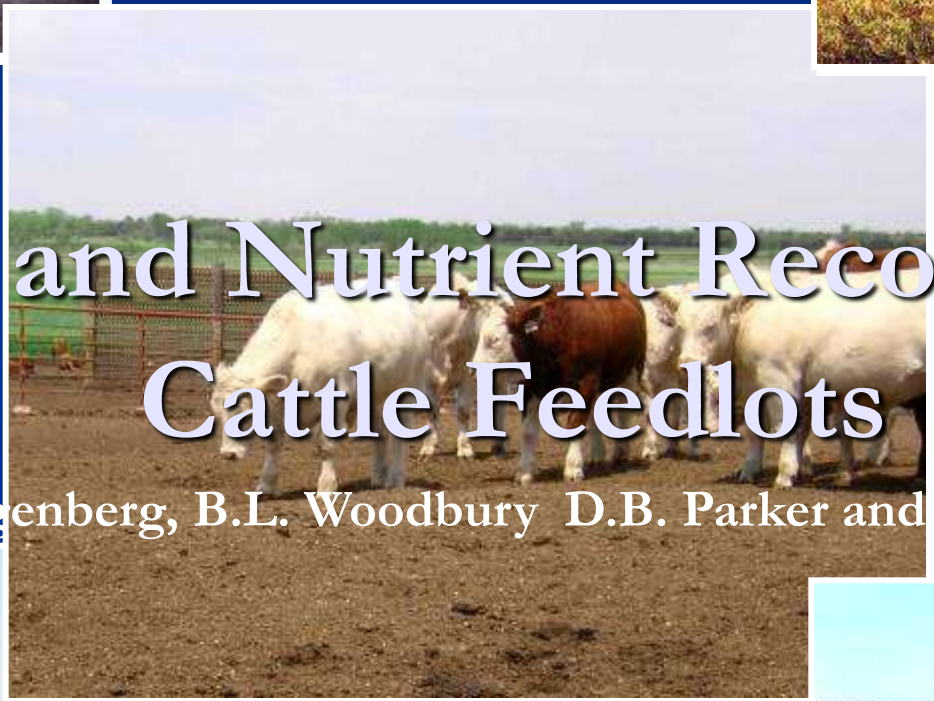


Energy and Nutrient Recovery from Cattle Feedlots

R.A. Eigenberg, B.L. Woodbury D.B. Parker and Mindy Spiehs

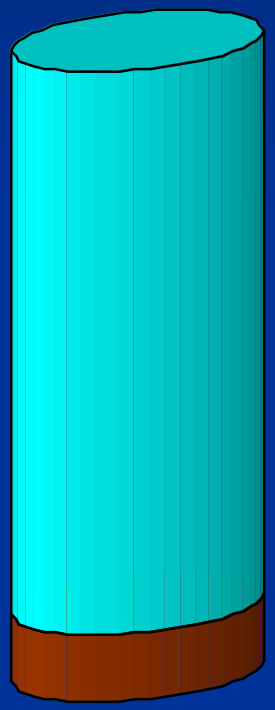
US Meat Animal Research Center, Clay Center, NE

Objective:

- Demonstrate methods that enhance the value of feedlot manure

Composition of Manure

1000 lb steer excretes approximately 60 # of manure / day

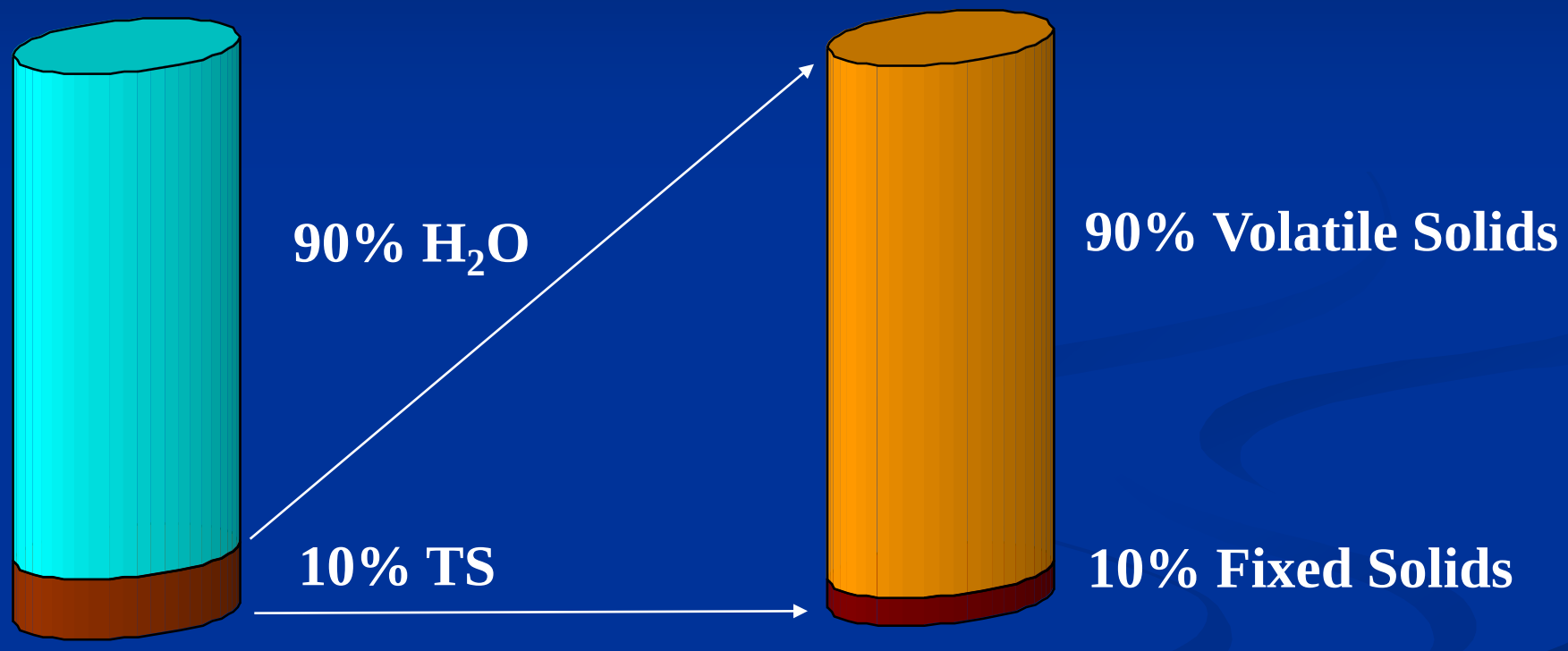


90% H_2O

10% Total Solids

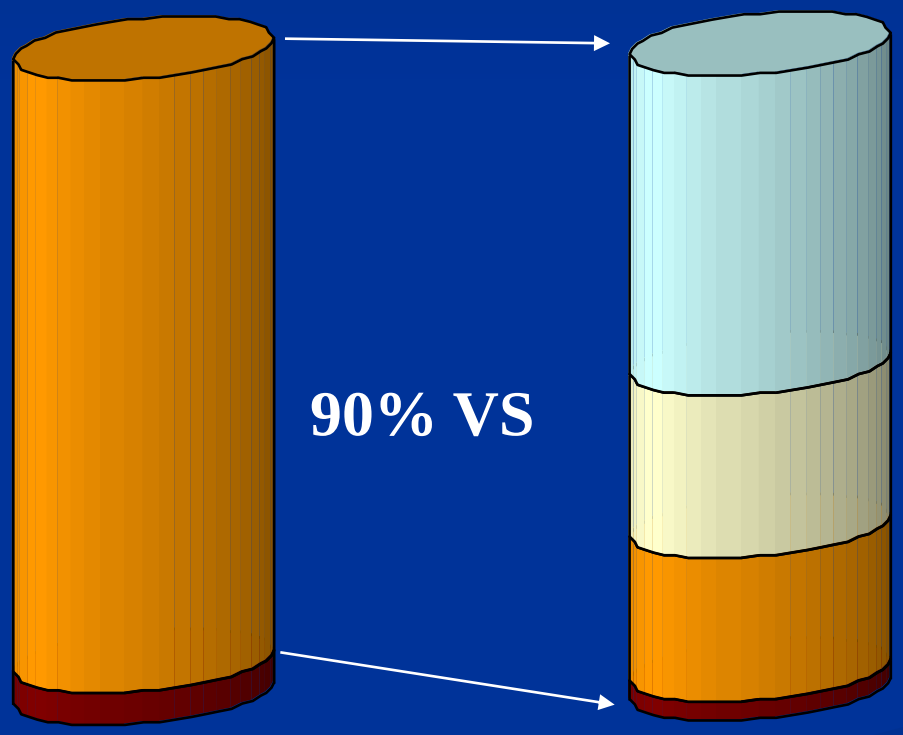
[1]Agricultural Waste Management Field Handbook, 1992

1000 lb steer excretes approximately 60 # of manure / day



[1]Agricultural Waste Management Field Handbook, 1992

1000 lb steer excretes approximately 60 # of manure / day – Of the 10% of Total Solids – 90% are Volatile Solids which contain[2]:



49% Sugars/Starches

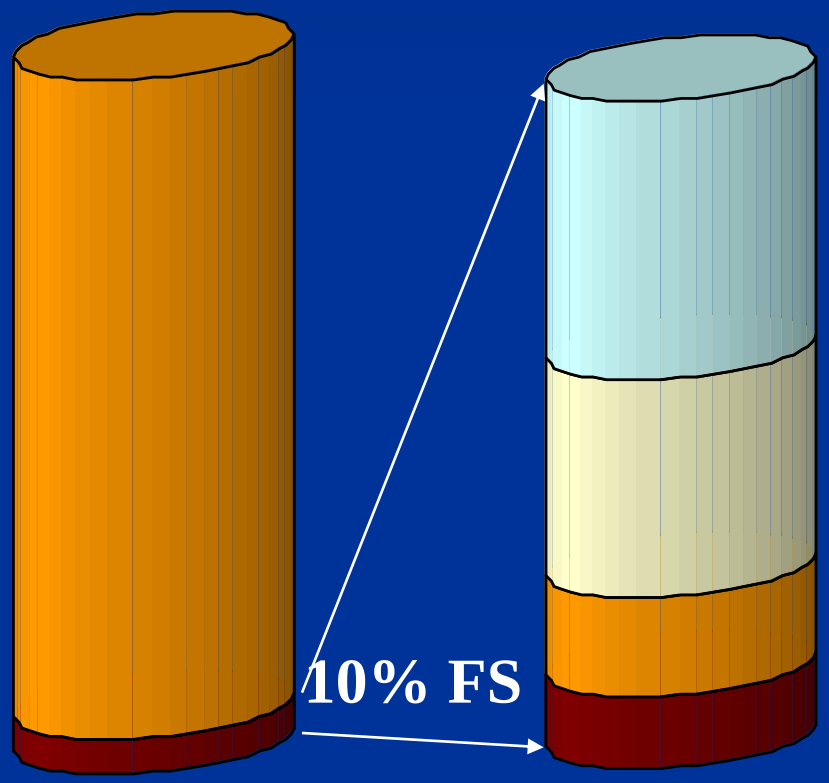
25% Crude Fiber

22% Crude Protein

3% Fats and Fatty Acids

[2]North and Garrett, J. Anim. Sci. , 1986

1000 lb steer excretes approximately 60 # of manure / day – Of the 10% of Total Solids – 10% are Fixed Solids which contain[1]:



42% Nitrogen

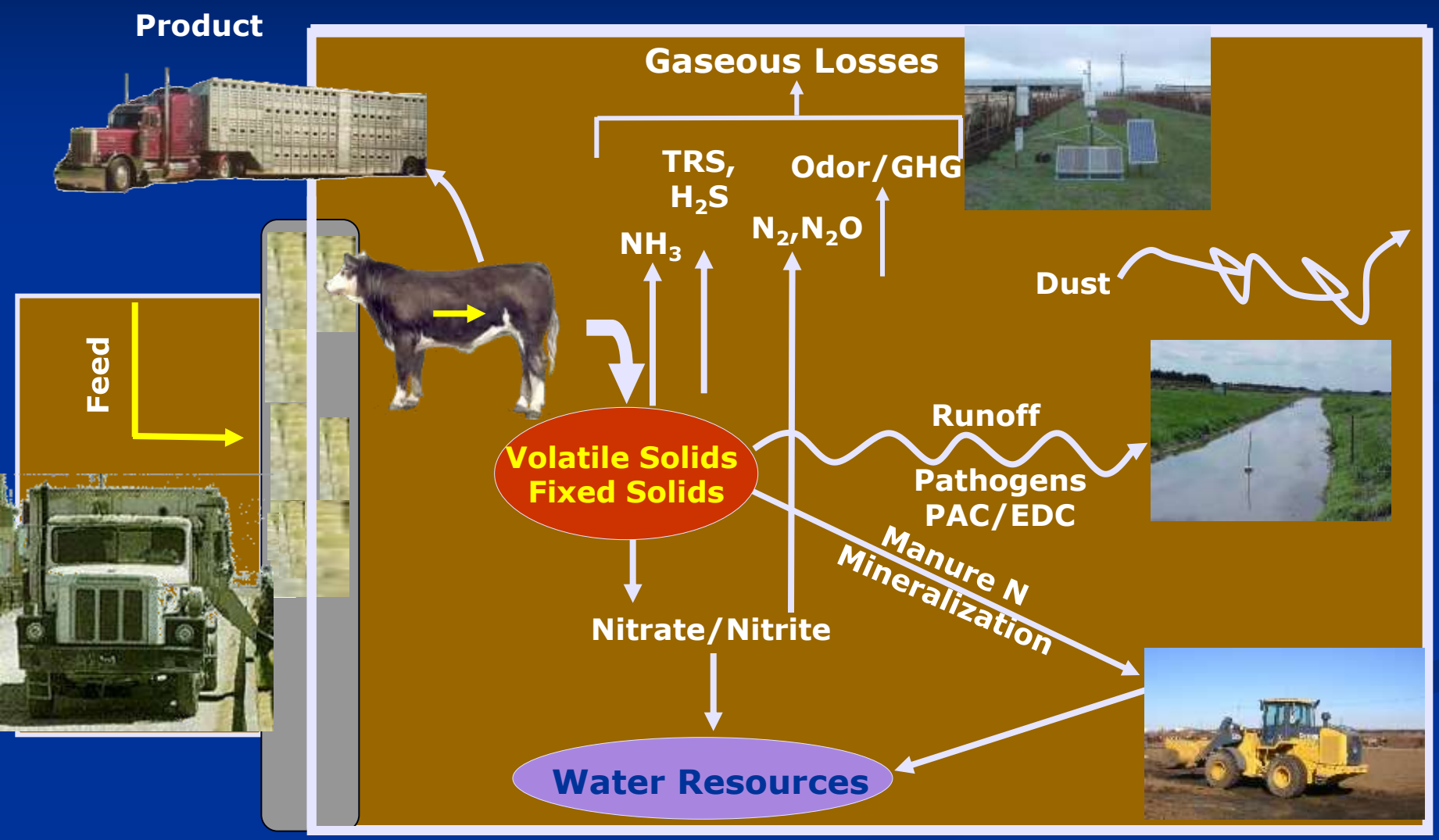
32% Potassium

15% Phosphorus

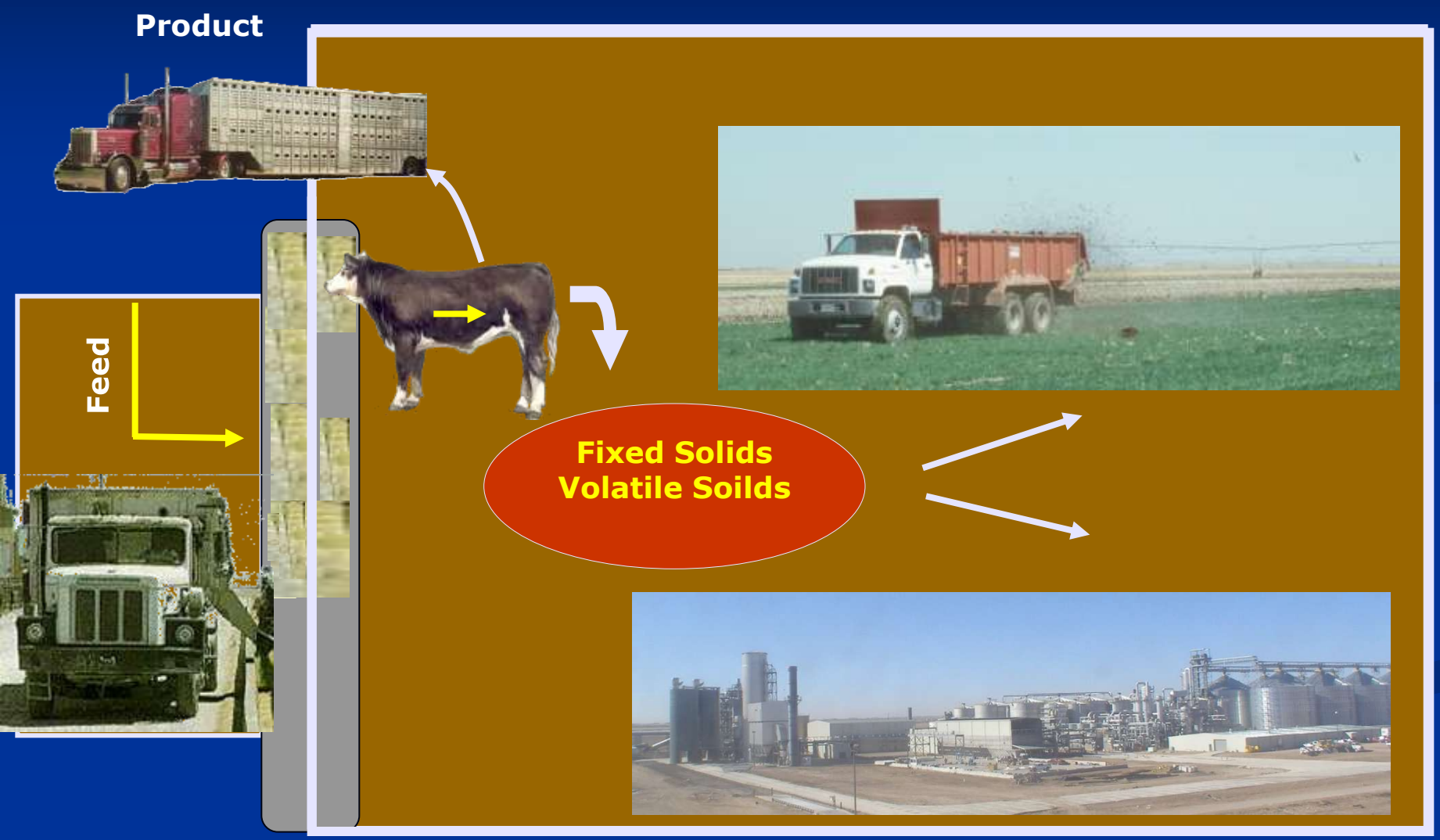
11% Other Minerals and Salts

[1]Agricultural Waste Management Field Handbook, 1992

Pathways for Environmental Contamination from Pen Surfaces



Opportunities to harvest nutrients/energy from the pen

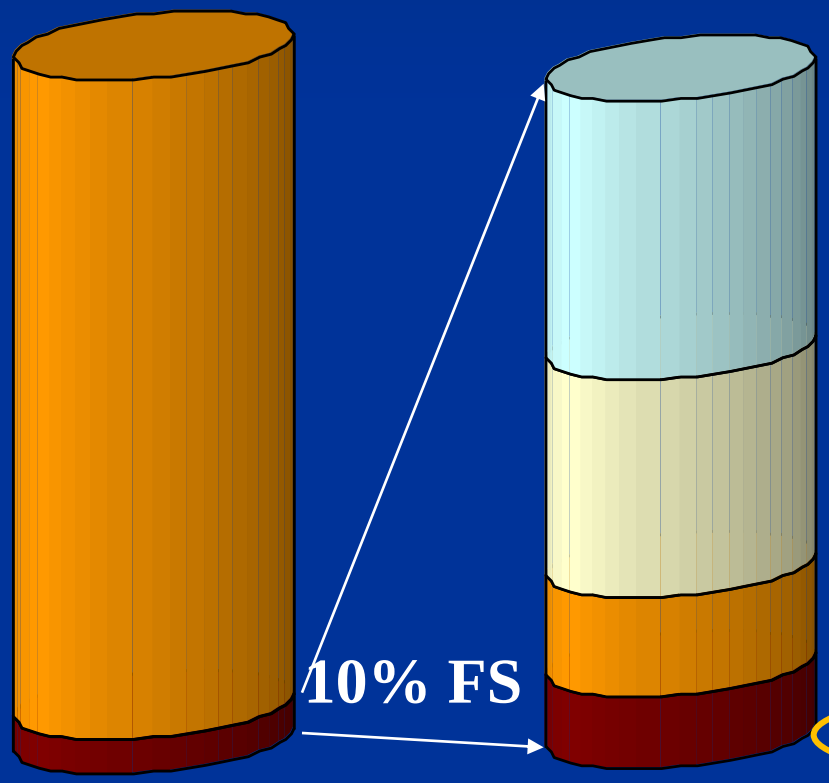


Where is the manure?

- USMARC research established protocols to monitor manure distribution across cattle feedlot pens*

*Woodbury et al. 2009
Eigenberg et al. 2007

Theoretical basis for detection of manure using electromagnetic induction based on manured soils being from 10 to 1000 times more conductive that typical soils. High conductivity indicates high fixed and volatile solid concentrations



42% Nitrogen

32% Potassium

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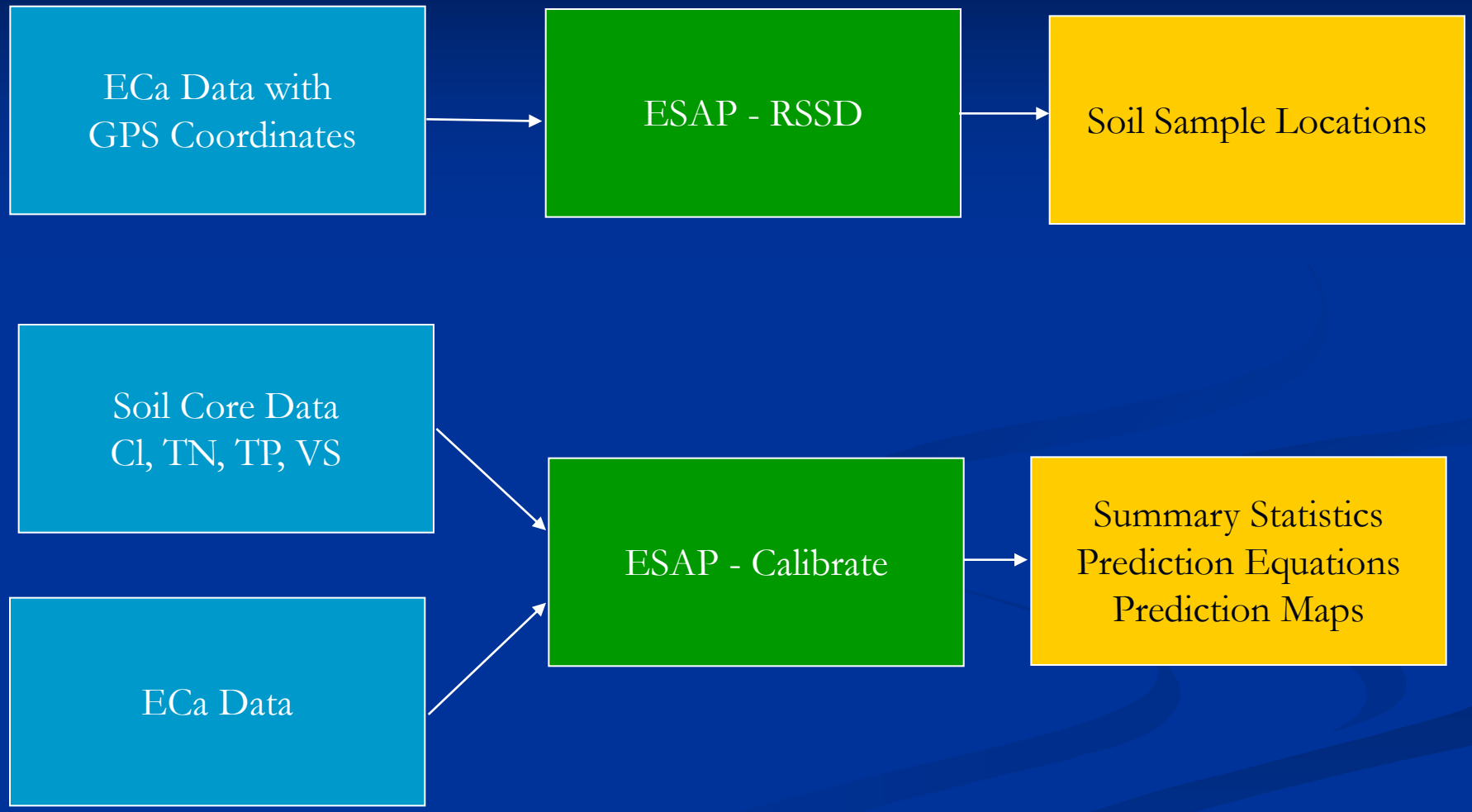
Electromagnetic Soil Conductivity Meter

ESAP Software Suite



The protocols can be used to predict any parameter correlated to ECa

- Total Nitrogen
- Total Phosphorus
- Volatile Solids
- Pathogens
- PACs
- EDCs

- Gaseous emissions
  - CO_2
  - NH_3
  - N_2O

Application of methods to feedyards near Amarillo, TX - Nutrients

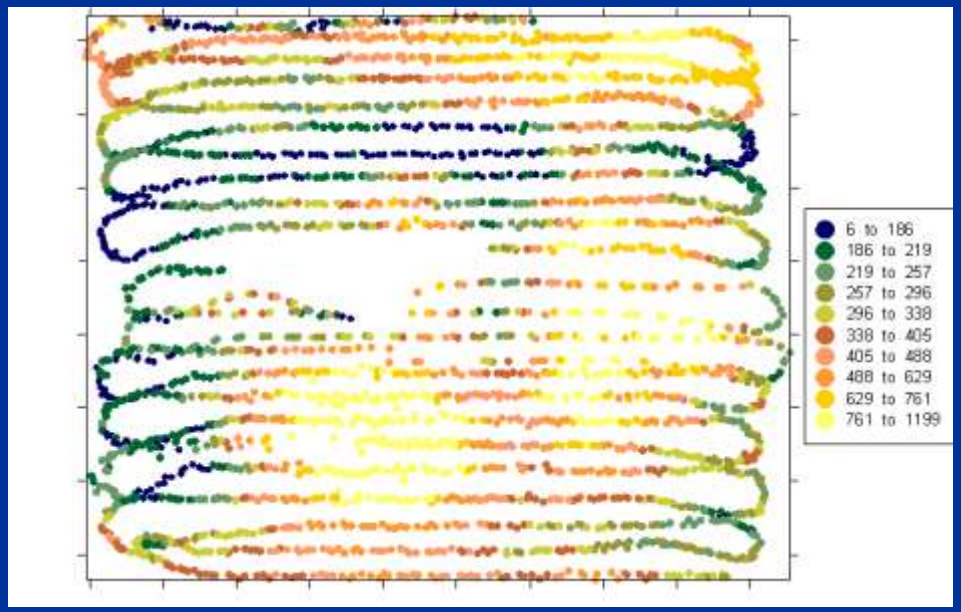
Feedyard A, Pen A

Feedyard B, Pen B

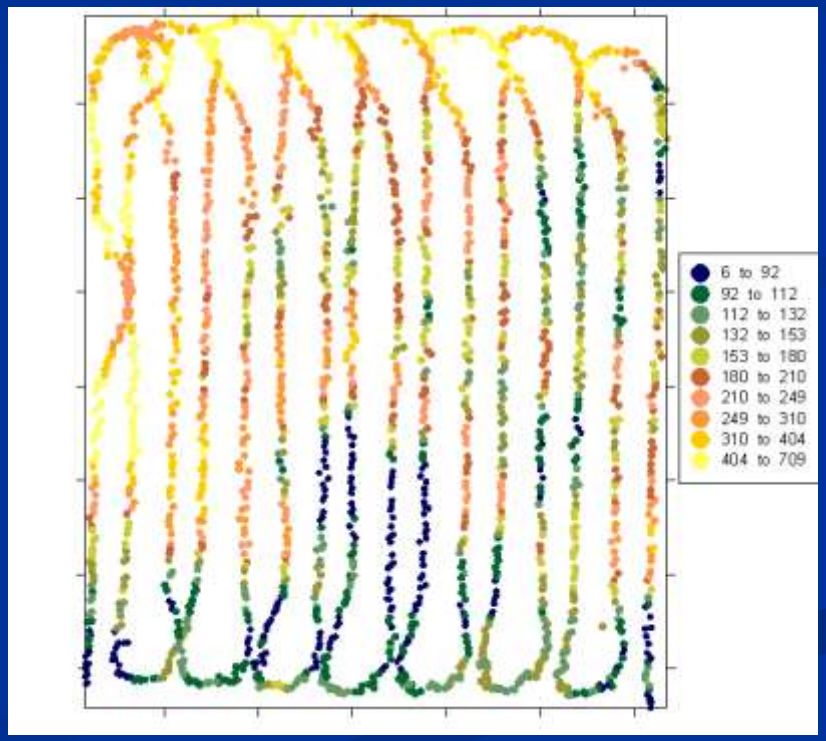
Soil Conductivity Maps

N

Feedyard A, Pen A



Feedyard B, Pen B



Assume: Predictive sigmoidal equations apply –

$$TN = 22816.9/(1+\exp(-(EC_a^2 - 146.5)/21.6))$$

$(R^2=0.874)$

$$TP = 8628.5/(1+\exp(-(EC_a^2 - 152.4)/30.0))$$

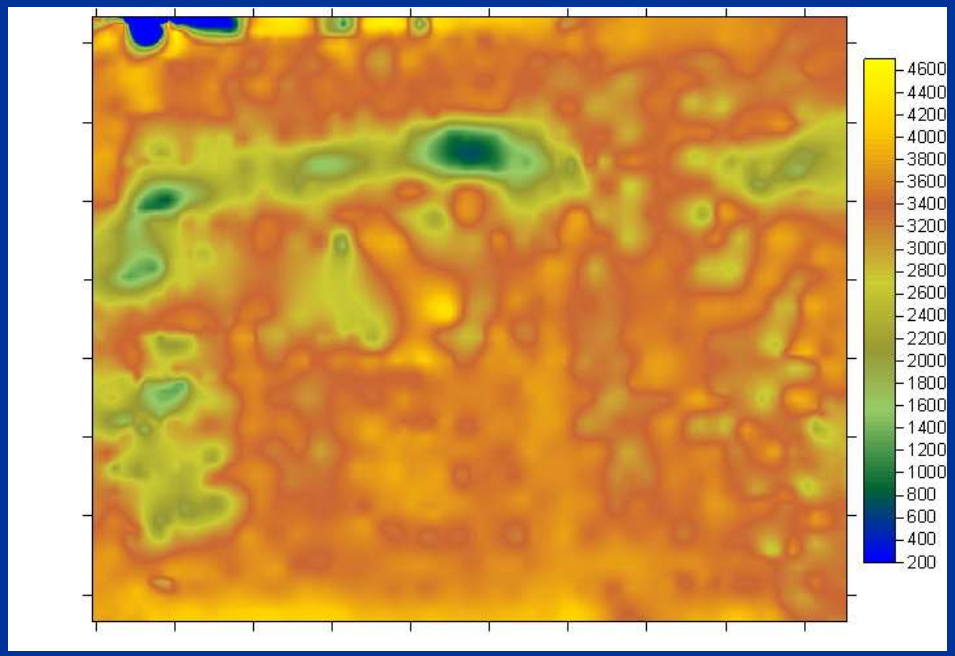
$(R^2=0.868)$

- Assume:
  - Soil density = 0.9 gm/cm3
  - Collect surface material to 15 cm depth
  - 22% of TP available in first year
  - 35% of TN available in first year
  - Price of phosphate fertilizer is $510/ton (April 2010 price)
  - Price of anhydrous ammonia is $425/ton (April 2010 price)

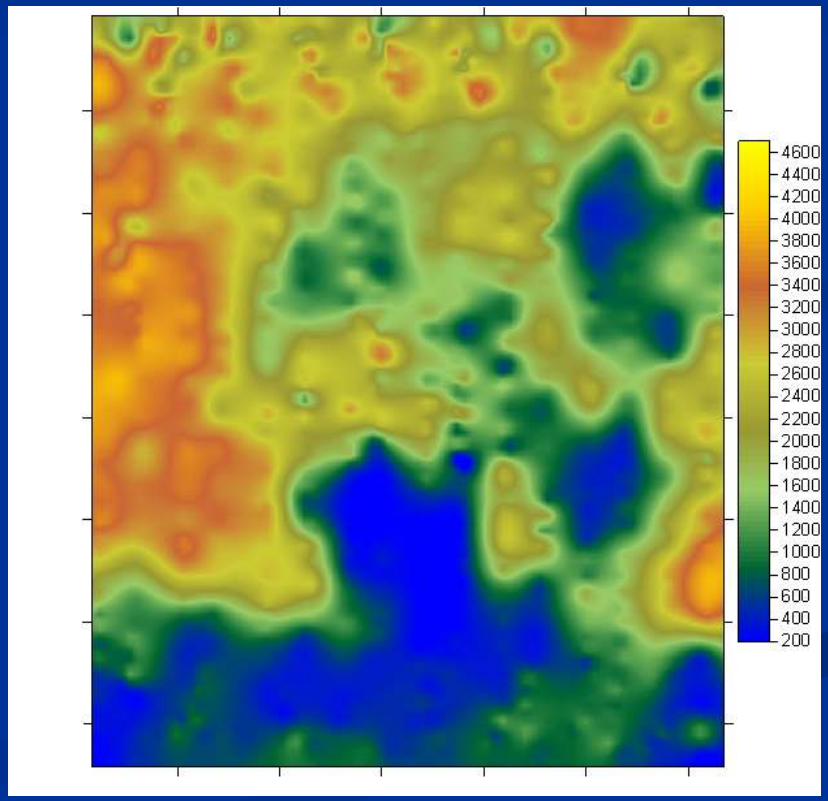
Estimated Total Nitrogen

N

Feed yard A, Pen A



Feed yard B, Pen B



Based on predictive equations and assumptions harvesting 100% of area

	Feedyard A, Pen A	Feedyard B, Pen B
Area Harvested	100%	100%
Average TP, ppm	8,025	5,387
Average TN, ppm	21,724	14,712
Mass, TP, kg	2,193	969
Mass, TN, kg	5,939	2,647
Total mass, kg	273,000	180,000
Value/m3, TP, $/m3	0.89	0.60
Value/m3, TN, $/m3	3.20	2.17
$/m3, total	4.09	2.77

Based on predictive equations and assumptions

	Feedyard A, Pen A	Feedyard B, Pen B
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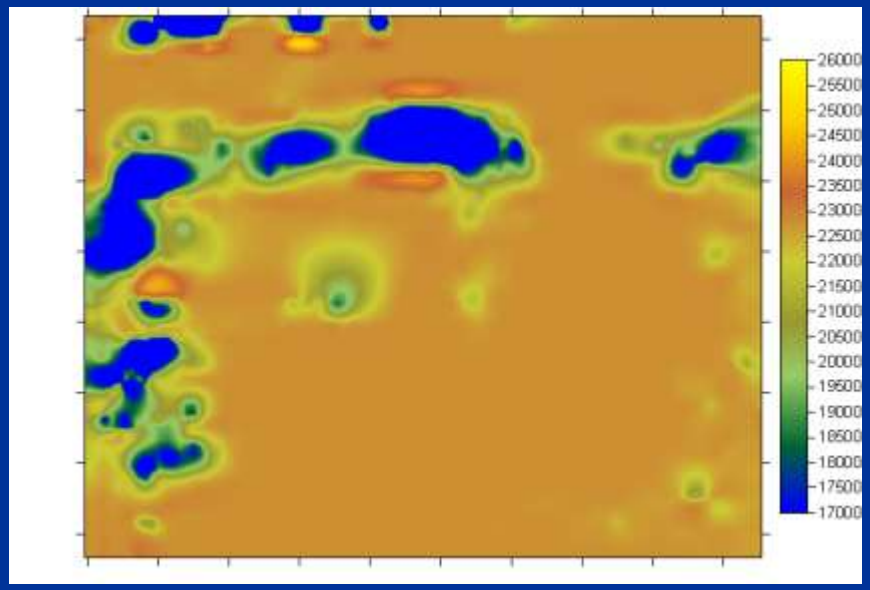
Value/m3, TN, $/m3	3.20	2.17
$/m3, total	4.09	2.77

- Examine the potential of selective harvesting manure
- For example, set a threshold at TN>1.7%

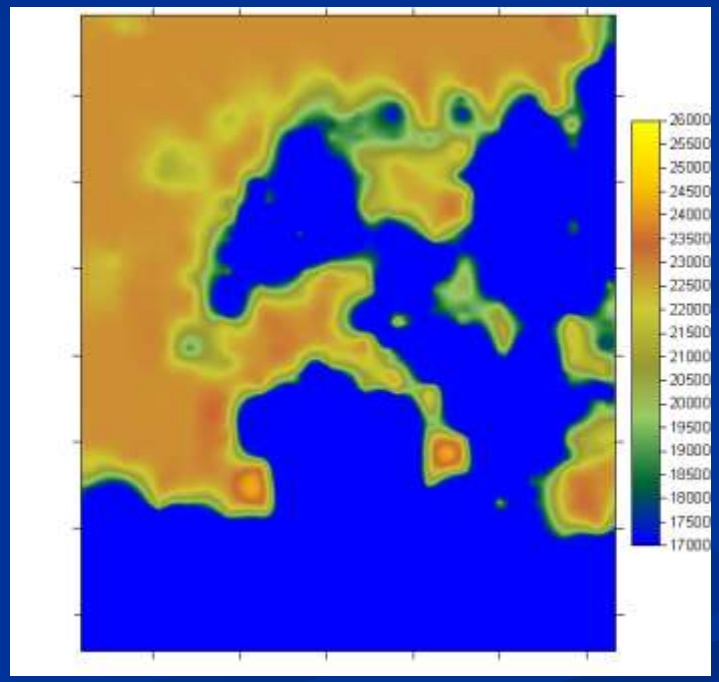
Selectively harvest, TN>1.7%

N

Feed yard A, Pen A



Feed yard B, Pen B



Based on predictive equations and assumptions

	Feedyard A, Pen A	Feedyard B, Pen B	Feedyard A, Pen A TN>1.7%	Feedyard B, Pen B TN>1.7%
Area Harvested	100%	100%	94%	54%
Average TP, ppm	8,025	5,387	8,306	7,943
Average TN, ppm	21,724	14,712	22,420	21,891
Mass, TP, kg	2,193	969	2,126	772
Mass, TN, kg	5,939	2,647	5,738	2,128
Total mass, kg	273,000	180,000	256,000	97,000
Value/m3, TP, $/m3	0.89	0.60	0.92	0.88
Value/m3, TN, $/m3	3.20	2.17	3.30	3.22
$/m3, total	4.09	2.77	4.22	4.10

Based on predictive equations and assumptions

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Value/m3, TN, $/m3	3.20	2.17	3.30	3.22
$/m3, total	4.09	2.77	4.22	4.10

Cost to transport

- Assume a shipping cost of $.55/ton/mi
  - Cost to haul 1 m^3 for 10 miles is $4.96

Cost to haul manure and against value of manure

	Fyd A, Pen A	Fdyd B, Pen B	Fyd A, Pen A TN>1.7%	Fdyd B, Pen B TN>1.7%
$/m3, total	4.09	2.77	4.22	4.10
$/m3, Cost to haul 10 miles	4.96	4.96	4.96	4.96
$/m3, total	-0.87	-2.19	-0.74	-0.86

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$/m3, total	-0.87	-2.19	-0.74	-0.86

The net value of the nutrients in manure diminishes with distance. Using the nutrients in the fixed solids portion of manure has limited economic return.

- Is the volatile solids portion of manure more valuable as a possible source of recoverable energy?

- Feedlot manure, especially in the high plains, has unique qualities
  - The dry climate results in a product that is suitable for direct combustion
  - Concentrated production assures sufficient supplies; approximately 4.7 million head of cattle in the Texas panhandle with energy potential of 30-50 trillion BTU.

- Energy content of feedlot manure is defined:
  - HHV (higher heating value)= f(VS, % moisture)*

* Sweeten, 1980

Assumptions

- Use established relationships between ECa and VS
- Use new methods of estimating moisture
- Soil density = 0.9 gm/cm3
- Collect surface material to 15 cm (about 6”)
- Price of Powder River coal is $12.40/ton, energy content 8,800BTU/lb (April, 2010)
- Price of of natural gas is $0.617/therm (100,000 BTU/therm, January 2010 price)

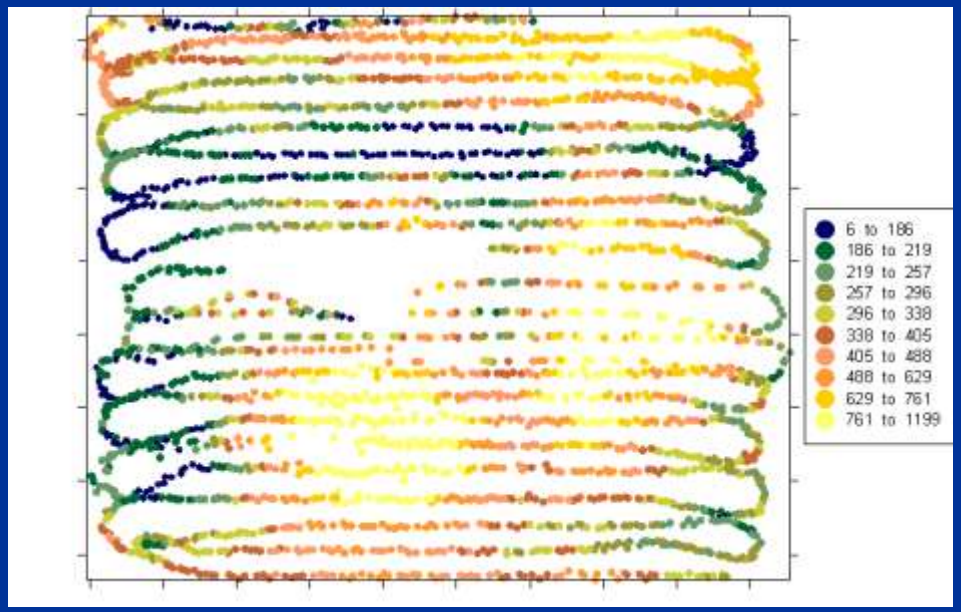
Application to energy recovery

Feedyard A, Pen A

Feedyard B, Pen B

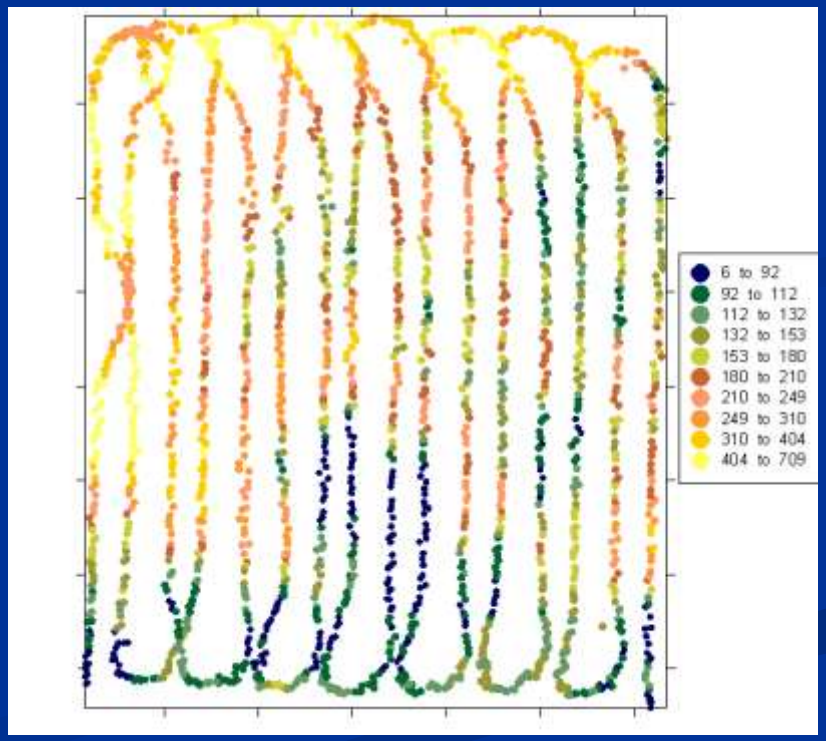
Soil Conductivity Maps

Feedyard A, Pen A



Feedyard B, Pen B

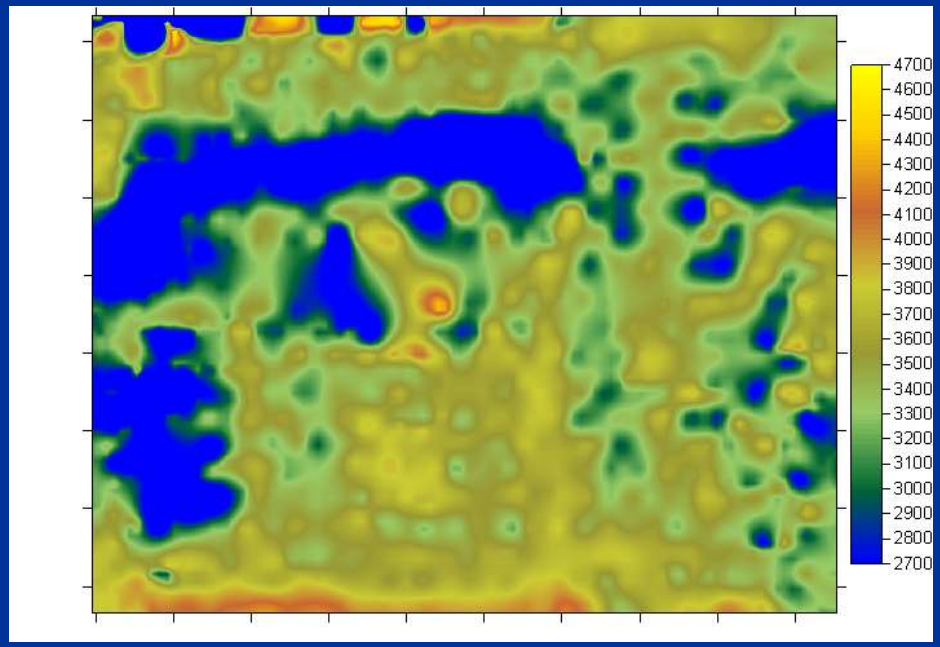
N



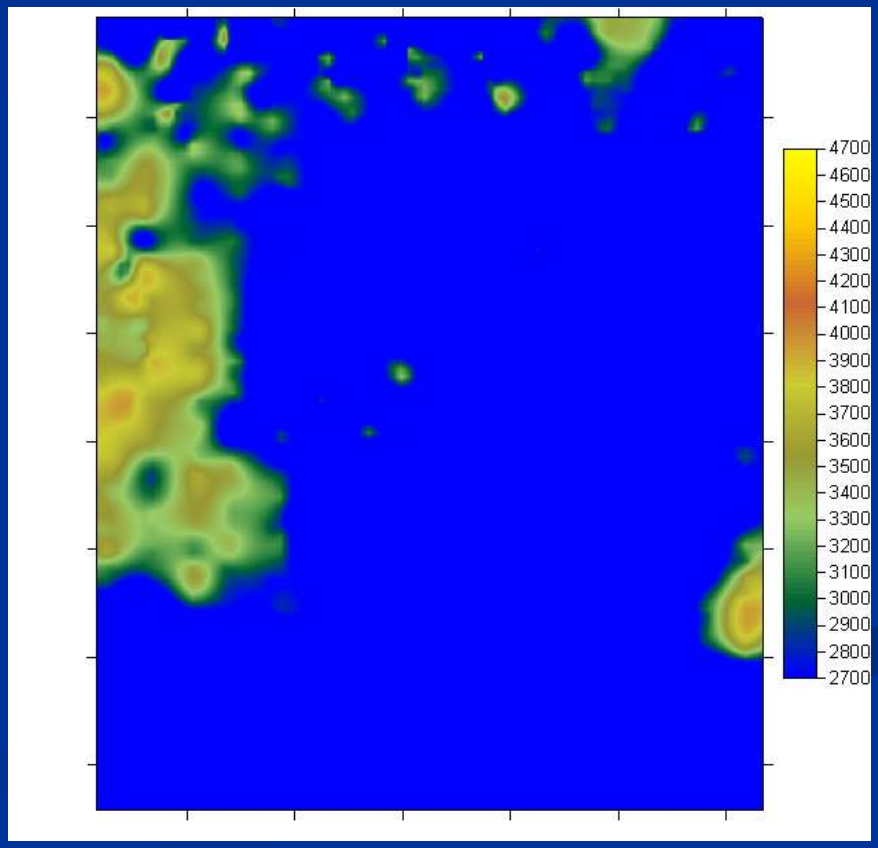
- Constraints on energy,
  - Unlike nutrients, the harvested manure only has value if the VS>50% and the energy content, HHV, is greater than 2700 BTU/lb

Estimated energy content for areas > 2700 BTU/lb

Feed yard A, Pen A



Feed yard B, Pen B



Energy Estimates

	Feedyard A, Pen A	Feedyard B, Pen B	Feedyard A, Pen A HHV> 2700	Feedyard B, Pen B HHV > 2700
Area Harvested, %	100	100	85	24
Average Energy, BTU/lb	3,224	1,771	3,450	3,228
Harvested mass, kg	273,000	180,000	233,000	43,000
Value/m3, energy, $/m3 (coal)	21.87	12.01	23.40	21.90
Value/m3, energy, $/m3 (gas)	39.48	21.69	42.25	39.53

Energy Estimates

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Value/m3, energy, $/m3 (gas)	39.48	21.69	42.25	39.53

Comparative Values with Transportation

Nutrients

	Fyd A, Pen A	Fdyd B, Pen M5	Fyd A, Pen A TN>1.7%	Fdyd B, Pen B TN>1.7%
$/m3, total	4.09	2.77	4.22	4.10
$/m3, Cost to haul 10 miles	4.96	4.96	4.96	4.96
$/m3, total	-0.87	-2.19	-0.74	-0.86

Energy

	Fyd A, Pen A	Fdyd B, Pen B	Fyd A, Pen A HHV>2700	Fdyd B, Pen B HHV>2700
$/m3, energy, total (coal)	21.87		23.40	21.90
$/m3, Cost to haul 10 miles	4.96		4.96	4.96
$/m3, total	16.91		18.44	16.94

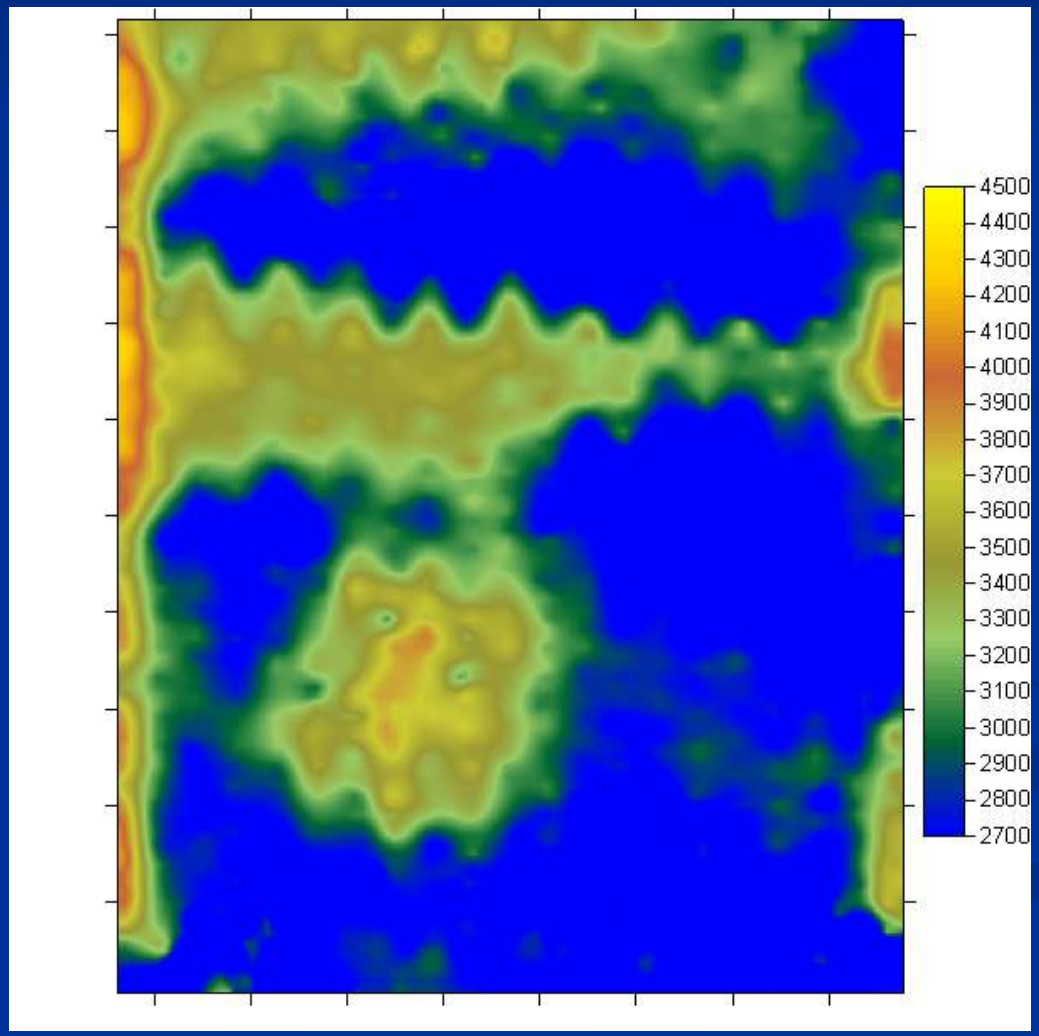
Energy Locator

- The economics are dependent on locating high quality material for combustion
- The protocols and models that have been developed may provide the tools needed for energy recovery

Feed yard C, Pen C

Energy Locator Demonstration Pen

Estimated HHV



N

Software Interface and Controls for Energy Locator

Feedlot Engery Manager

3449.8 HHV	3531.9 HHV FILTER

21.8% Moisture	51.9% VS

2700 HHV SET	50% VS SET

Latch AUTO Relay ON

250.3 HCP 248.8 PRP

Conclusions:

- Selective harvesting of nutrients from a cattle feedlot for use as a soil amendment can increase the of value of the harvested manure up to 50%
- Combustible biomass can be harvested as a coal supplement for use in a direct combustion process. This results in a nearly ten-fold value increase when compared to manure used for nutrients

Conclusions, cont'd:

- Selective harvesting methods have been demonstrated that identify manure concentrations on feedlot pens

Questions, comments, observations?

Direct Combustion, Manure Powered Ethanol Plant, Hereford, TX