Tightening the Phosphorus Cycle on Texas CAFO Dairies:

Some of the pieces fall into place

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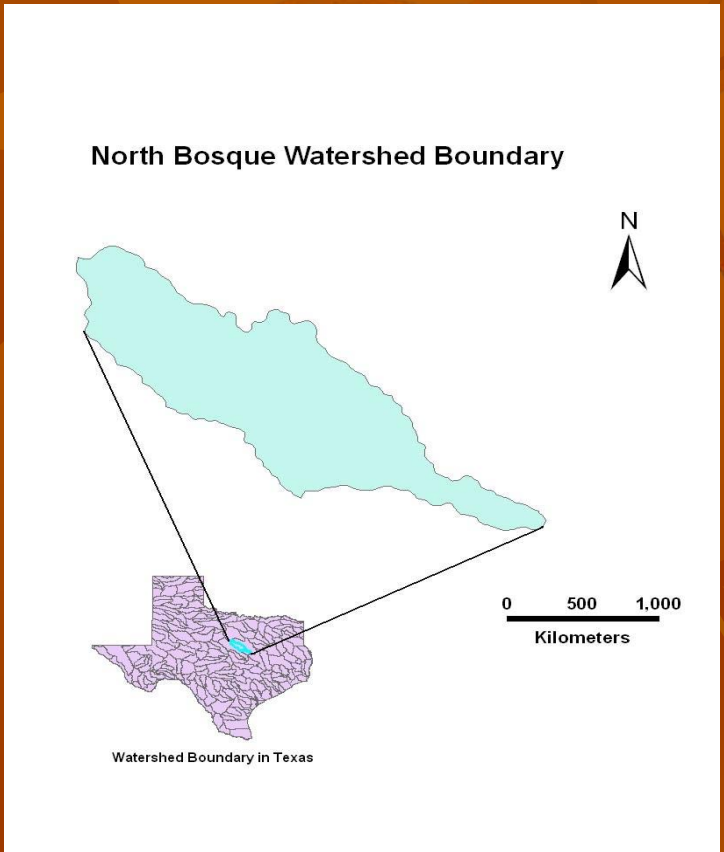
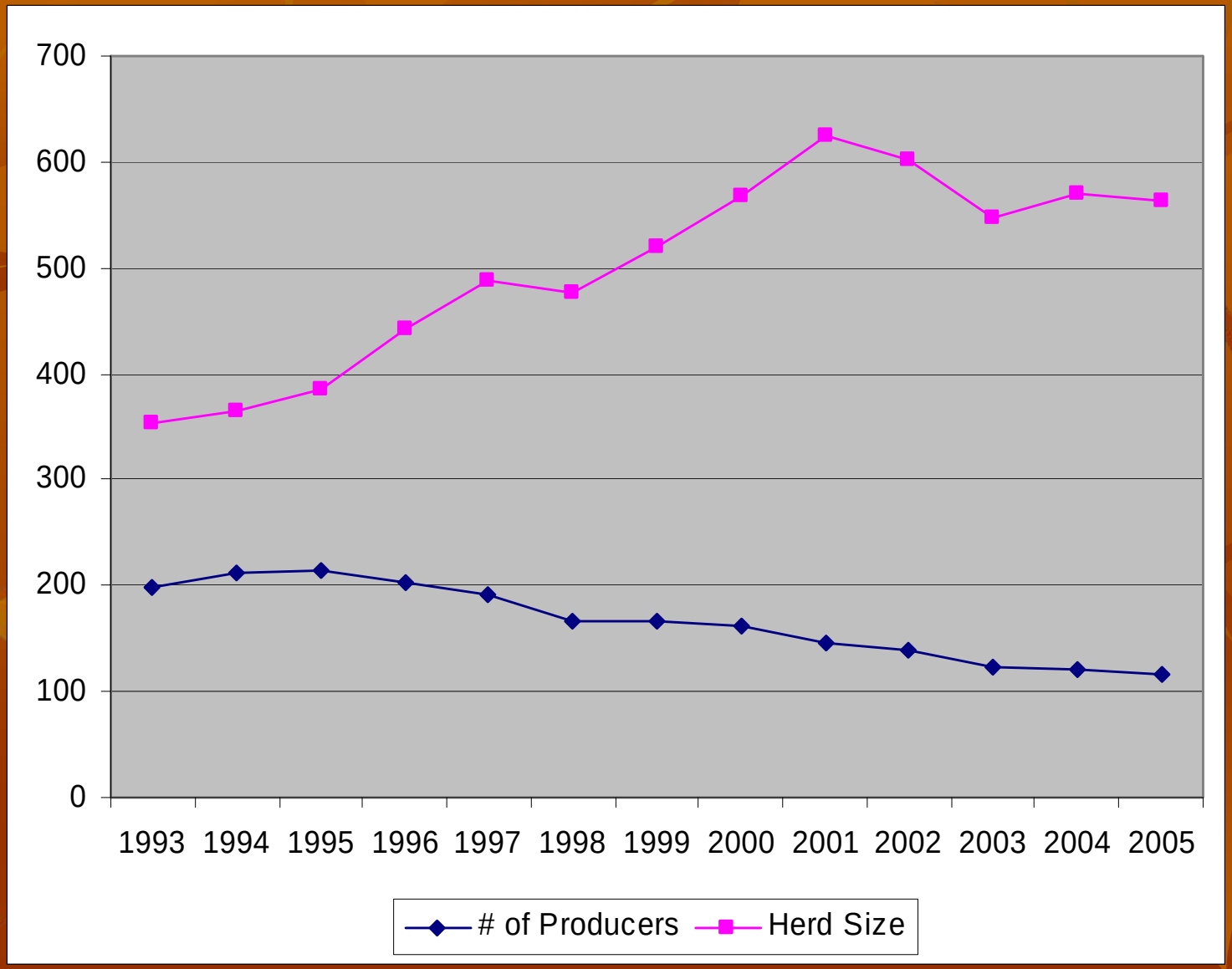
Background Information

- Highly concentrated Dairy operations
- Runoff of pollutants such as P from the waste application fields an environmental concern
- Impaired segments of North Bosque River



Trends of Dairy Cattle Producers and Average Herd Size for Erath County, TX from 1993 to 2005

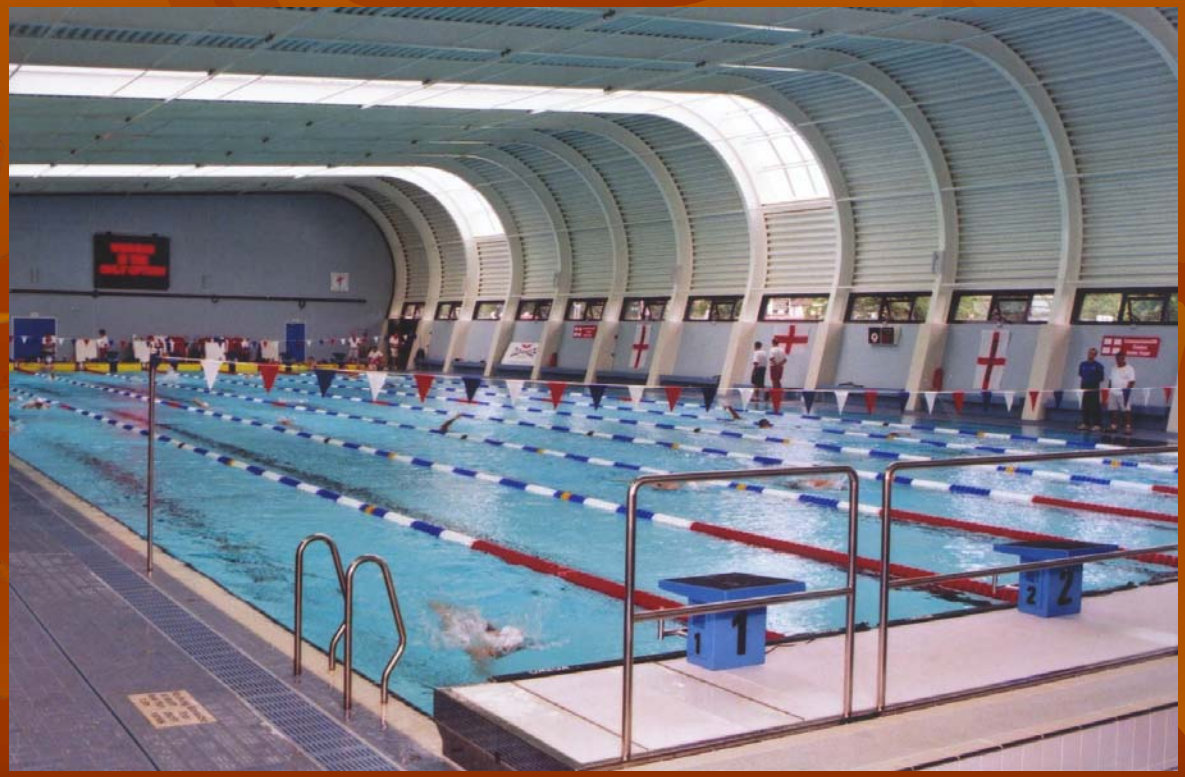


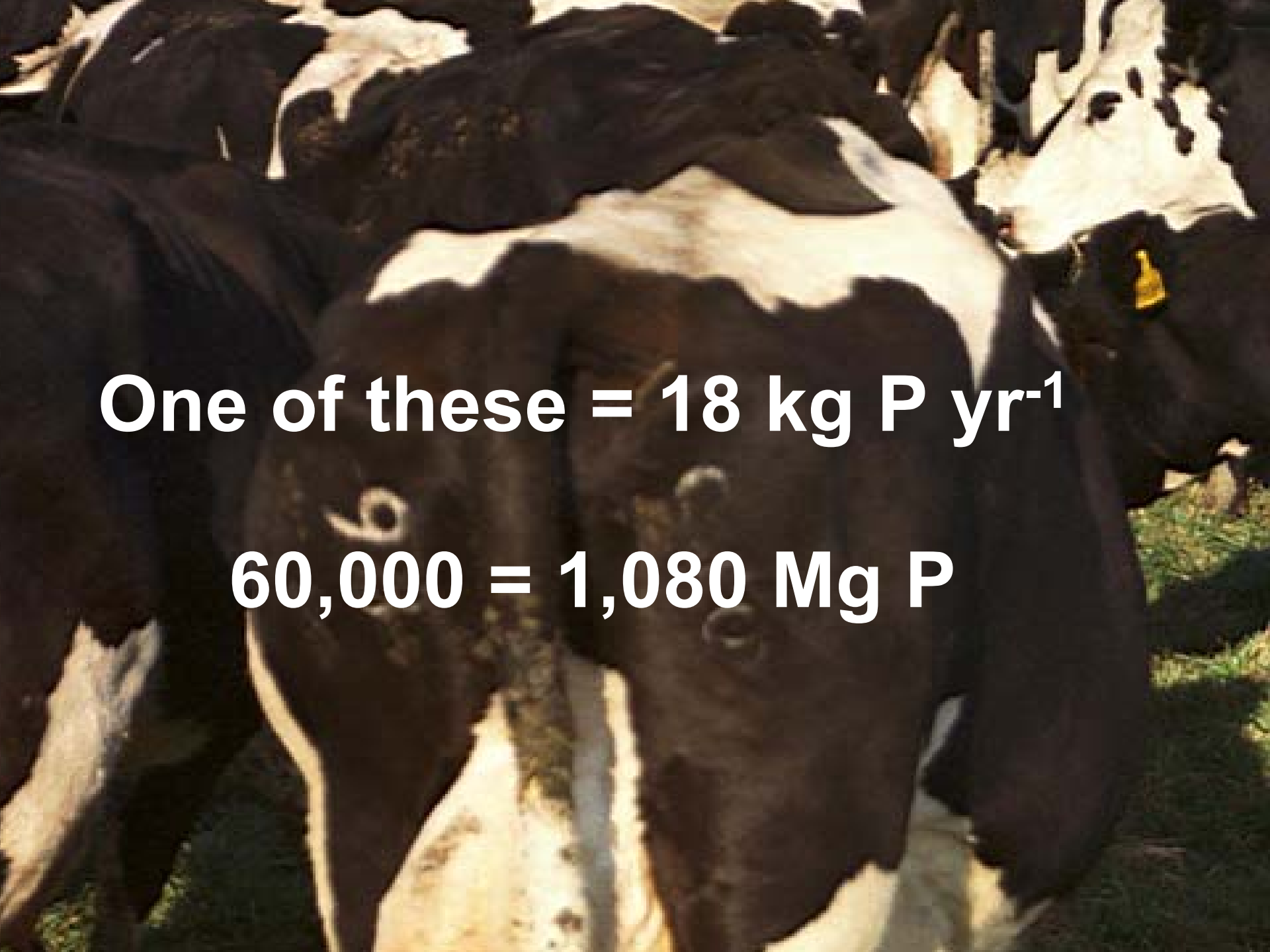
Texas Dairies

- CAFO's import majority of feed
- 60,000 cows in upper Bosque & Leon River Basins
- Manure P exceeds sequestration capacity on dairies

Dairy Manure in Erath County in 2005

- Almost 1.7 billion liters of manure
- Enough to fill 663 Olympic size swimming pools





One of these = 18 kg P yr^{-1}

60,000 = 1,080 Mg P

Soils in the region low in P (< 6 ppm)

Regulatory Agencies

Where do data originate?

- Data from colder climates
- Different soils
- Different vegetation
- Different feeds
- Different insects
- Different stream ecology

NIWQP Funding

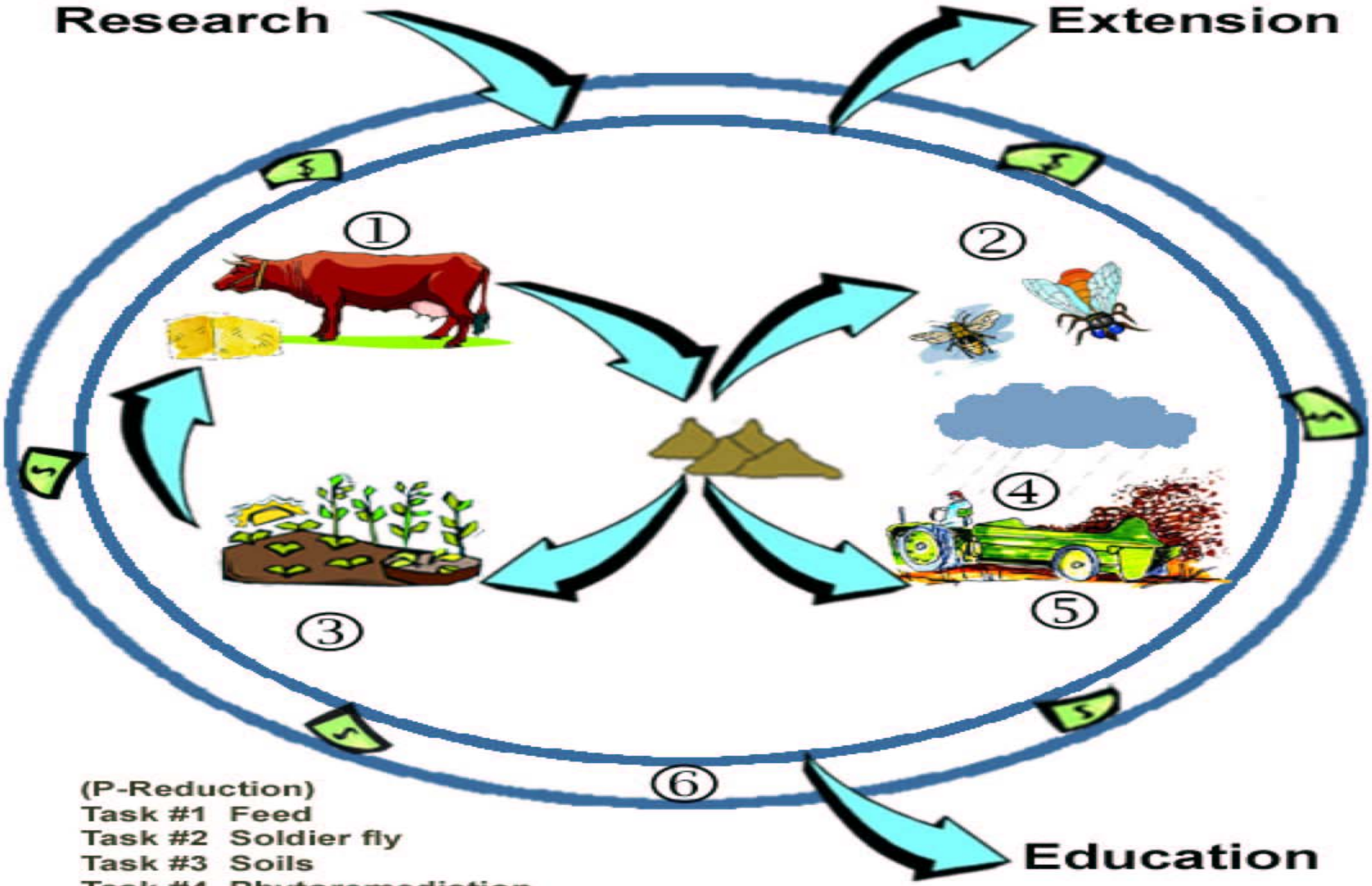
- 2004 – 51130-02237
- “Strategies for phosphorus reduction from land receiving dairy manure on the North Bosque and Leon Rivers”
- North-central Texas
- Integrated (research, extension, education &… production)

NIWQP Grant

- Multi-disciplinary
  - Dairymen
  - Animal scientists
  - Plant scientists (cultivated & rangeland)
  - Soil scientist
  - Ag engineer
  - Ag economist
- Multi-institutional
  - Dairies
  - Texas AgriLife Research
  - Texas AgriLife Extension
  - Tarleton State University

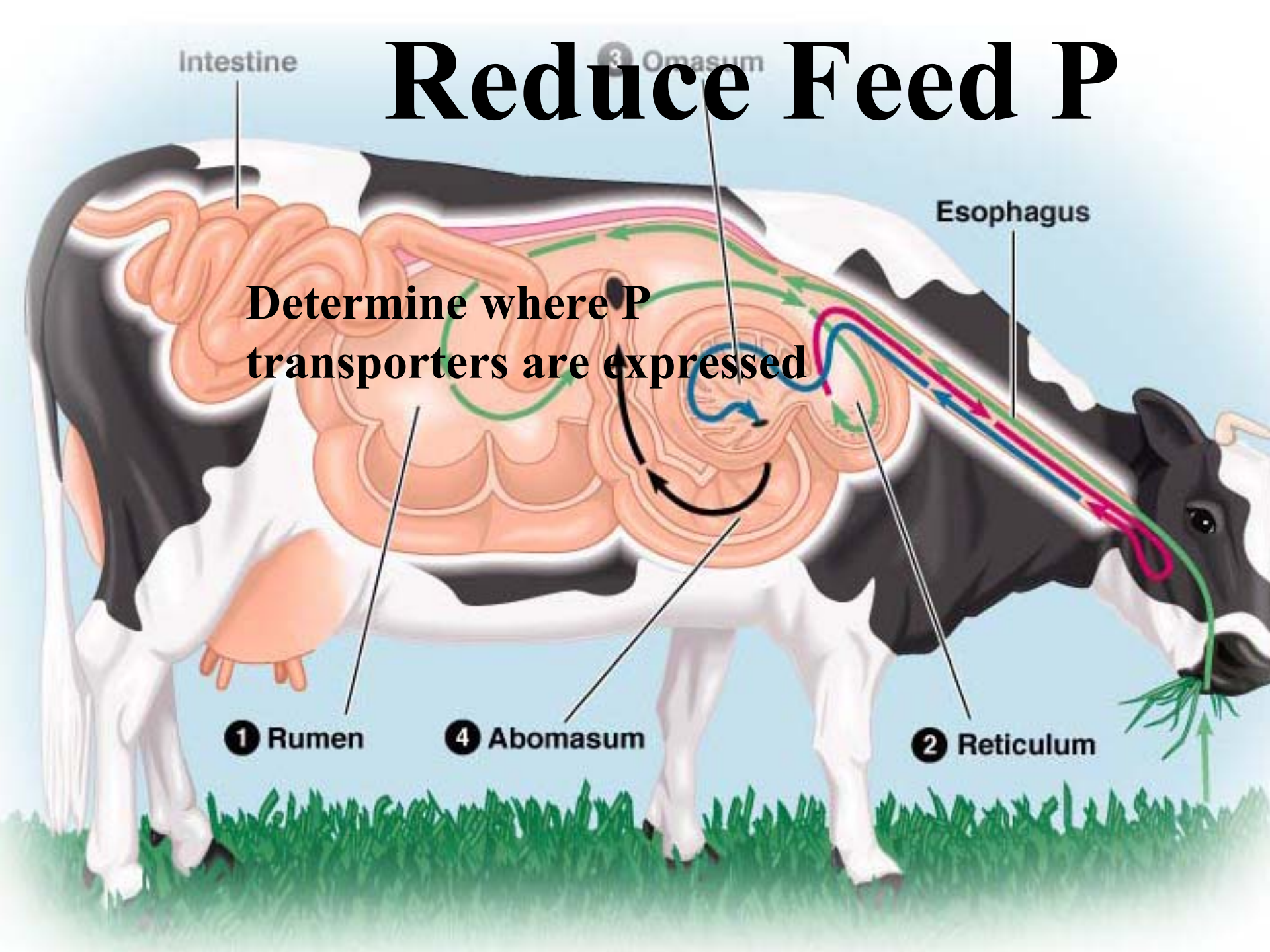
Goals:

- Precisely define P picture within Dairies
- Tighten P cycles by developing BMPs
- Integrate “real” production with Research/Extension/Education



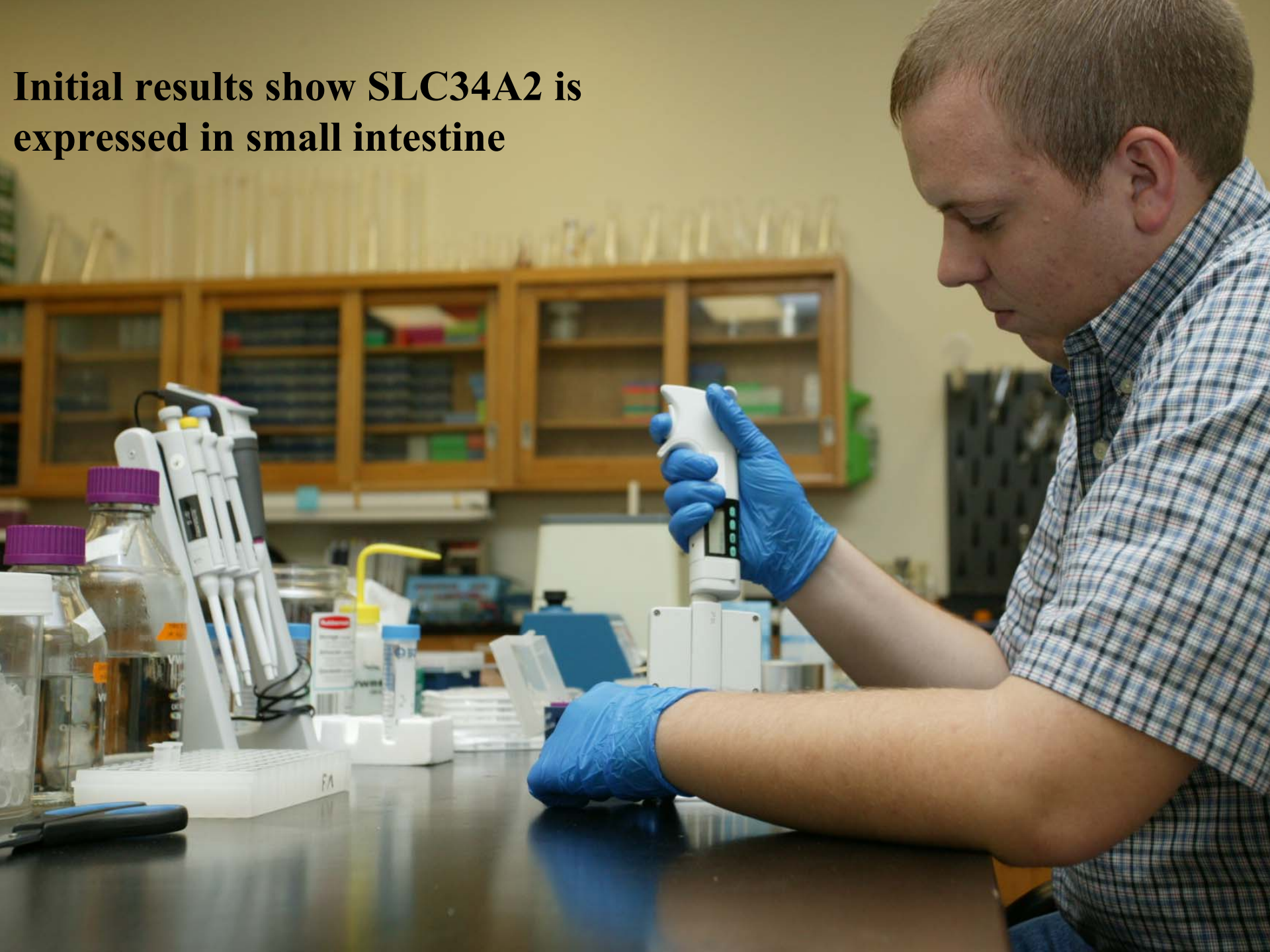
(P-Reduction)
Task #1 Feed
Task #2 Soldier fly
Task #3 Soils
Task #4 Phytoremediation
Task #5 Buffer Strips
Task #6 Economics

Reduce Feed P



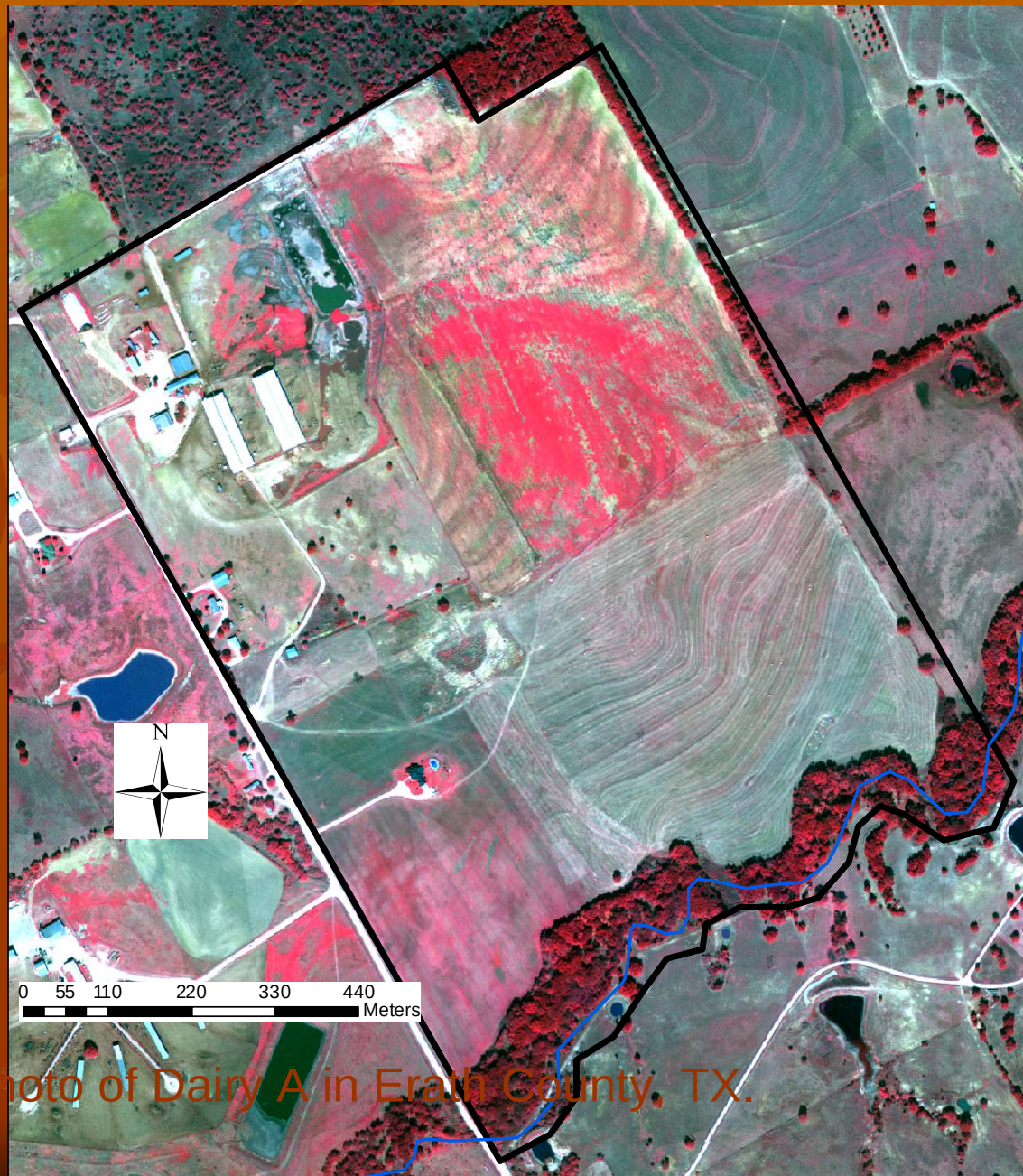
Determine where P transporters are expressed

Initial results show SLC34A2 is expressed in small intestine



Not all forage P equally available
Combination of concentration & availability
= excreted P

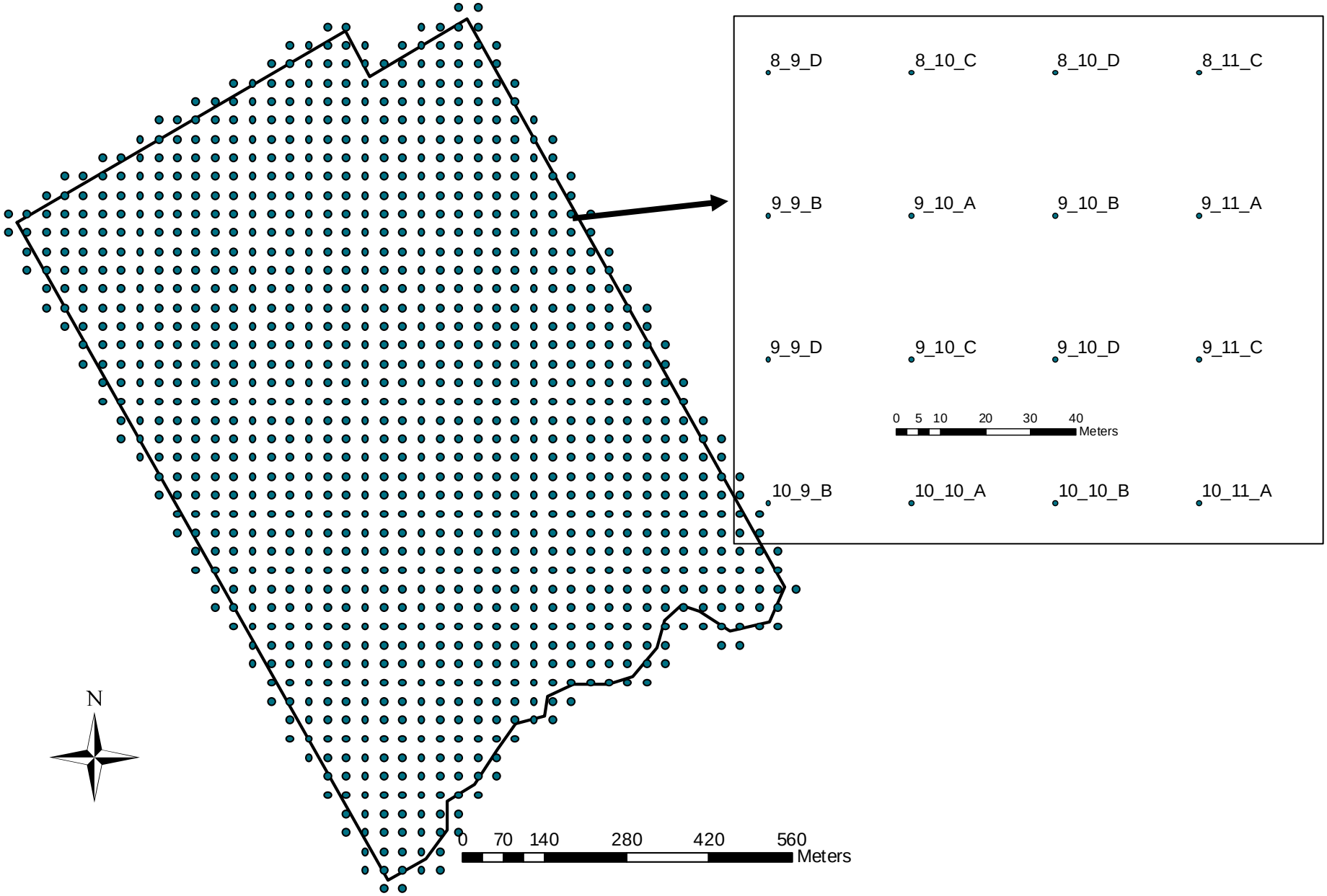
Where is soil P?



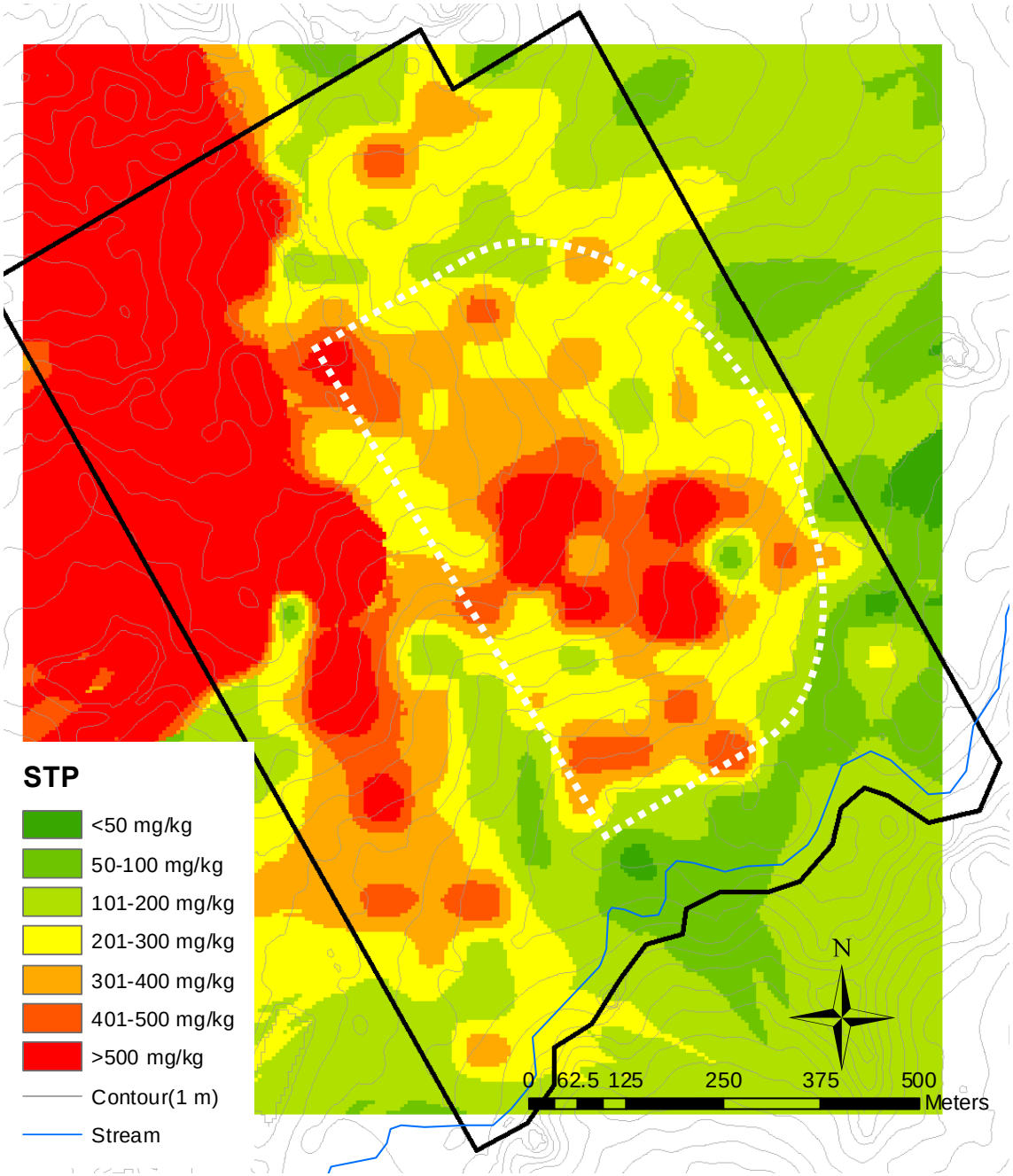
hoto of Dairy A in Erath County, TX.

Soil maps tell only part of story

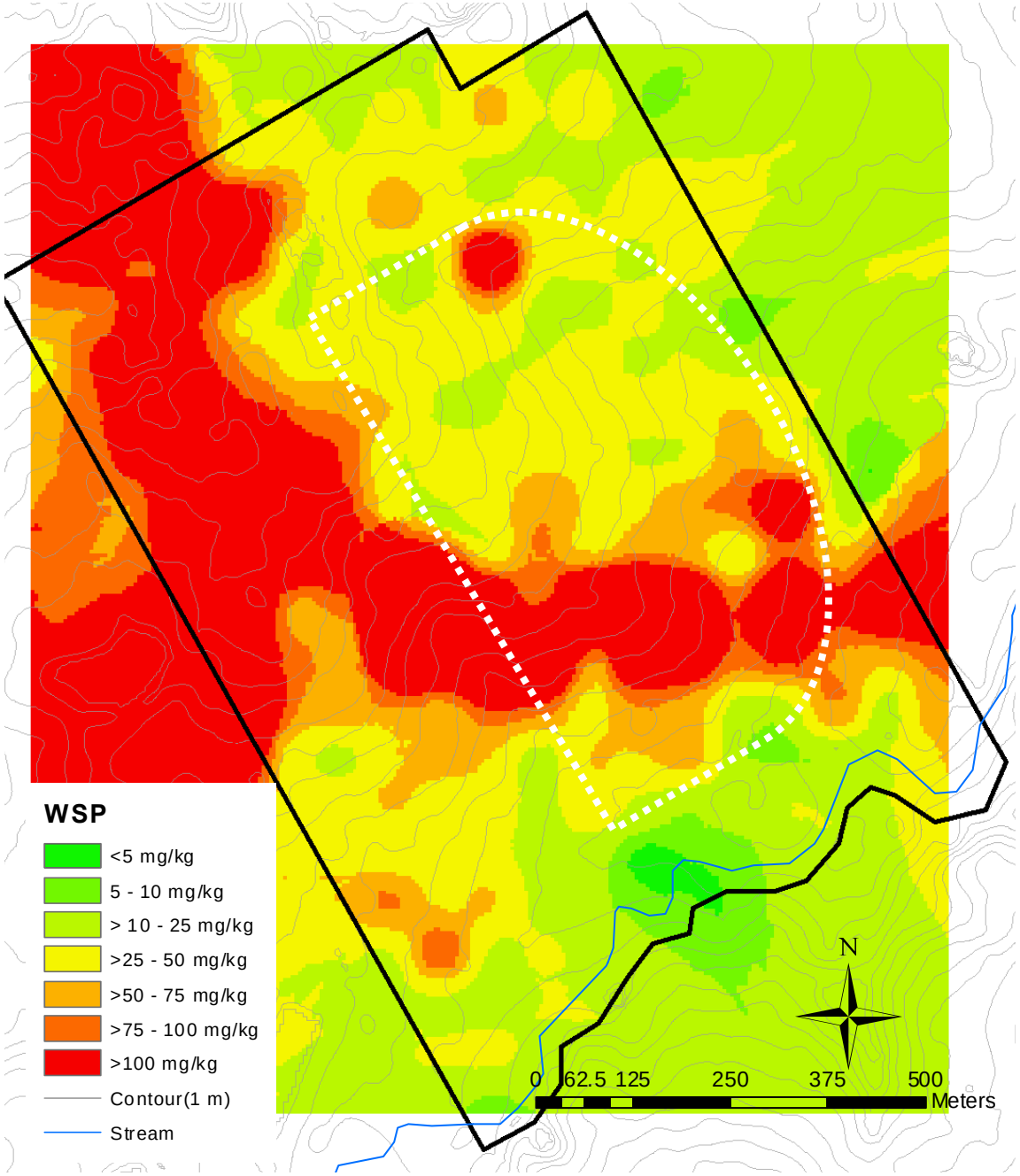
of Dairy A in Erath County, TX.



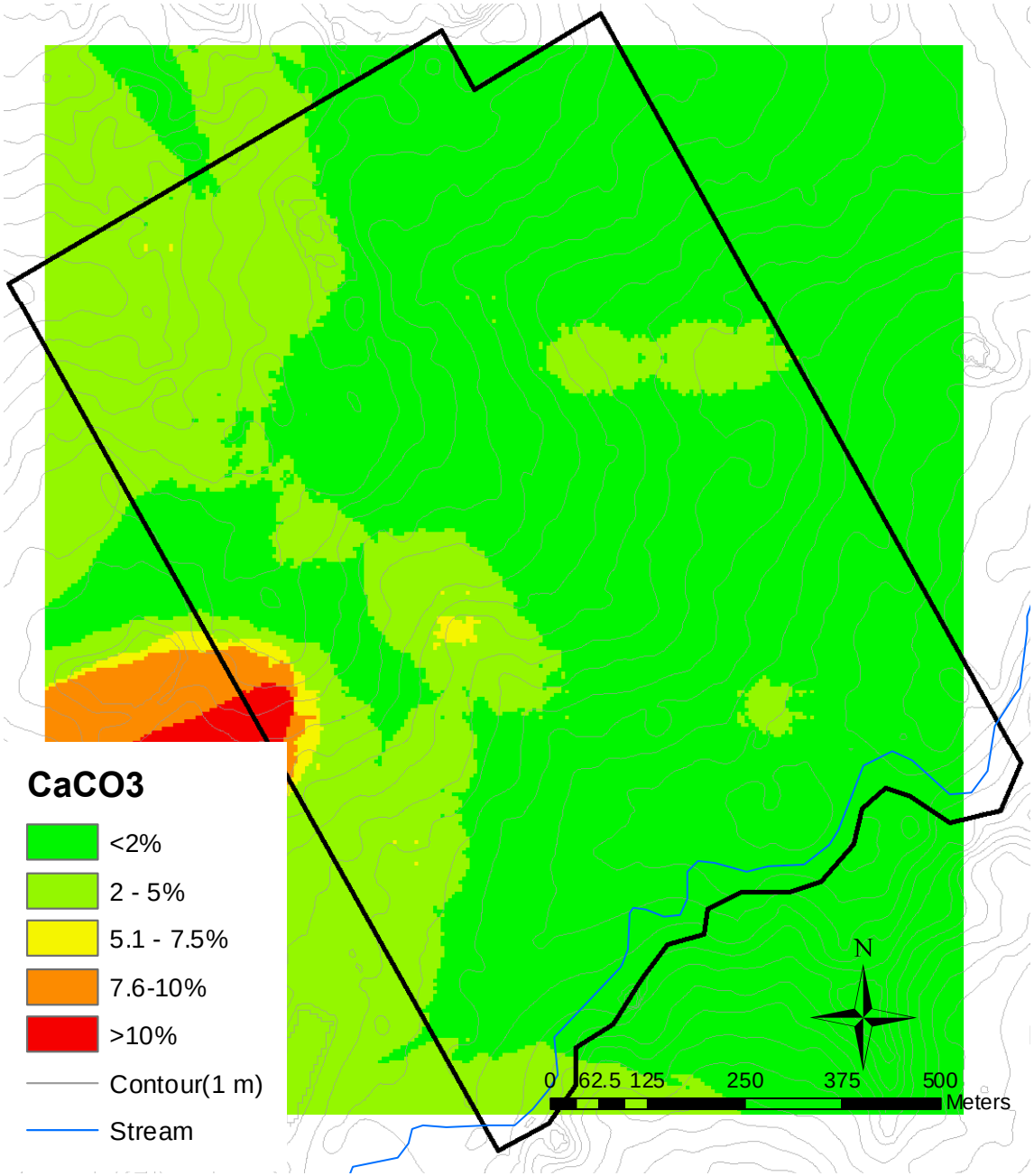
Hypothetical sampling grids at Dairy A in Erath County, TX.



Soil test phosphorus levels in Dairy A in Erath County, TX.

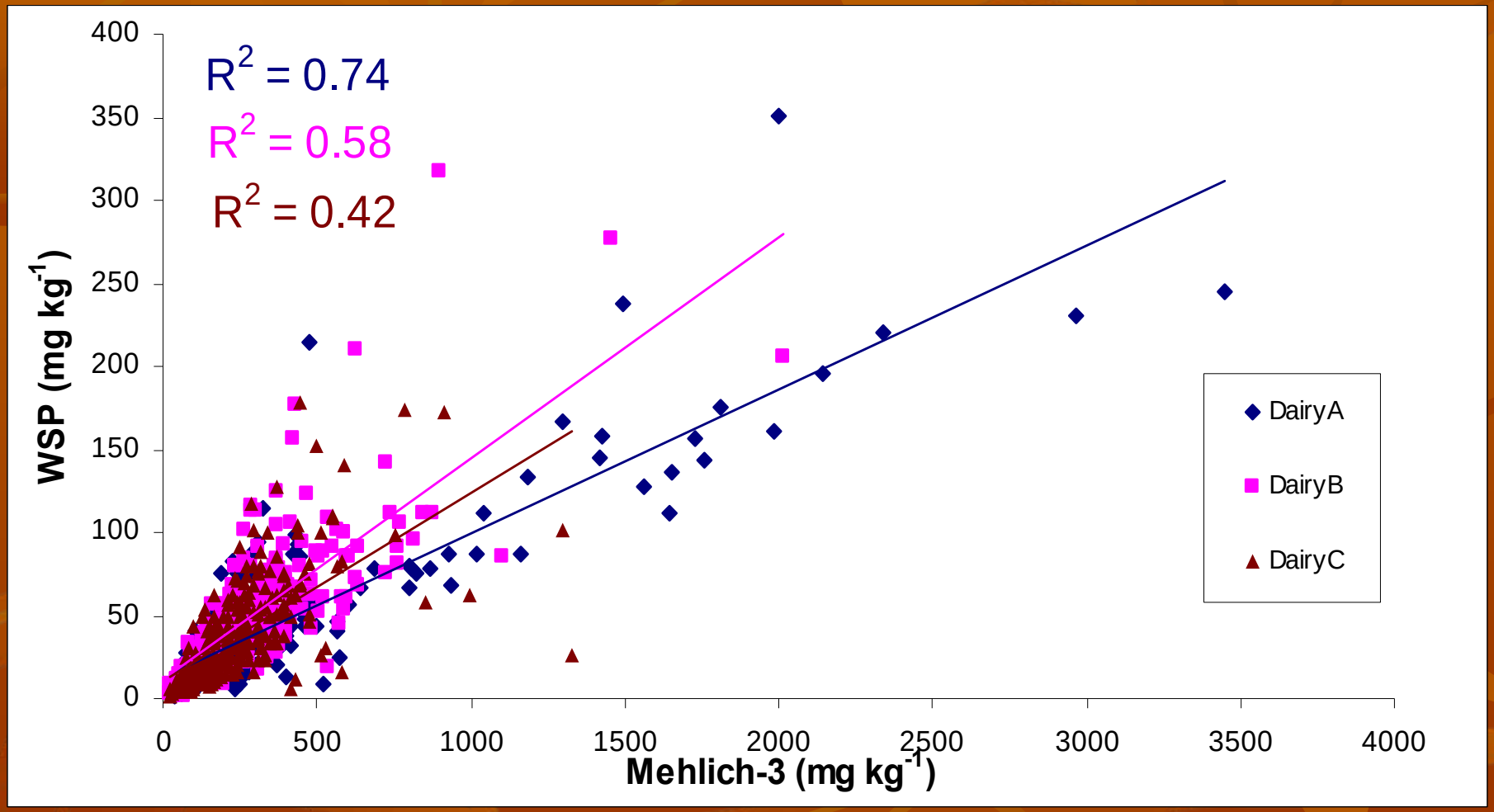


Water soluble P levels in Dairy A in Erath County, TX.



Calcium carbonate equivalent levels in Dairy A in Erath County, TX.

Relationship between Mehlich-3 and Water Soluble Phosphorus



Conclusions

- **Both STP and WSP varied greatly in dairy farms.**
  - *Current practice of one or two grab samples for entire dairy cannot account for soil P variability.*

- **Sixty-six percent of the samples in the dairies recorded a STP value of more than 200 mg kg^{-1} P.**

- **Mehlich-3 was more stable and extracted higher P levels under varying soil conditions, whereas, water soluble P varied with different soil conditions.**

Where to locate new dairies?

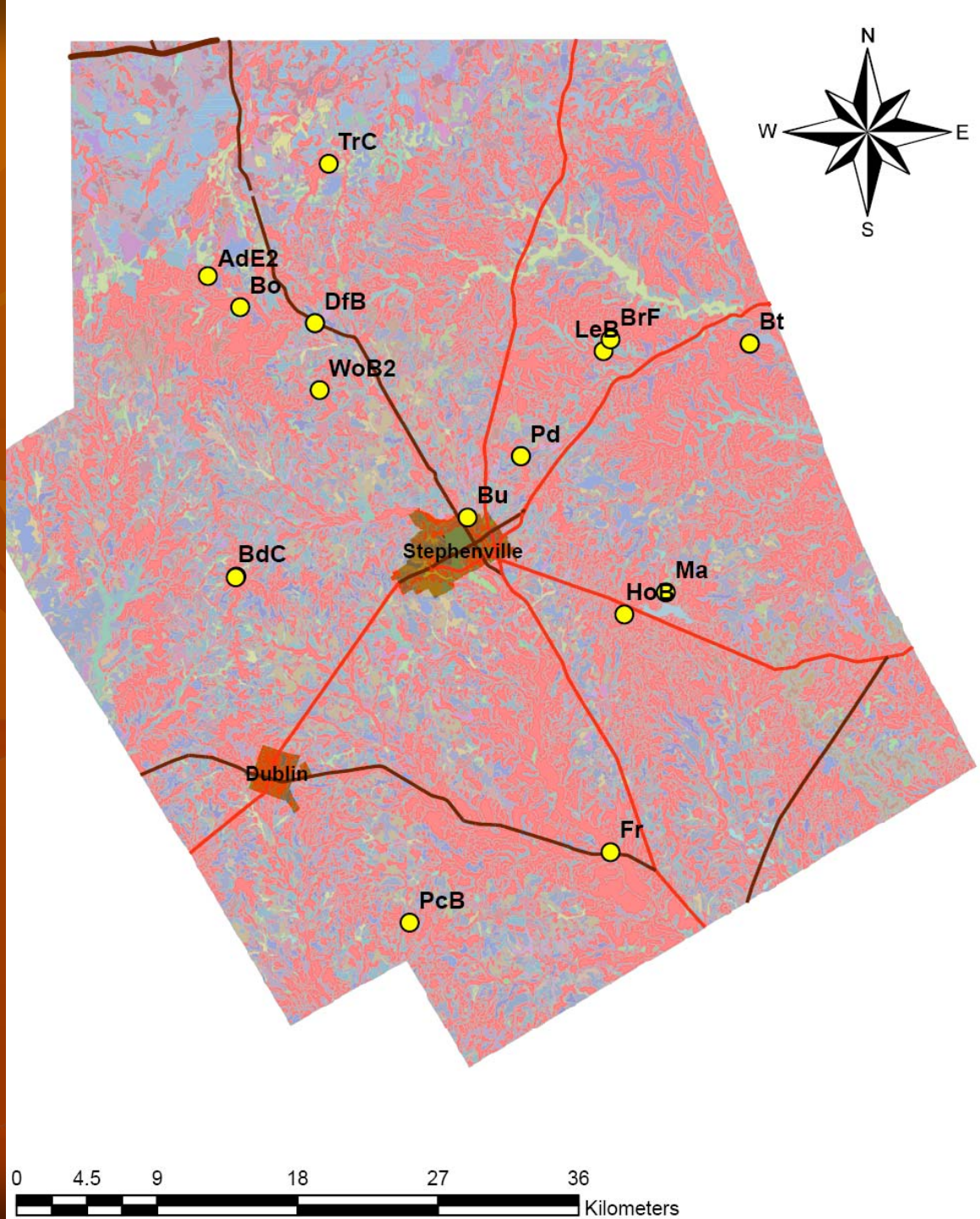
- Identify chemical and physical soil properties in Erath County which contribute to P sequestration

- Identify specific soils in Erath County which effectively sequester P for manure effluent application

- Determine best management practices of dairies in Erath County for manure effluent application on soils

Soil Mapping Units

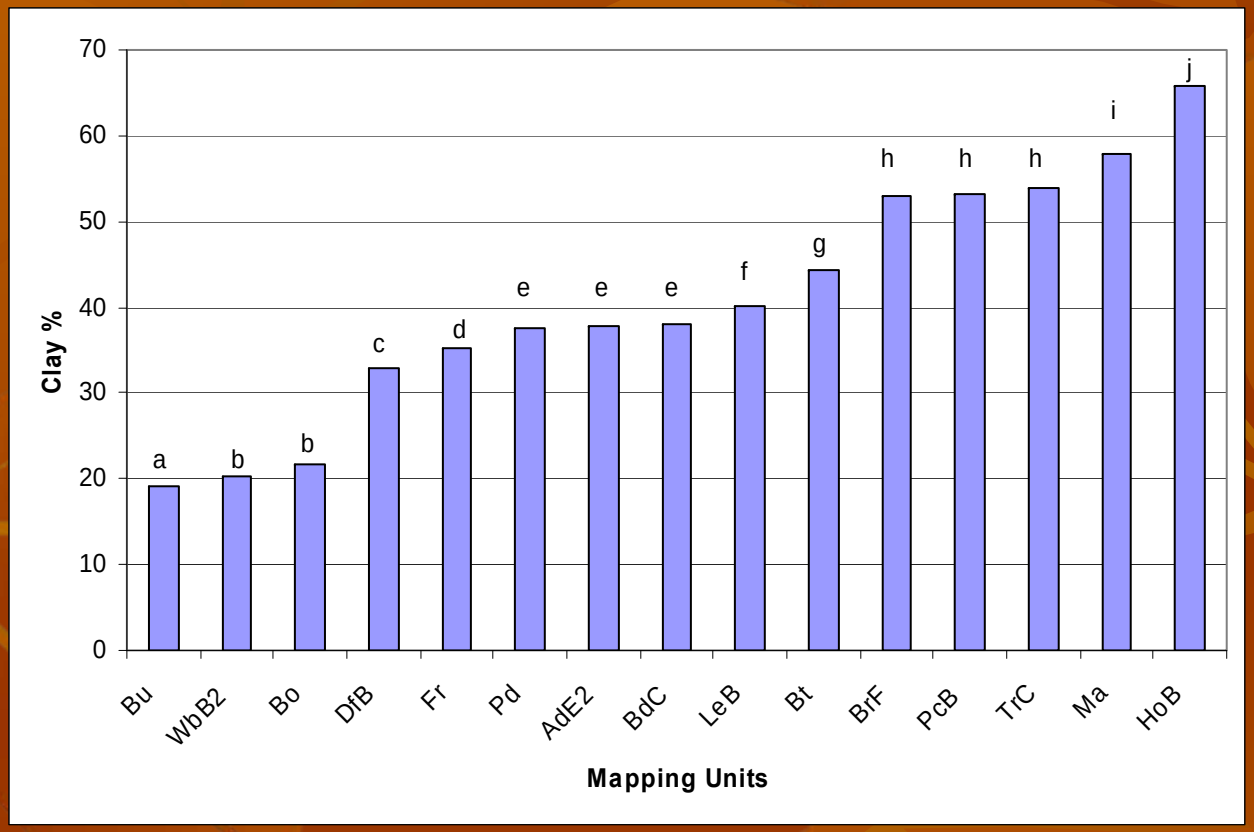
- 78.2% of soil in Erath County
- Tested soils are in red



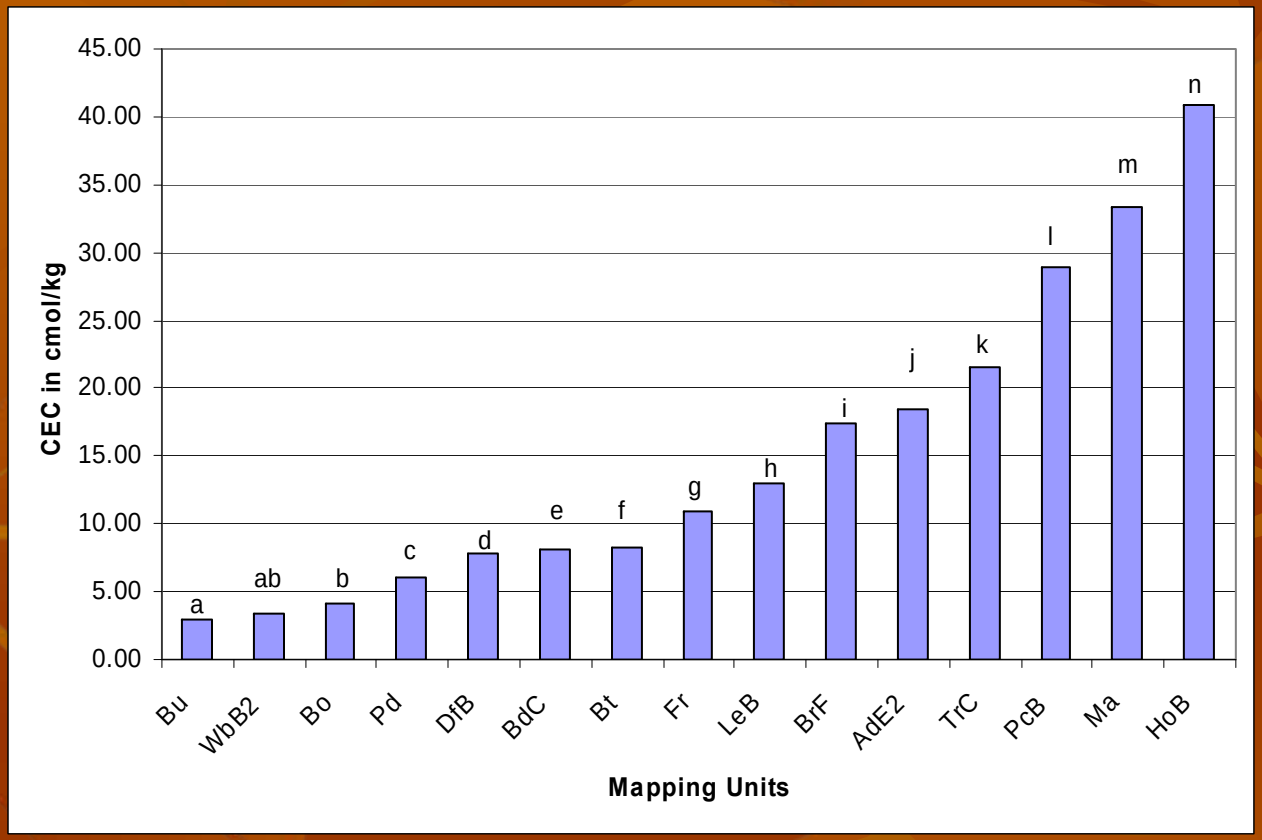
Ex-situ Lysimeters

Soil from each series was flushed with manure effluent

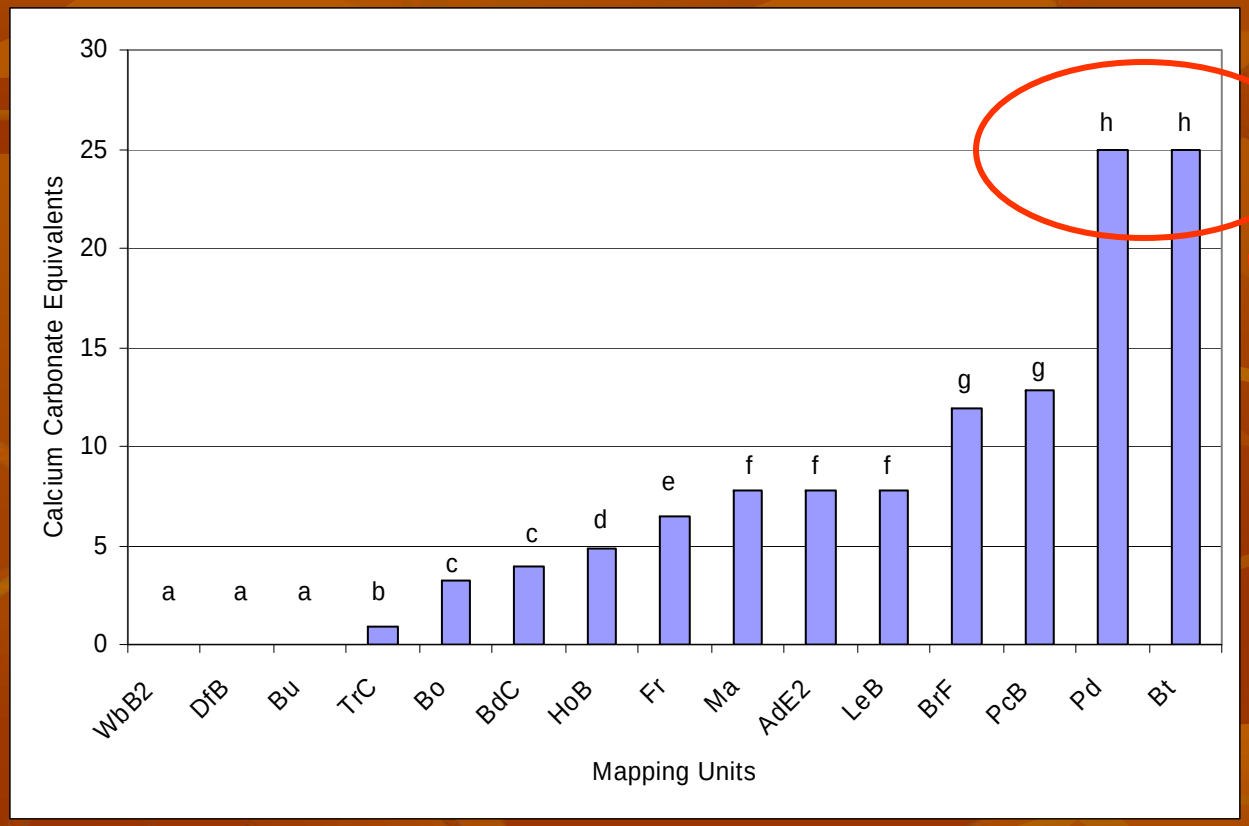
Clay Percentage



Cation Exchange Capacity

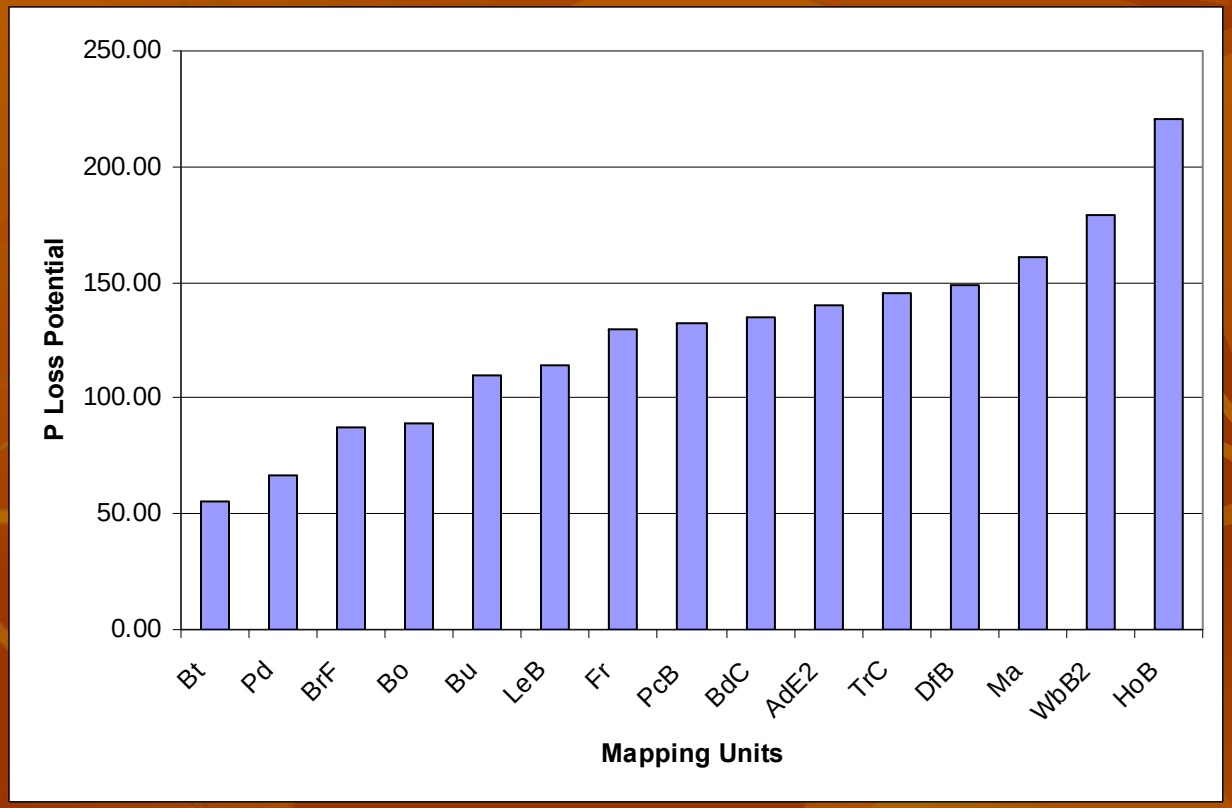


Calcium Carbonate Equivalents



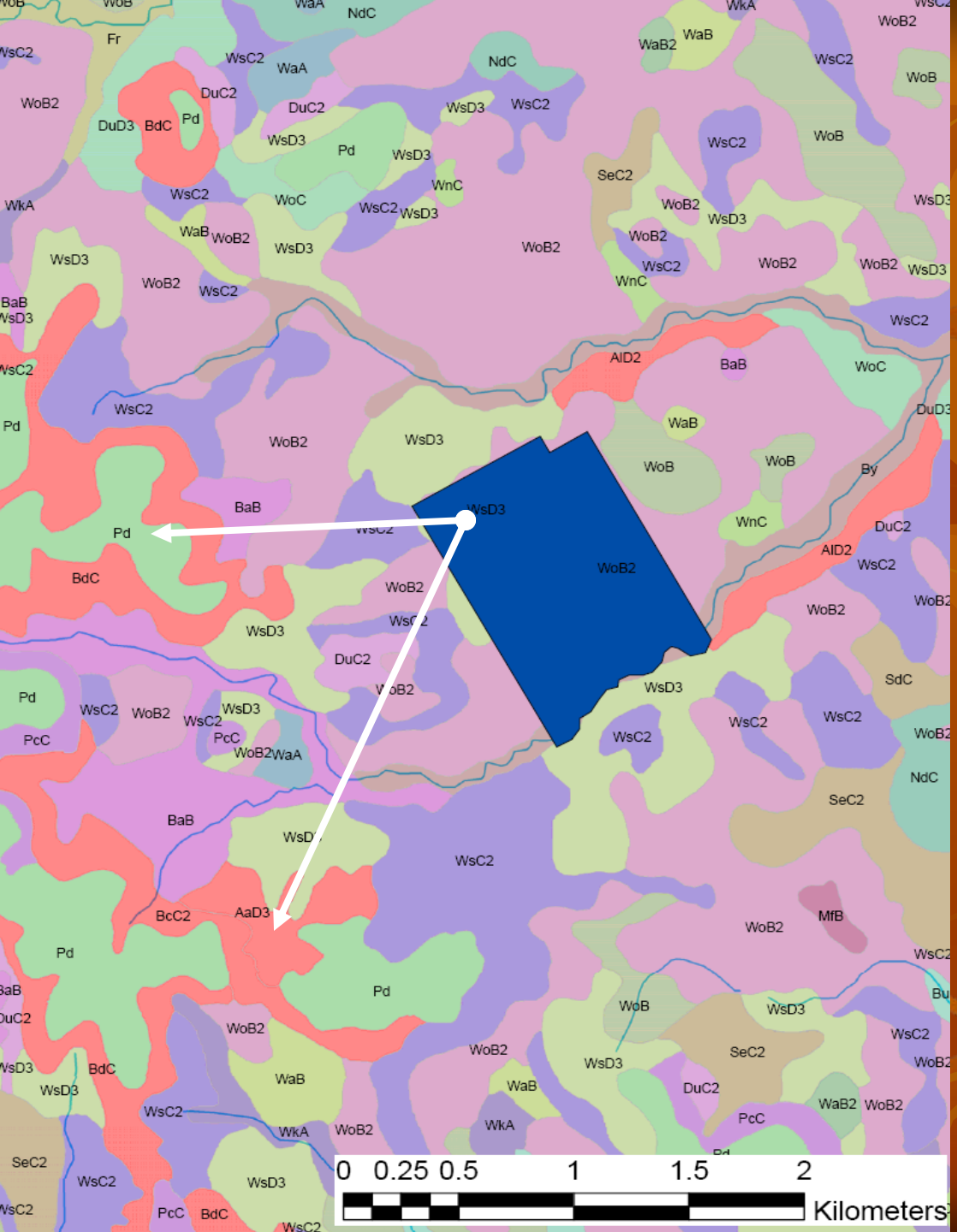
Upper detection limit of $CaCO_3$ was 25%.

Phosphorus Loss Potential According to P Sorption Test



Overall P Loss Potential

Mapping Units	Overall P Loss Potential
Brackett-Purves	6.39
Purves-Dugout	9.99
Brackett-Dugout	14.8
Lewisville	31.54
Duffau	34.99
Bolar-Denton	40.38
Truce	47.59
Altoga-Duffau	50.74
Windthorst	57.79
Purves	58.87
Maloterre	64.77
Houston Black	105.92
Bosque	139.09
Frio	151.25
Bunyan	172.54



Dairy A

- Four sizeable polygons of high P sequestration potential soils
- Two are too near a tributary for effluent application
- Two fields within 2 kilometers would make good potential effluent application sites

Conclusions

- $CaCO_3$, clay percentage, and pH were identified as chemical and physical soil properties in Erath County which contribute to P sequestration

- Six soil mapping units, comprising 12.8% of the county were identified as specific soils in Erath County which effectively sequester P

Phytoremediation

Intensify Present Forage Systems:

- Species
- Irrigation
- Fertilizers
- Harvests
- Removal
- Multi-seasonal

Winter Legumes Overseeded on Tifton 85

Legume	Total	Coastal % Loss
	----------kg/ha----------	
Control		(6100)
Hairy Vetch	4800	80
Crimson Cl	2400	47
Rose Cl	1800	71
Arrowleaf Cl	800	64
Burr Medic	0	0

Thesis:

Phytoremediation benefits do not always reflect at the landscape level.

Plant P removal does not always translate into lower soil P analyses as interpreted by regulatory agencies.

Phytoremediation Disconnect

Scientist: Plant P removal = lower total P in soil

Dairyman: Plant P removal = lower soil P analysis

Regulator: Plant P removal = lower plant-available P

Environment: Plant P removal = decrease P runoff

Are Scientists misleading industry & agencies?

Phytoremediation ≠ lower soluble P

≠ lower soil P analyses

≠ reduce P runoff

LAR
(Land Area Requirement)

One of these = 45 kg P yr^{-1}

? ha will recycle 45 kg P yr-1 ?

Land Area Requirments (LAR)

- Cultivated vs. rangeland
- Irrigated vs. dryland
- Uni-seasonal vs. multi-seasonal
- Productive species vs. less productive
- Good soils vs. infertile soils
- Intensive harvesting vs. low input
- Compost vs. manure vs. lagoon phosphorus

Soil Tests & Regulatory Agencies

Plant-available P vs. total P

CONCLUSIONS:

- Phytoremediation has been hyped
- Soil P removal ≠ lower soil tests!!!
- Total P vs. Plant-available P vs. Soluble P
- Soils & climate = different LAR

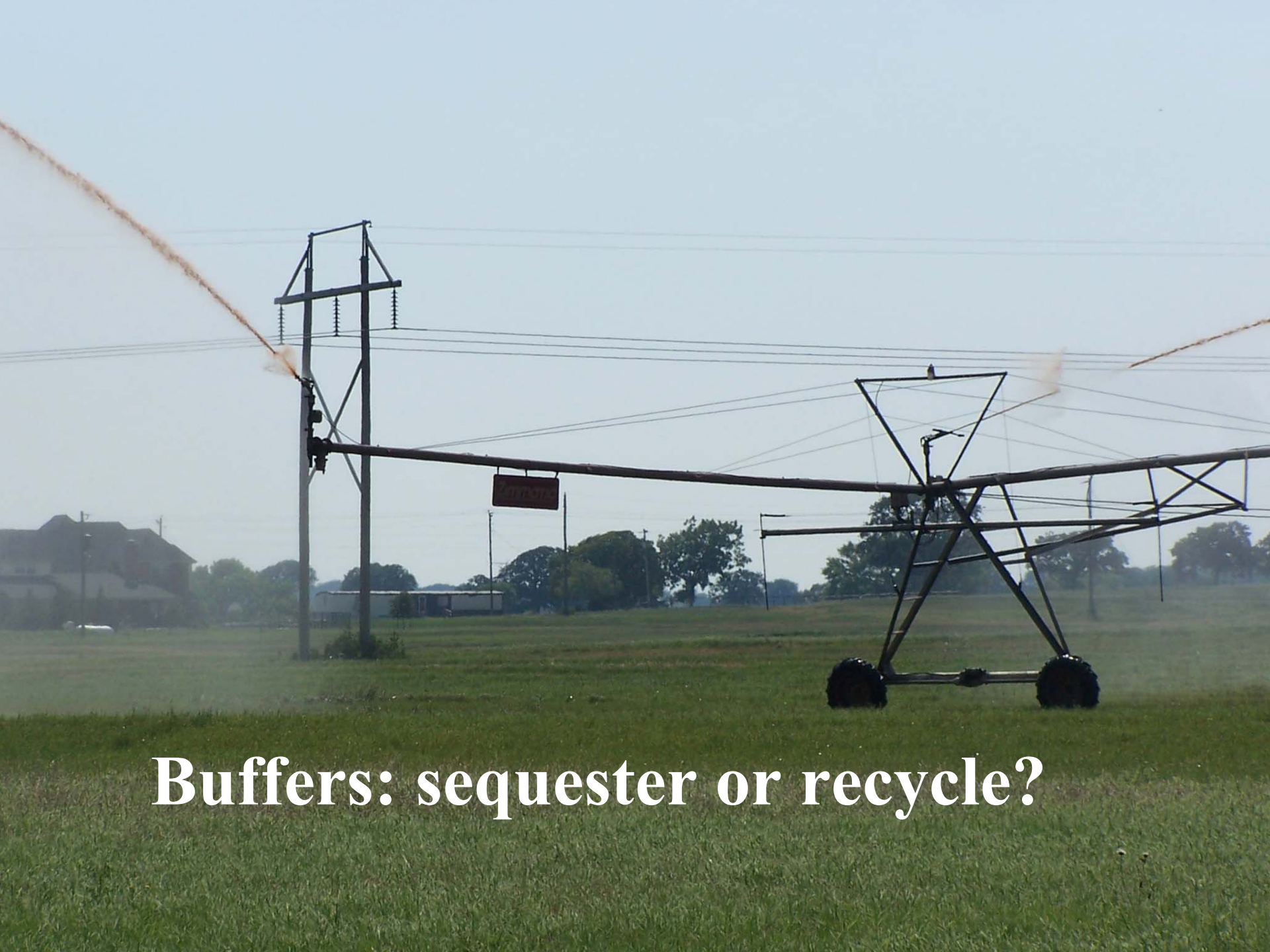
Nutrient Sequestration and Buffering in the Agricultural Landscape

When is P stable in the environment?

- Soil
- Topography
- Vegetation
- Rainfall

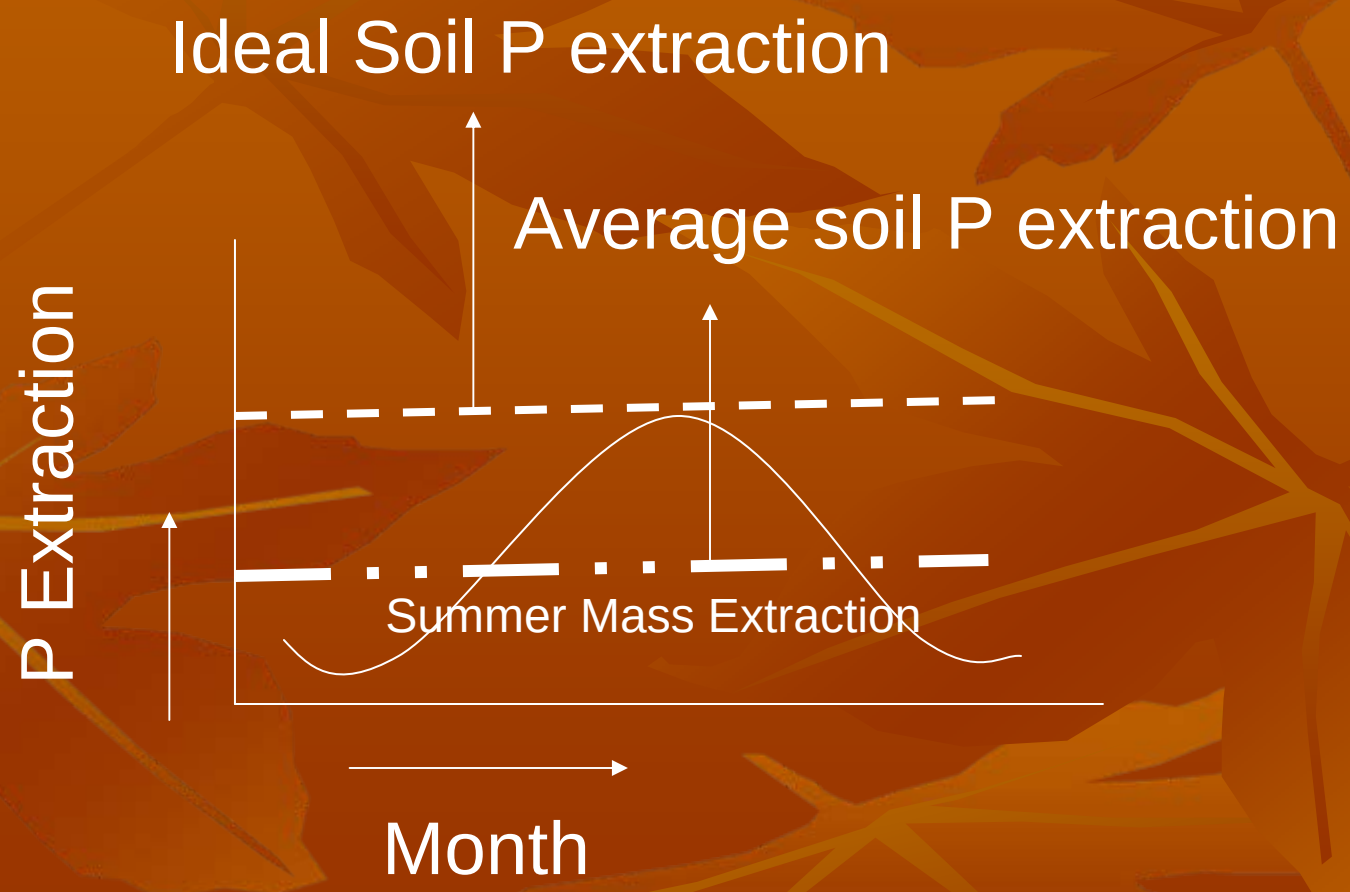
Stabilizing soil-P

- If we can keep P from moving = no runoff
- Application method
- Incorporated into soil?
- Soil types
  - Texture: sand vs. clay
  - Deep vs. shallow
  - Slope
  - Organic matter
  - Fertility
- Vegetation

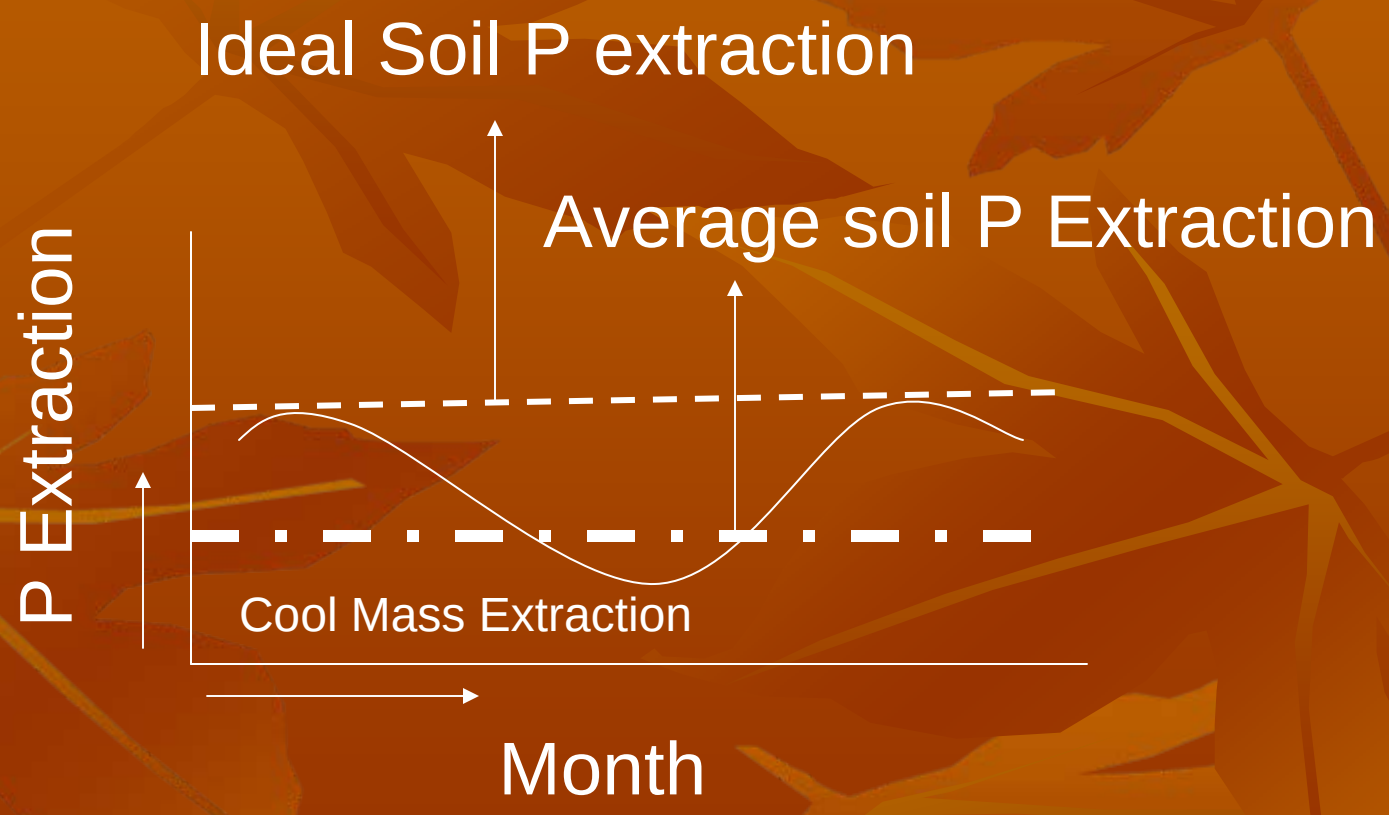


Buffers: sequester or recycle?

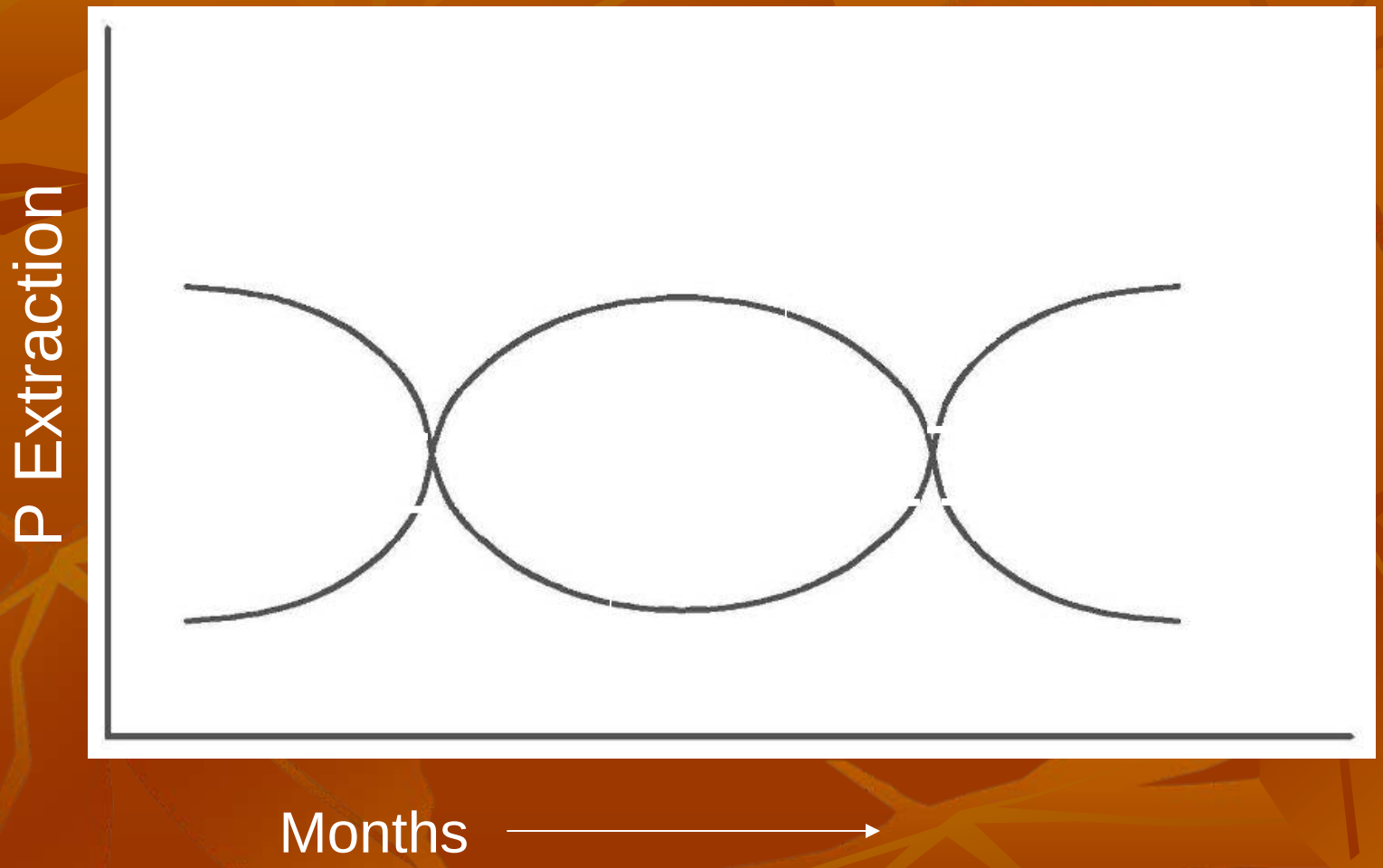
Phosphorus Extraction Curve for Warm Season Plants



Phosphorus Extraction Curve for Cool Season Plants



Phosphorus Extraction Curve for Warm & Cool Season



Storm Runoff Collection

Storm Runoff Collection

Grass Species Evaluated

Warm season Grasses:

- Bermudagrass (*Cynodon dactylon*)
- Switchgrass (*Panicum virgatum*)
- Gamagrass (*Tripsacum dactyloides*)
- Indiangrass (*Sorghastrum nutans*)

Cool season Grasses:

- Wildrye (*Elymus spp*) – CS
- Tall Fescue (*Festuca arundinacea*) – CS
- Wheatgrass (*Agropyron smithii*) – CS
- Tall Wheatgrass (*Agropyron elongatum*) - CS

Legumes and Herbs Evaluated

Warm season legumes:

- Bundleflower (*Desmanthus illinoensis*)
- Prairie Acacia (*Acacia angustissima*)

Cool season legumes:

- Hairy vetch (*Vicia villosa*)
- Arrowleaf clover (*Trifolium vesiculosum*)
- Black medic (*Medicago lupulina*)

Warm season herb:

- Maximilian sunflower (*Helianthus maximiliani*)

Black Soldier Fly

- Non-pest species
- Temperate and tropic areas
- Reduce house fly populations
- Reduce manure accumulation
- Self-harvest & used as feed

Reduction of Dairy Waste

- Phosphorus reduction = 61-70%
- Nitrogen reduction = 30-50%
- Dry matter reduction = 33-58%

Whole-dairy Cycle

- Waiting on component data
- Missing data already
- Will we ever really quantify?
- How applicable from dairy to dairy?

It wasn't me!!
It was the UFO shi…p!