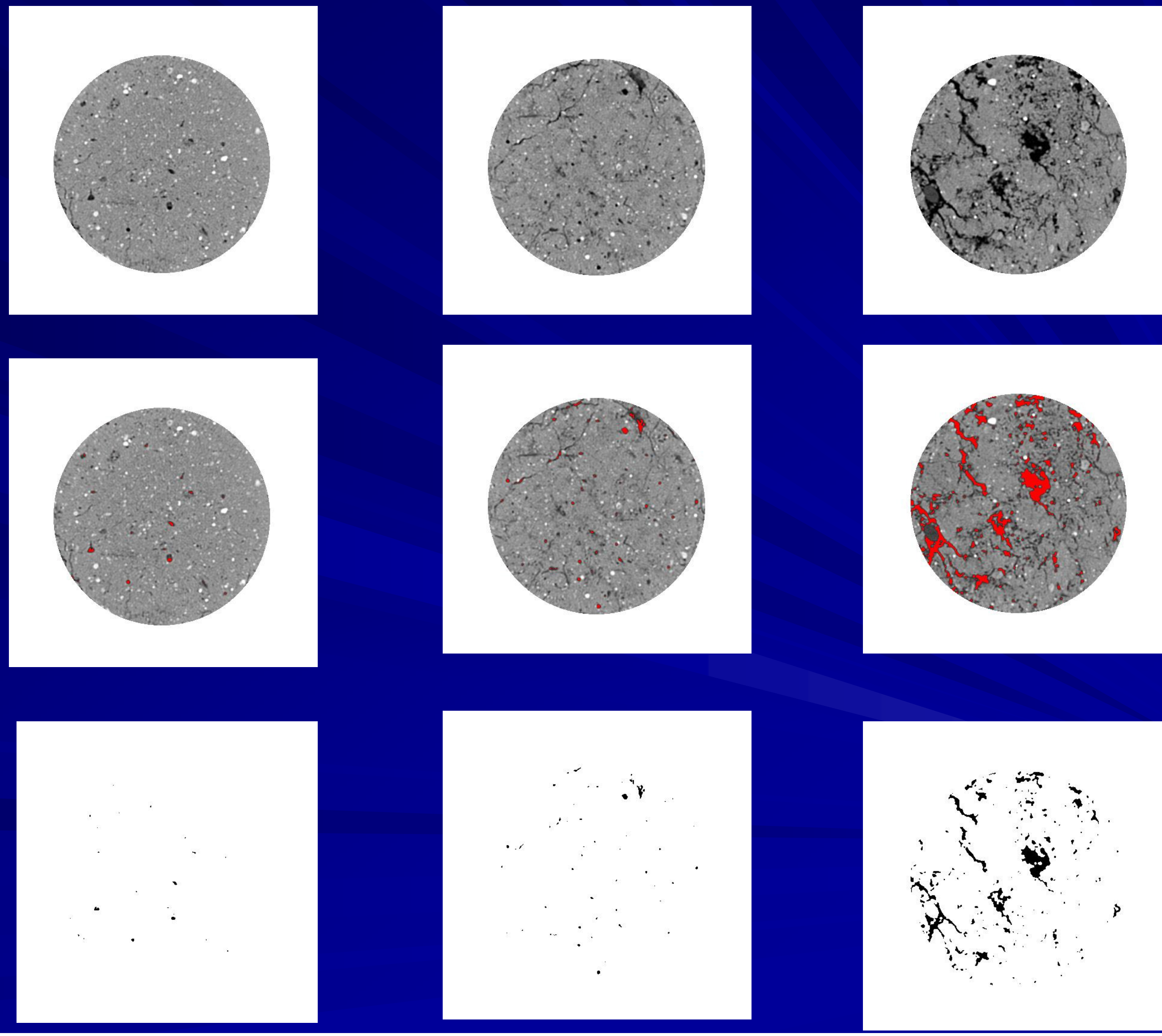

SIEMENS
APR 16 2006

Row crop | Grass buffer | Agroforestry

Typical scan images 68 mm diam. area

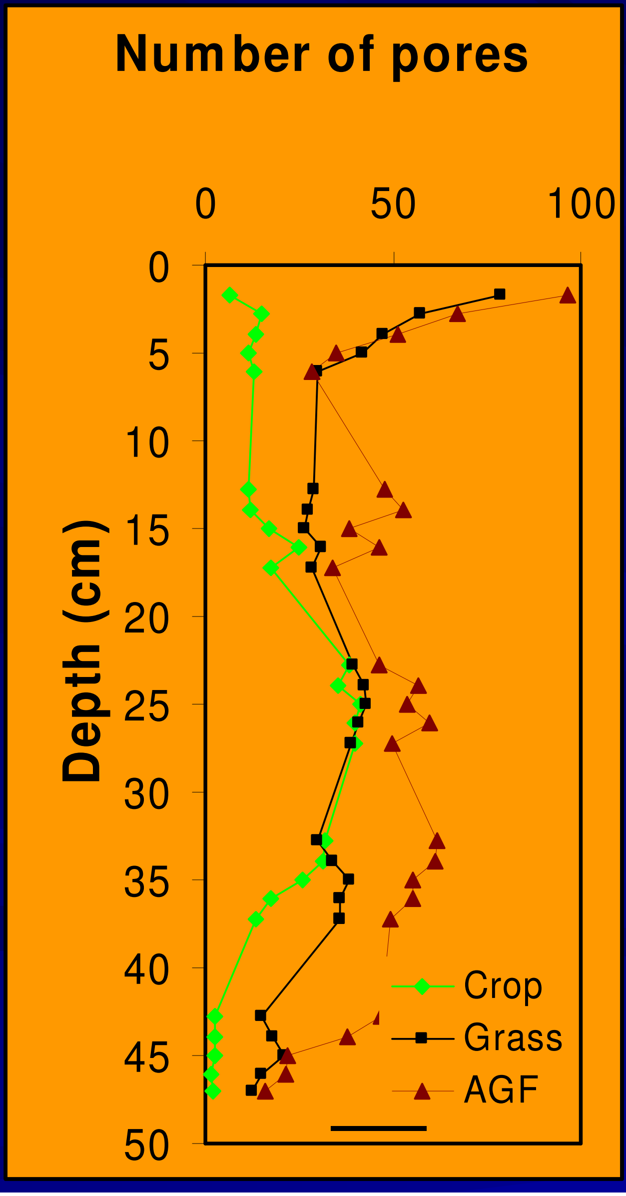
After thresholding, air-filled pores are in red

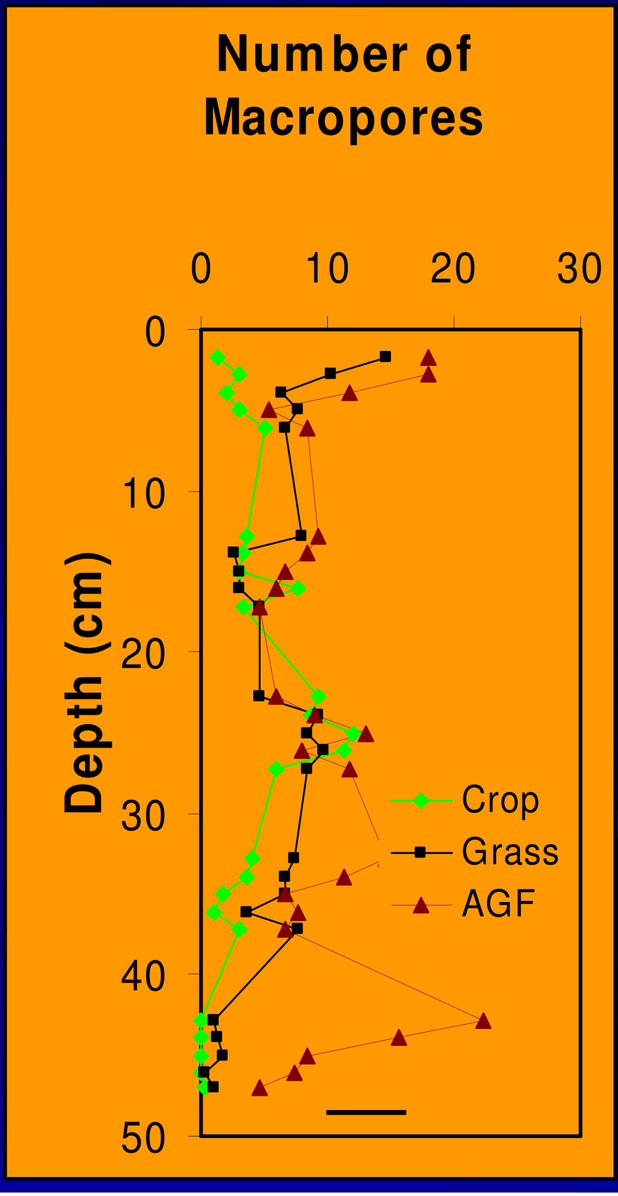
Isolated pores within the scans



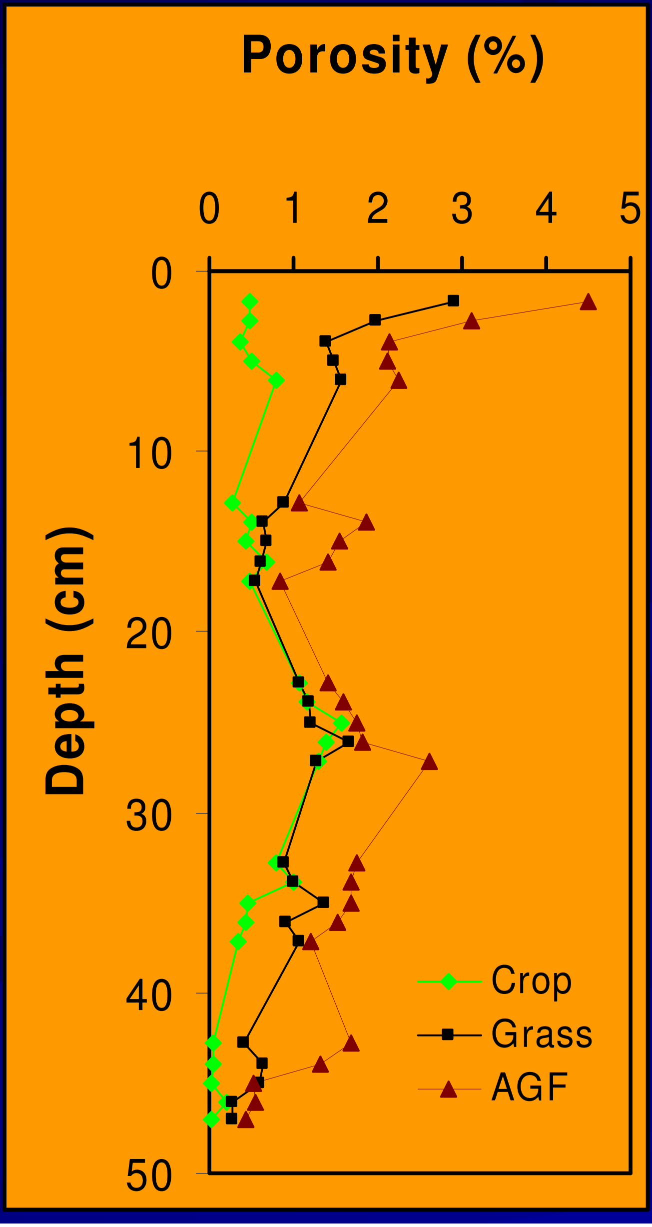
Udawatta et al., 2006

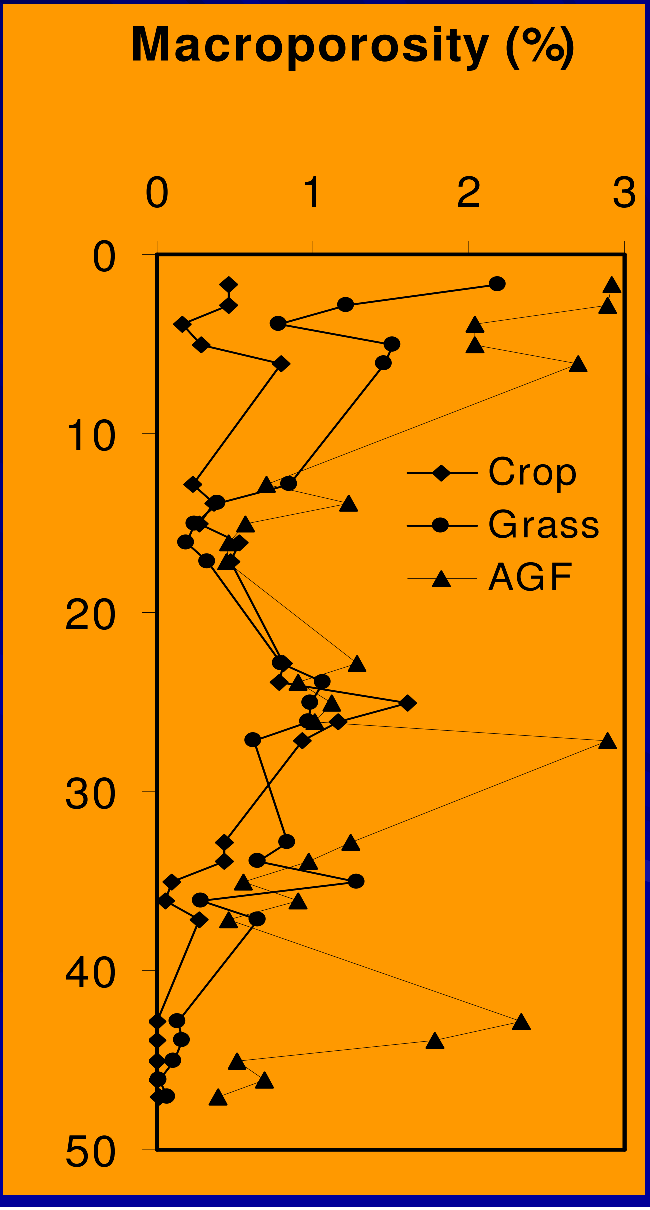
CT-measured Number of Pores and Macropores/2500 mm^2





CT-measured Porosity and Macroporosity





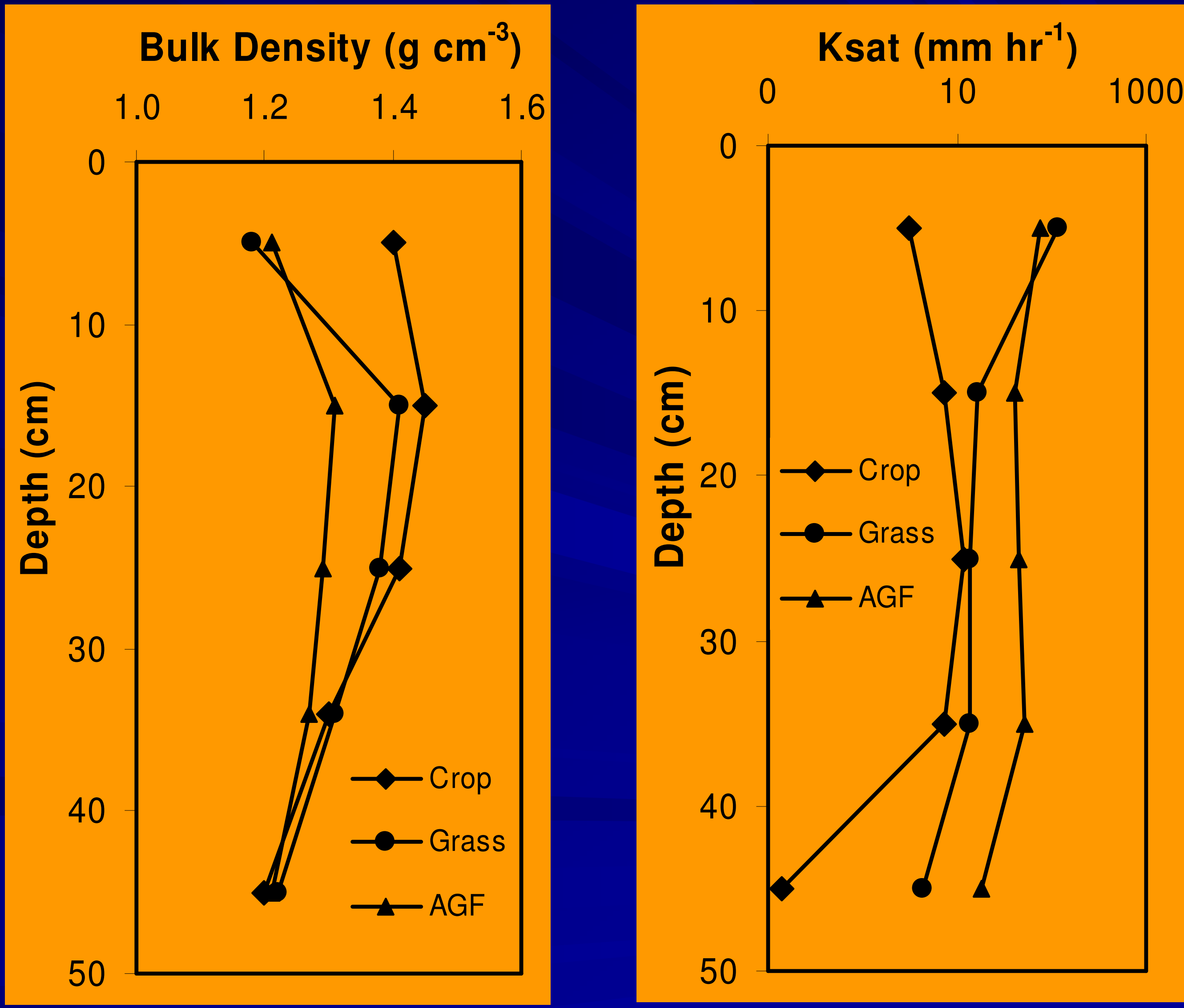
Water Infiltration/Storage Capacity and Macroporosity

Poisulle law $Q = \frac{6 \quad \pi \quad \text{Radius}^4}{\eta \quad L}$

30 µm (0.03 mm) and 500 µm (0.5 mm) radius

$\frac{Q_{500}}{Q_{30}} = \frac{0.5^4}{0.03^4} = 77{,}160$

Bulk density and saturated hydraulic conductivity (*K*sat) for row crop, grass buffer, and agroforestry buffer treatments by soil depth.



Seobi et al., 2006

Predicted *Ksat* using measured pore parameters

Variable	R^2
Number of macropores	0.32
Number of macropores + Largest pore size	0.43
Number of pores + Total porosity + Macroporosity	0.68

Summary:

- Significantly higher number of CT-measured pores and number of macropores were found for the agroforestry buffer relative to the other treatments for all five depths.

- Significantly higher CT-measured total porosity and macroporosity were found for the agroforestry buffer relative to the other treatments for the first three depths.

- Significantly lower bulk density was found for the buffer treatments. Significantly higher *Ksat* was found for the buffer treatments compared to row crop management.

* CT-measured total number of pores, number of macropores, total porosity, macroporosity, diameter of the largest pore, mean macropore diameter and mean coarse mesopore diameter correlated positively with *Ksat*.
* Among the 7 CT-measured parameters evaluated, the total number of macropores explained the largest percentage of variability in *Ksat*.
* Total number of pores and the diameter of the largest pore appeared to be the best 2 parameter equation. Number of pores, total porosity and macroporosity appeared to be the best combination with 3 parameters.

CONCLUSIONS

Results of this study show that agroforestry and grass buffers improve soil physical properties such as bulk density, hydraulic conductivity, and CT-measured pore parameters.

Adoption of these practices may reduce runoff, nutrient, and herbicide loss and improve surface water quality.

1. **Agroforestry and Grass Buffer Effects on Non Point Source Pollution Reduction from Row-crop Watersheds**

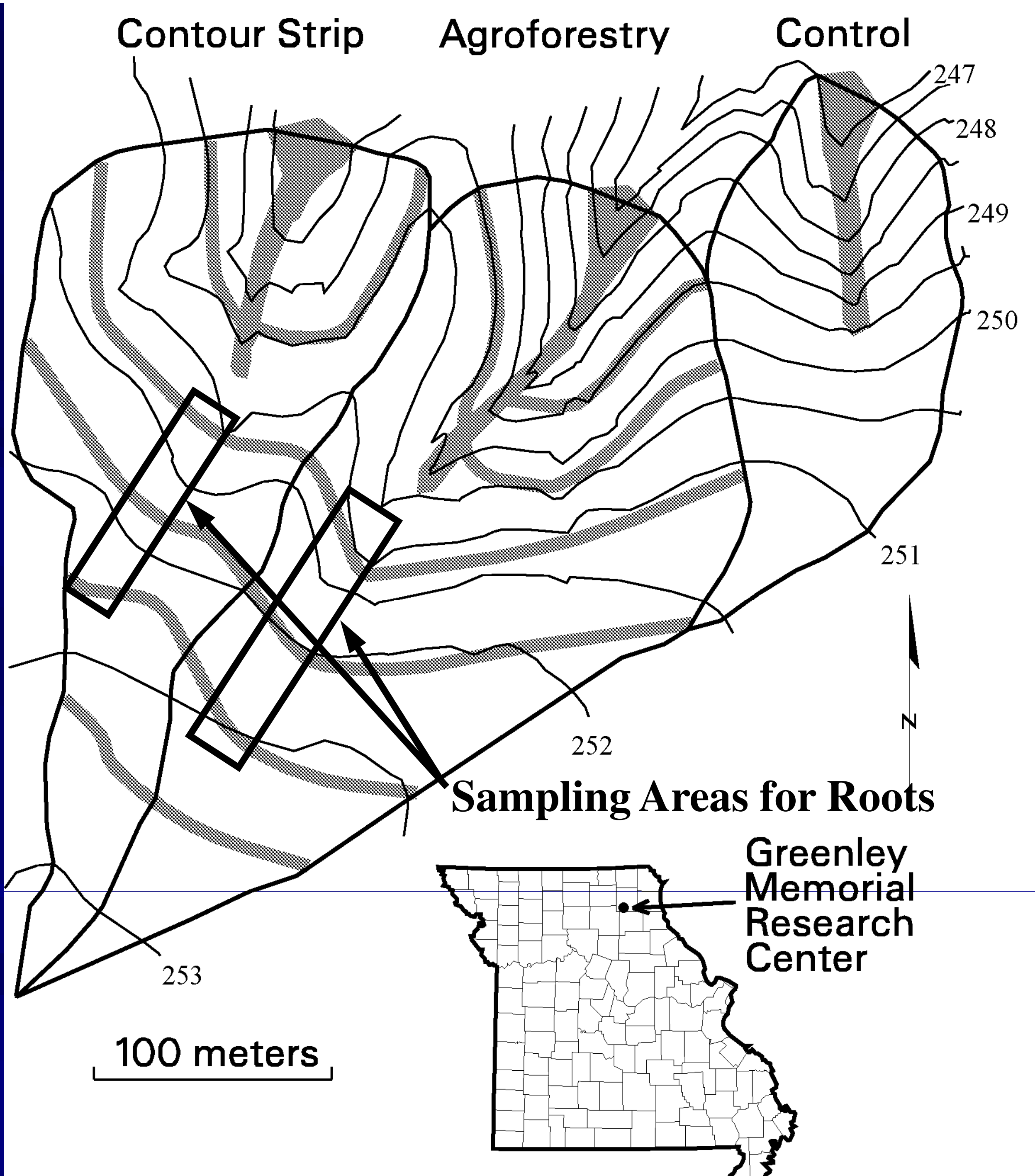
2. **Seasonal Soil Water Differences in Row-crop, Grass buffer and Agroforestry Buffers.**

3. **Soil Properties and Pore Characteristics as Influenced by Grass and Agroforestry Buffers**

4. **Root Length Density as Influenced by Grass and Agroforestry Buffers.**

5. **Water Stable Soil aggregates, Soil carbon, Soil Nitrogen, and Enzyme Activities as Influenced by Agroforestry Buffers**

Root Length Density as Influenced By Grass and Agroforestry Buffers

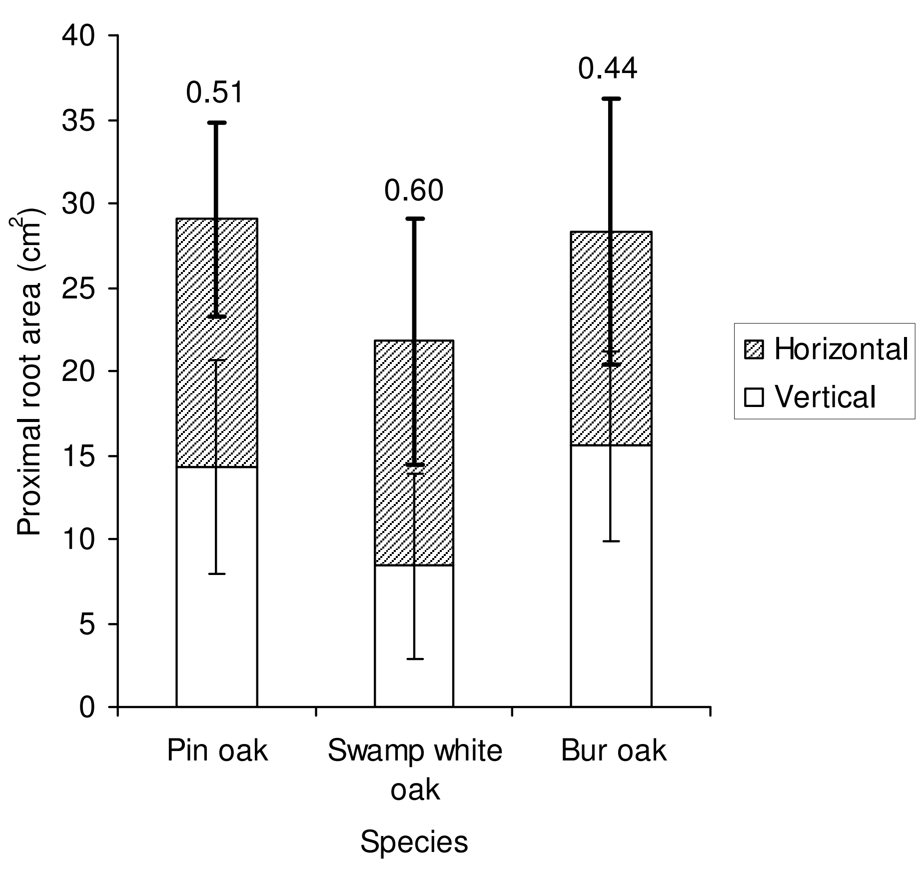


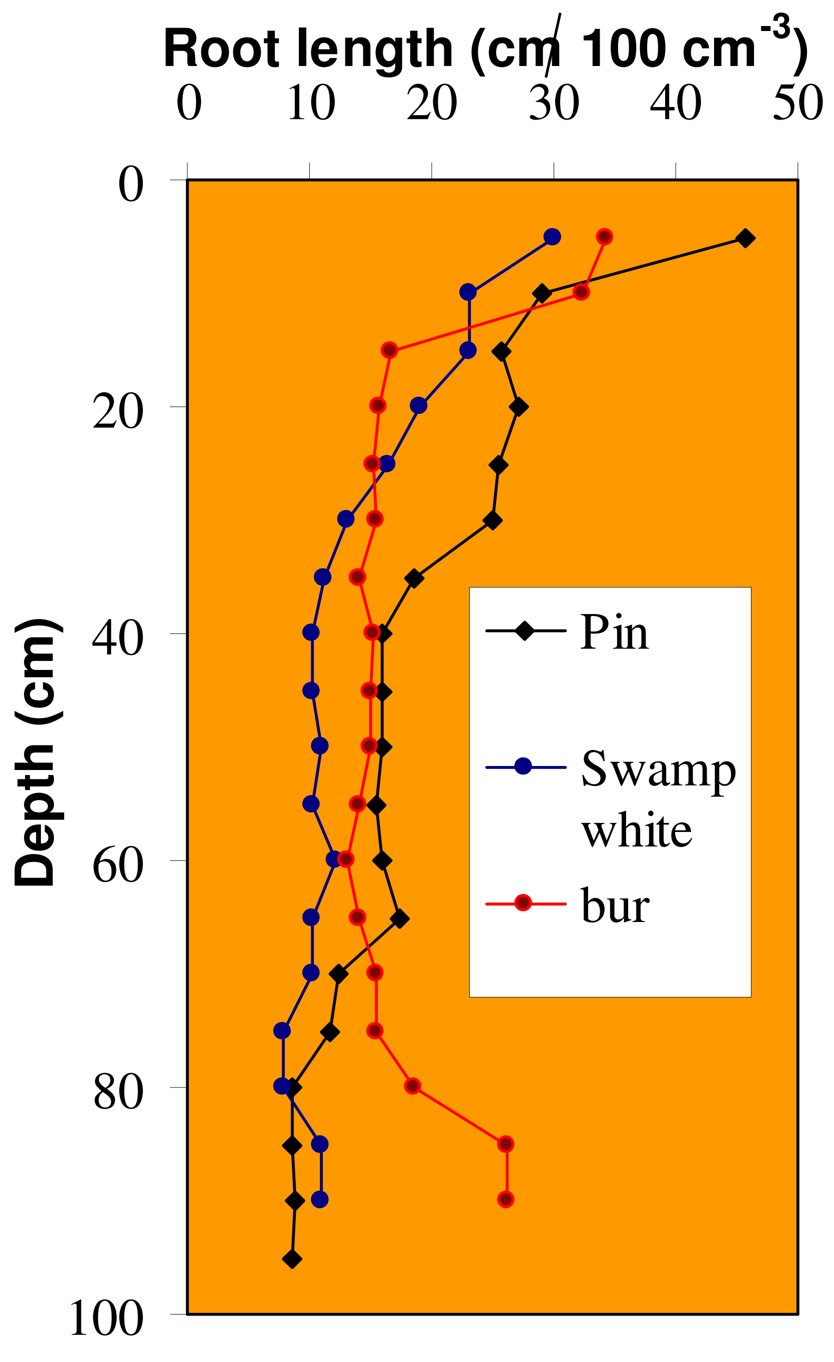
Study site location and 0.5 m interval contour lines.

Gray bands indicate grass buffers and agroforestry buffers and grass waterways.

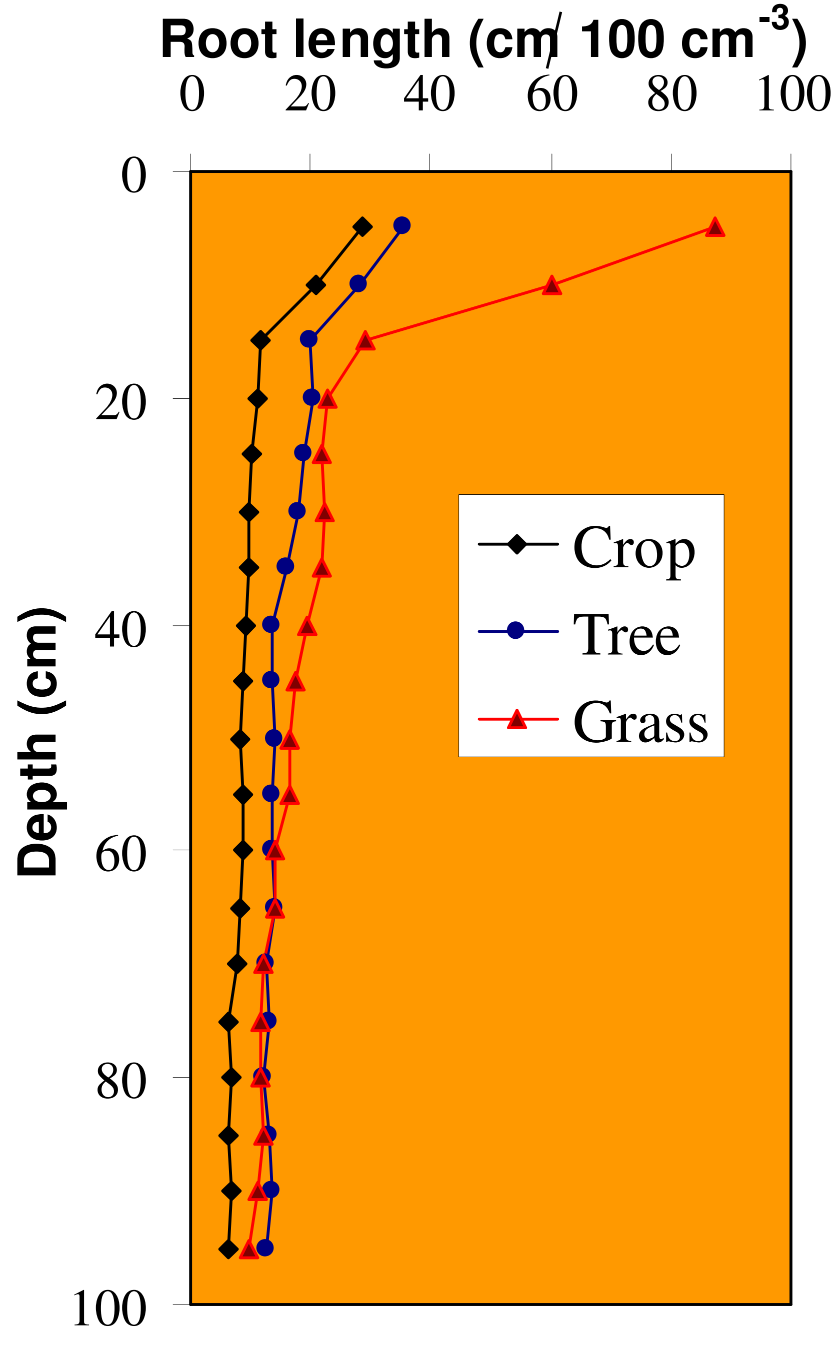

CAUTION
ROTATING HEAD

Vertical distribution of root length for pin oak, swamp



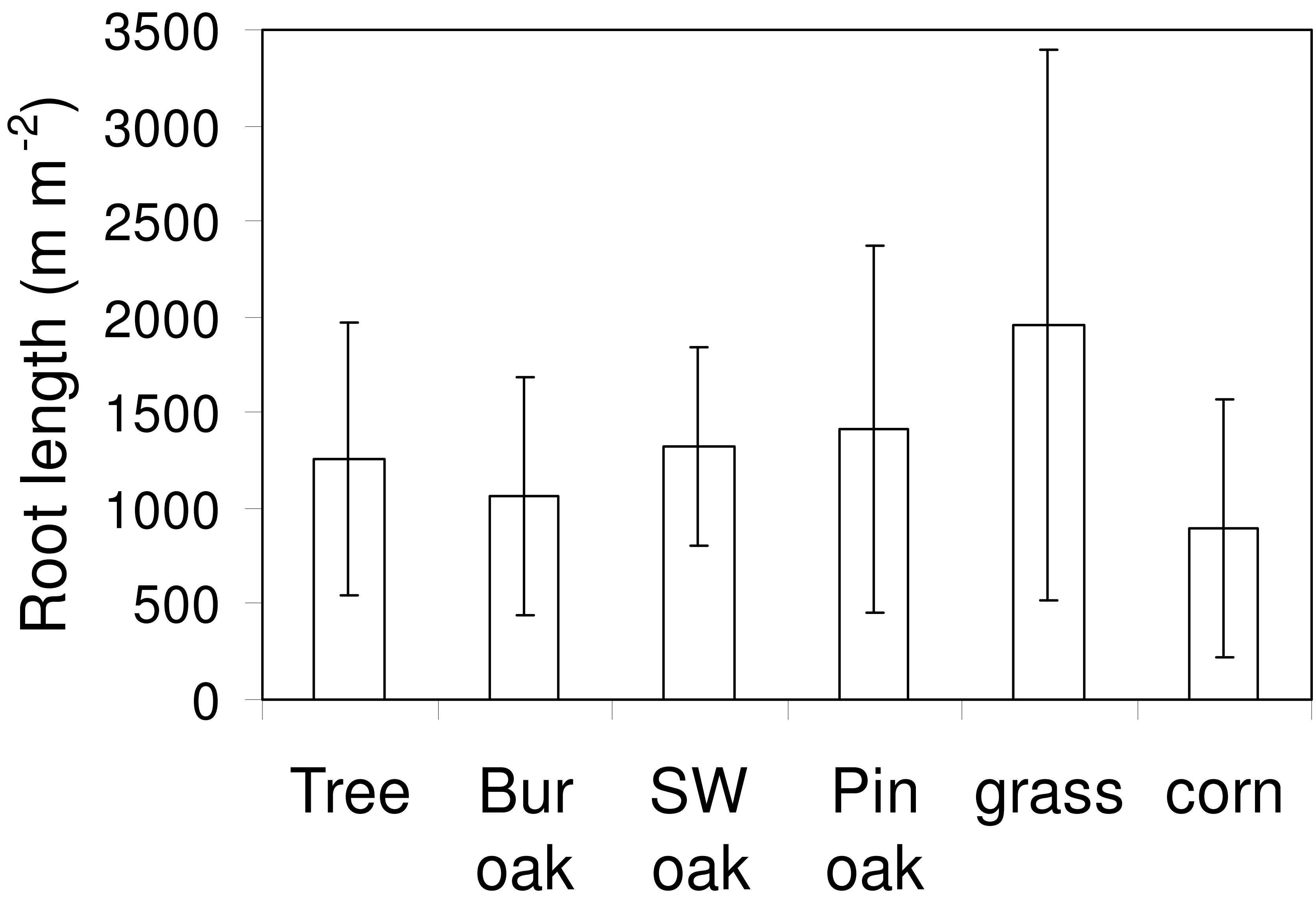


Vertical distribution of root length for corn, tree and grass treatments



Udawatta et al., 2005

Root Length Density from 0 to 1.0 m Depth by Treatment



1. Agroforestry and Grass Buffer Effects on Non Point Source Pollution Reduction from Row-crop Watersheds

2. Seasonal Soil Water Differences in Row-crop, Grass buffer and Agroforestry Buffers.

3. Soil Properties and Pore Characteristics as Influenced by Grass and Agroforestry Buffers

4. Root Length Density as Influenced by Grass and Agroforestry Buffers.

5. **Water Stable Soil aggregates, Soil carbon, Soil Nitrogen, and Enzyme Activities as Influenced by Agroforestry Buffers**

Water Stable Soil aggregates, Soil carbon, Soil Nitrogen, and Enzyme Activities as Influenced by Agroforestry Buffers

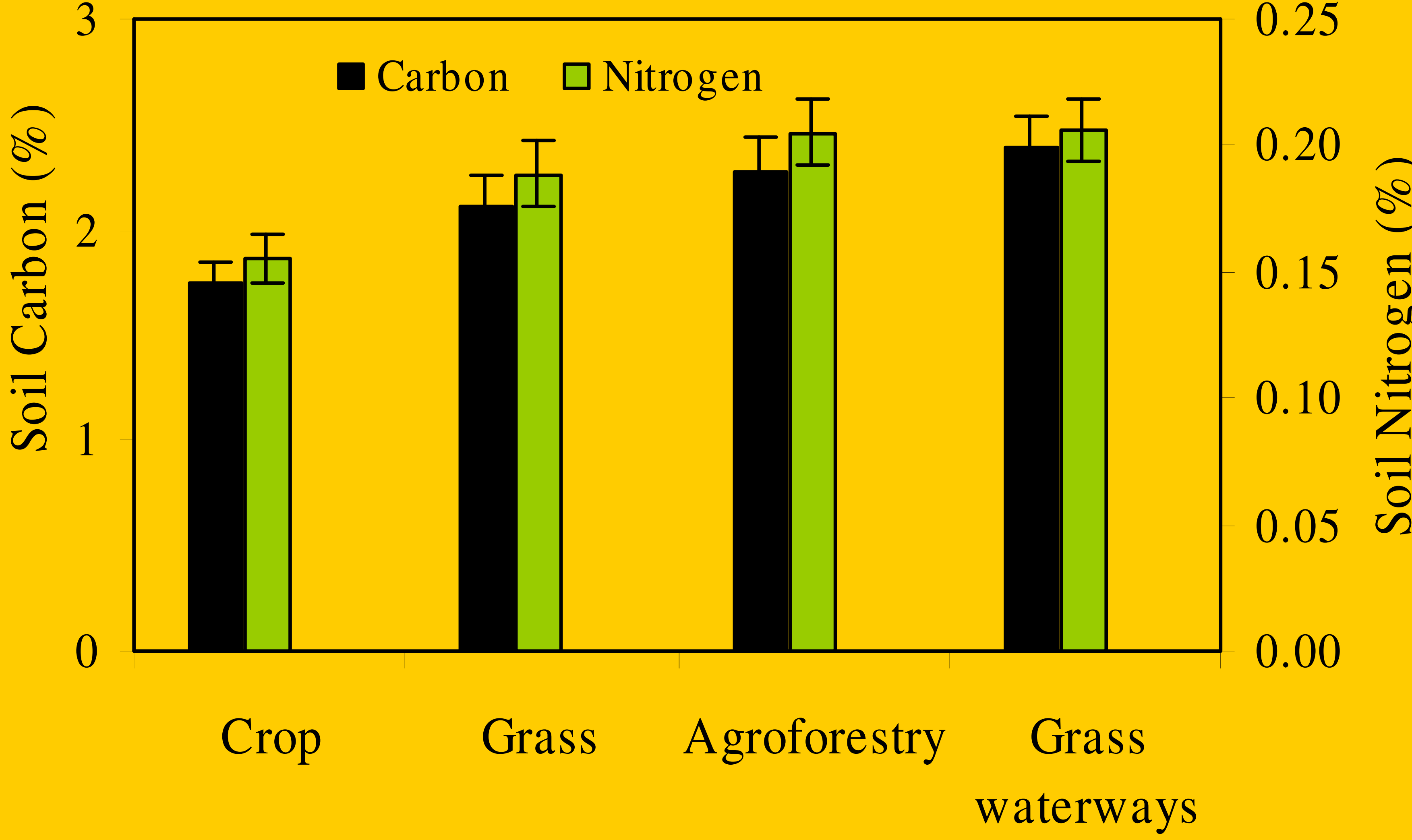
Rationale

* Agroforestry and grass buffers increase water stable aggregates and thereby improve soil structure providing better soil aeration and water availability for maximum aerobic microbial activity.

* Soil enzymes are both mediators and catalysts of important soil functions and their measurement indicates the influence of natural processes and anthropogenic (tillage, vegetation removal etc.) activities on soil quality.

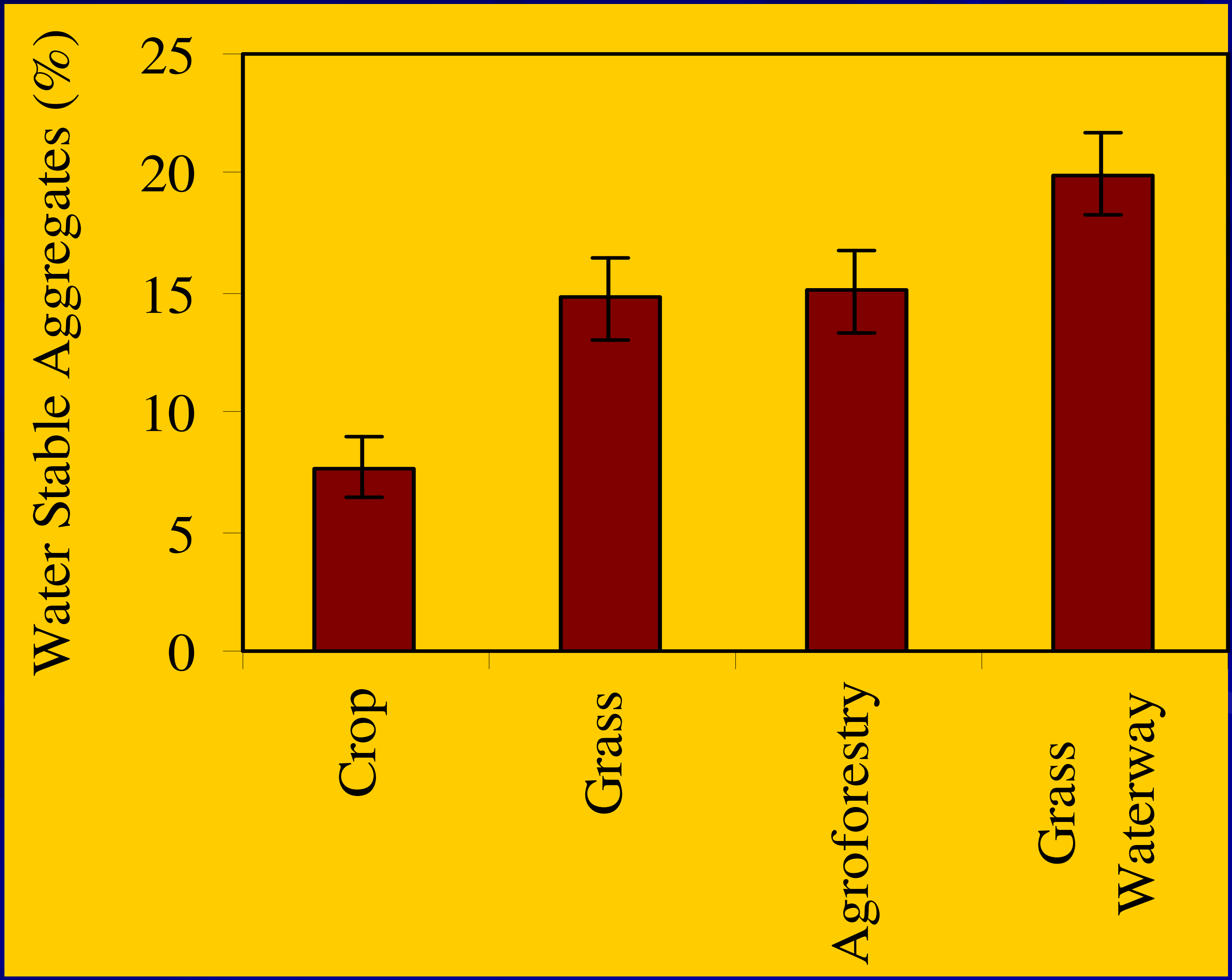
WSA will be measured using the wet-sieving method on aggregates >250µm diameter.

Soil Carbon and Nitrogen as Influenced by Agroforestry Buffers

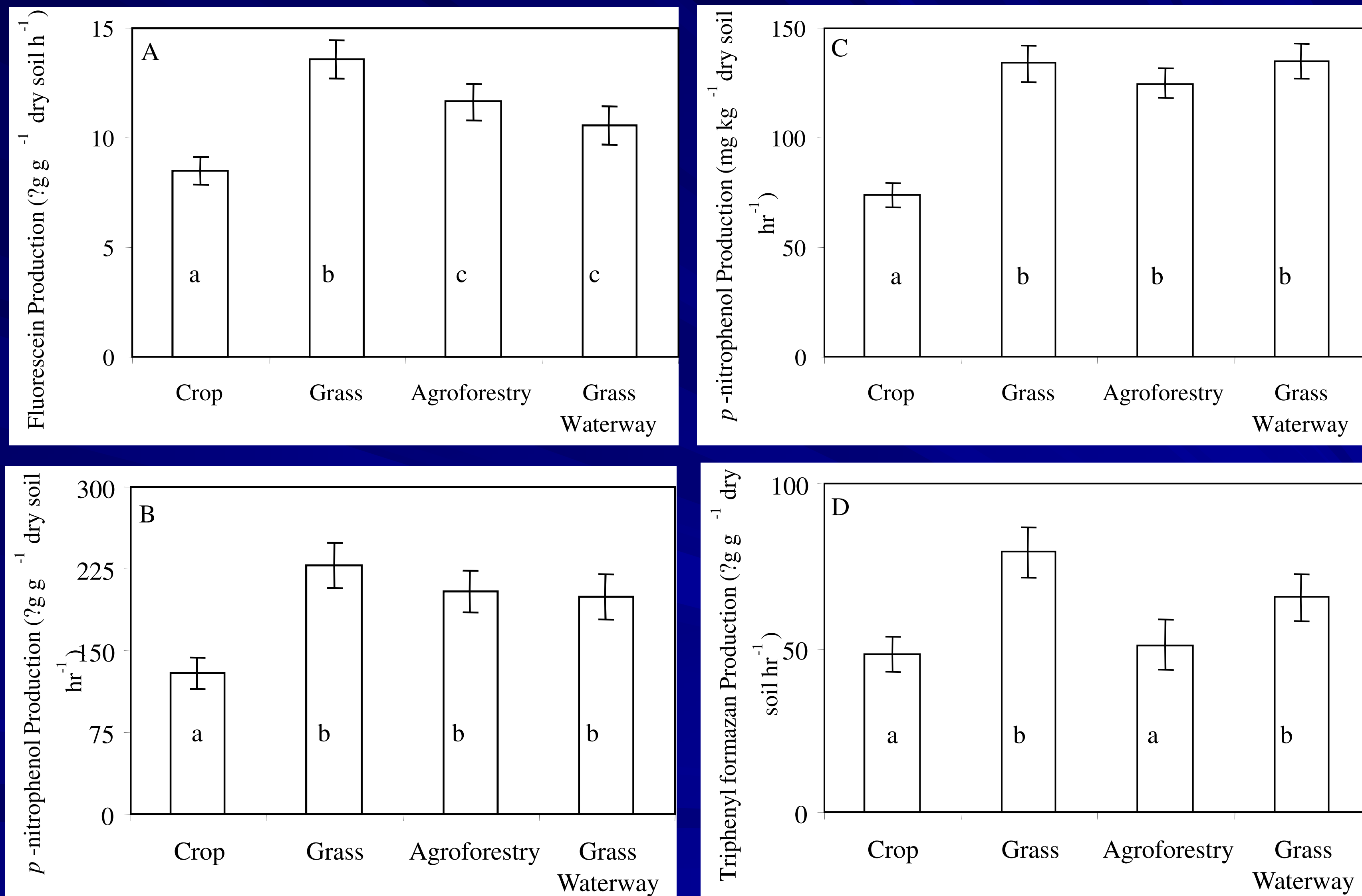


Udawatta et al., 2007

Water Stable Soil aggregates as Influenced by Agroforestry Buffers



Soil Enzymes as Influenced by Agroforestry Buffers



CONCLUSIONS

Results of this study show that agroforestry and grass buffers increase water stable soil aggregates and soil enzyme activity.

Adoption of these practices may improve soil physical properties and biological activity and may help reducing runoff, nutrient, and herbicide loss and improve surface water quality.

Does this Study Answer questions Related to Water and Soil Quality?

Yes, It showed reduction in non-point source pollution due to incorporation of agroforestry and grass buffers on row crop watersheds.

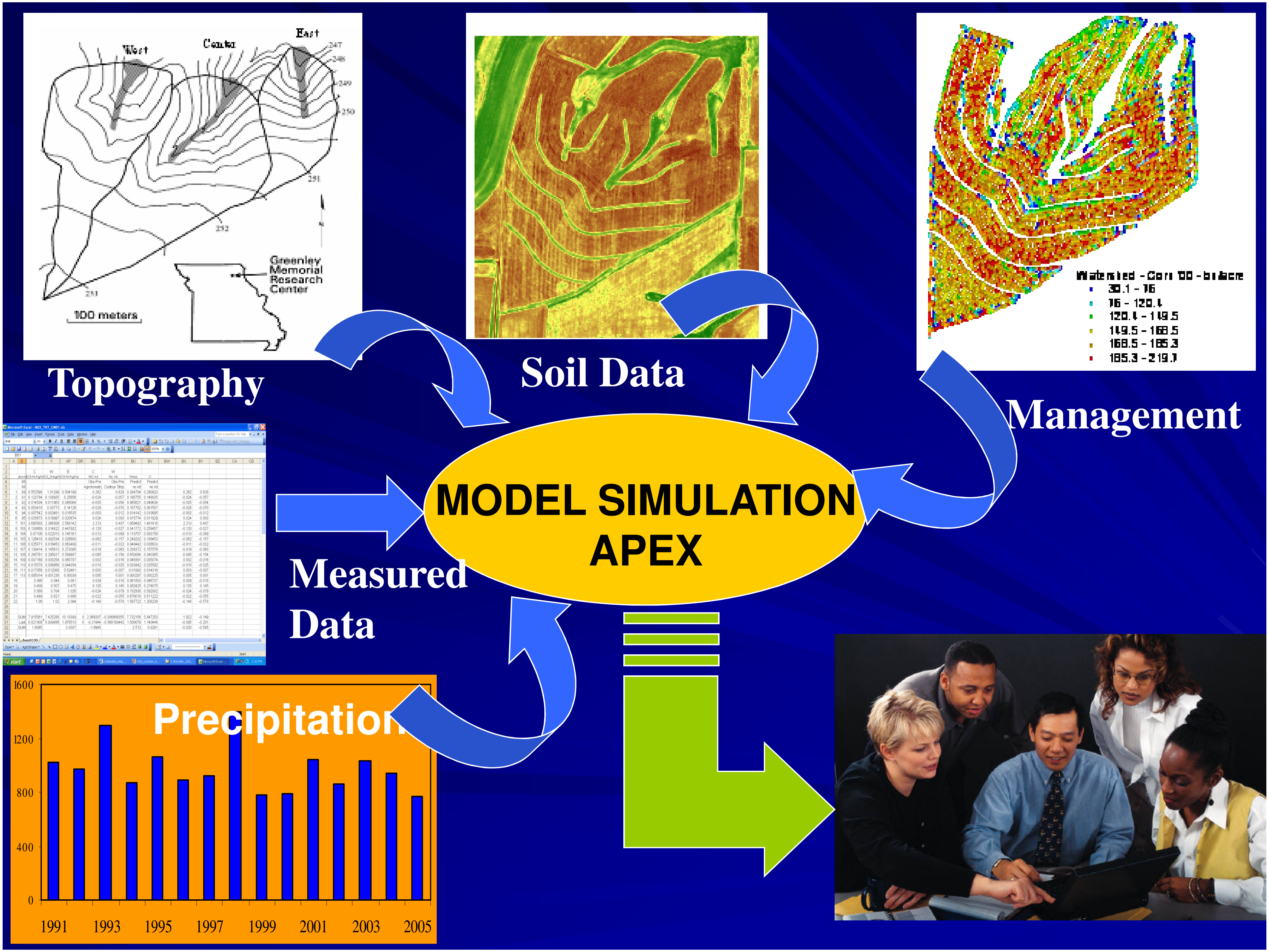
Results showed that sediment, N, and P loads in runoff were low in agroforestry and grass buffer watersheds.

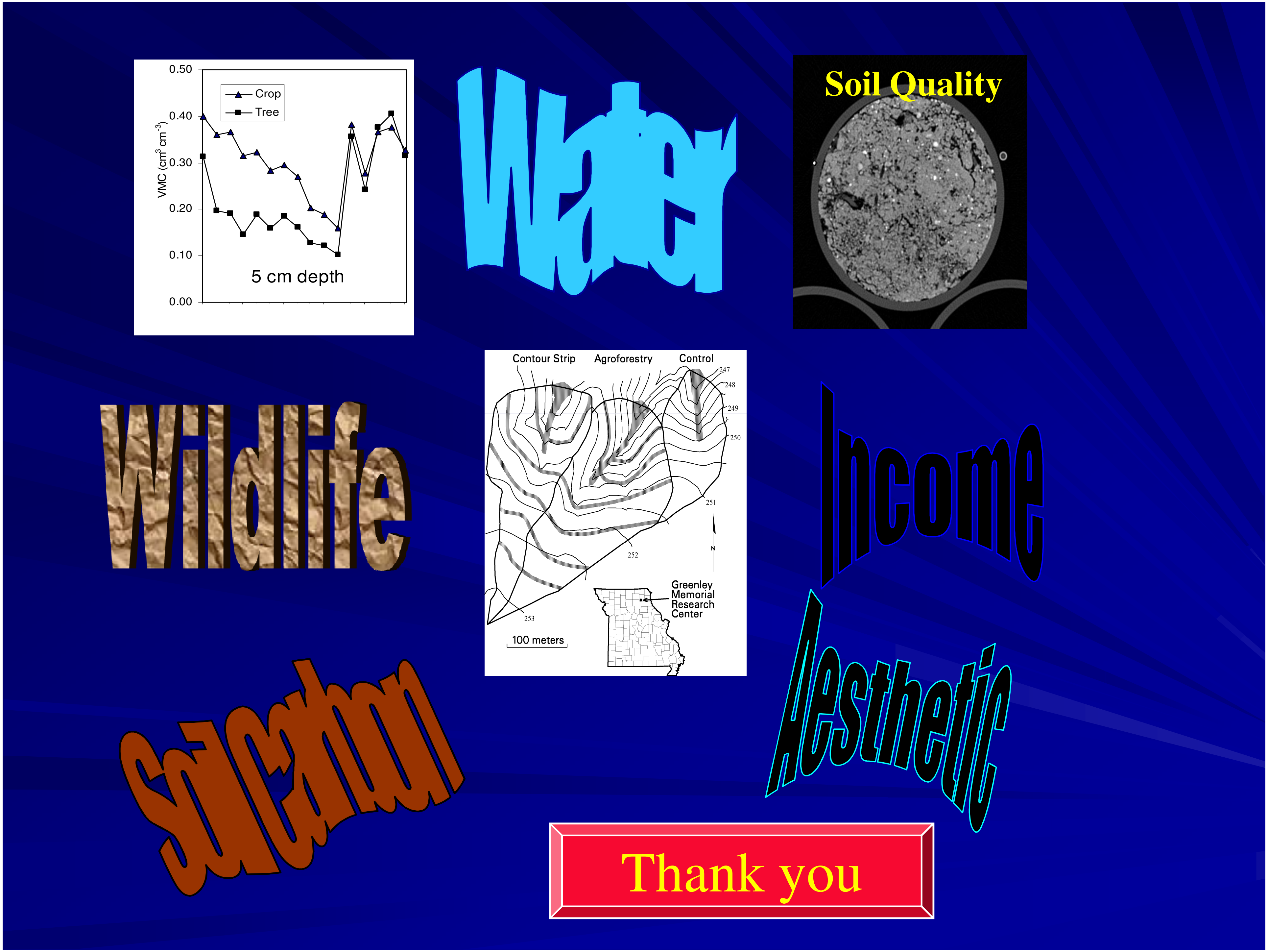
Soil Quality?

Yes, agroforestry and grass buffers on row crop watersheds improved Soil physical parameters such as bulk density, Ksat, soil porosity.

Soil Quality?

Yes, Incorporation of agroforestry and grass buffers on row crop watersheds improved water stable aggregates, Soil C, Soil N, Microbial diversity and soil enzyme activity (Mineralization, degradation of agri chemicals).


West
Center
East
Greenley
Memorial
Research
Center
100 meters
Topography
Soil Data
30.1 - 76
76 - 120.4
120.4 - 149.5
149.5 - 168.5
168.5 - 185.3
185.3 - 219.7
Management
MODEL SIMULATION
APEX
Measured
Data
Precipitation
1600
1200
800
400
0
1991
1993
1995
1997
1999
2001
2003
2005


0.50
0.40
0.30
0.20
0.10
0.00
VMC (cm3 cm-3)
Crop
Tree
5 cm depth
Water
Soil Quality
Contour Strip
Agroforestry
Control
247
248
249
250
251
252
253
N
Greenley
Memorial
Research
Center
100 meters
Wildlife
Income
Aesthetic
Soil Carbon
Thank you