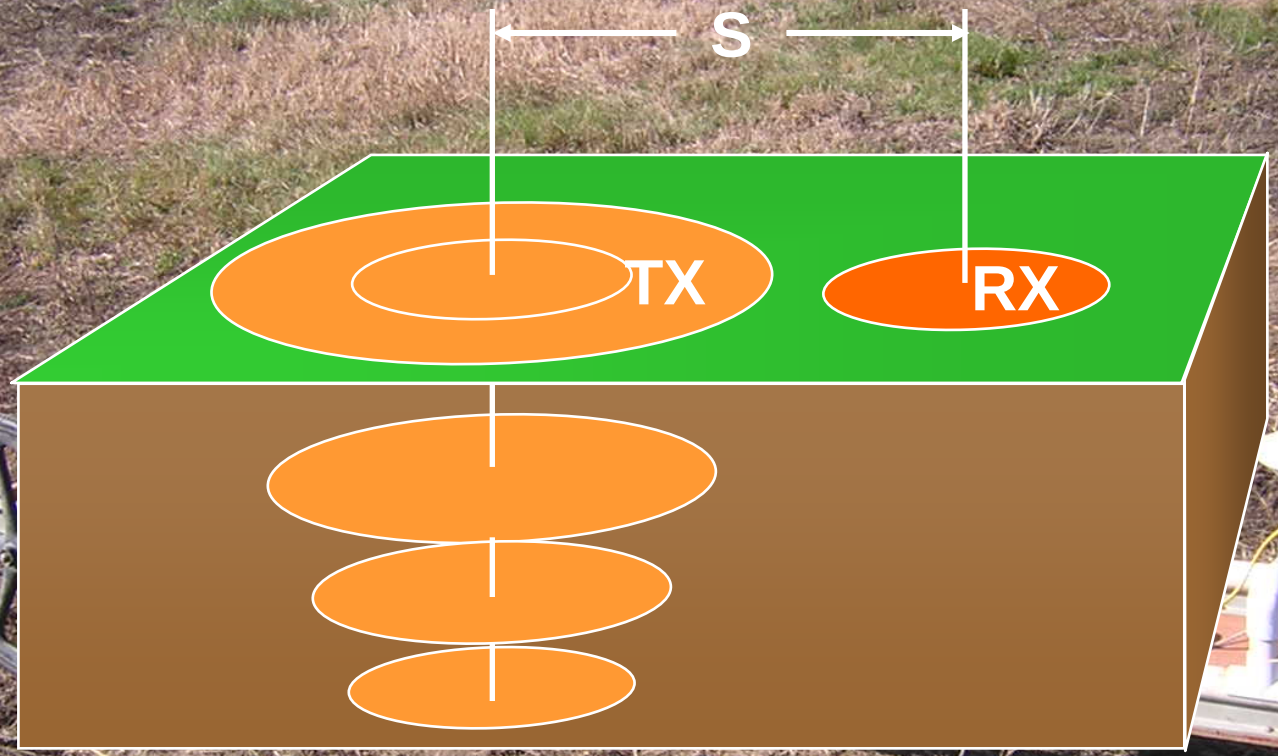
U.S. Meat Animal Research Center
Environmental Management Research Unit
Animal Waste Management Group
Clay Center, NE

J.A. Nienaber, R.A. Eigenberg, V. Varel, M. Spiehs and B.L. Woodbury

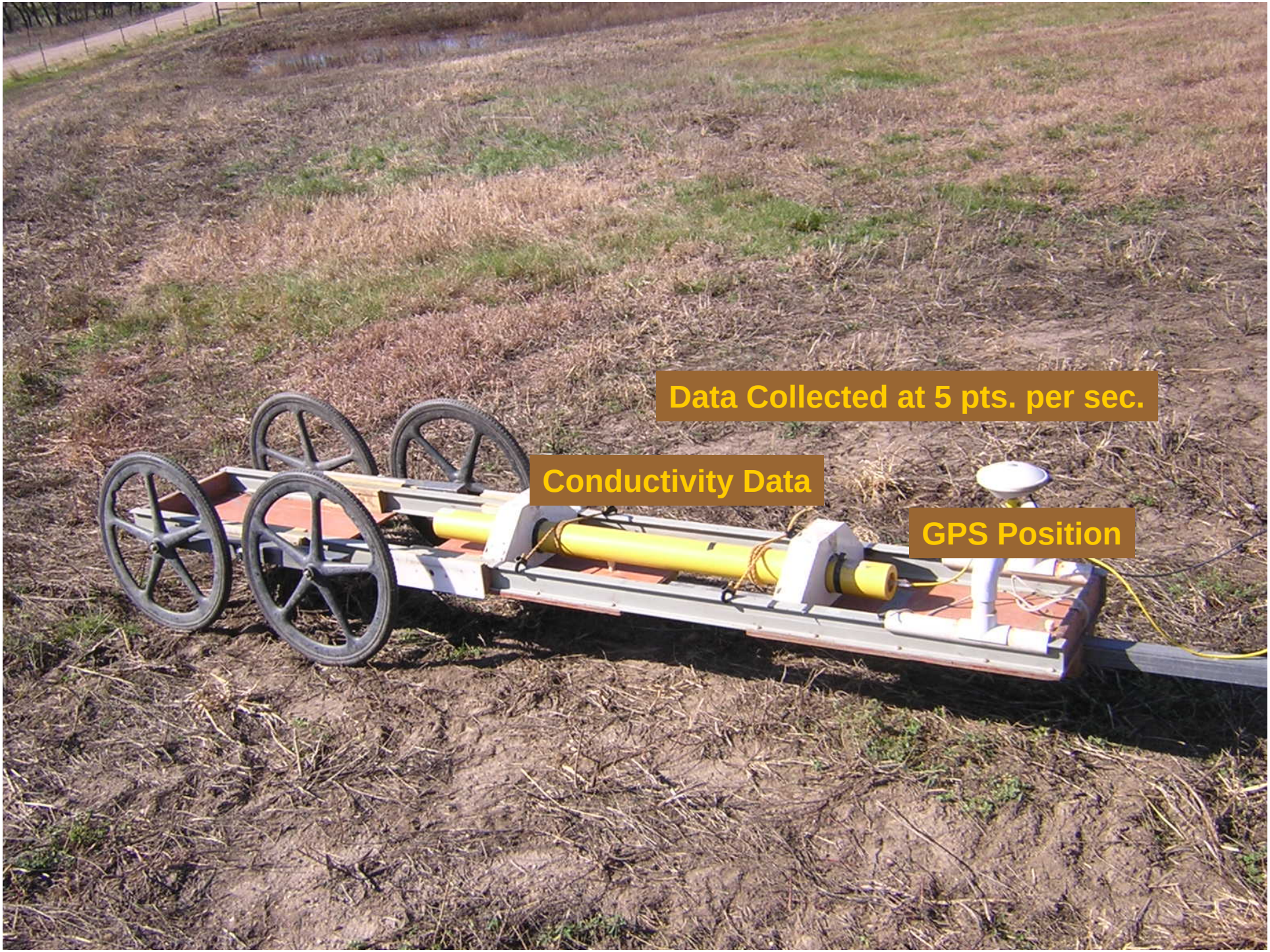
USMARC Research Controlling Environmental Impact from CAFOs


Electromagnetic Soil Conductivity
Meter, ECa

Electromagnetic Induction Principles



The transmitter coil (TX) is placed near the earth and is energized with an alternating current. The small currents induced into the earth generate a secondary signal which is picked up by a receiver coil (RX) at a distance S away. The ratio of the two signals gives a measure of the soil's conductivity beneath the two coils.


Data Collected at 5 pts. per sec.
Conductivity Data
GPS Position

OBJECTIVES

- Measure Spatial Seasonal Soil Dynamics
  - Temperature
  - Moisture Content
  - Nitrate
- Which dynamic drives soil conductivity?

Treatments
Established in 1992

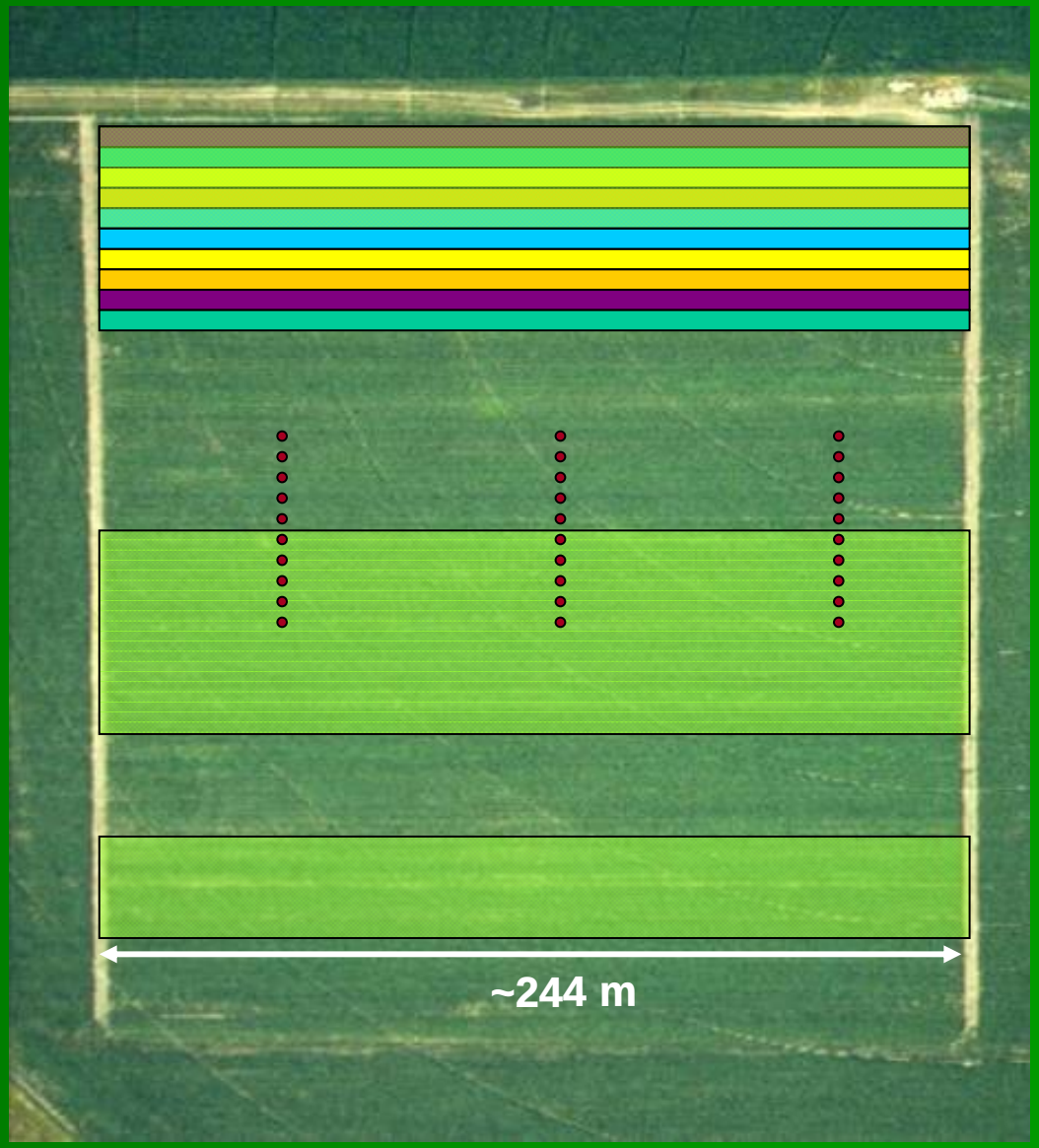
- Winter cover crop destroyed with herbicide and tillage, late March

- Beef feedlot manure or composted beef feedlot manure applied to treatment strips, late March and incorporated with disk; planted to corn, mid-April

Experimental Design

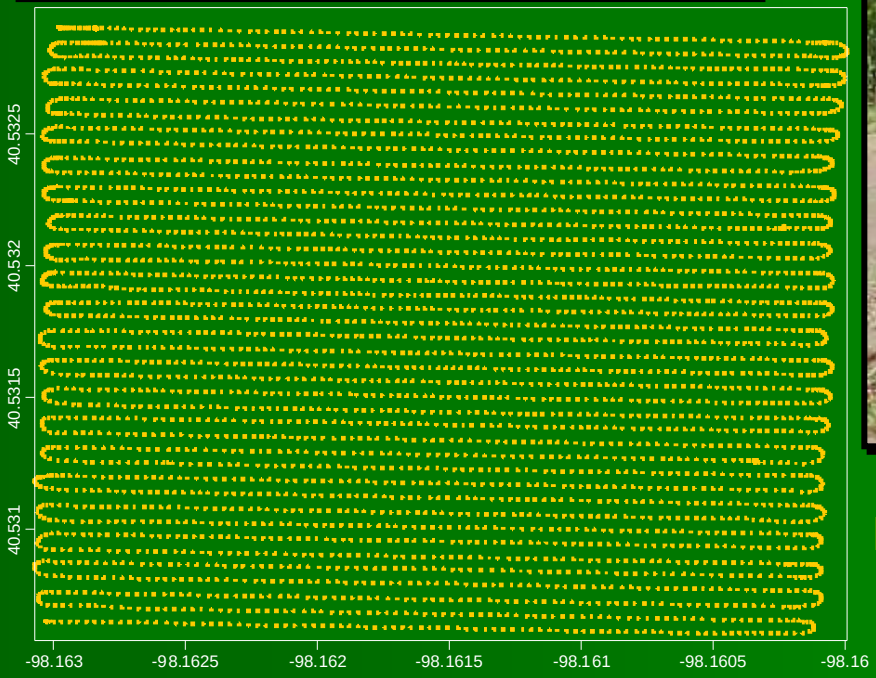
Aerial view of study, July 1995

- Main plots: With (green) or without winter cover crop
- Sub plots:
  - NCK - N only check
  - MN - Manure @ N rate
  - MP - Manure @ P rate
  - CN - Composted manure @ N rate
  - CP - Composted manure @ P rate
- Four replicates
  Soil cores in Rep 2



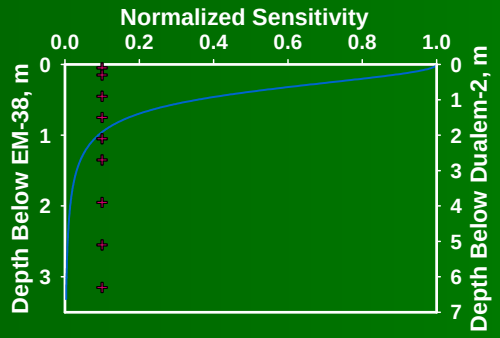
Materials and Methods

- Dualem with integrated GPS
  - Pulled on sled by ATV or person-power

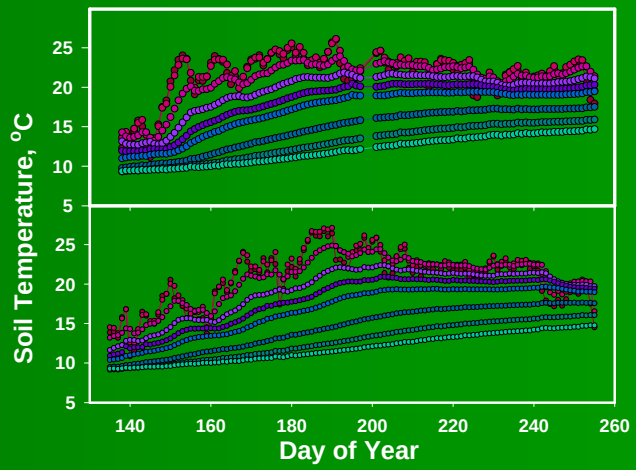


Map of Survey Points

Materials and Methods - Temperature Correction



$$r_{cp} = 2h/(4h2 + 1)^{1/2}$$



Profile-weighted Temperature (t) for a Given Date

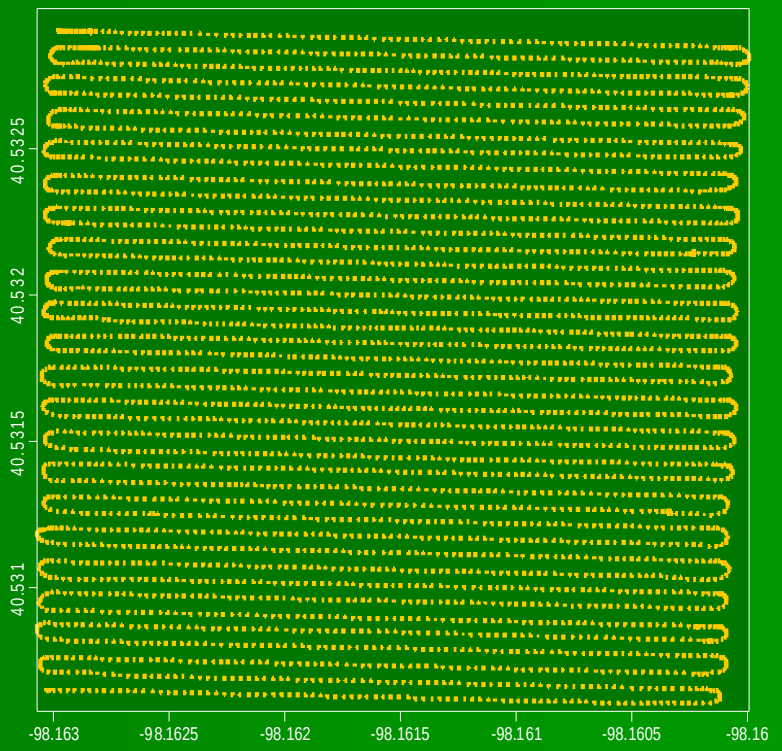
$$CF = 7.29 * 10^{-7} * t^3 + 9.39 * 10^{-4} * t^2 - 5.34 * 10^{-2} * t + 1.86$$

McKenzie, 1989

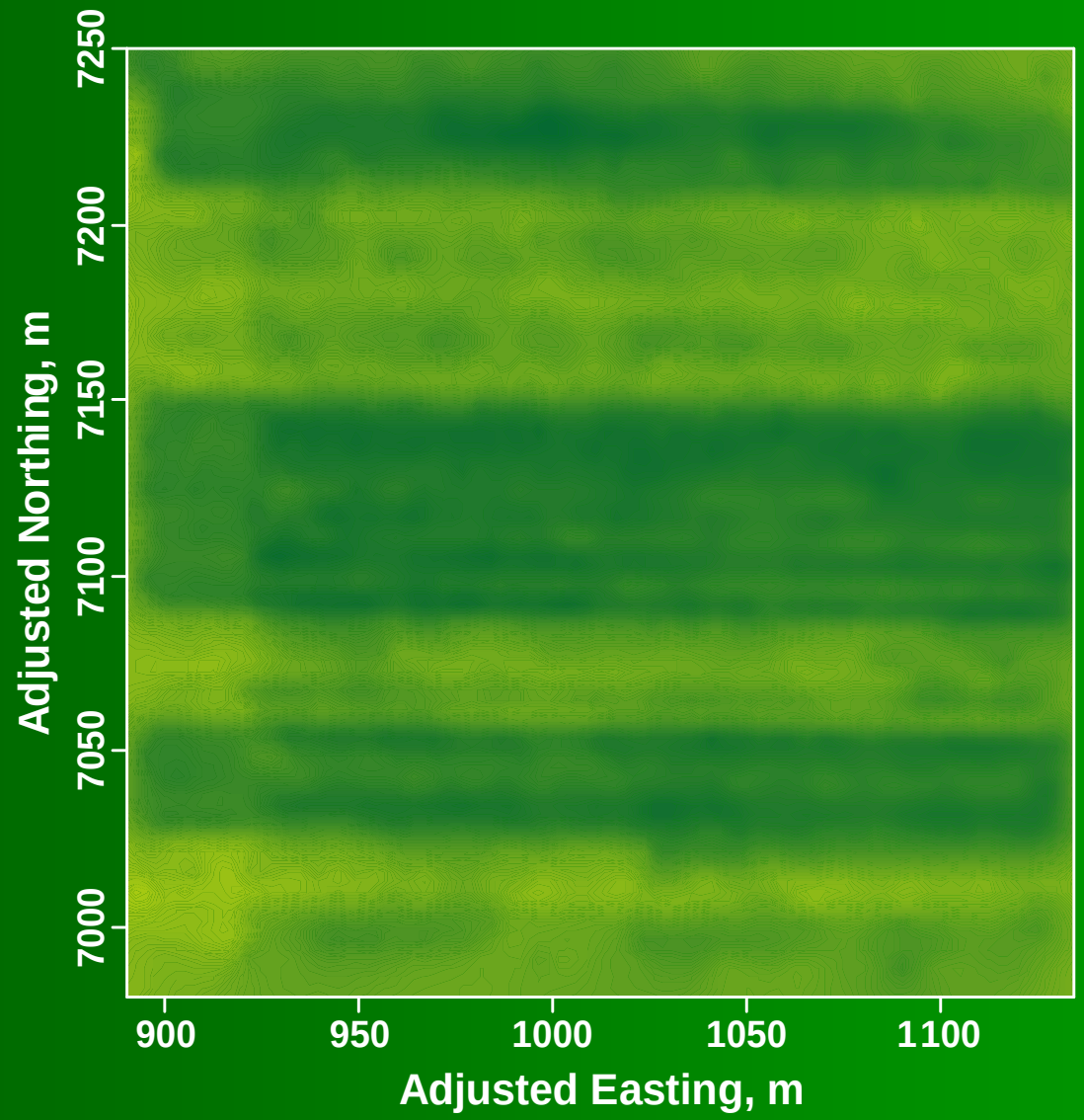
Temperature Correction Factor

Results

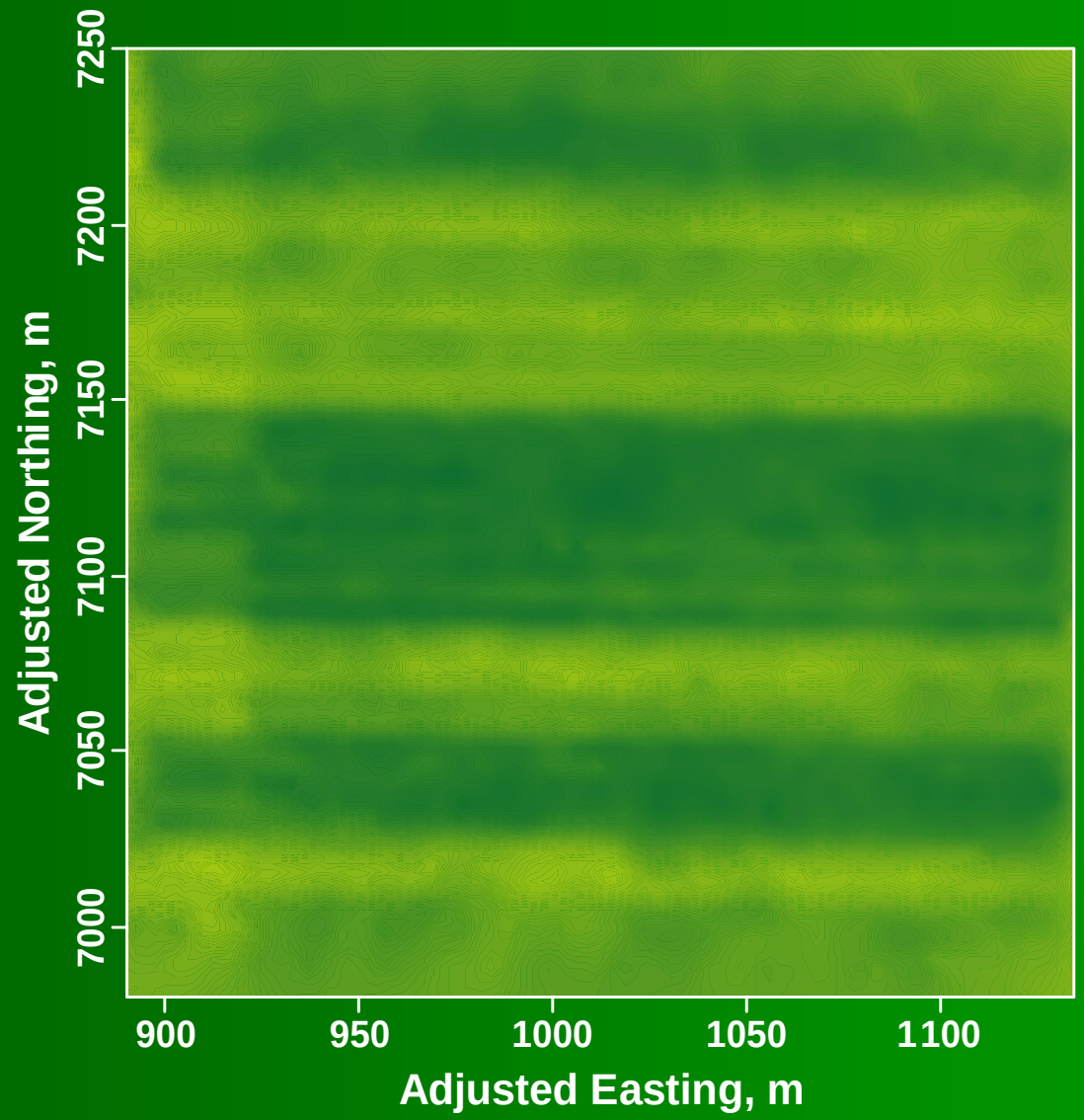
- **Data corrected for temperature, axis alignment, velocity and offset to produce image maps**



04/18/2002
Organics Applied



04/30/2002
Field Planted



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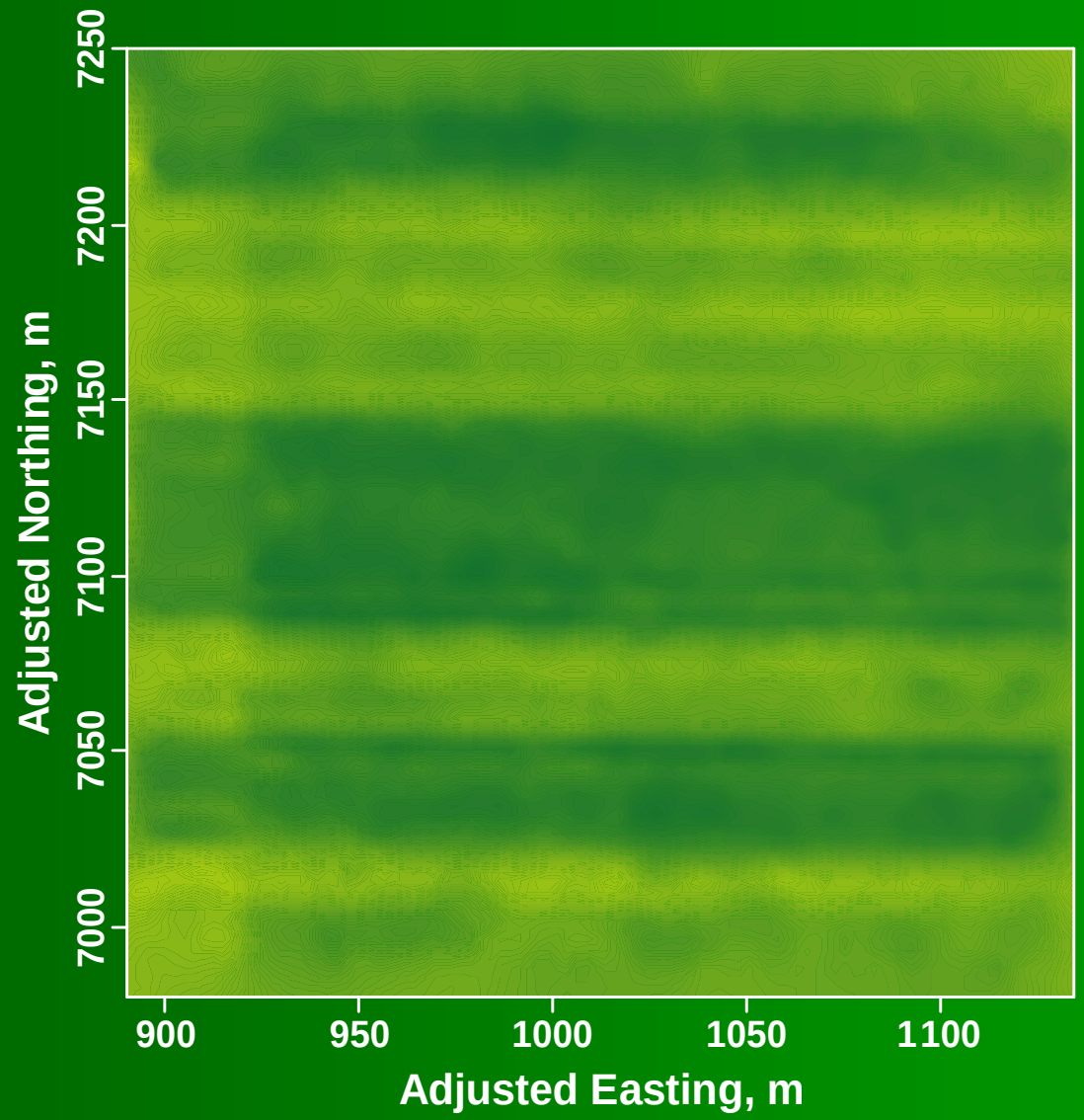
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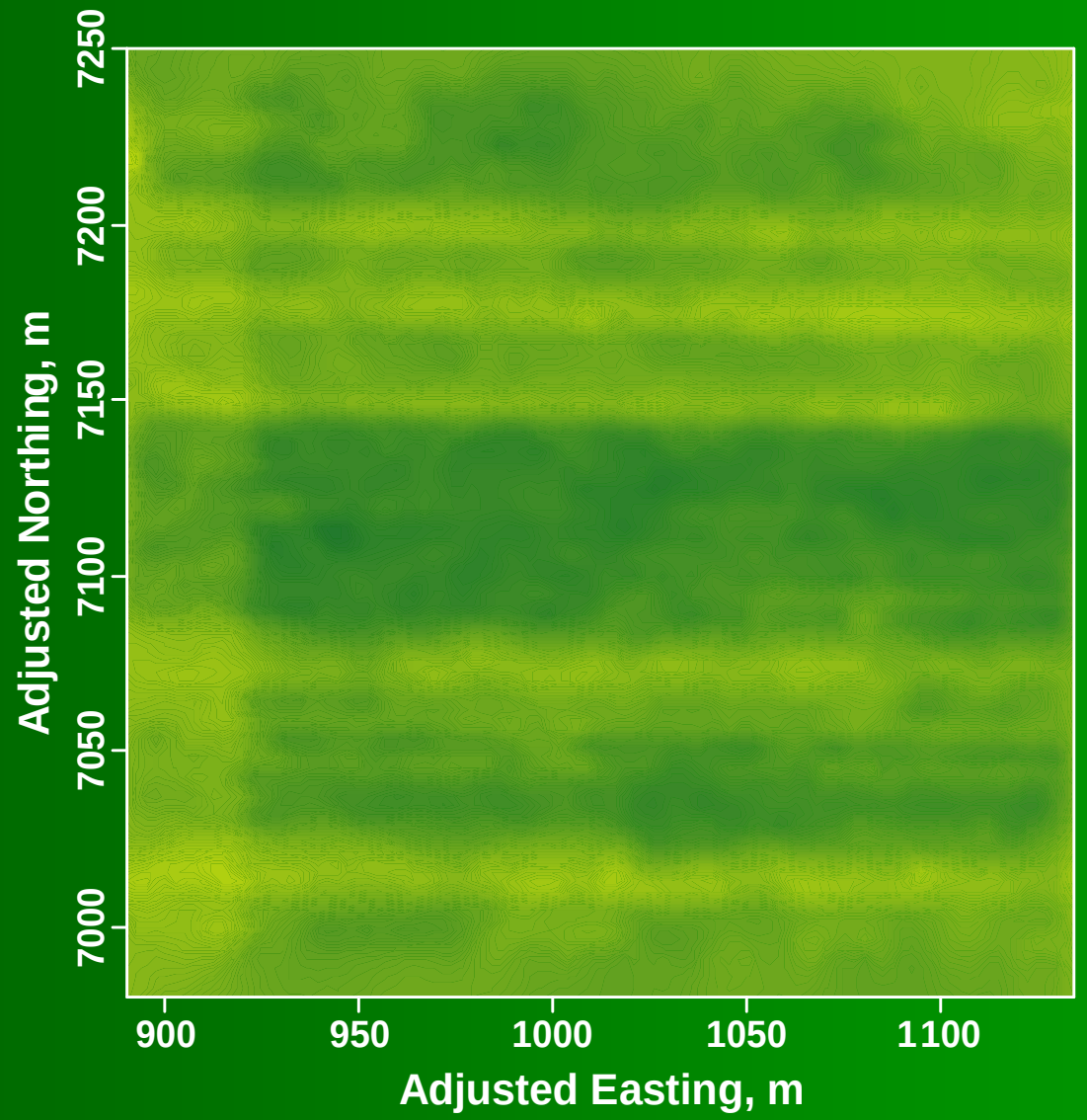
05/14/2002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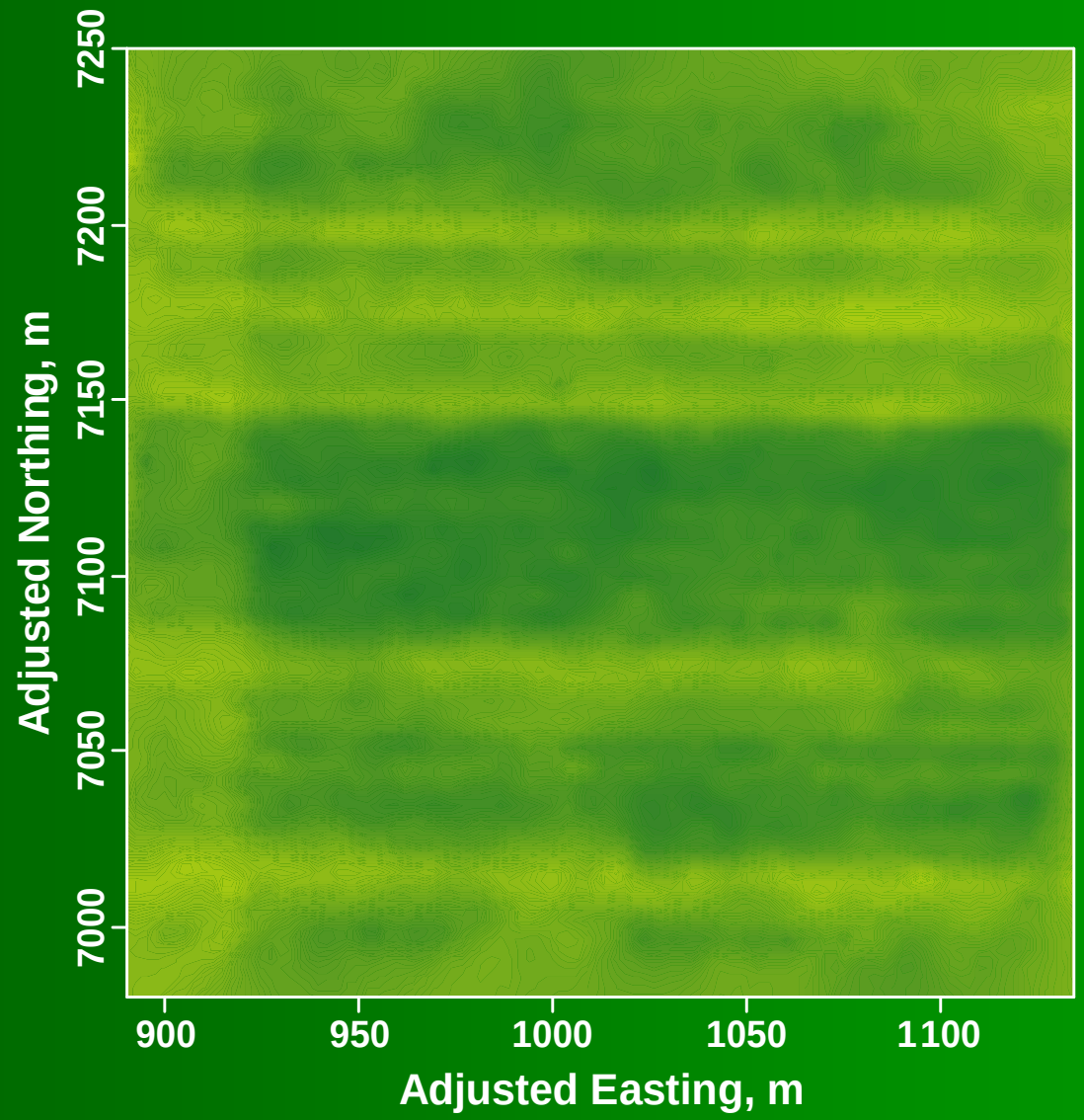
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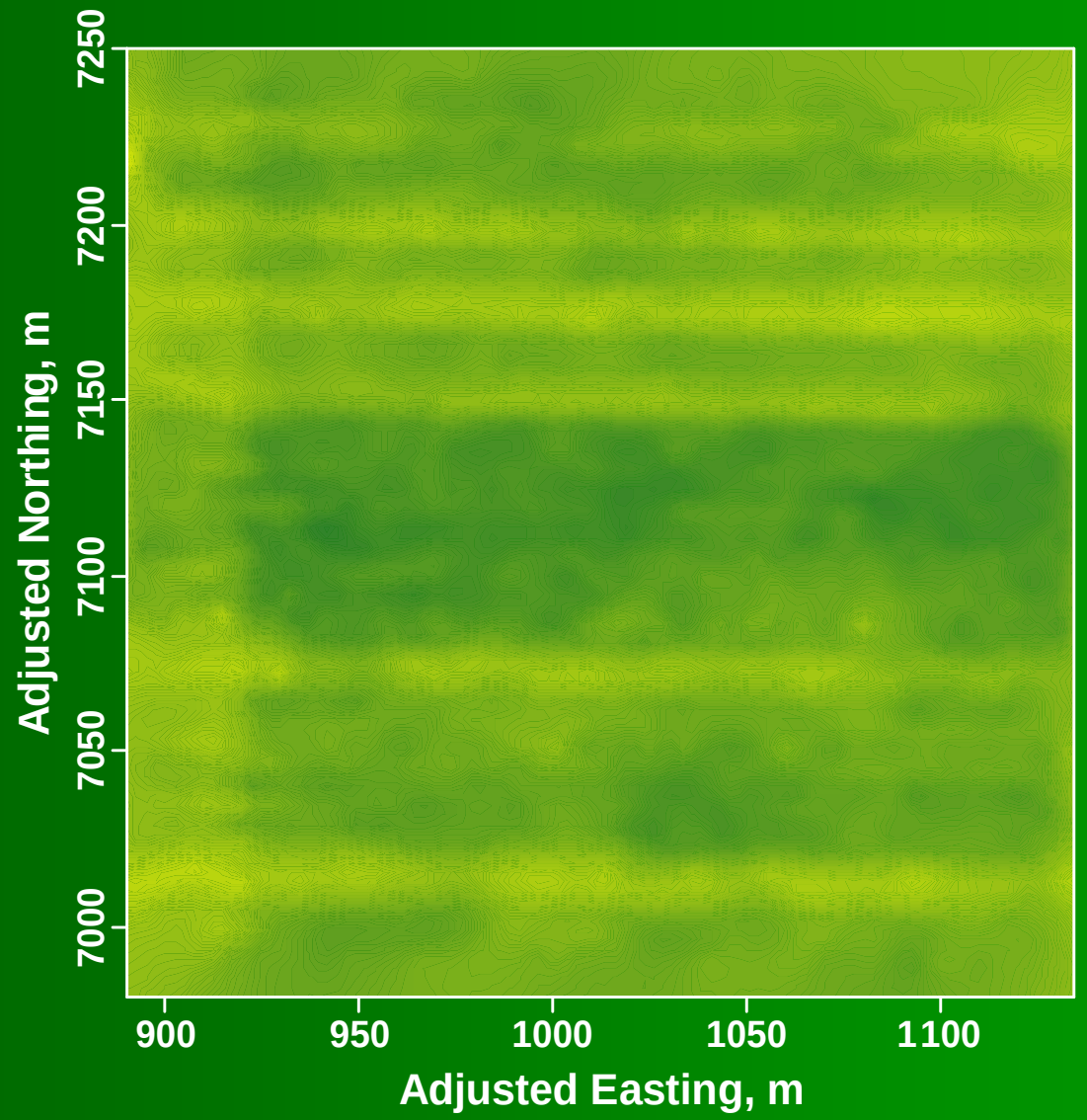
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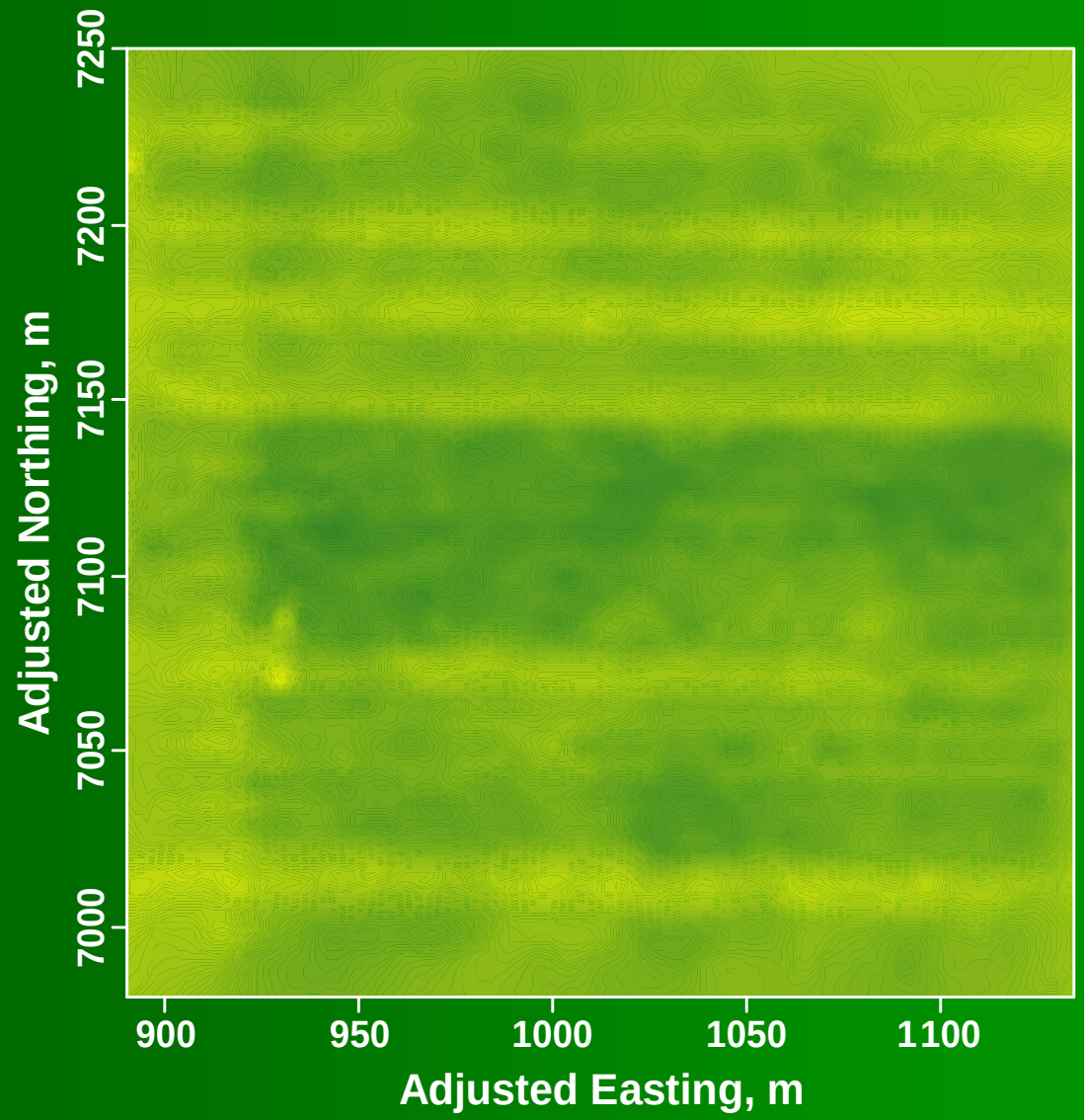
06/06/2002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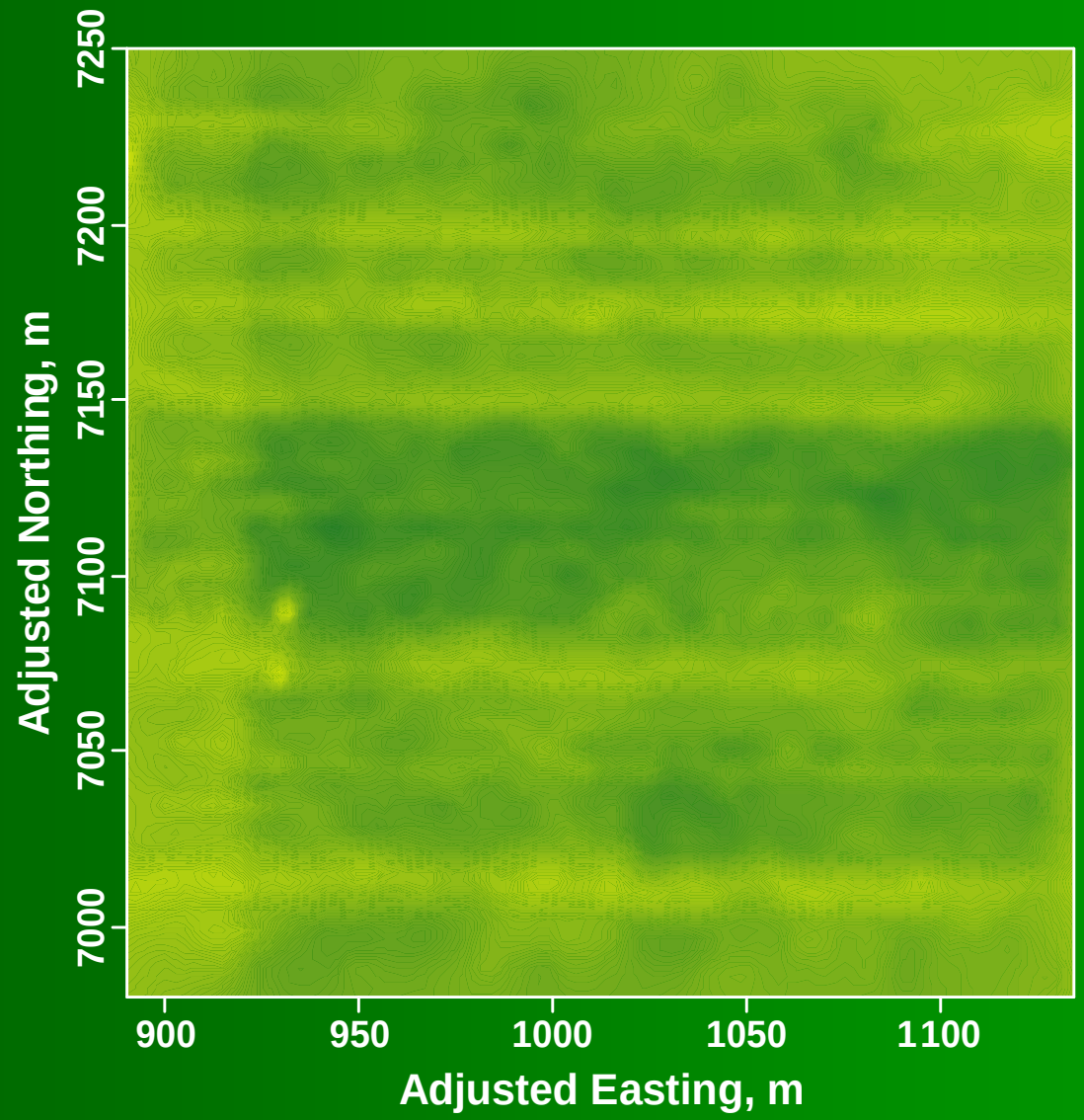
06/11/2002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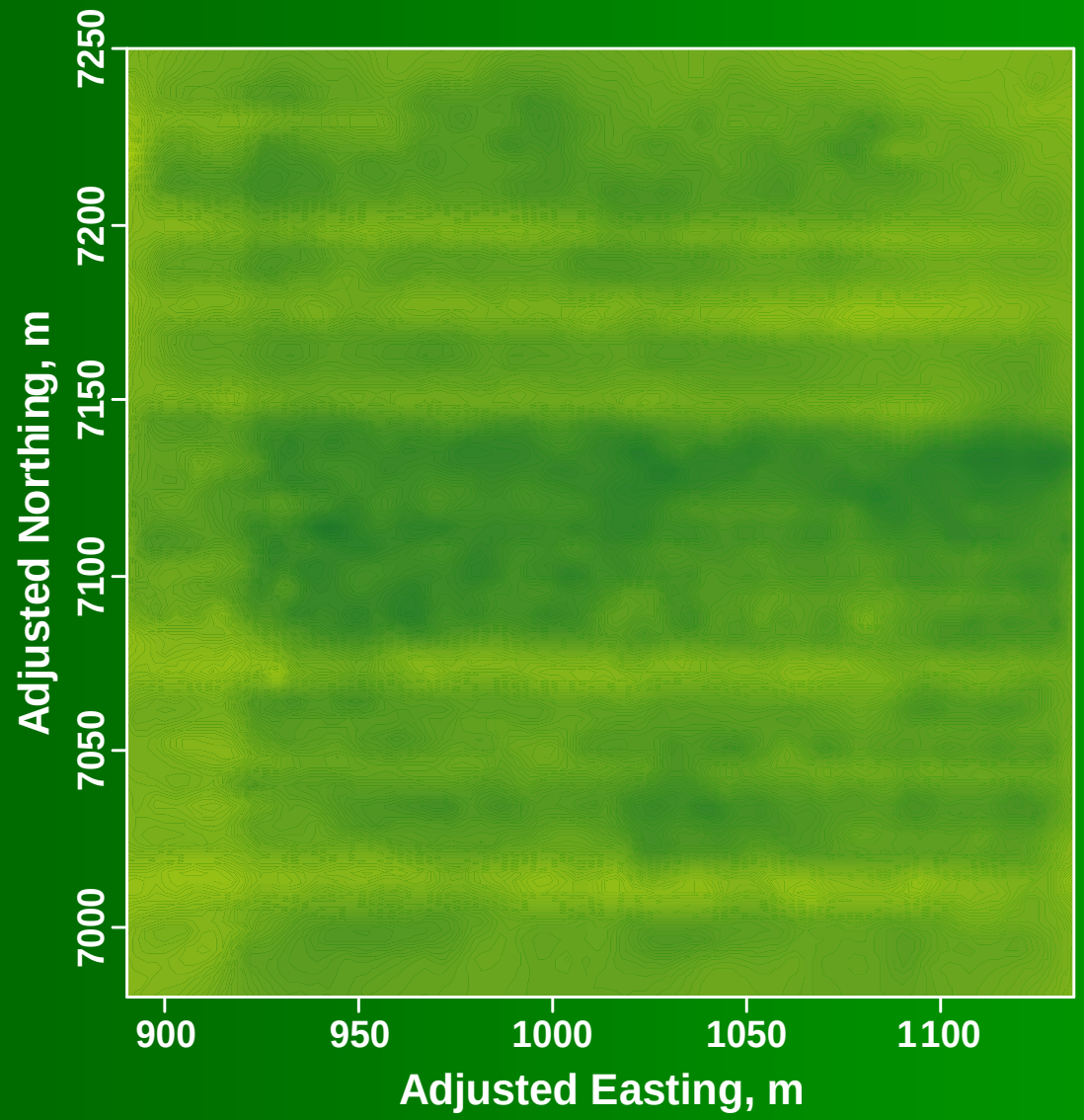
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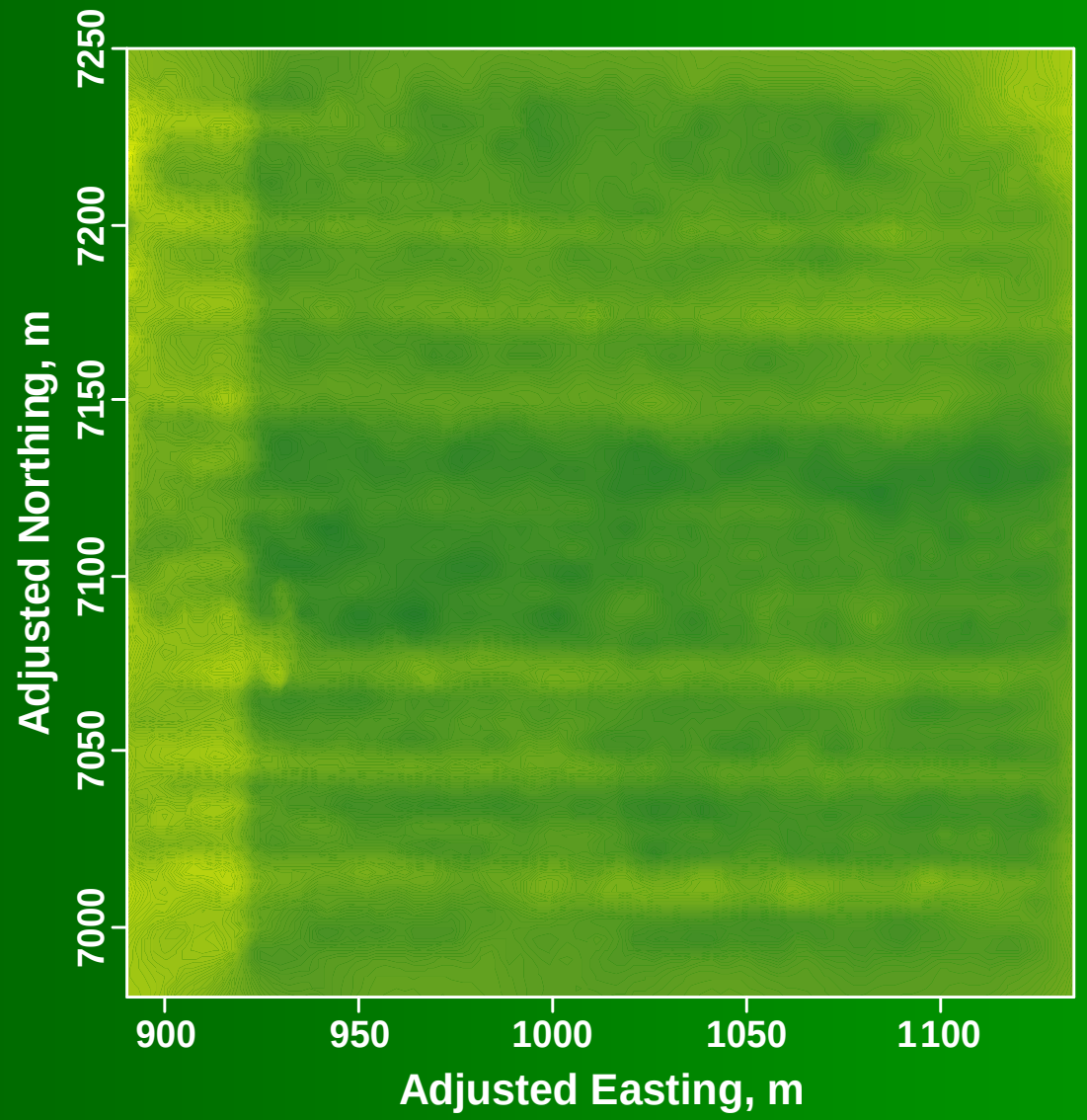
06/27/2002
Corn 1' Tall



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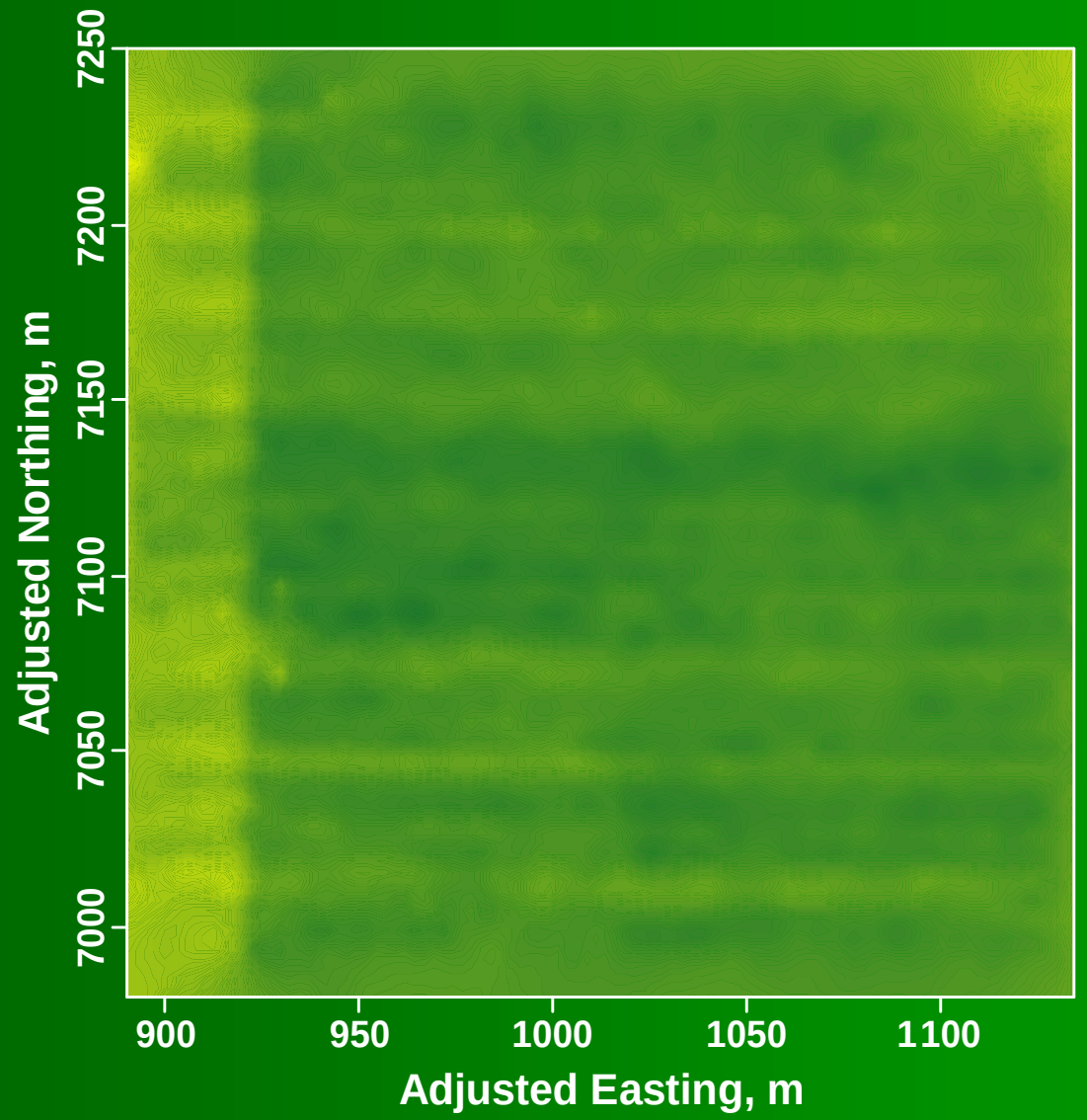
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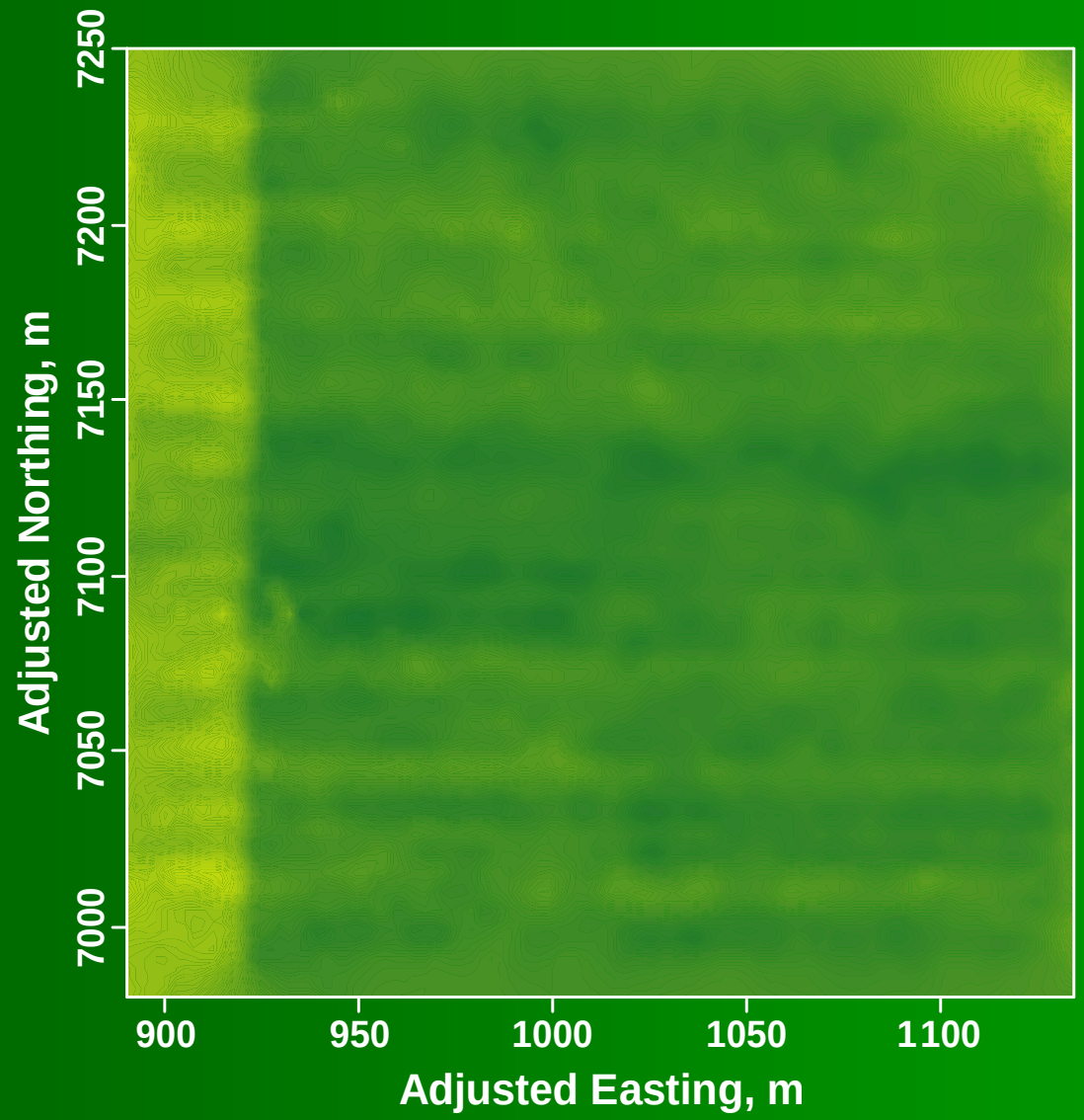
07/08/2002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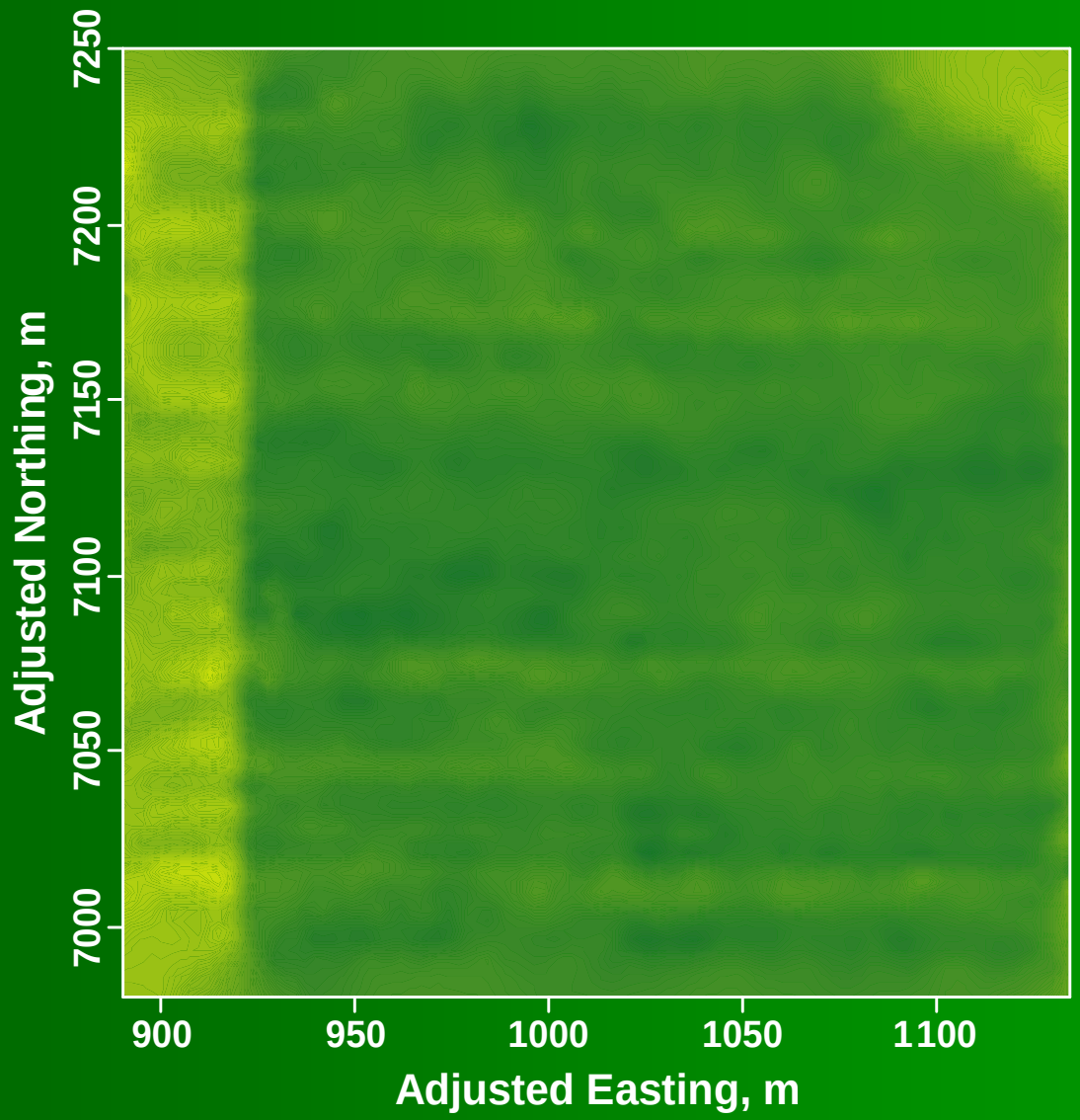
07/15/2002
Corn Silked



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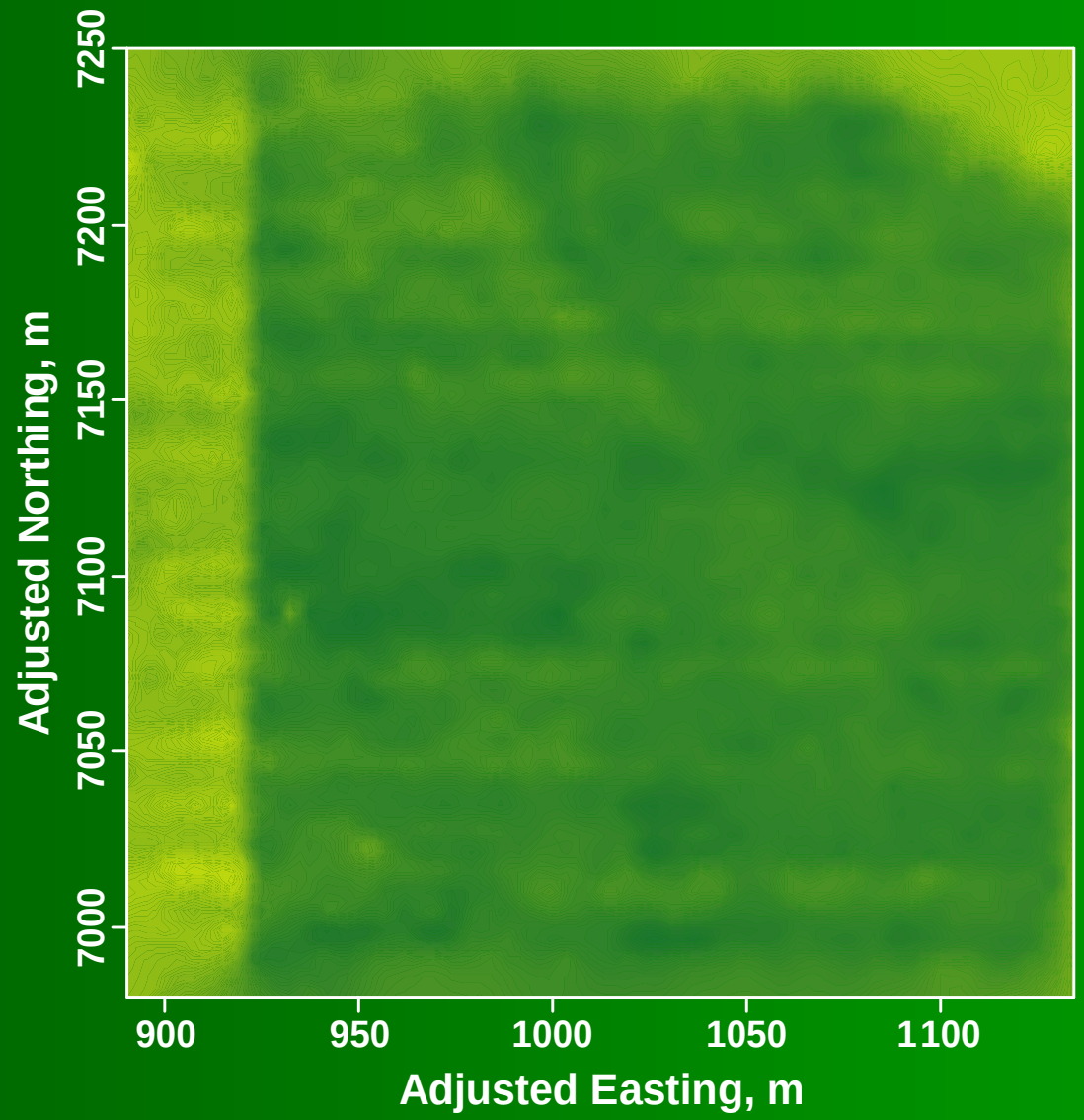
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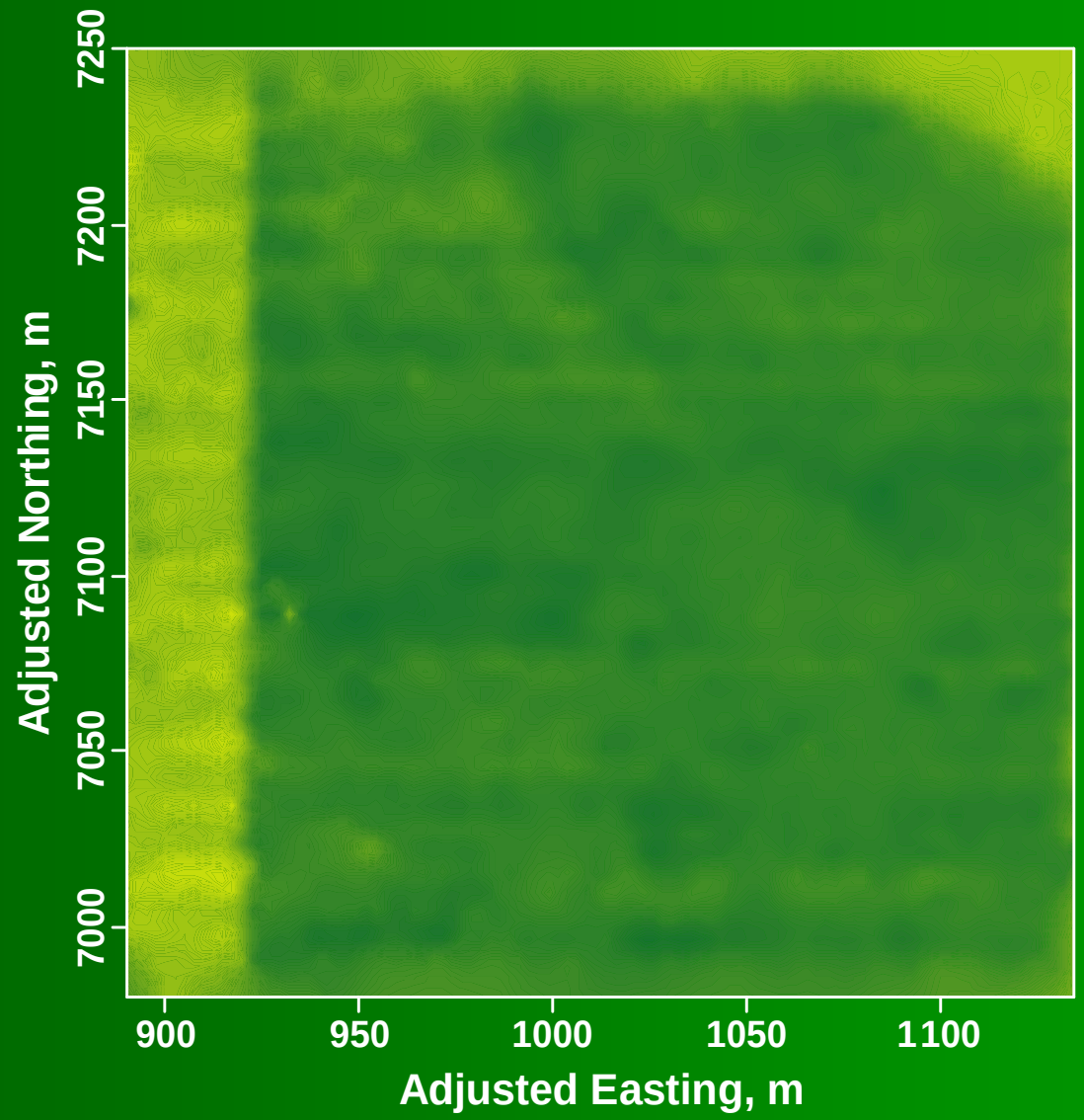
08/09/2002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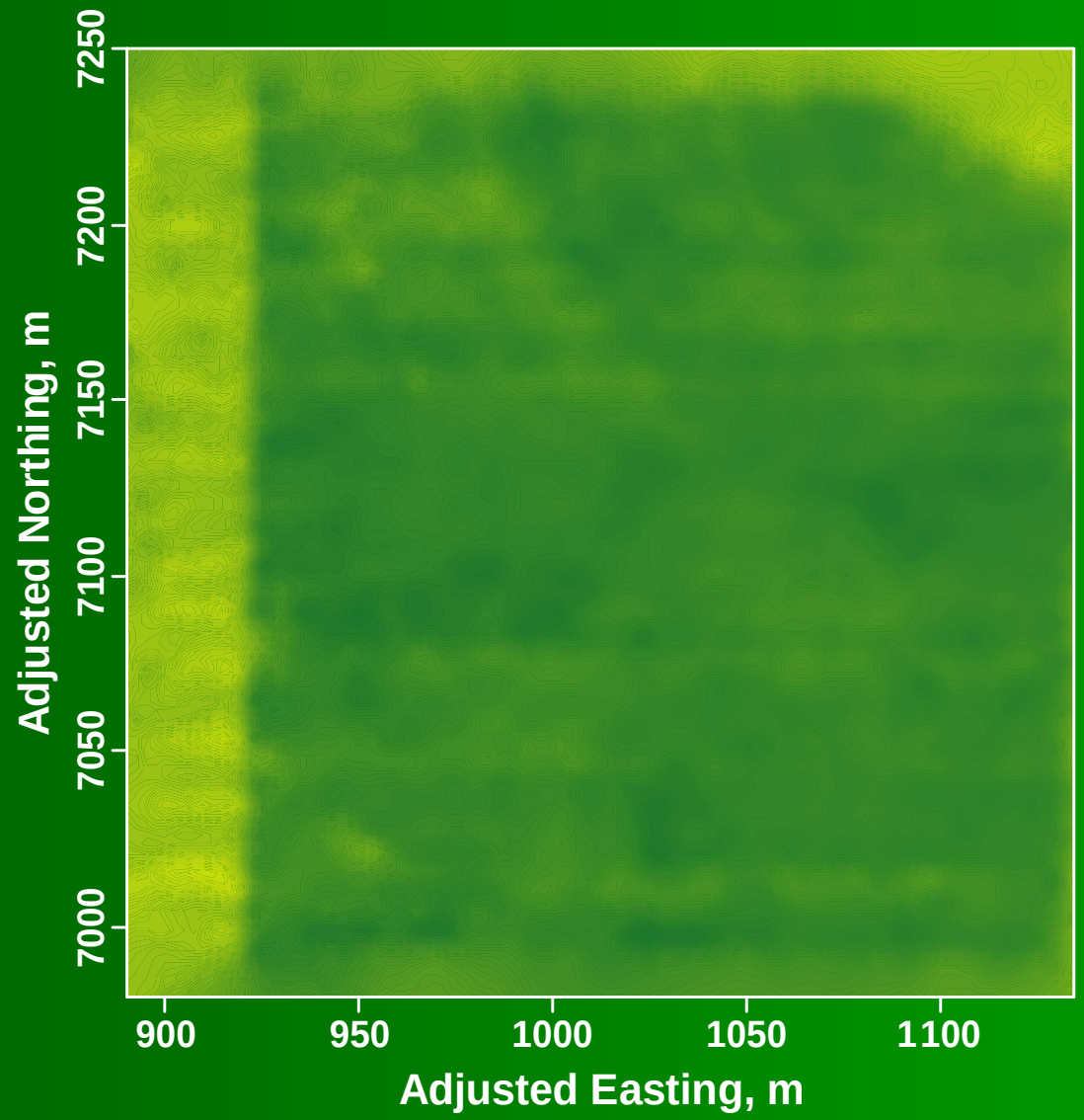
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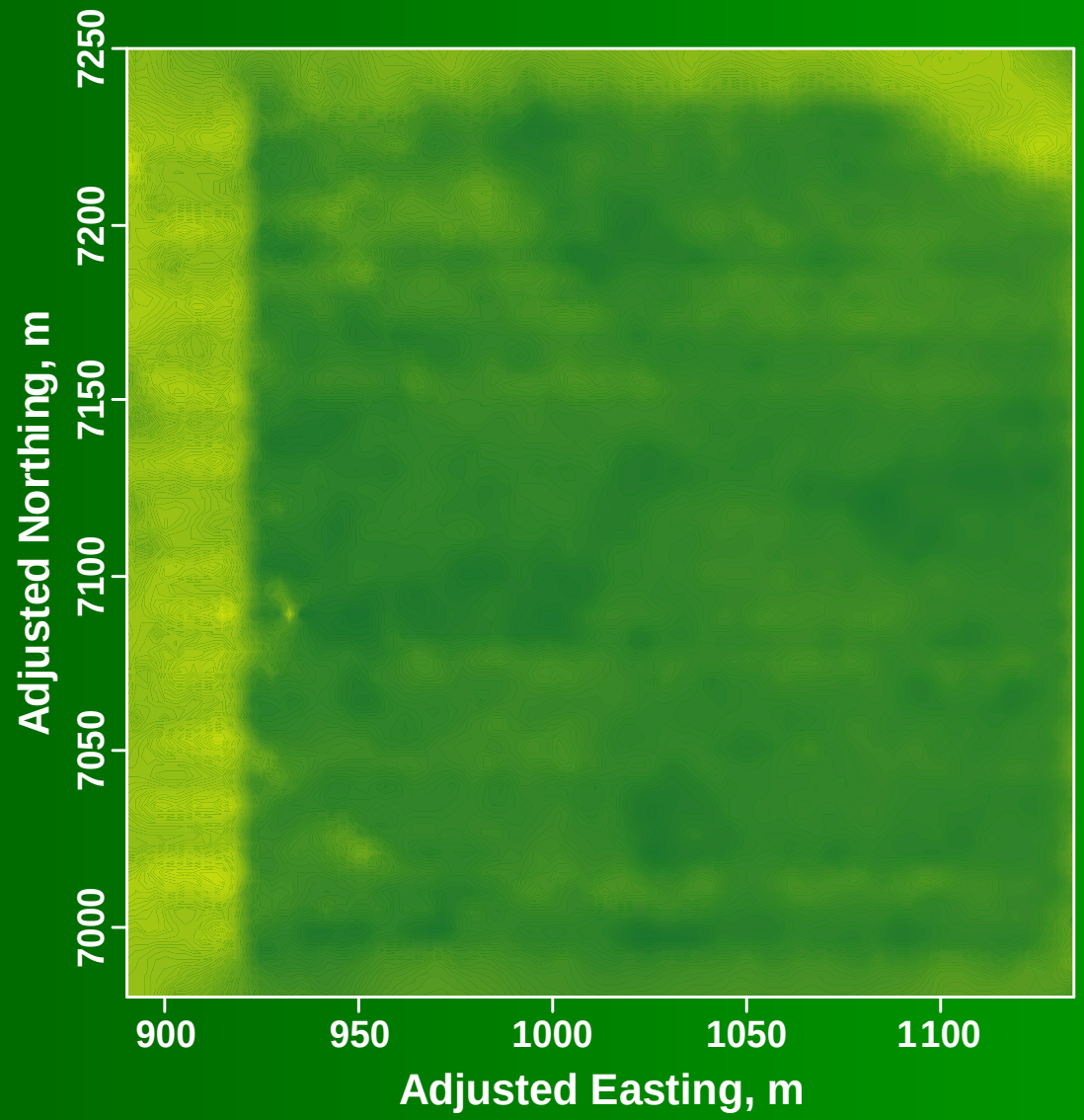
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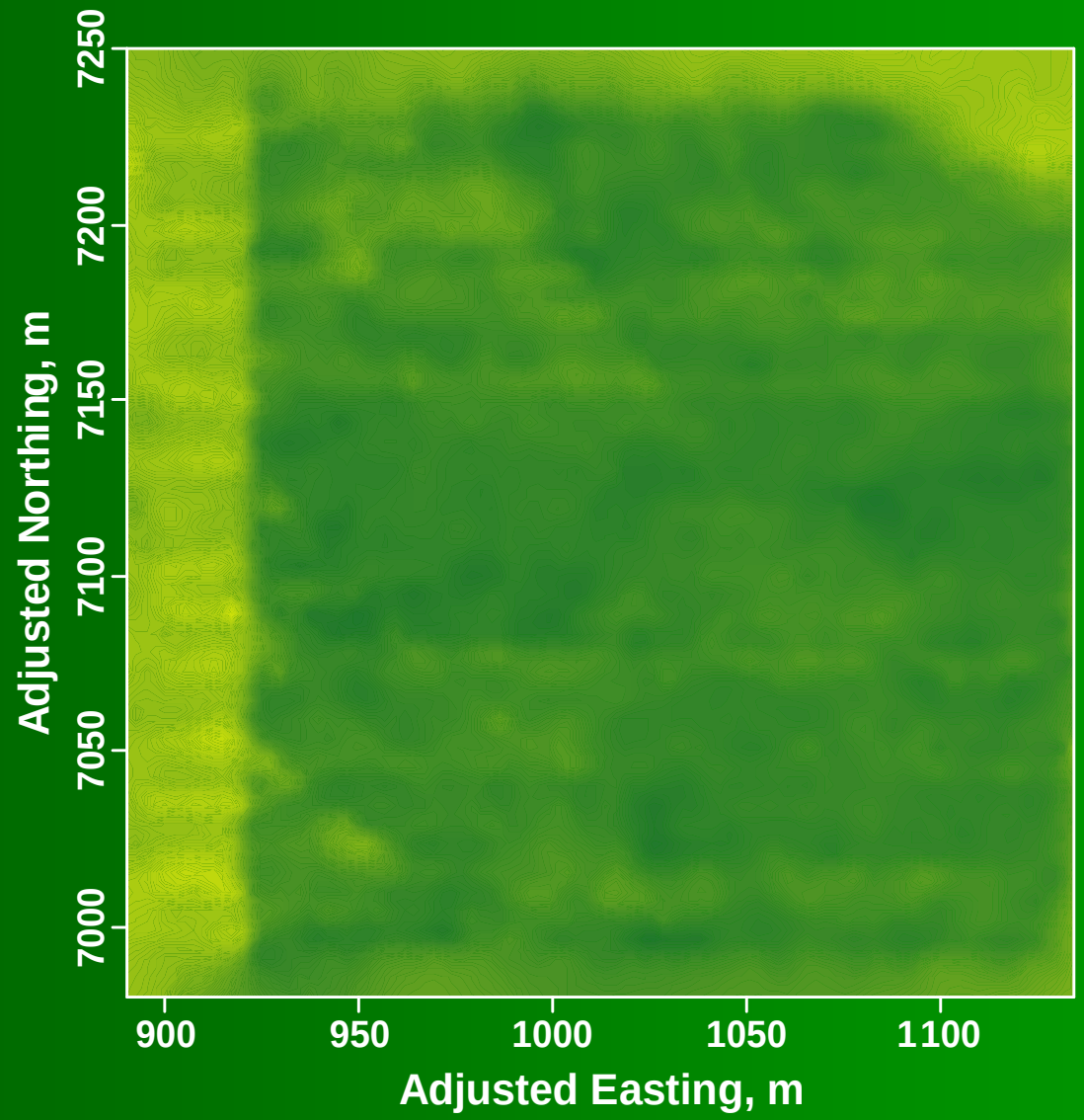
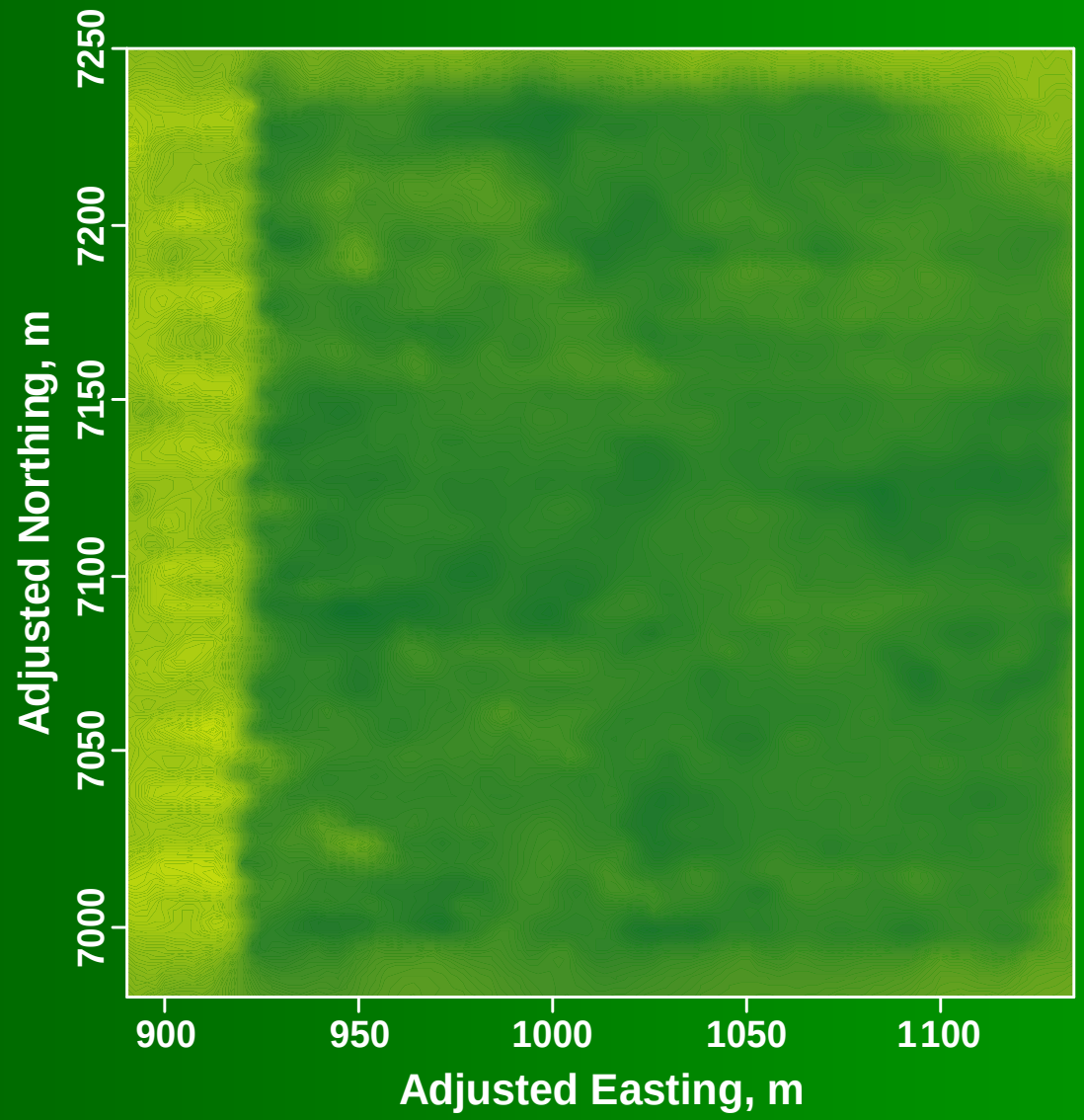
08/30/2002
Corn Harvested



09/11/2002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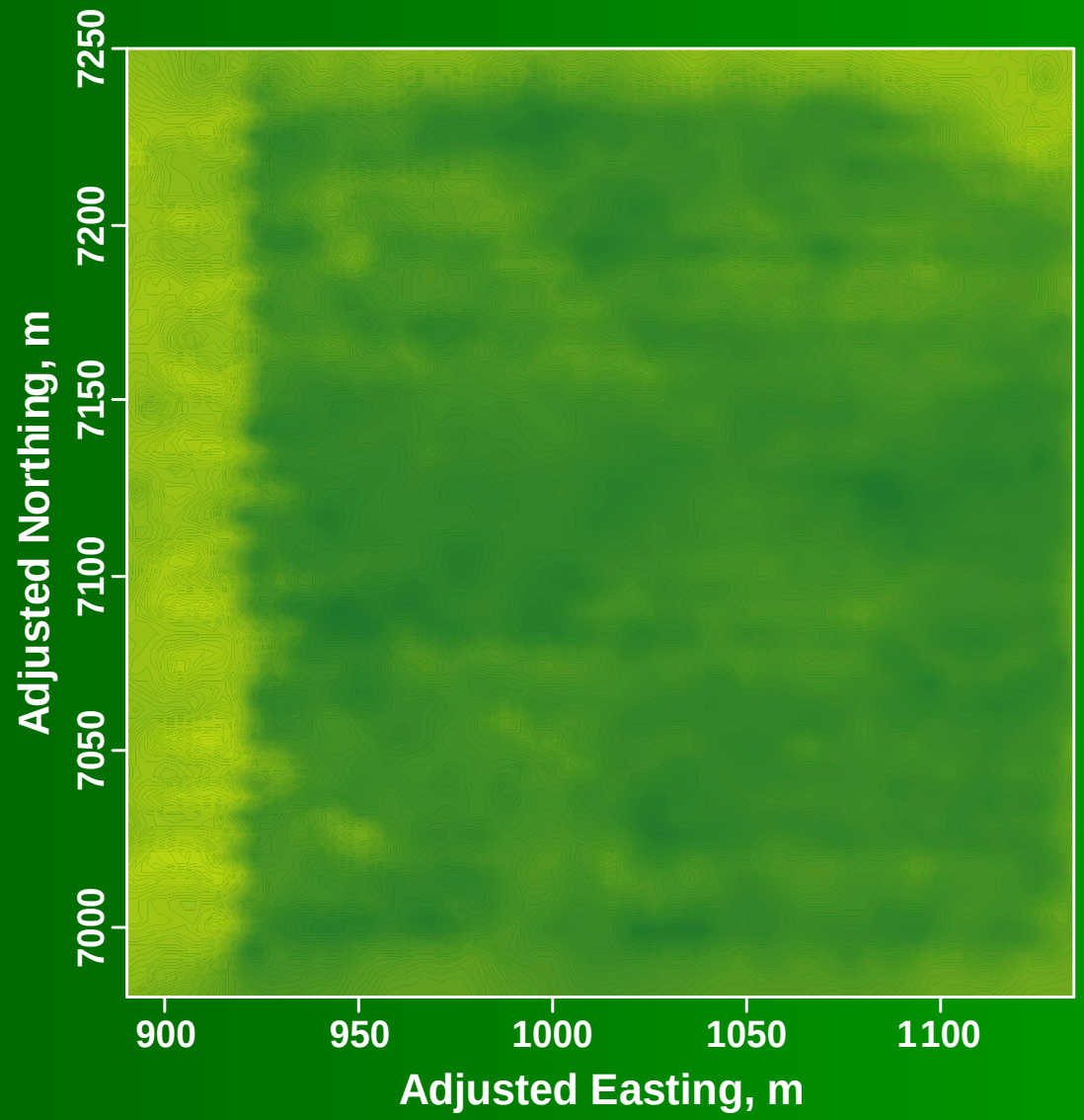
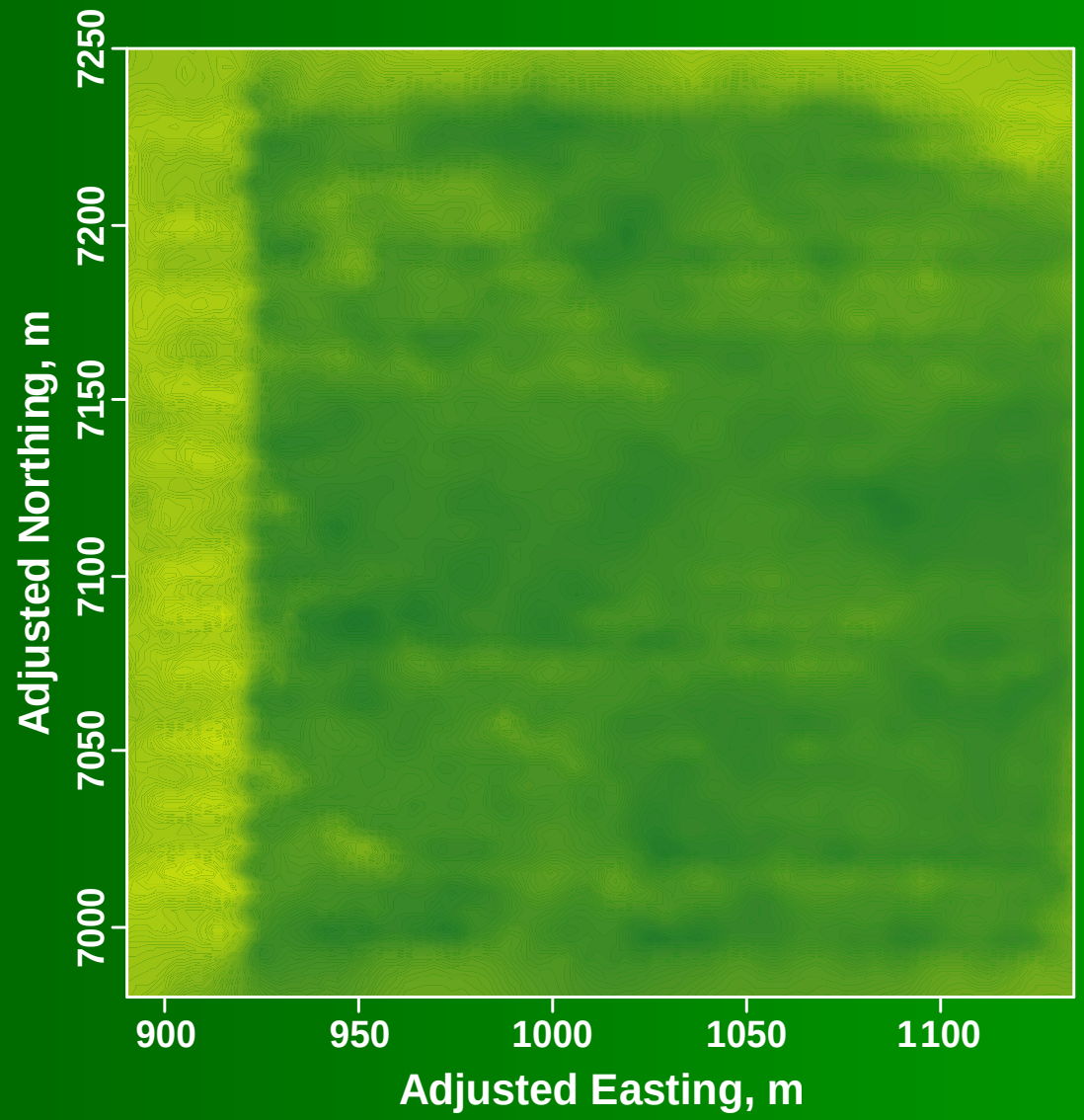
09/25/2002
Cover Crop Planted



10/01/2002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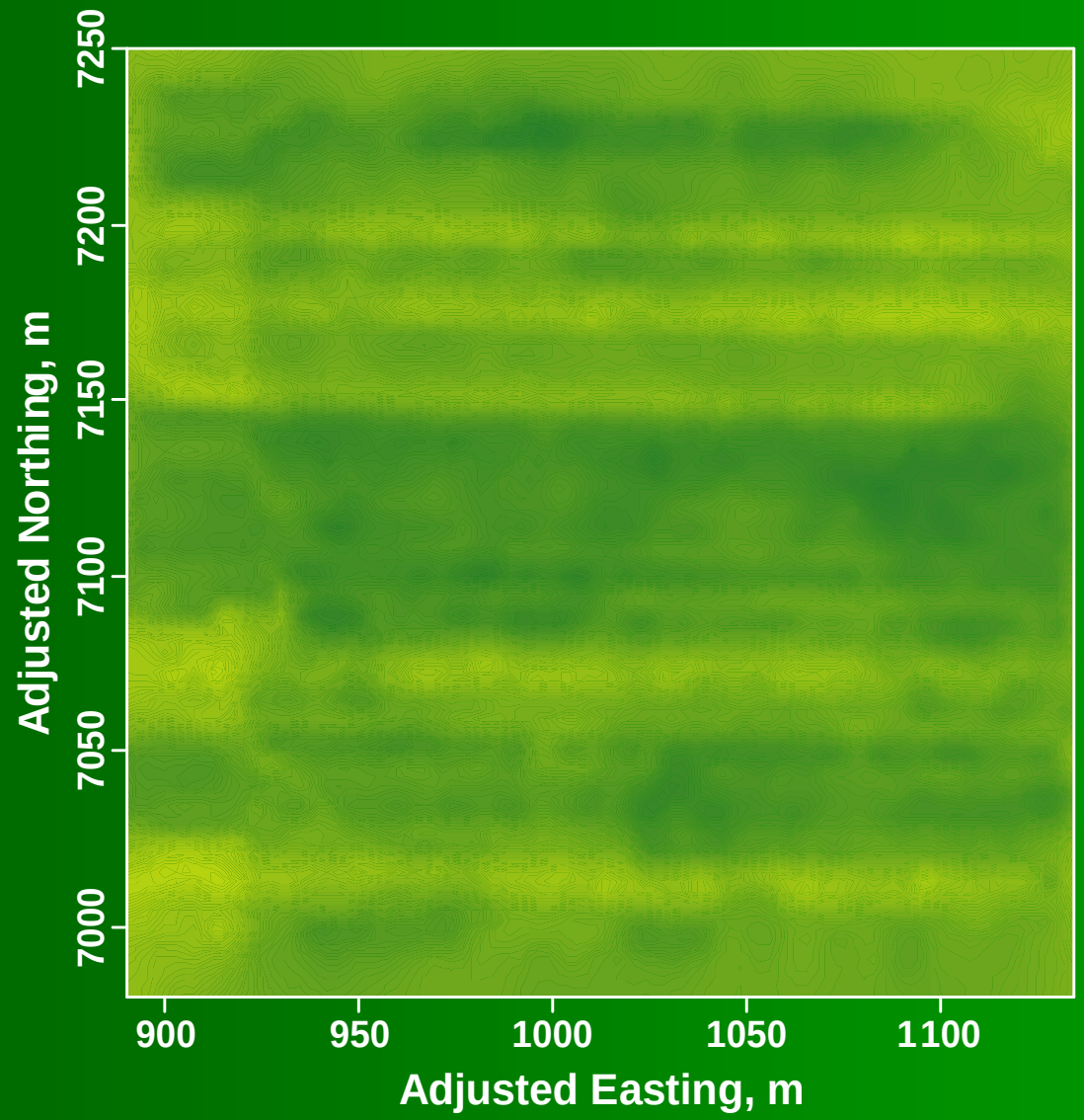
04/11/2003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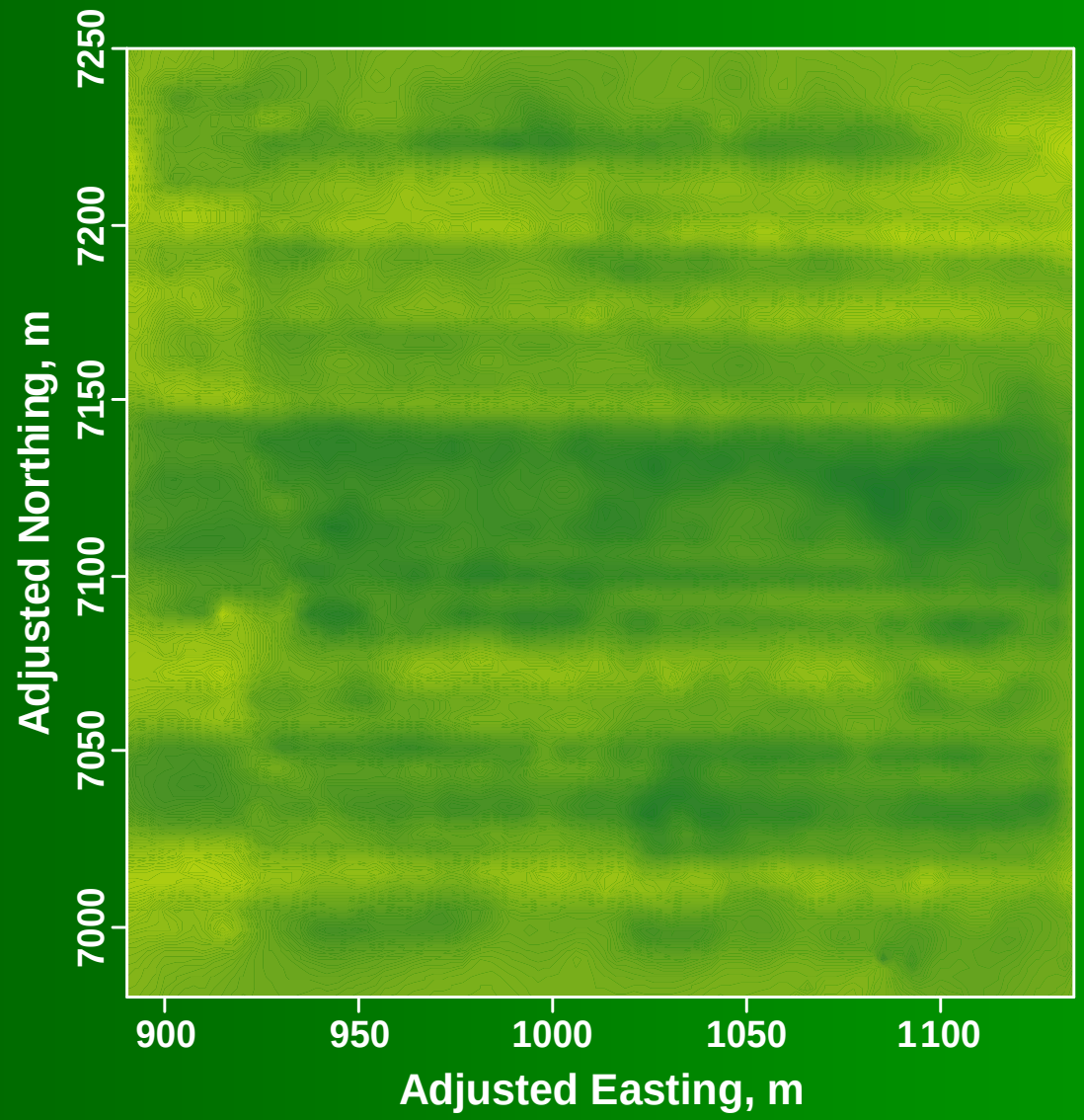
04/17/2003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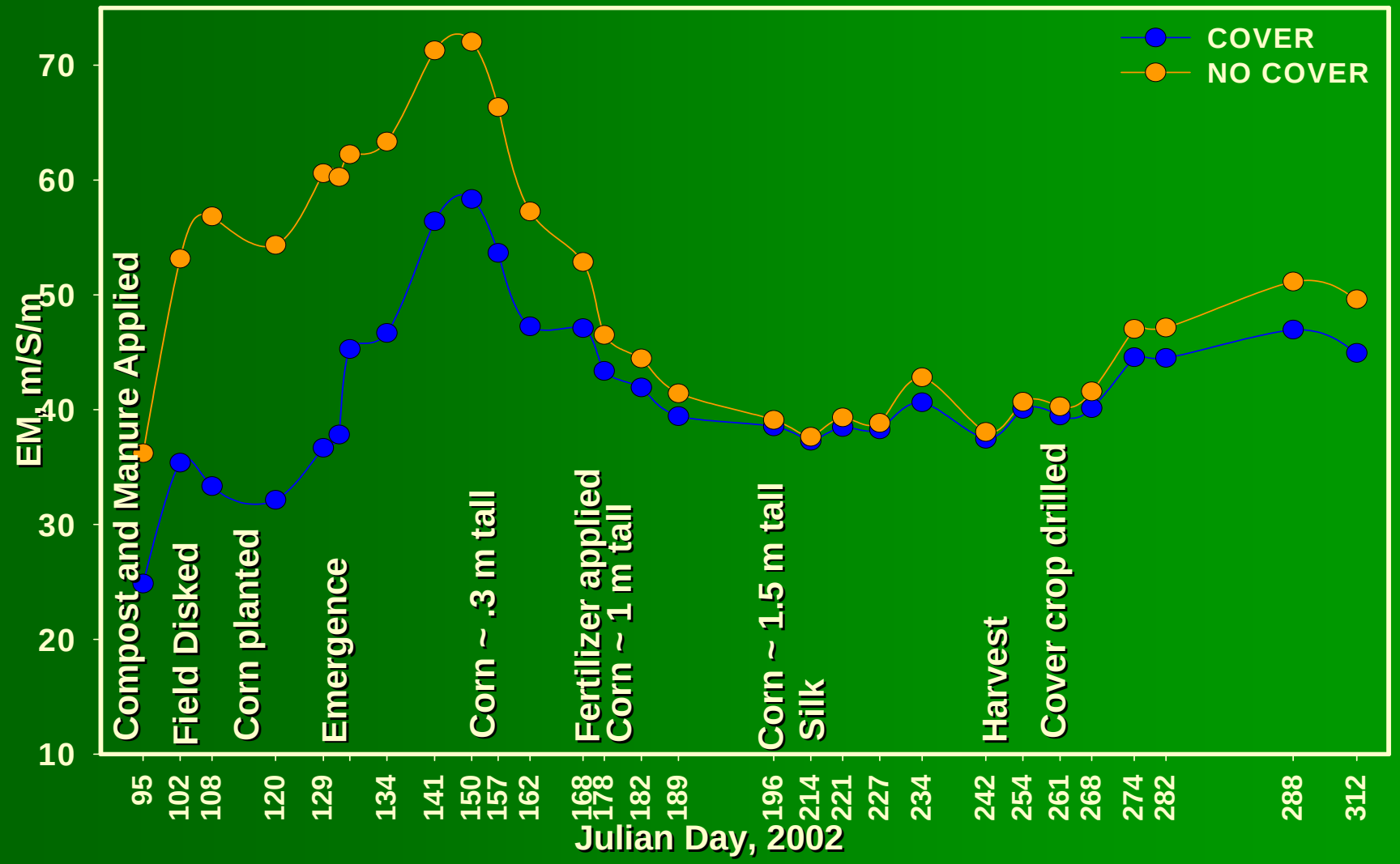
Results

MEAN OF ALL TREATMENTS BY COVER

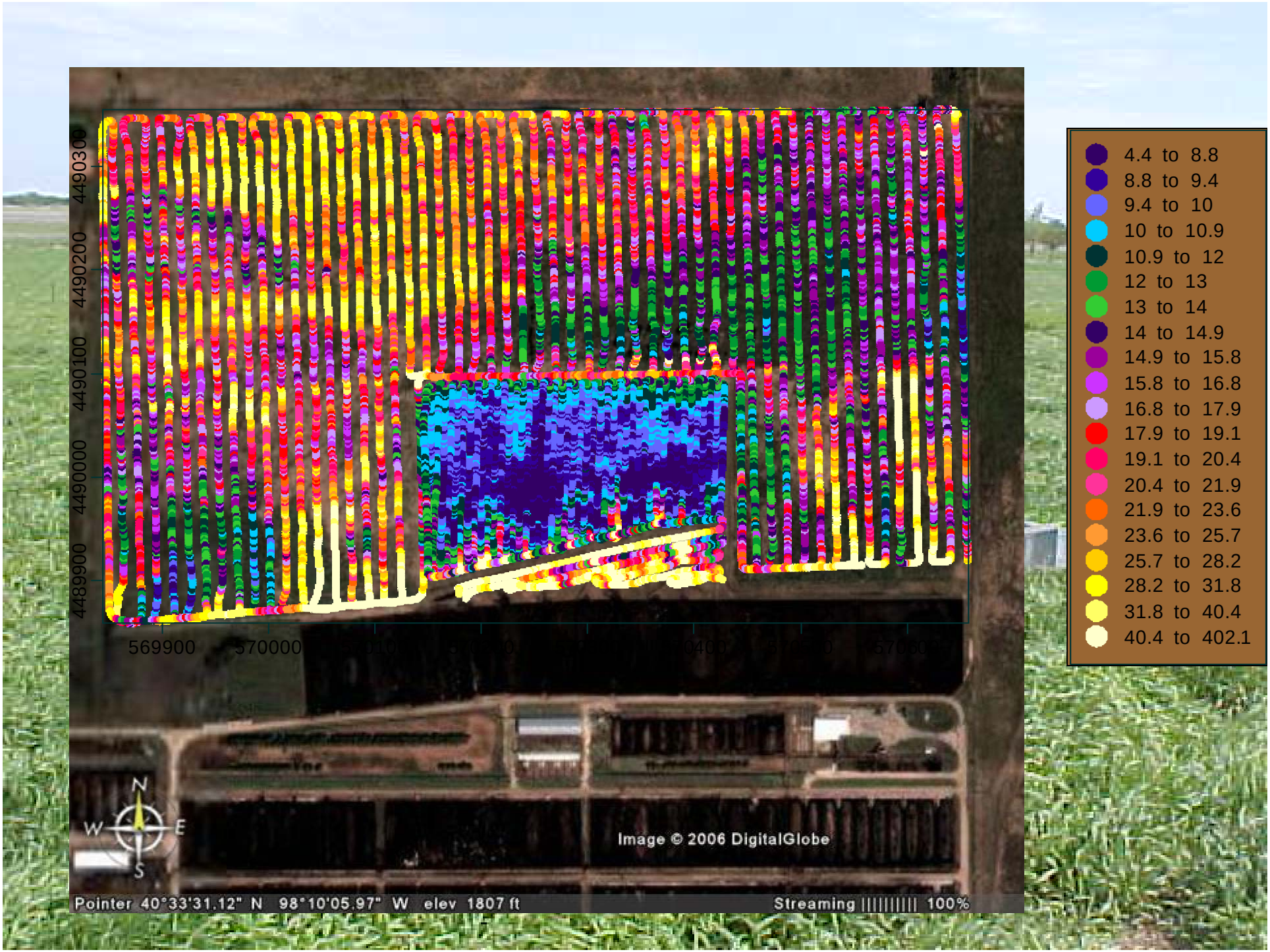
Crop Only, Temperature Corrected

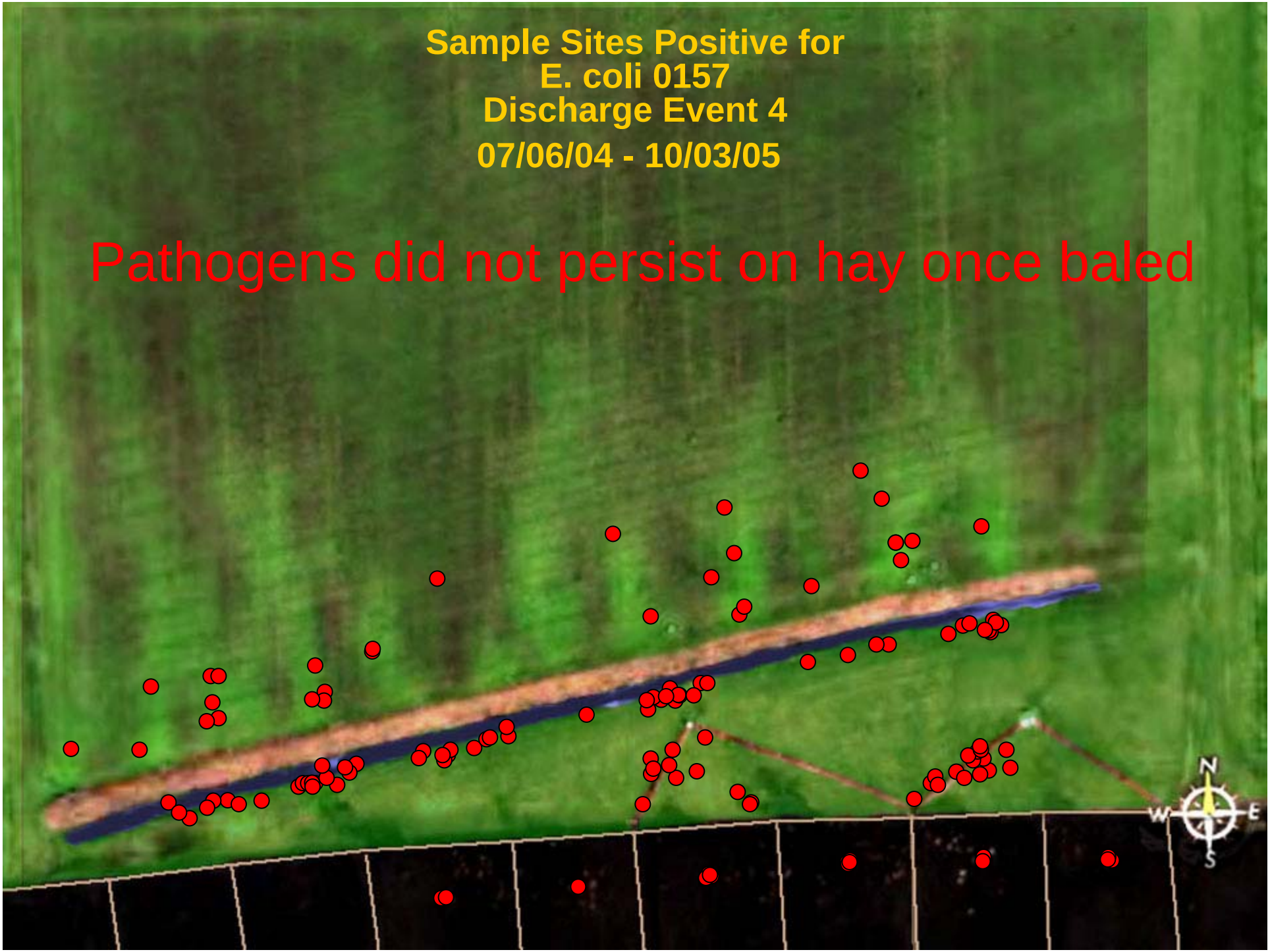


Results

Relative Contribution to EC_a Variability

Year	NO_3-N		WFPS	
	%	P≤	%	P≤
2000	79.5	0.0001	20.5	0.02
2001	98.0	0.0001	2.0	0.41
2002	93.4	0.0001	6.6	0.15
2003	98.4	0.0001	1.6	0.21


4490300
4490200
4490100
4490000
4489900
569900
570000
4.4 to 8.8
8.8 to 9.4
9.4 to 10
10 to 10.9
10.9 to 12
12 to 13
13 to 14
14 to 14.9
14.9 to 15.8
15.8 to 16.8
16.8 to 17.9
17.9 to 19.1
19.1 to 20.4
20.4 to 21.9
21.9 to 23.6
23.6 to 25.7
25.7 to 28.2
28.2 to 31.8
31.8 to 40.4
40.4 to 402.1
N
W
E
S
Image © 2006 DigitalGlobe
Pointer 40°33'31.12" N 98°10'05.97" W elev 1807 ft
Streaming 100%


Sample Sites Positive for
E. coli 0157
Discharge Event 4
07/06/04 - 10/03/05
Pathogens did not persist on hay once baled
N
W
E
S

EMI Technology: The Road to Measuring Nutrient Spatial Distribution

Goal:

Develop a tool to monitor VTA performance and provide information to refine management.

- Kriging and CoKriging require 75+ soil samples to describe nutrient distribution. (Where to sample?)
- CoKriging relies mostly on soil samples.
- EMI - Non-intrusive, inexpensive, indirect measure of soil health
- Co-locating soil samples in the EMI path reduces complexity and spatial uncertainty and allowed the use of MLR (6,12,20 samples)

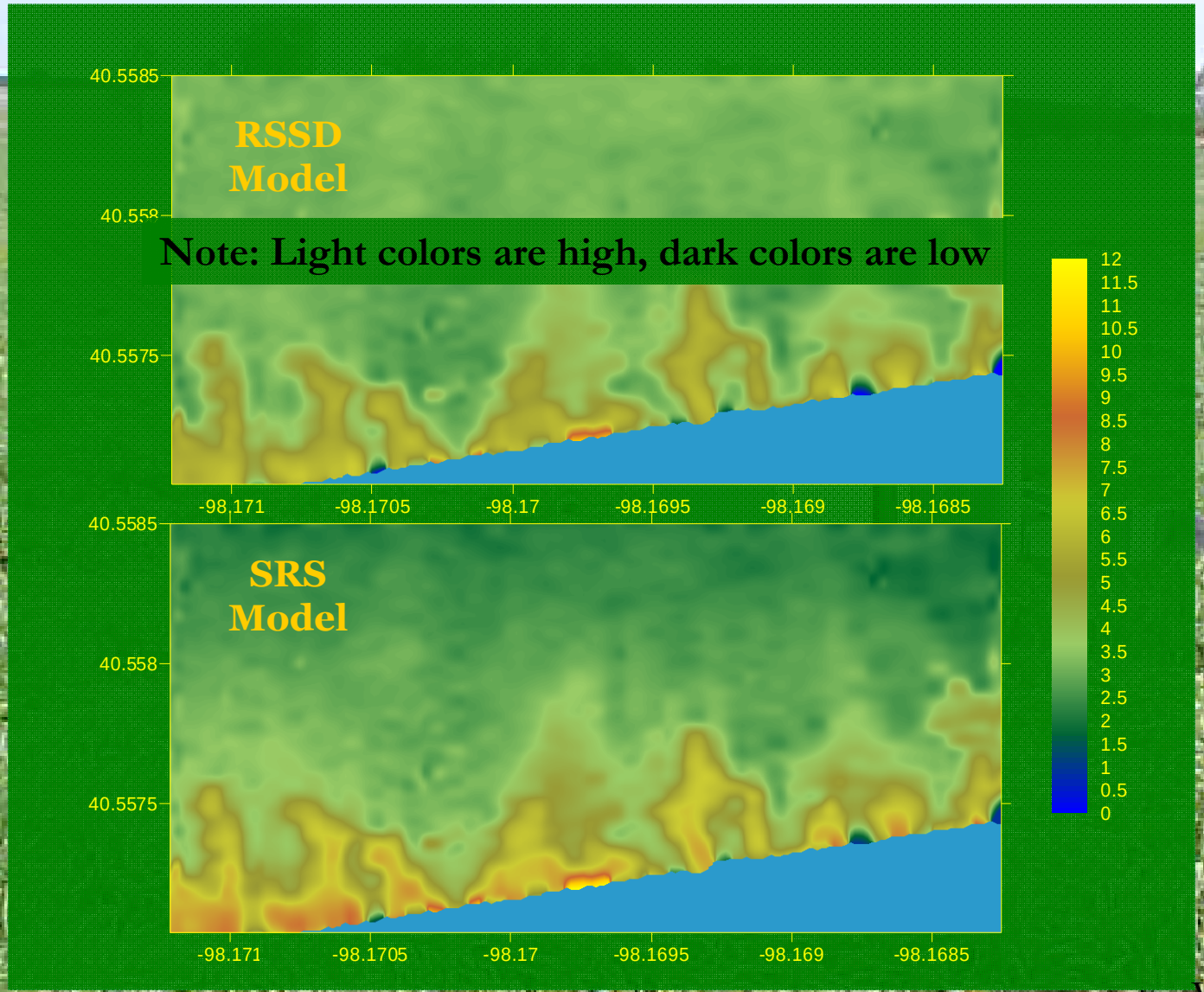
Create a Nutrient Image Map Based on the Correlation of the Nutrient with Conductivity

Method Validation

Use EMI, Spatial Statistical Software (ESAP), and MLR to predict nutrient distribution in VTA.

- **Two sampling strategies**
  - **Response Surface Sampling Design (RSSD)**
    - **Uses EMI data to identify sample locations by**
      1. **Sampling in areas to achieve maximum dynamic range**
      2. **Spreading sample locations apart (independence)**
  - **Stratified Random Sampling (SRS)**
    - **ECa data subdivided into 4 groups by conductivity level**
    - **Points are randomly assigned within the four groups**

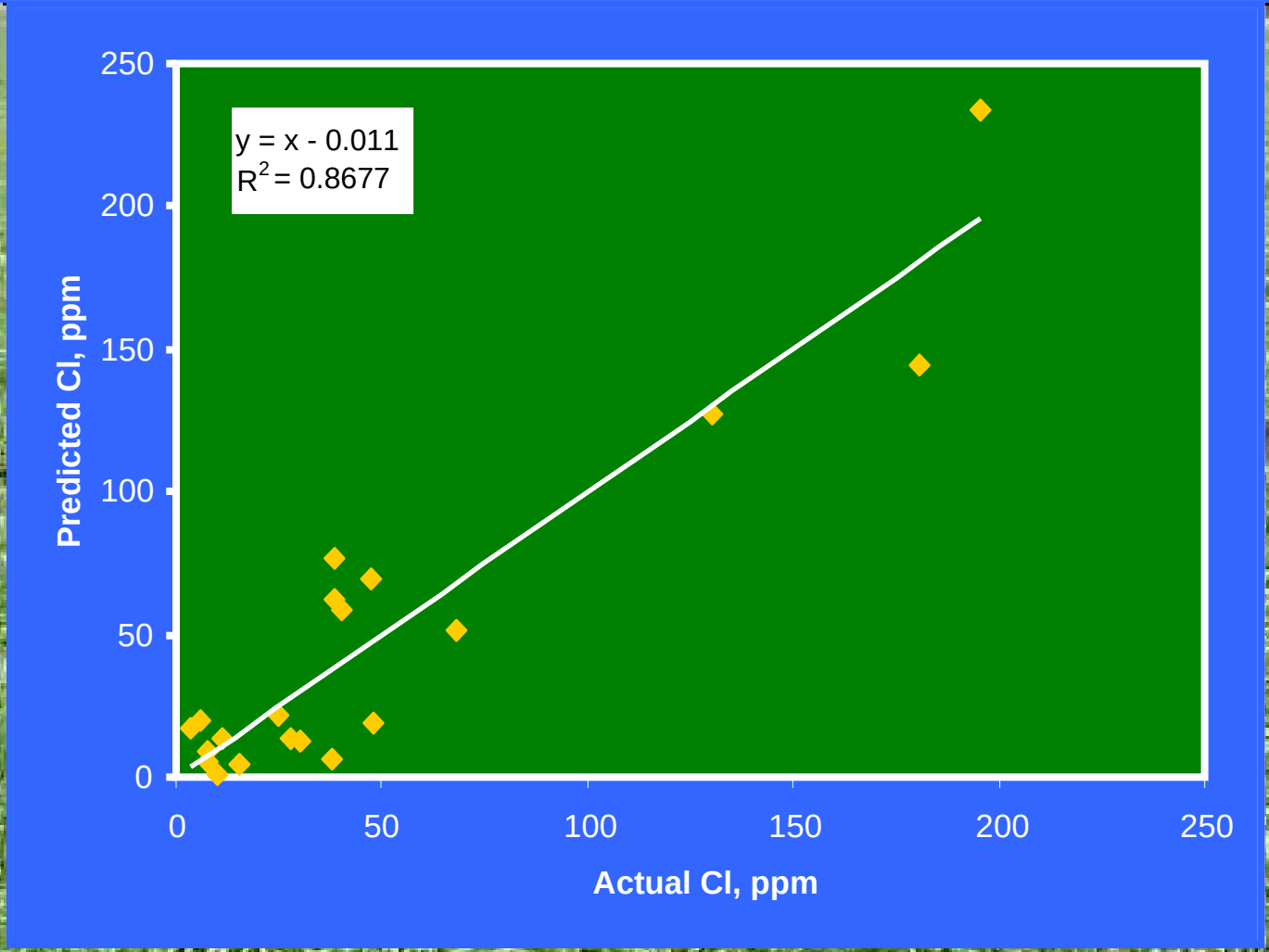
Chloride prediction maps



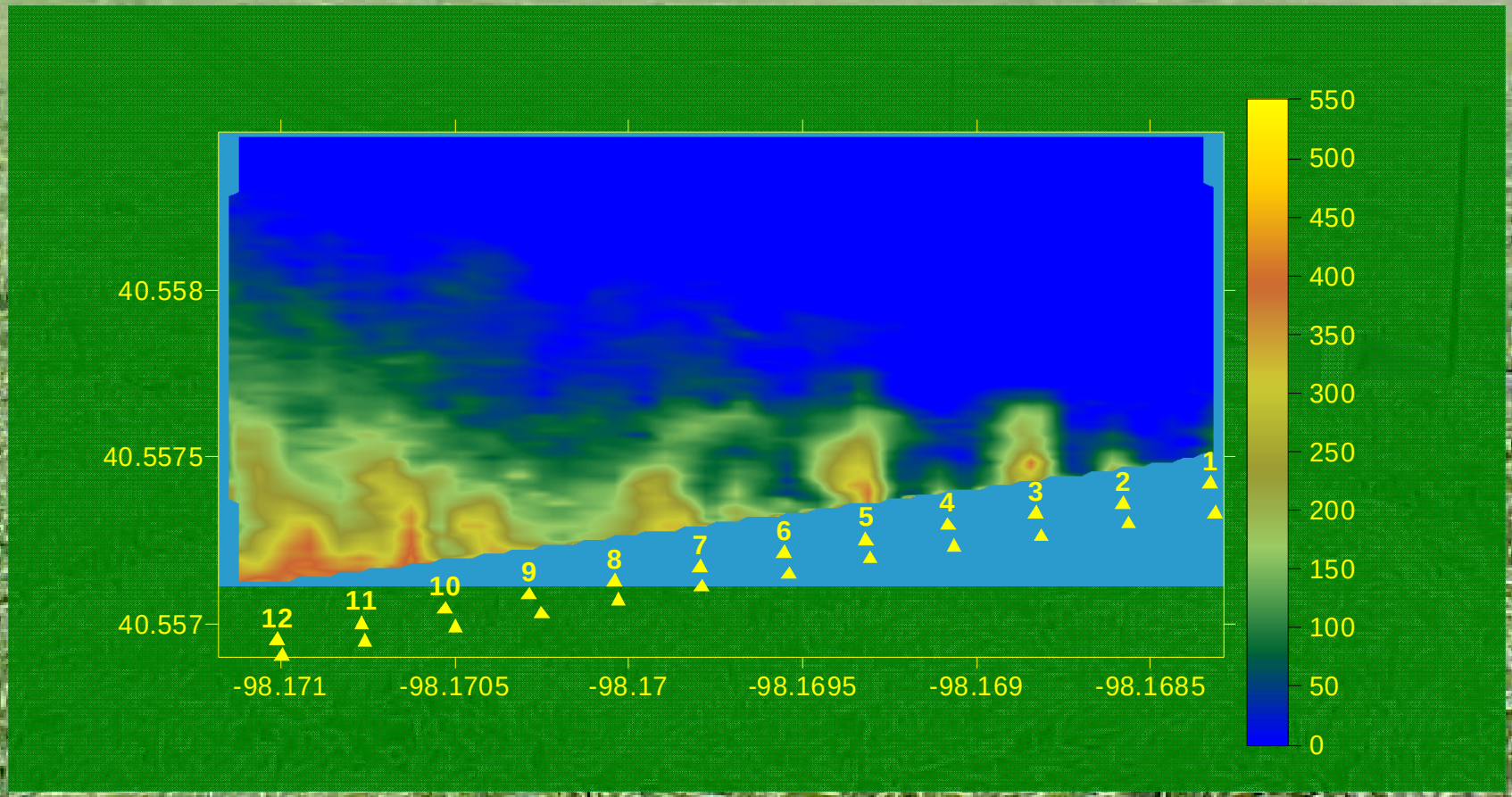
N

Validation

Ability to Predict Actual Points



Cl^- Prediction Map - August 2005



N

Application

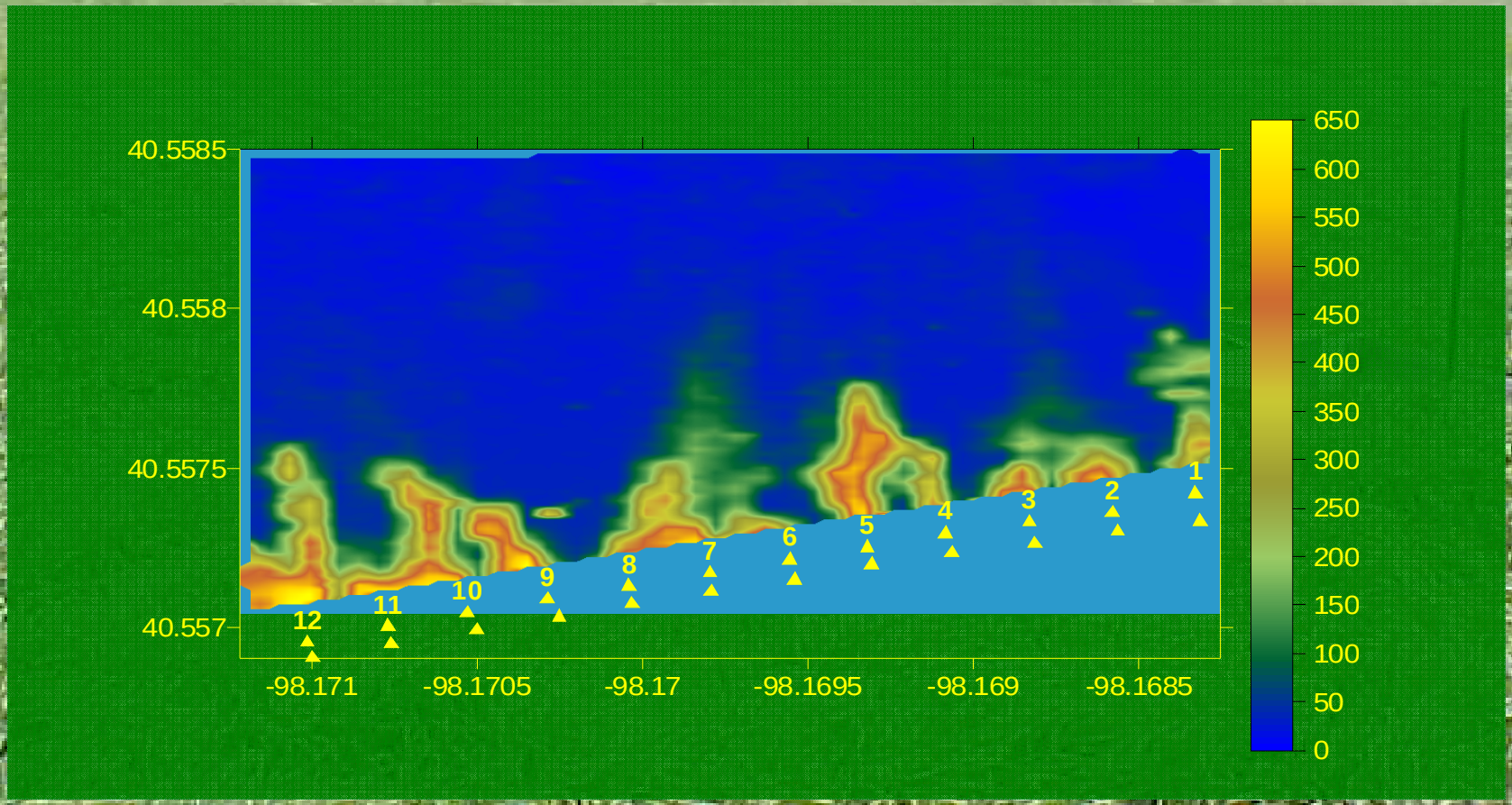
Management Changes

- Discharge inlets were modified in Spring of 2006

Original Inlet Design

New Inlet Design

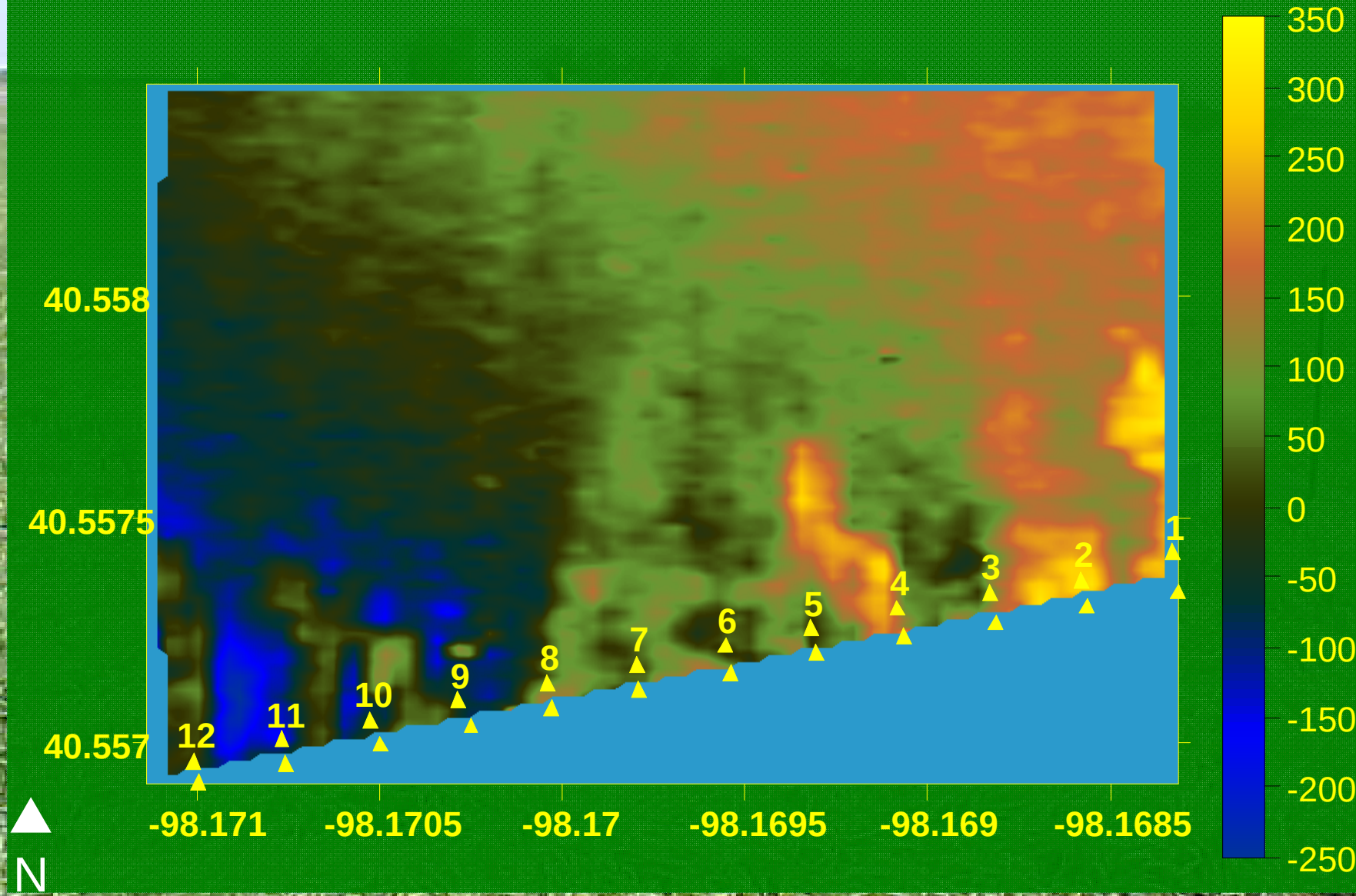
Cl^- Prediction Map - November 2006



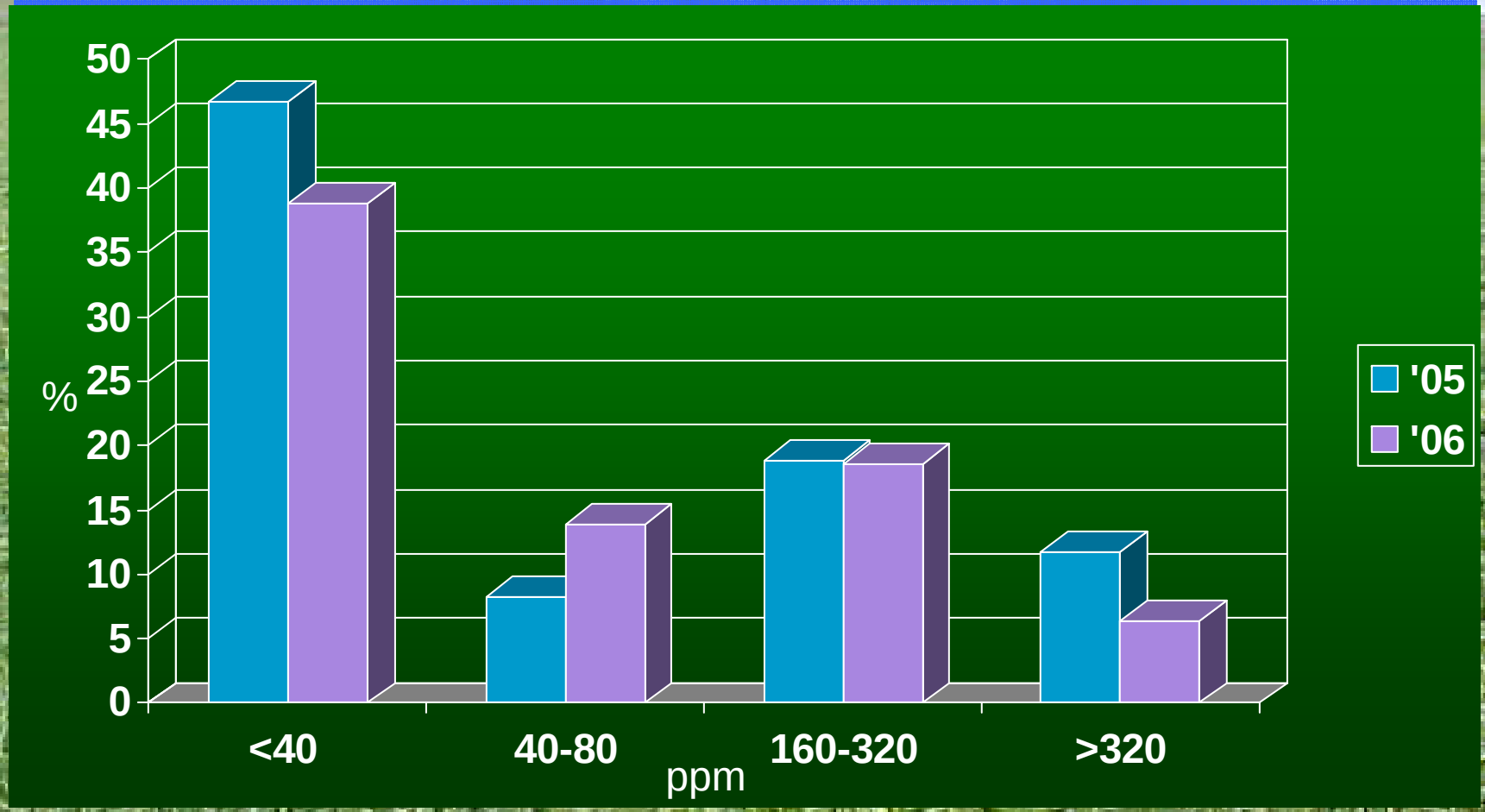
N

Application

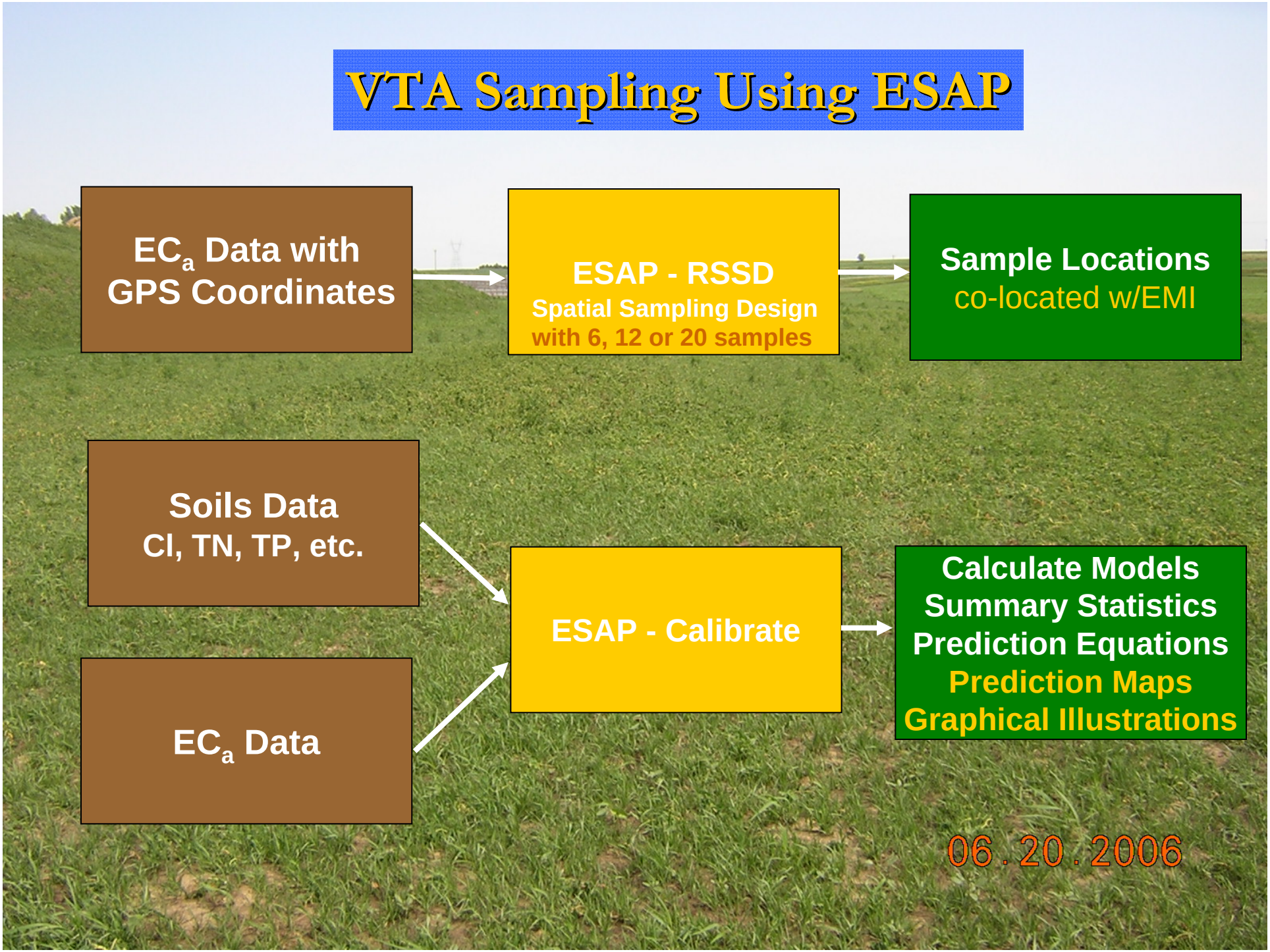
Diff. Maps Nov. ’06 minus Aug. ‘05

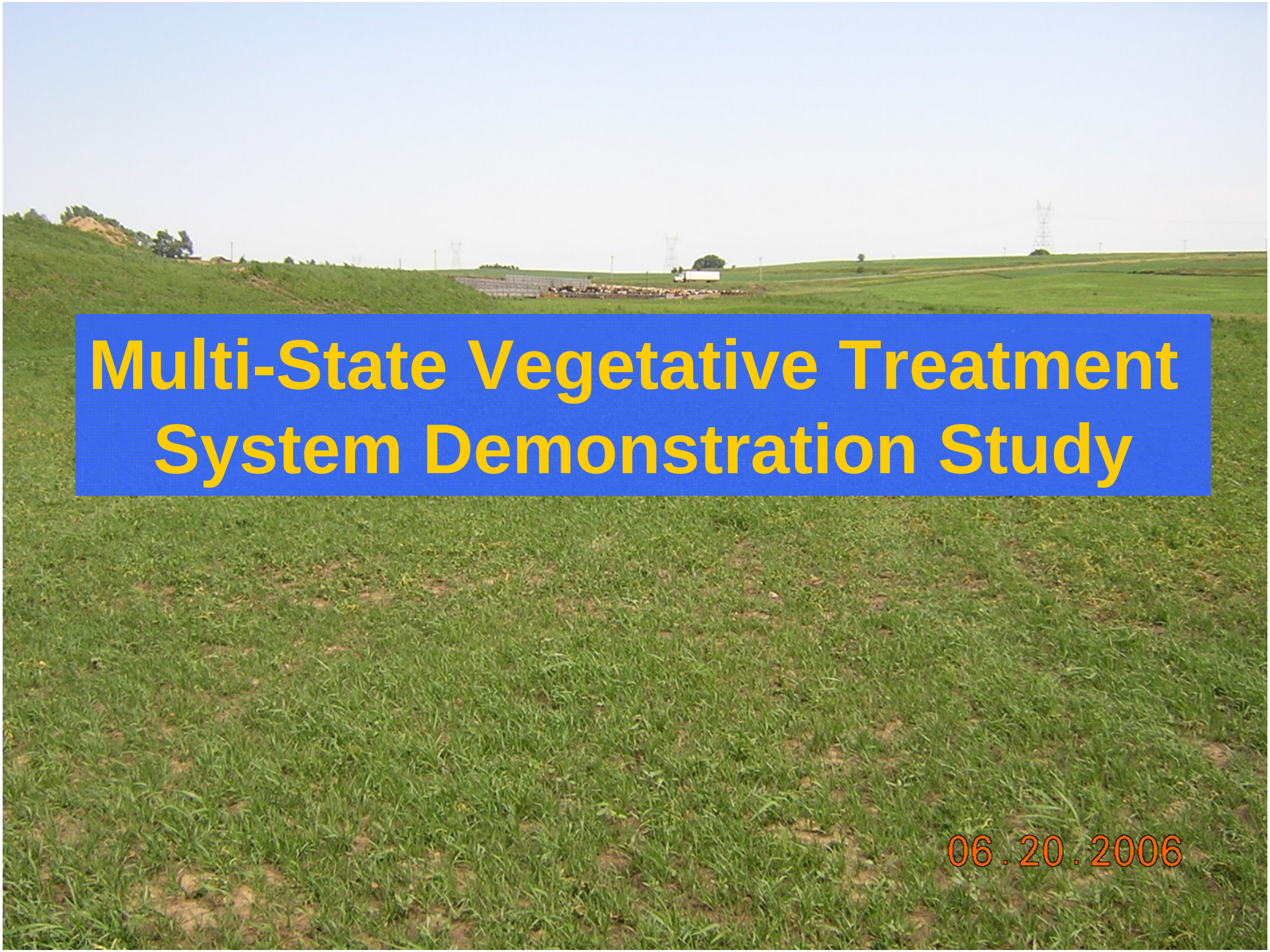


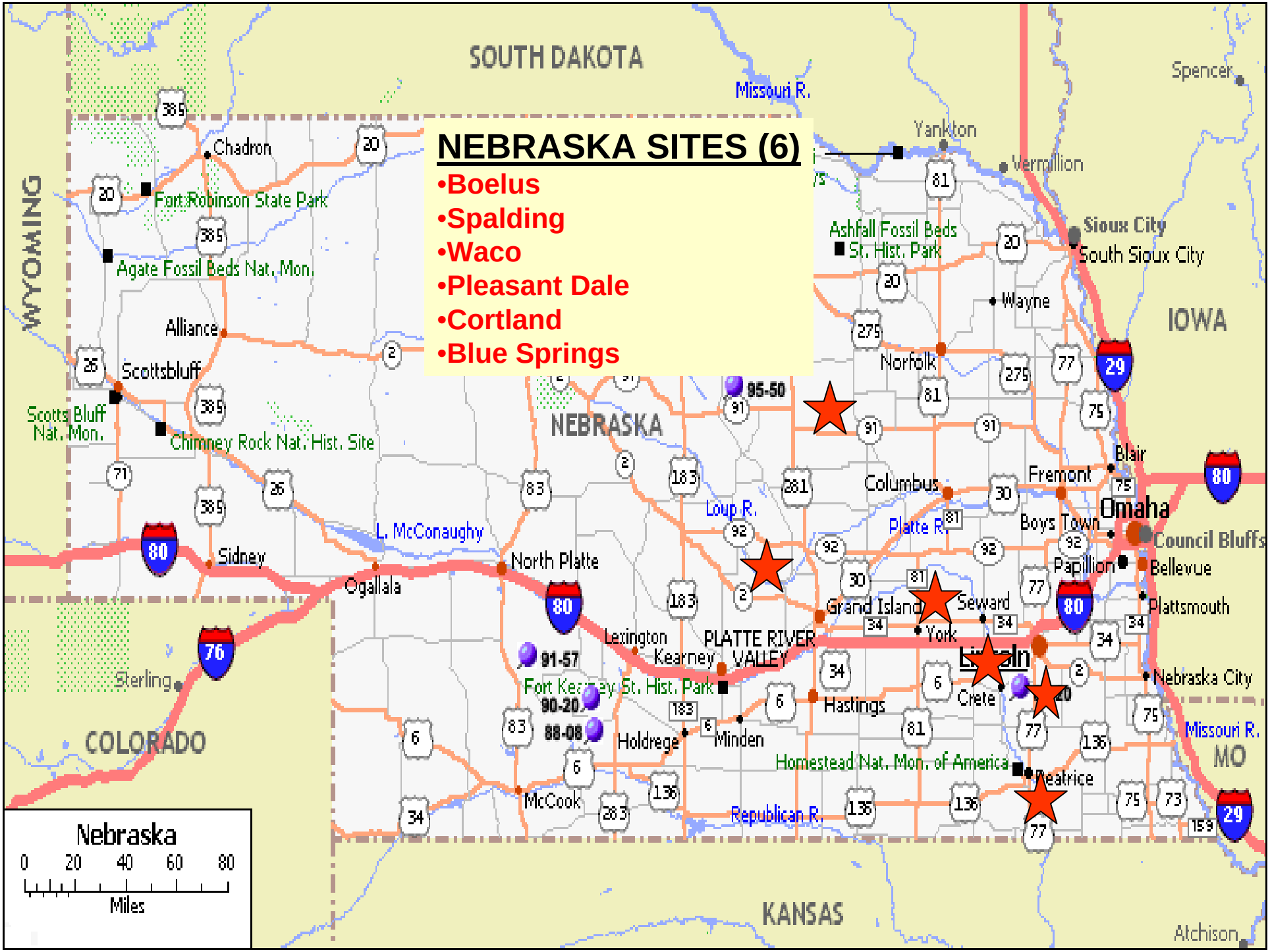
VTA Performance from 05 to 06

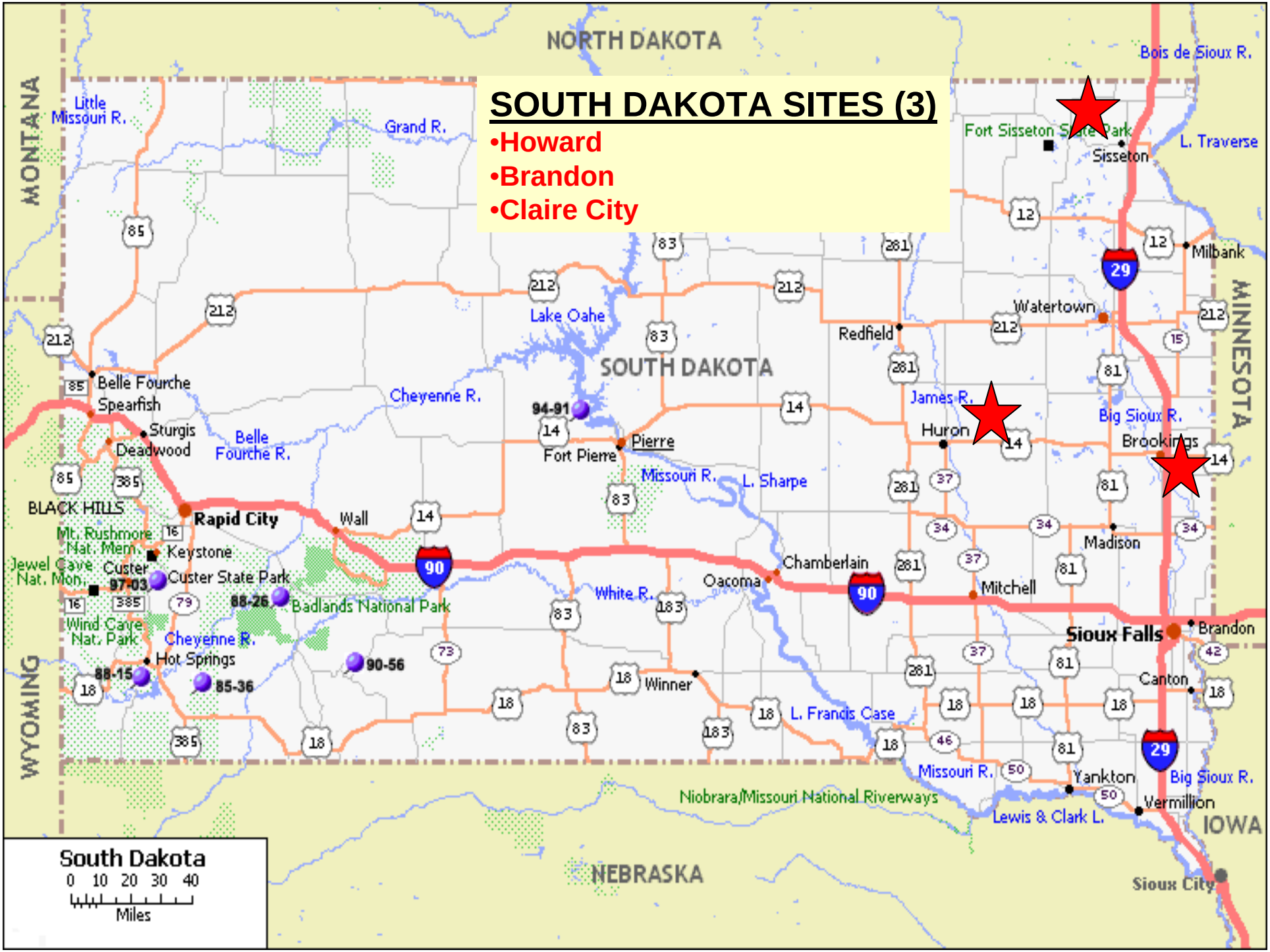


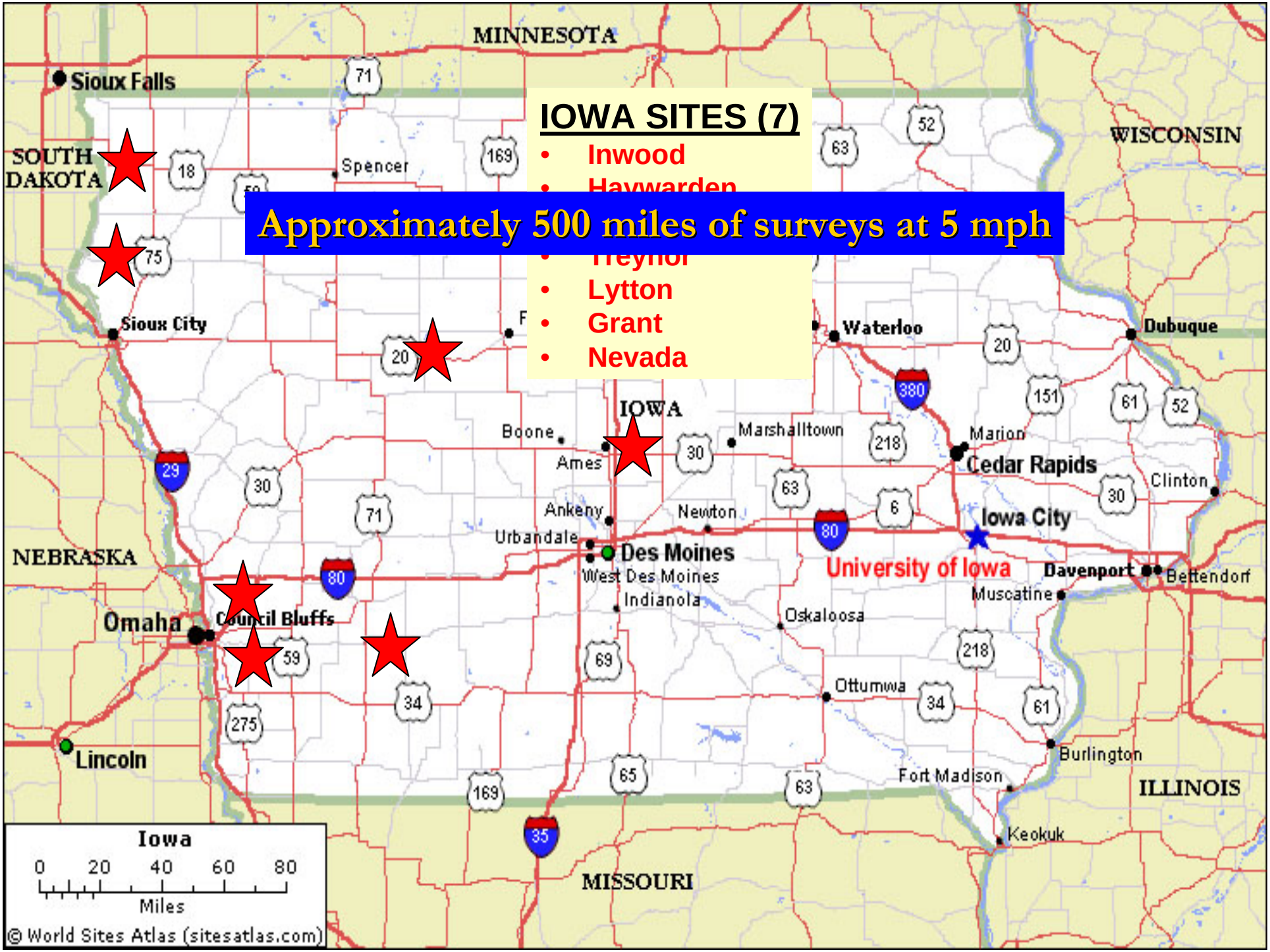
VTA Sampling Using ESAP



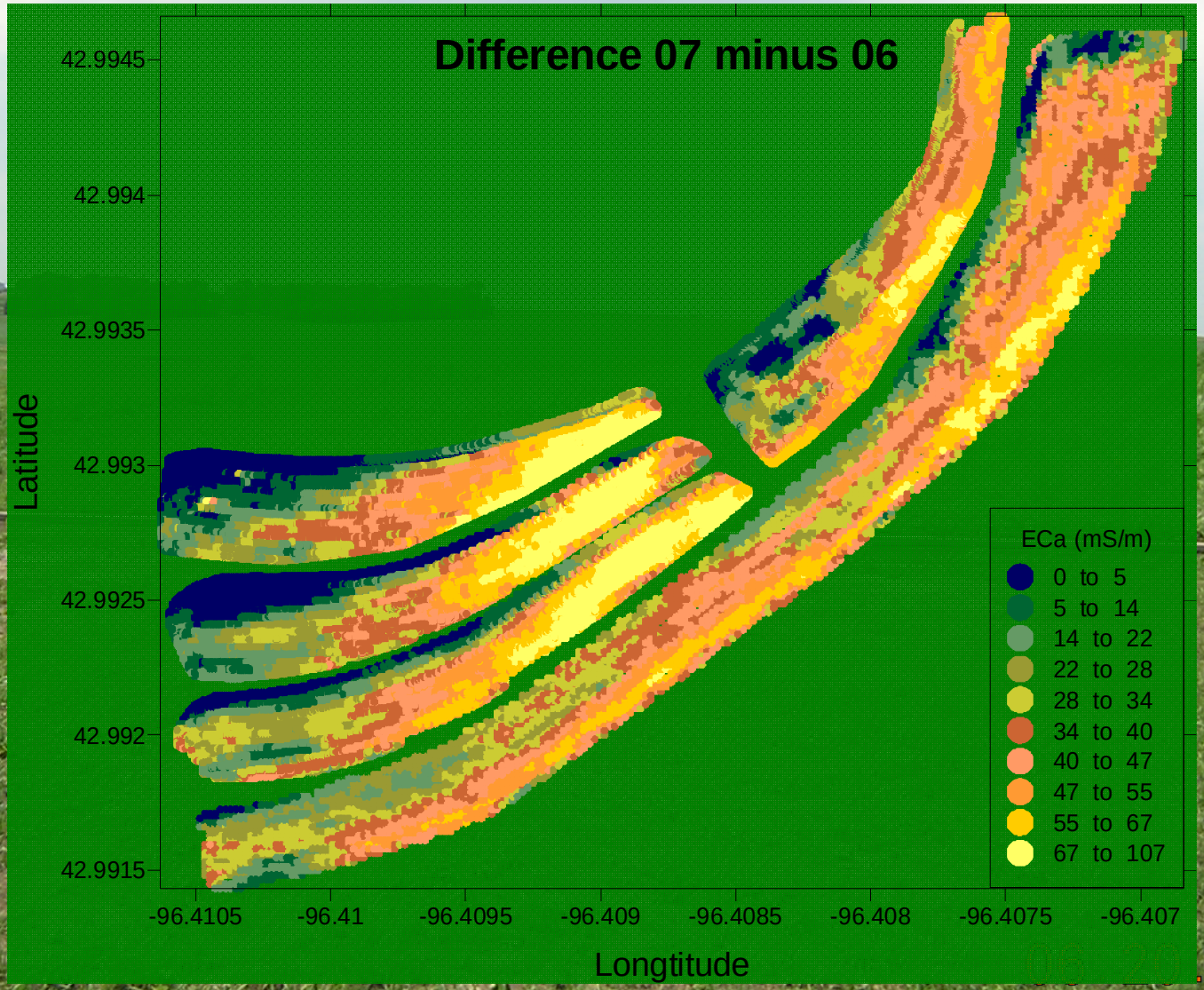

Multi-State Vegetative Treatment System Demonstration Study
06.20.2006


NEBRASKA SITES (6)
•Boelus
•Spalding
•Waco
•Pleasant Dale
•Cortland
•Blue Springs
SOUTH DAKOTA
WYOMING
COLORADO
KANSAS
IOWA
MO
NEBRASKA
Missouri R.
Republican R.
Loup R.
Platte R.
PLATTE RIVER VALLEY
L. McConaughy
Chadron
Fort Robinson State Park
Agate Fossil Beds Nat. Mon.
Alliance
Scottsbluff
Scotts Bluff Nat. Mon.
Chimney Rock Nat. Hist. Site
Sidney
Ogallala
North Platte
Lexington
Kearney
Fort Kearney St. Hist. Park
Holdrege
Minden
McCook
Hastings
Grand Island
York
Seward
Crete
Lincoln
Columbus
Norfolk
Wayne
Yankton
Vermillion
Ashfall Fossil Beds St. Hist. Park
Sioux City
South Sioux City
Spencer
Fremont
Blair
Omaha
Boys Town
Papillion
Bellevue
Council Bluffs
Plattsmouth
Nebraska City
Beatrice
Homestead Nat. Mon. of America
Sterling
Atchison
95-50
91-57
90-20
88-08
Nebraska
0 20 40 60 80
Miles


SOUTH DAKOTA SITES (3)
•Howard
•Brandon
•Claire City
NORTH DAKOTA
MONTANA
WYOMING
NEBRASKA
IOWA
MINNESOTA
SOUTH DAKOTA
Bois de Sioux R.
Little Missouri R.
Grand R.
Fort Sisseton State Park
Sisseton
L. Traverse
Milbank
Watertown
Redfield
Lake Oahe
Cheyenne R.
Belle Fourche R.
James R.
Big Sioux R.
Huron
Brookings
Pierre
Fort Pierre
Missouri R.
L. Sharpe
Belle Fourche
Spearfish
Sturgis
Deadwood
BLACK HILLS
Rapid City
Wall
Mt. Rushmore Nat. Mem.
Keystone
Jewel Cave Nat. Mon.
Custer
Custer State Park
Badlands National Park
Wind Cave Nat. Park
Hot Springs
Cheyenne R.
White R.
Oacoma
Chamberlain
Mitchell
Madison
Sioux Falls
Brandon
Canton
Winner
L. Francis Case
Missouri R.
Yankton
Vermillion
Big Sioux R.
Niobrara/Missouri National Riverways
Lewis & Clark L.
Sioux City
94-91
97-03
88-26
90-56
88-15
85-36
South Dakota
0 10 20 30 40
Miles

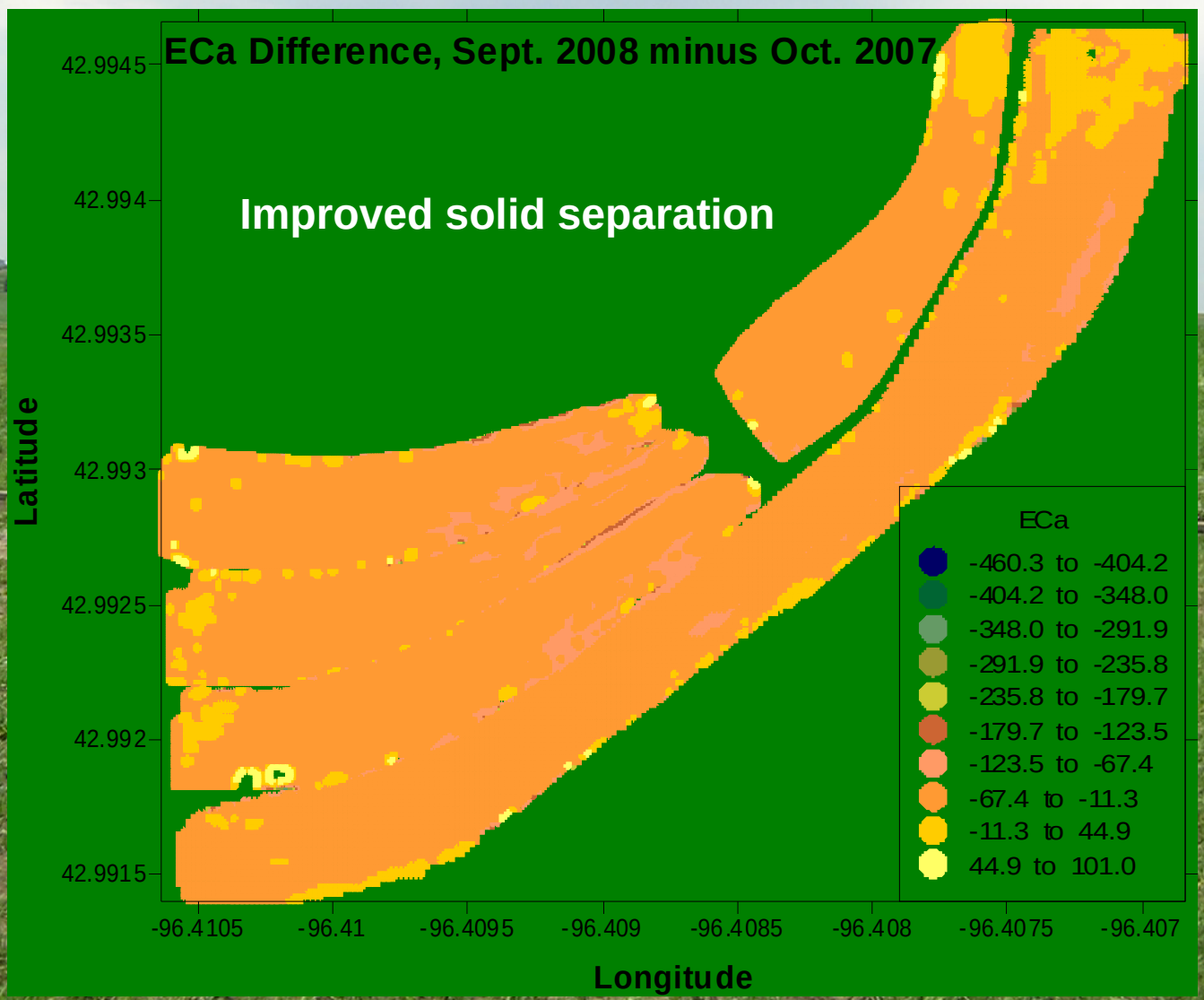

IOWA SITES (7)
• Inwood
• Haywarden
• Treynor
• Lytton
• Grant
• Nevada
Approximately 500 miles of surveys at 5 mph
MINNESOTA
WISCONSIN
SOUTH DAKOTA
NEBRASKA
ILLINOIS
MISSOURI
IOWA
Sioux Falls
Sioux City
Spencer
Waterloo
Dubuque
Boone
Ames
Marshalltown
Marion
Cedar Rapids
Clinton
Ankeny
Newton
Urbandale
Des Moines
West Des Moines
Indianola
Iowa City
University of Iowa
Davenport
Bettendorf
Muscatine
Oskaloosa
Ottumwa
Burlington
Fort Madison
Keokuk
Omaha
Council Bluffs
Lincoln
Iowa
0 20 40 60 80
Miles
© World Sites Atlas (sitesatlas.com)

Northwest Iowa 1



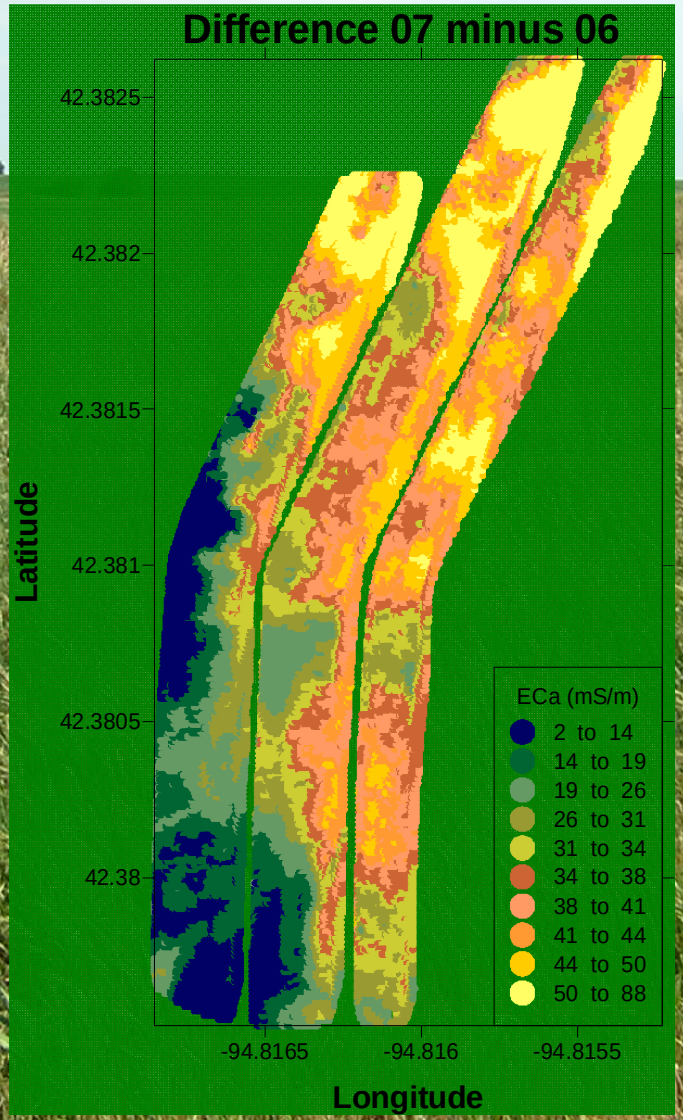
2006

Difference 6/07 to 10/08

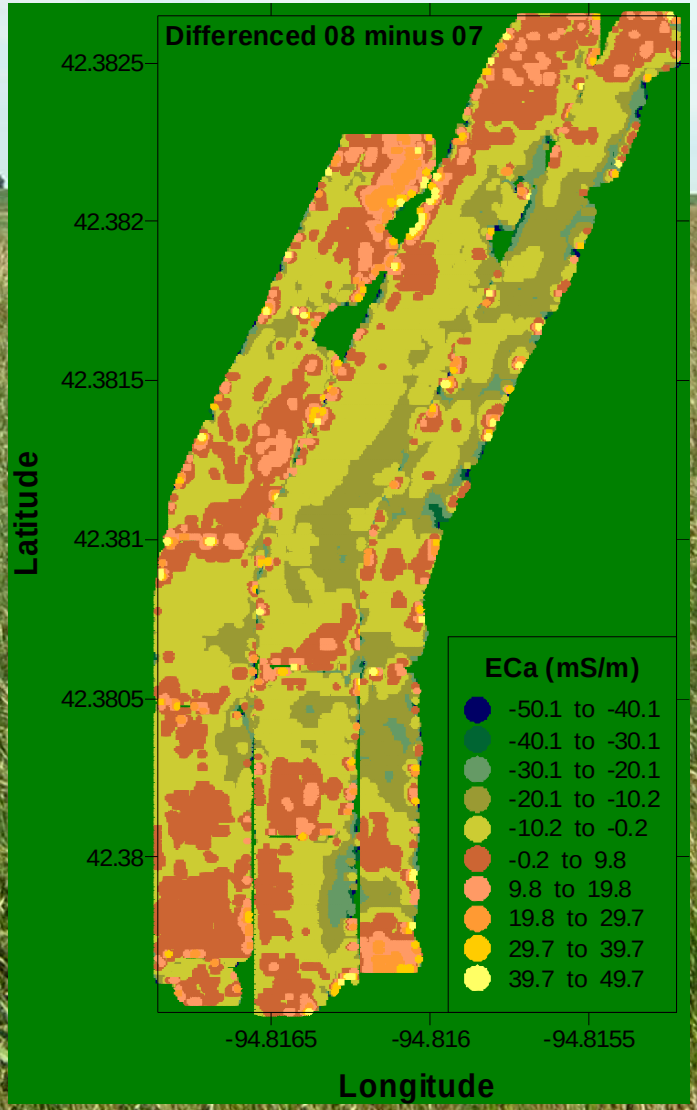


. 2006

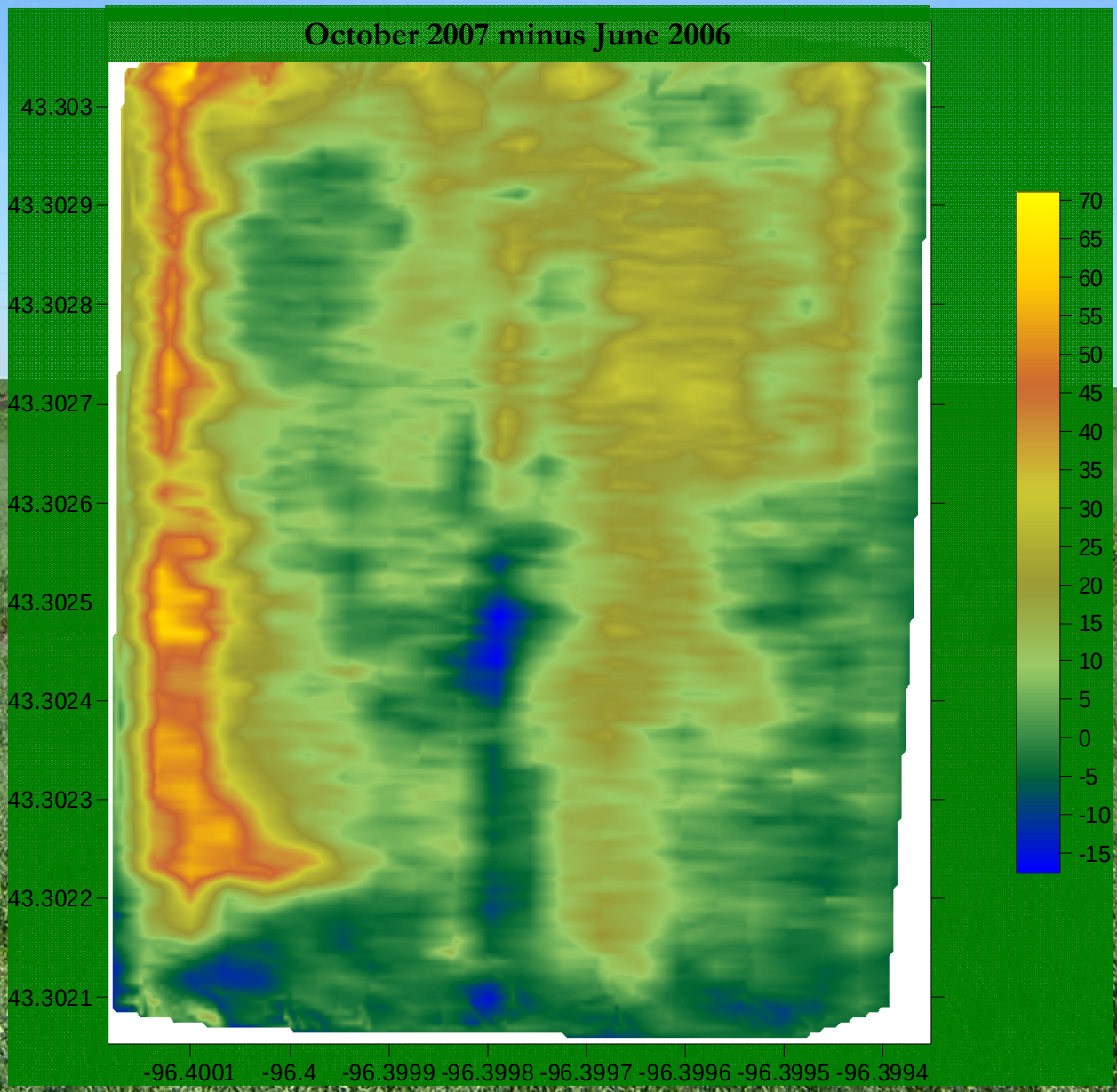
Central Iowa



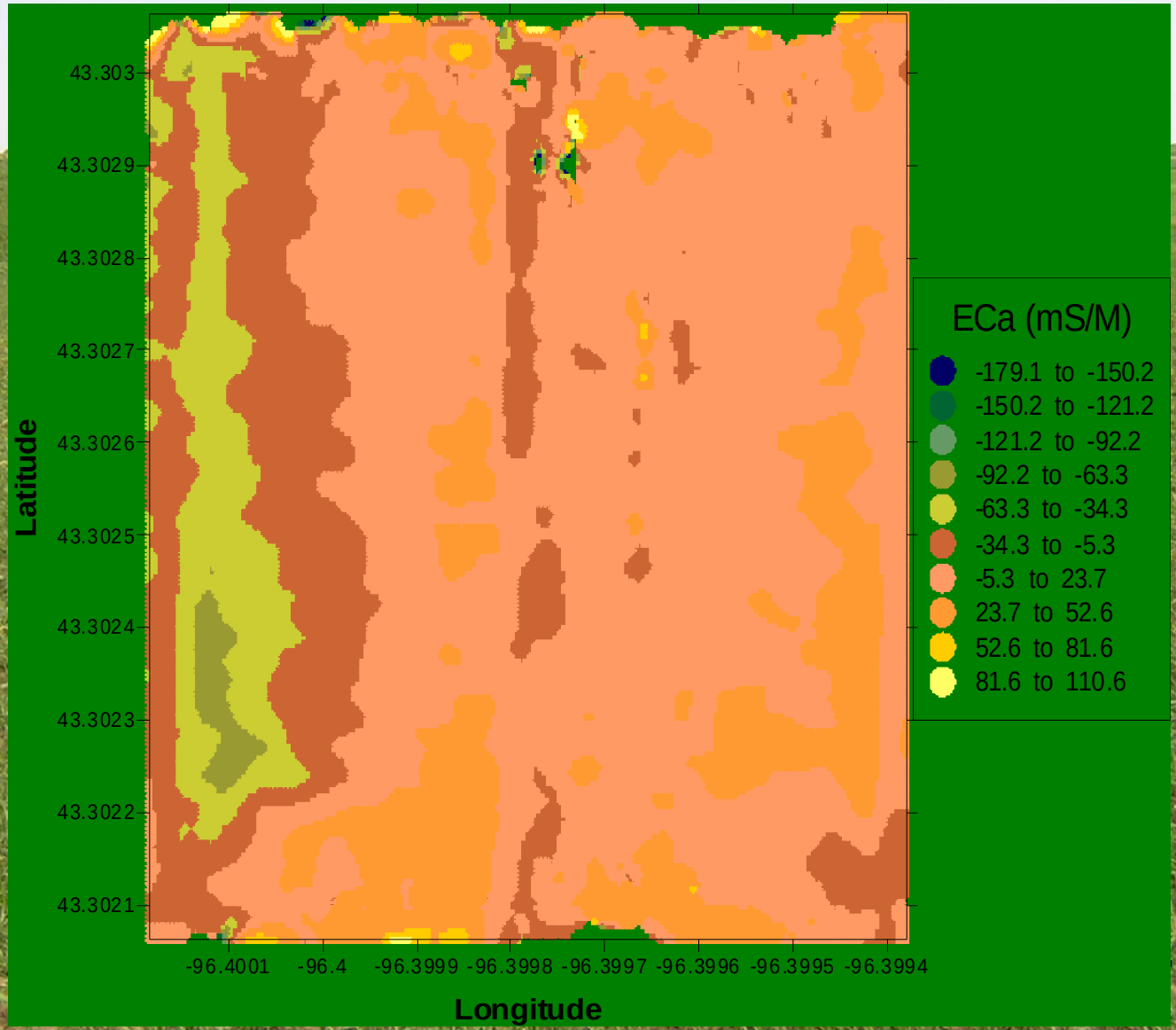
Central Iowa



Northwest Iowa 2

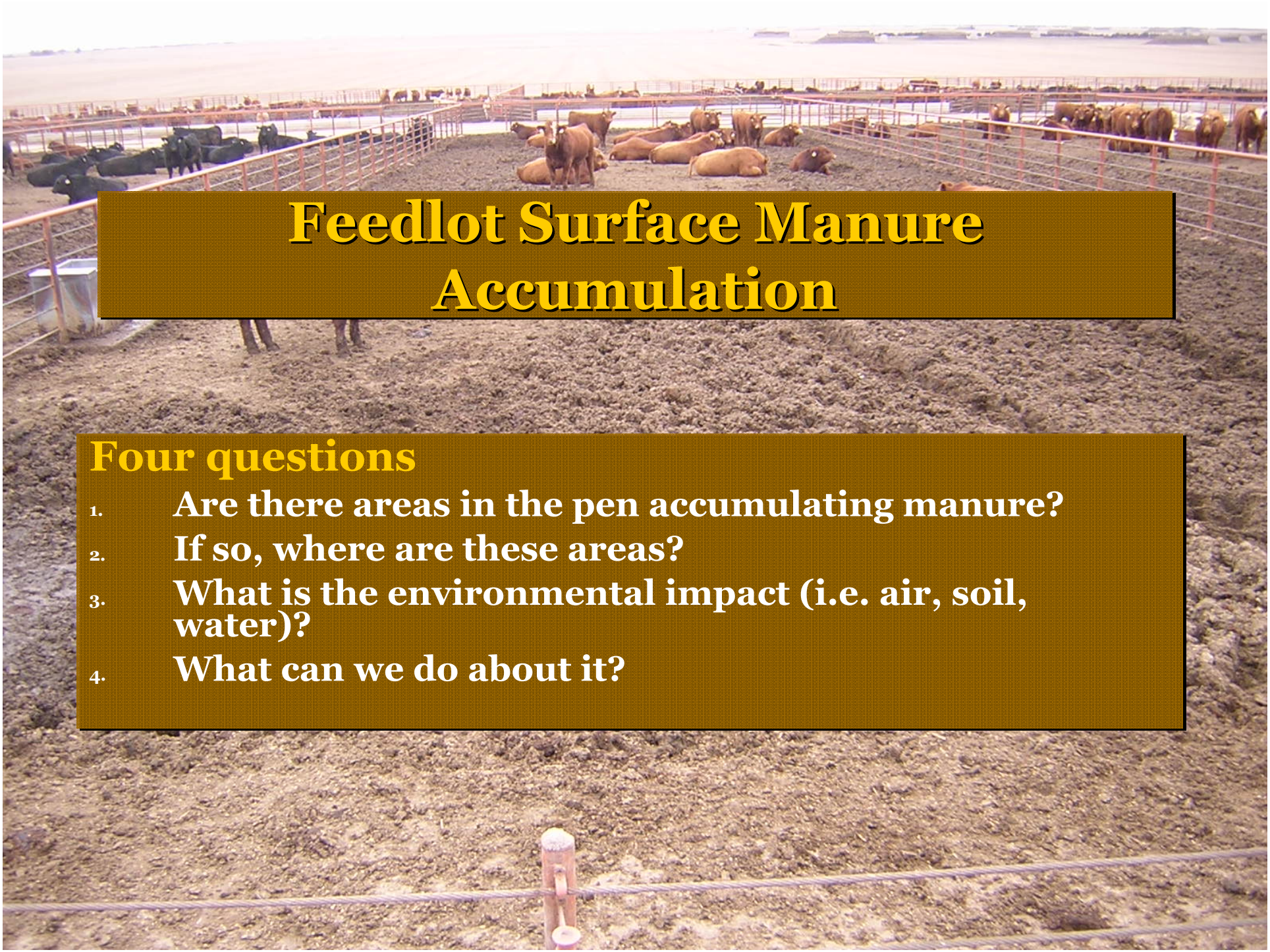


Northwest Iowa 2



2006


07 02 2004

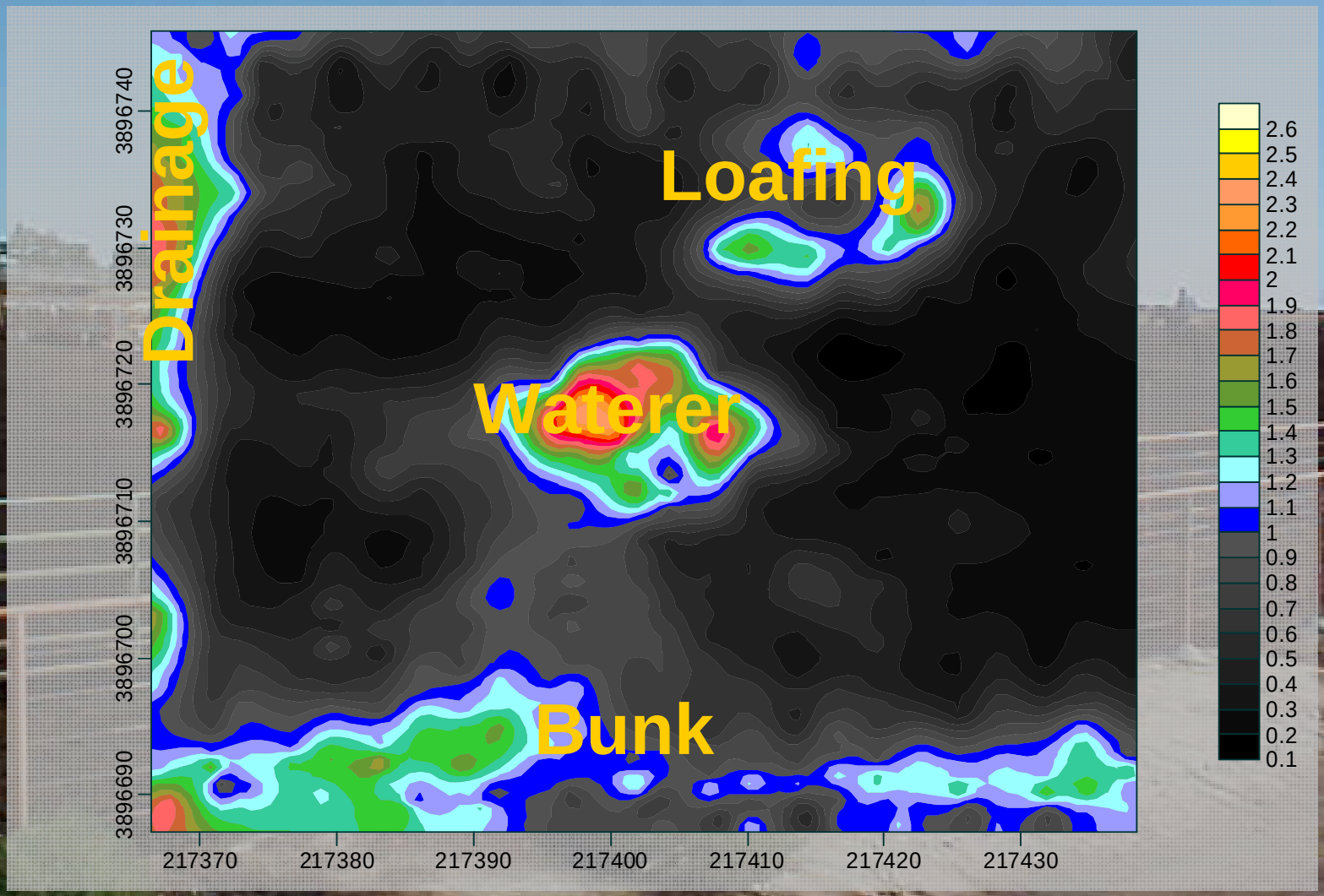


Feedlot Surface Manure Accumulation

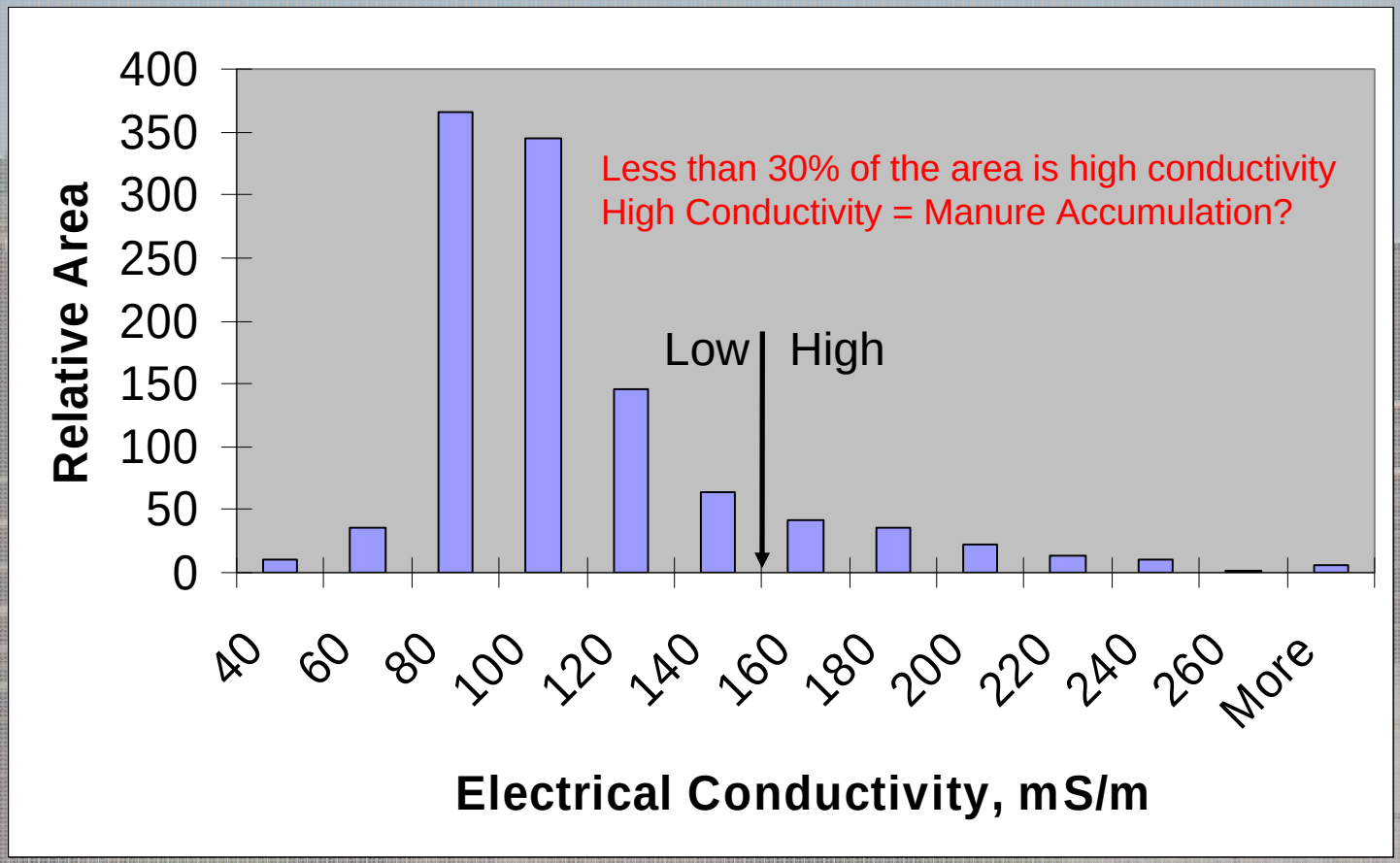
Four questions

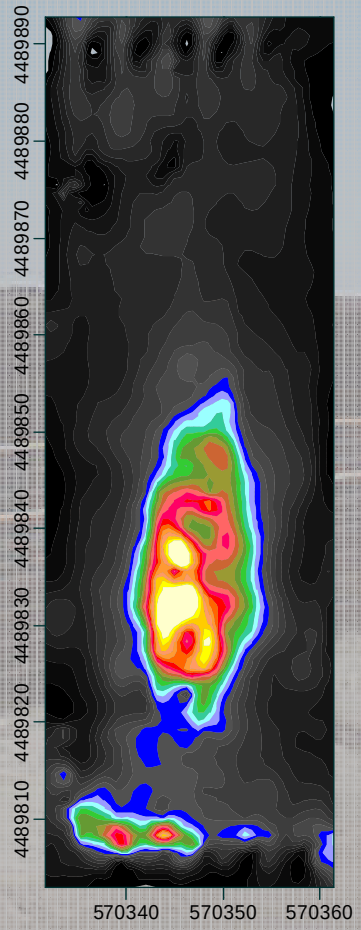
1. Are there areas in the pen accumulating manure?
2. If so, where are these areas?
3. What is the environmental impact (i.e. air, soil, water)?
4. What can we do about it?

Feedlot Survey in Cooperation with ARS-USDA, Bushland, TX

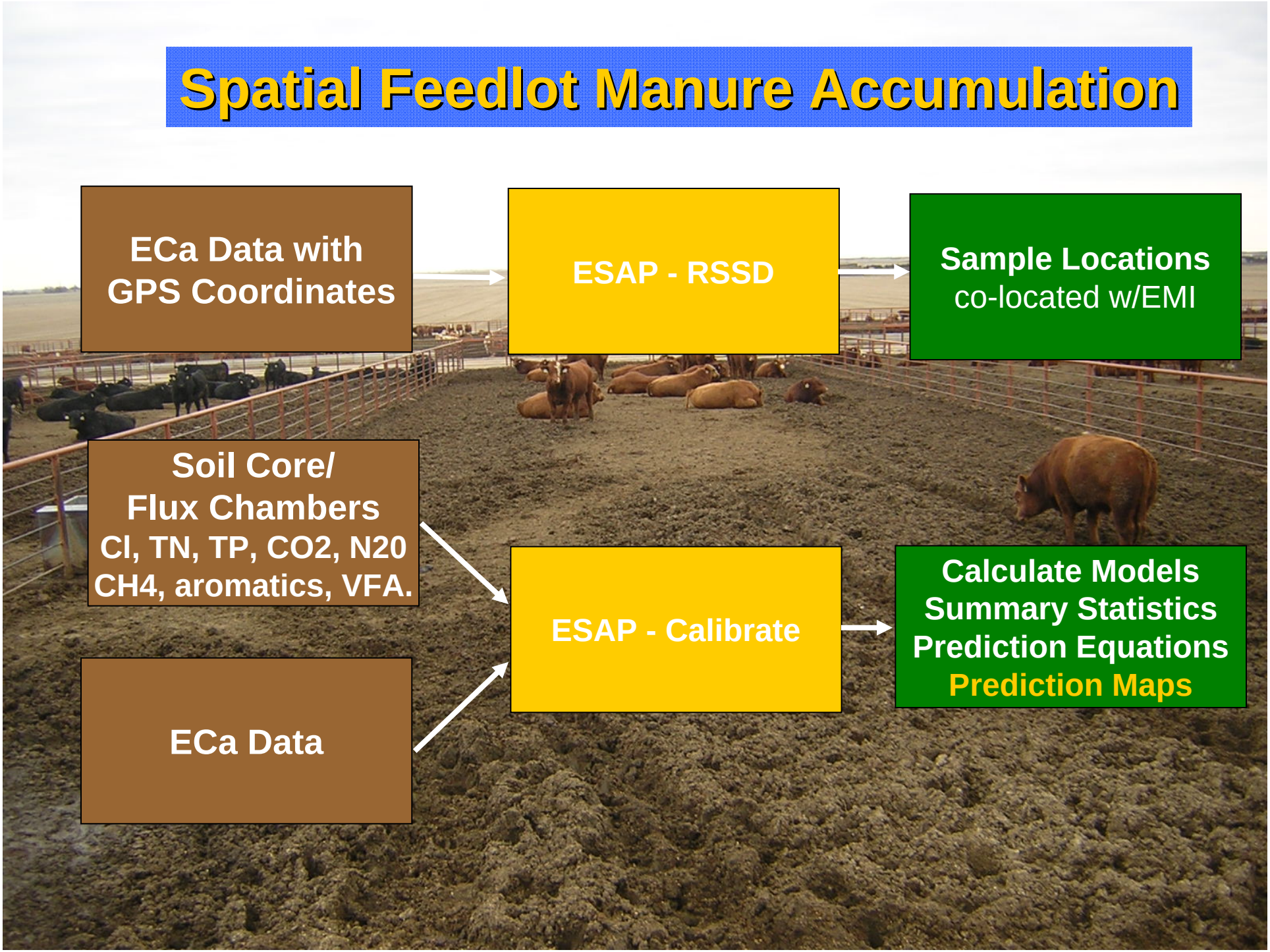


Area based on Conductivity

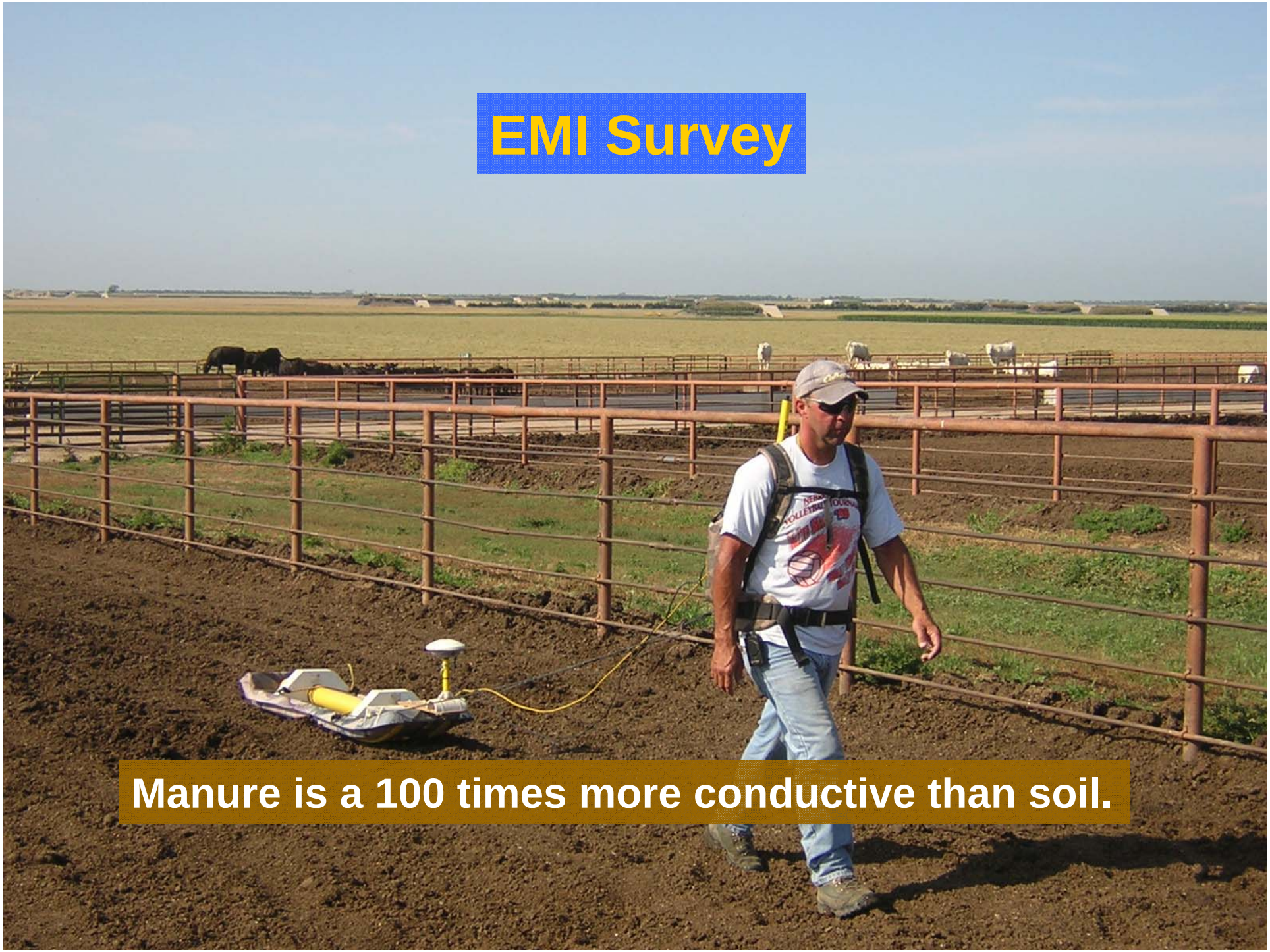




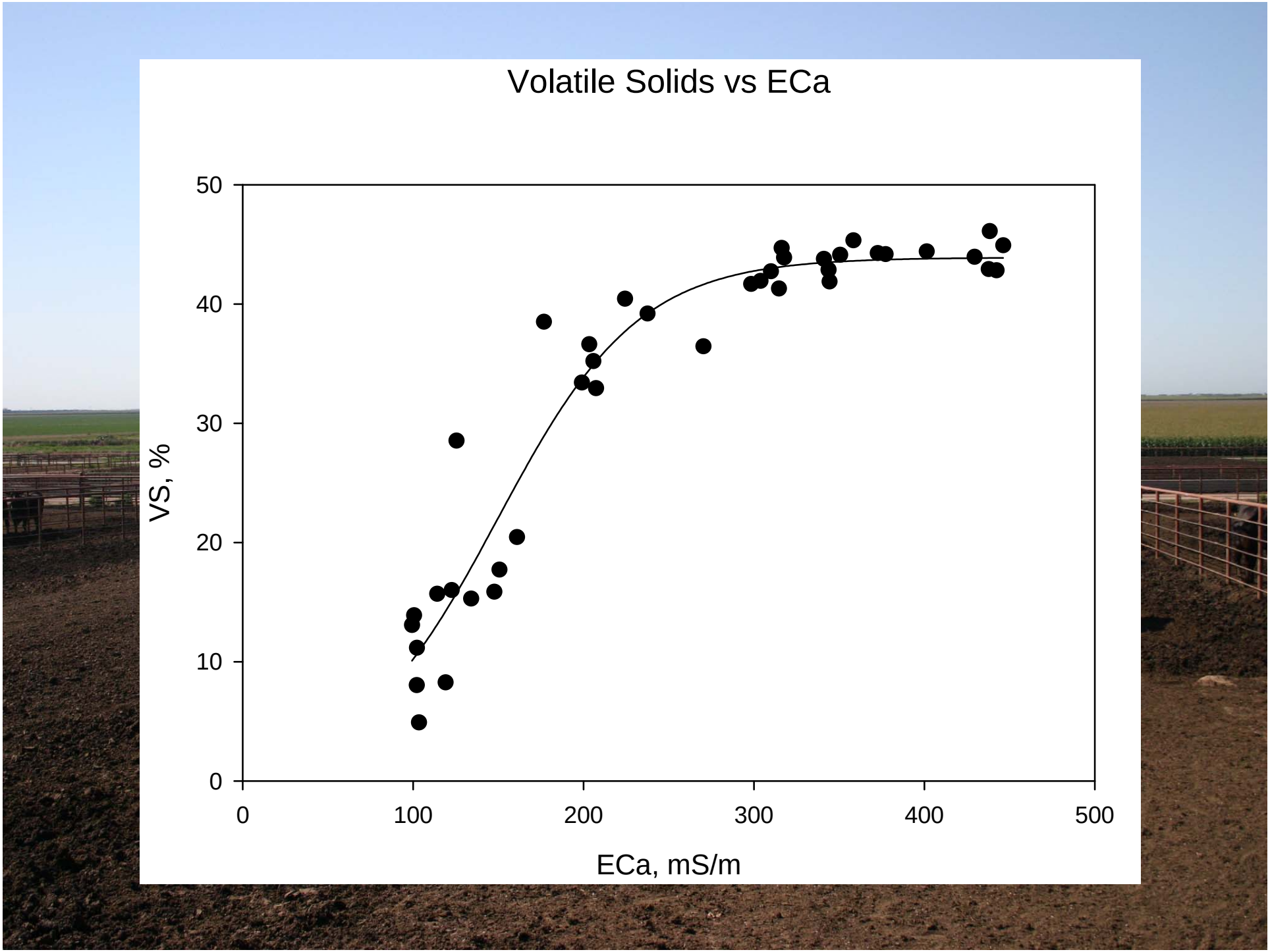
Spatial Feedlot Manure Accumulation

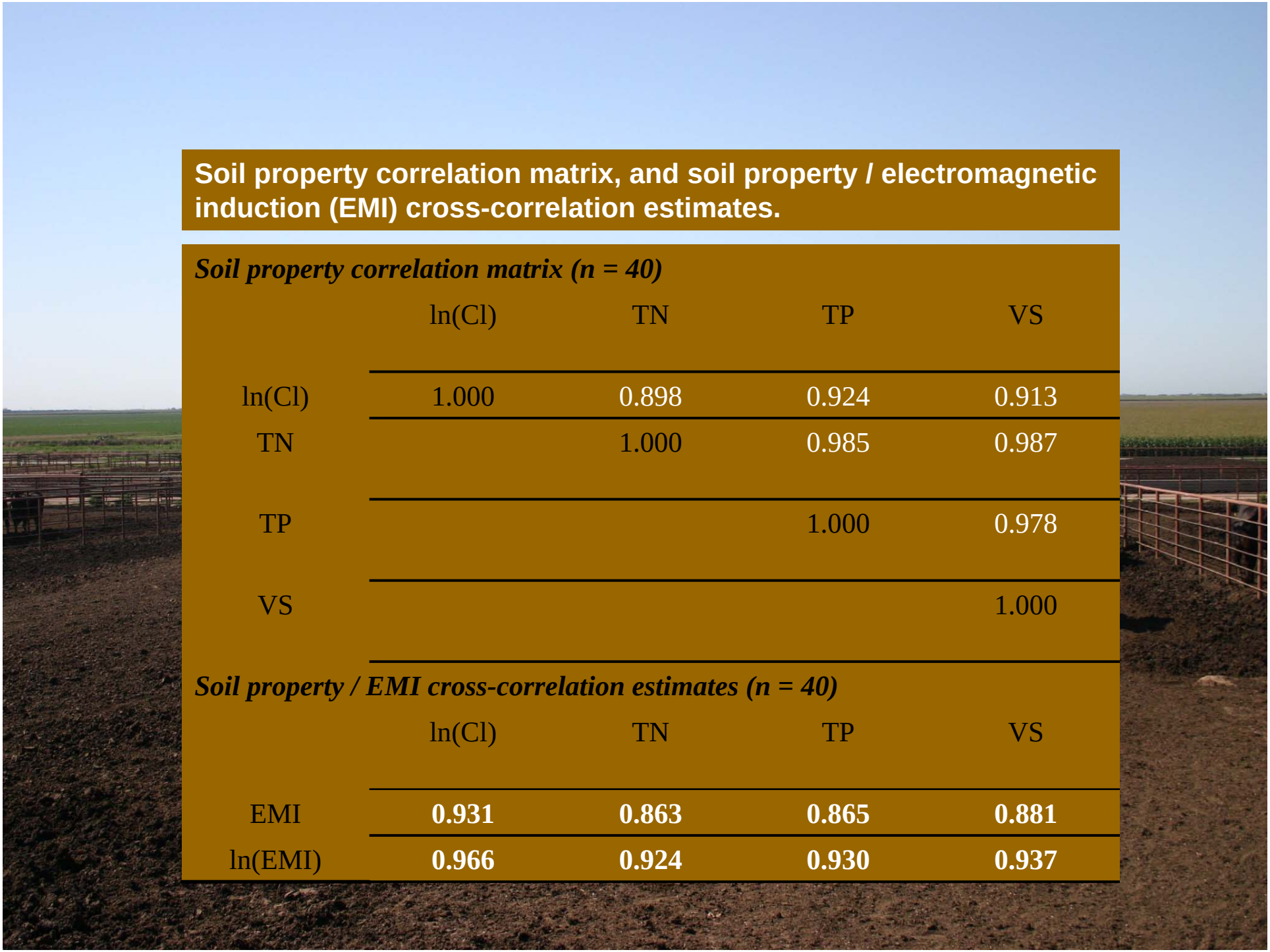


EMI Survey



Manure is a 100 times more conductive than soil.


Volatile Solids vs ECa
VS, %
ECa, mS/m
0
10
20
30
40
50
0
100
200
300
400
500



Soil property correlation matrix, and soil property / electromagnetic induction (EMI) cross-correlation estimates.

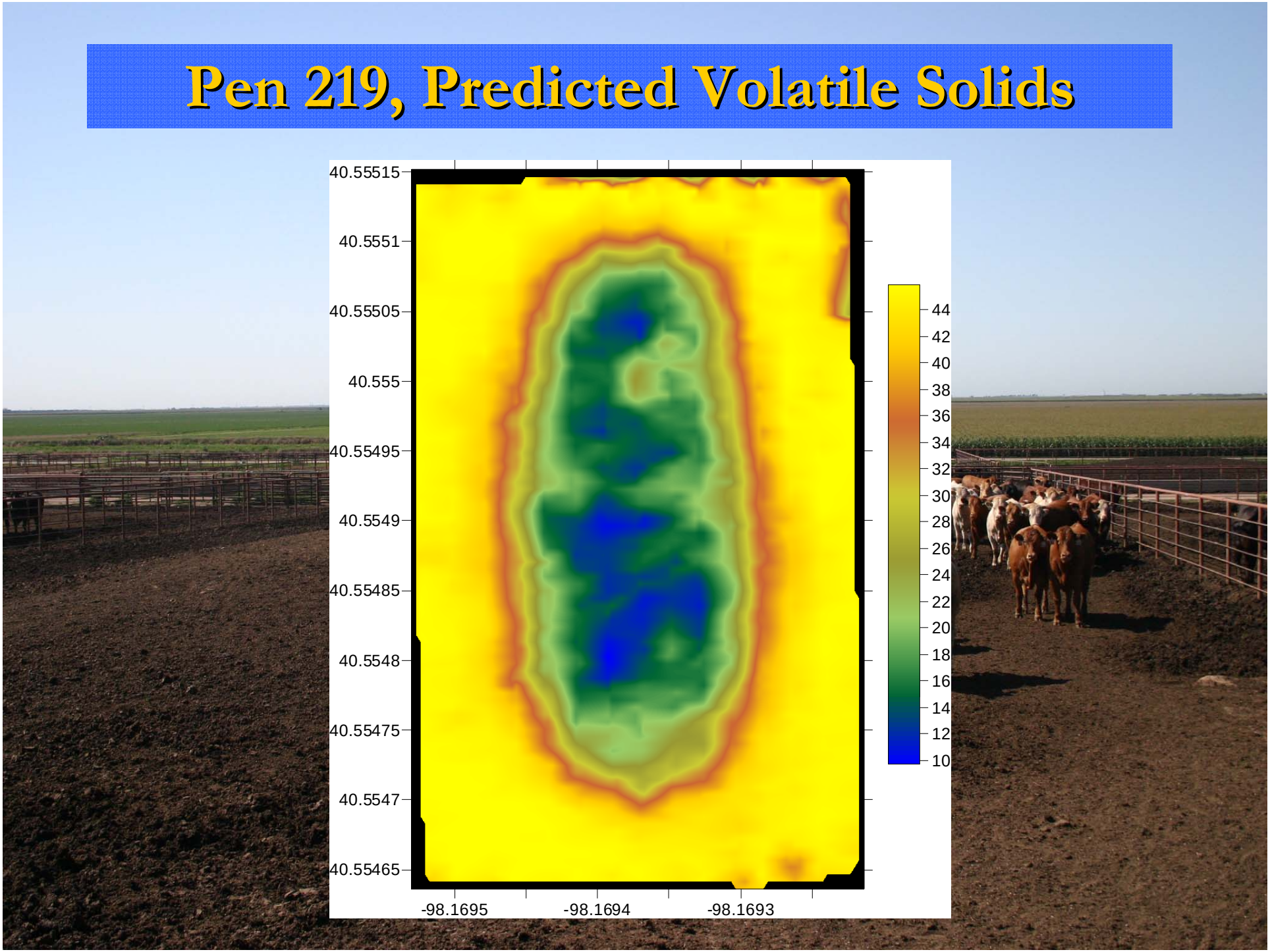
Soil property correlation matrix (n = 40)

	ln(Cl)	TN	TP	VS
ln(Cl)	1.000	0.898	0.924	0.913
TN		1.000	0.985	0.987
TP			1.000	0.978
VS				1.000

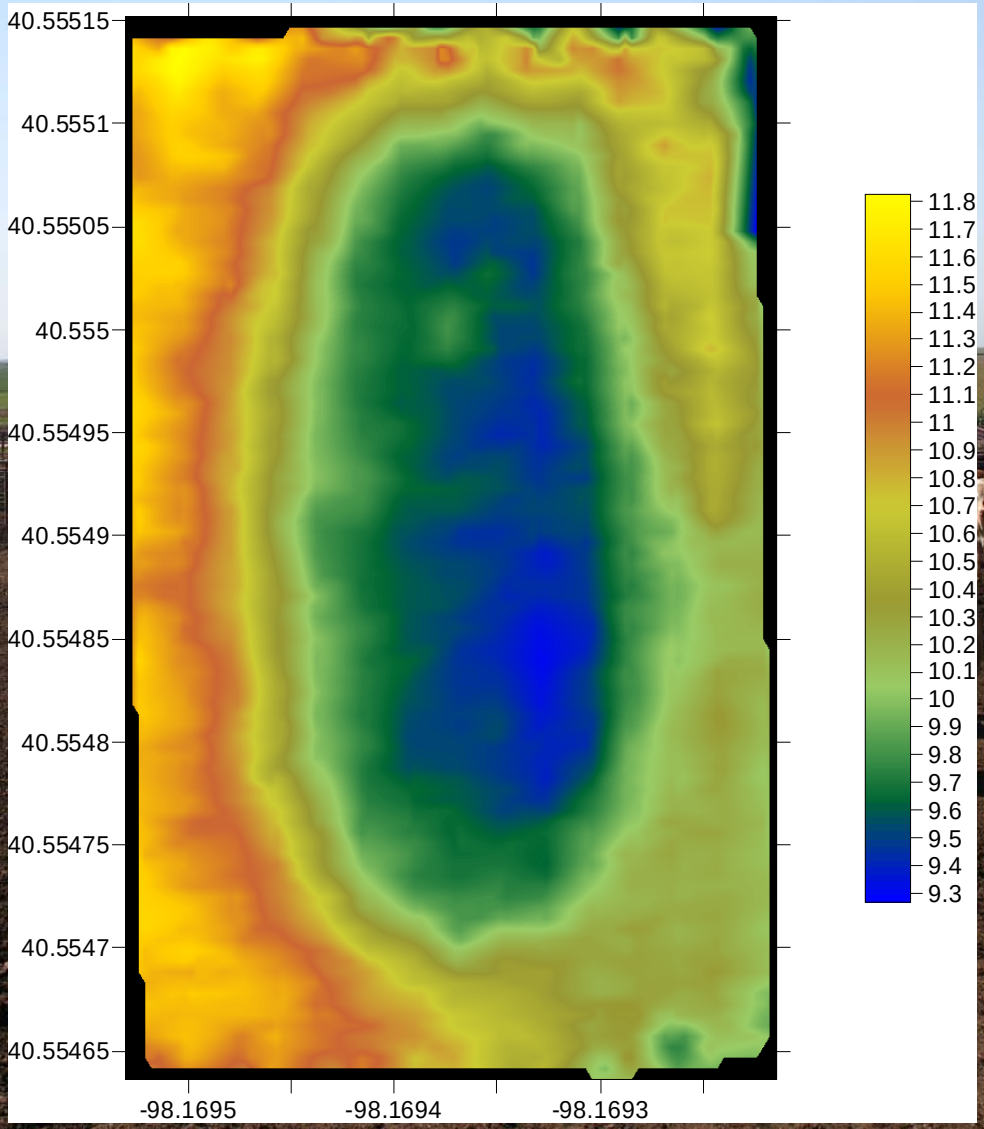
Soil property / EMI cross-correlation estimates (n = 40)

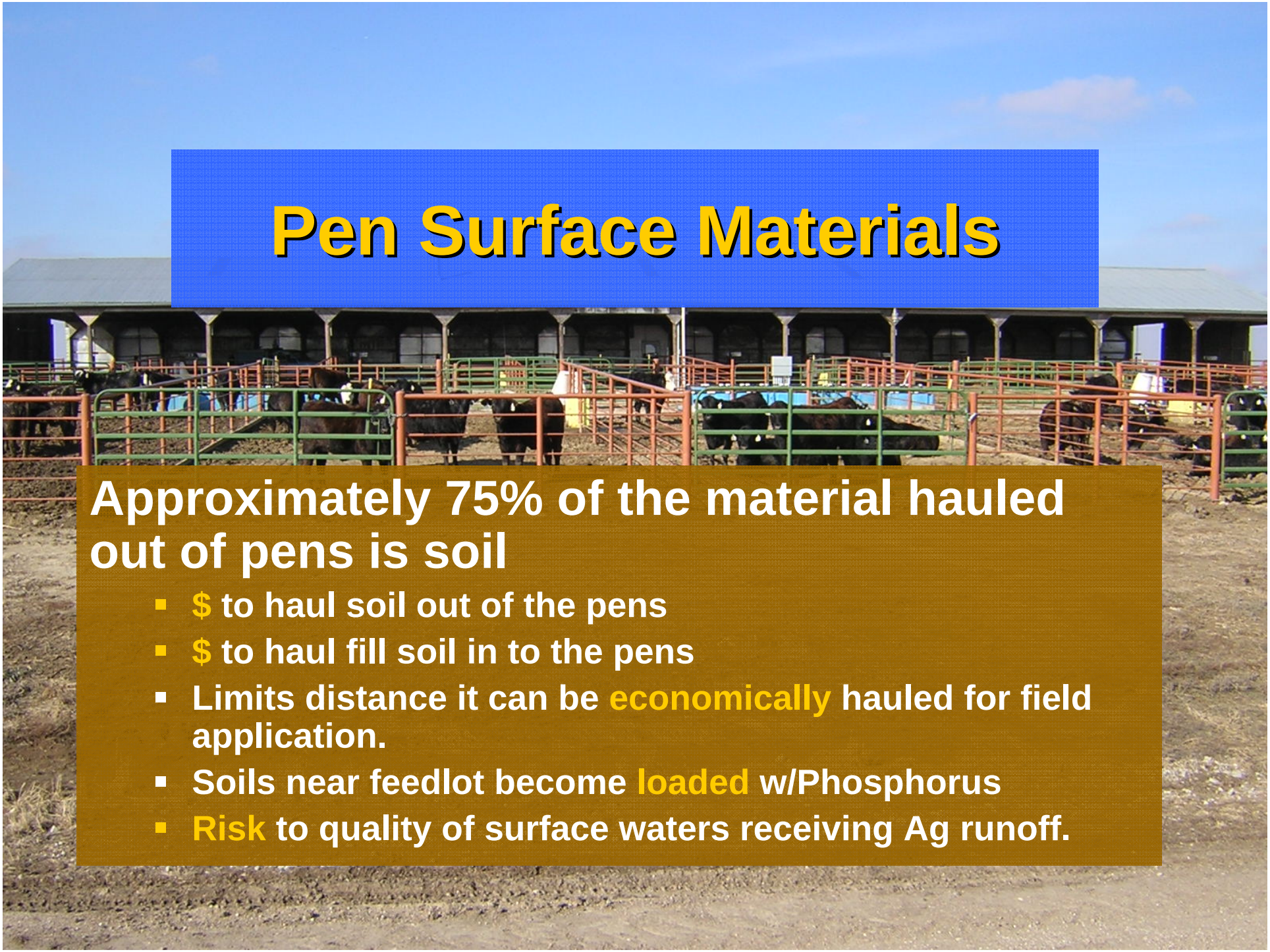
	ln(Cl)	TN	TP	VS
EMI	**0.931**	**0.863**	**0.865**	**0.881**
ln(EMI)	**0.966**	**0.924**	**0.930**	**0.937**

Pen 219, Predicted Volatile Solids



$Ln(CO2) = bo + b1(ECa) + b2\ (x)$





Pen Surface Materials

Approximately 75% of the material hauled out of pens is soil

- **$ to haul soil out of the pens**
- **$ to haul fill soil in to the pens**
- **Limits distance it can be economically hauled for field application.**
- **Soils near feedlot become loaded w/Phosphorus**
- **Risk to quality of surface waters receiving Ag runoff.**

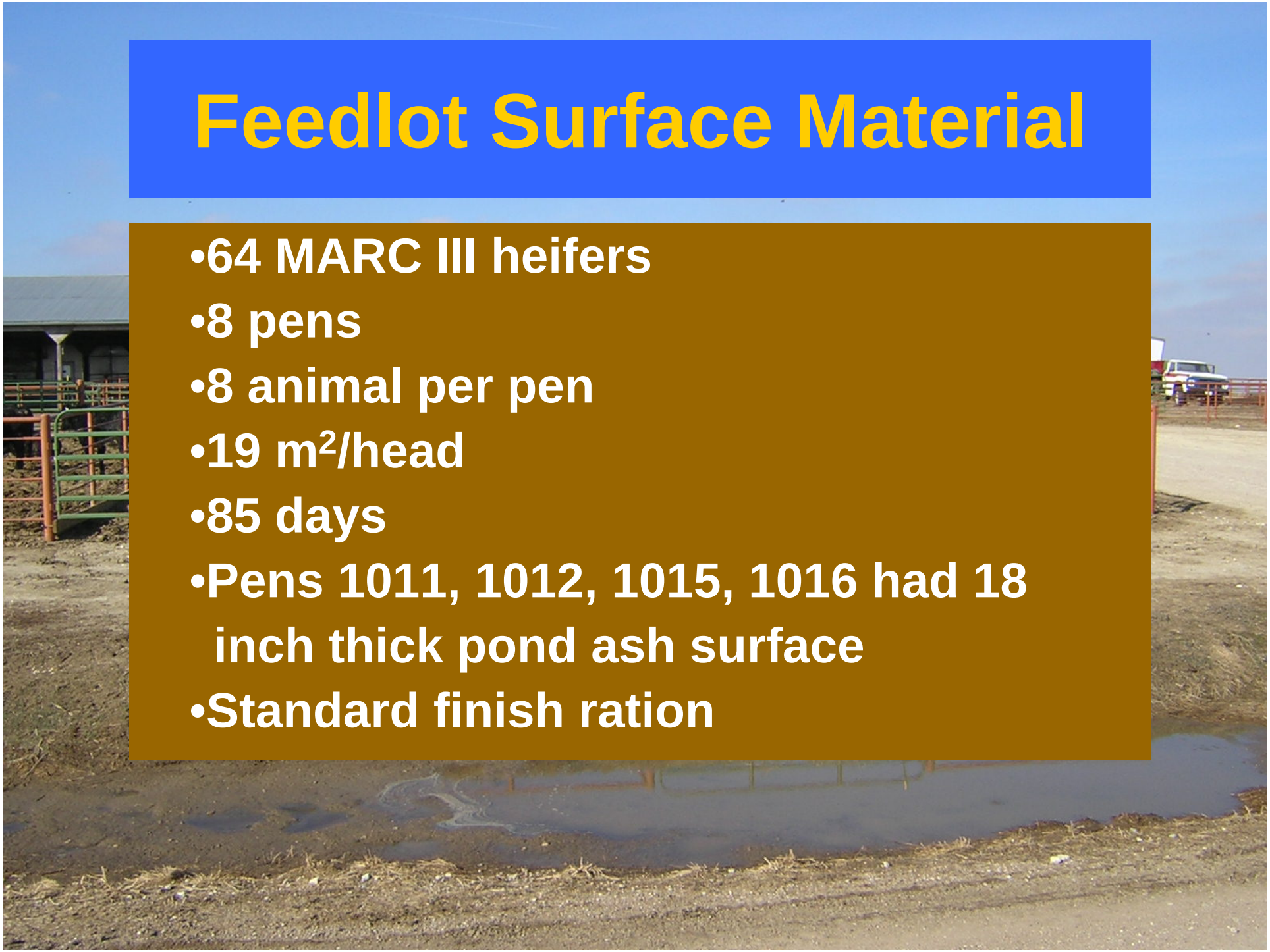
Pen Surface Materials

Need

- 70 – 85% of pen scrapings is non-volatile dirt from the feedlot surface
- Removing pen scrapings and hauling fill dirt in for maintaining pen conditions is expensive

Objectives

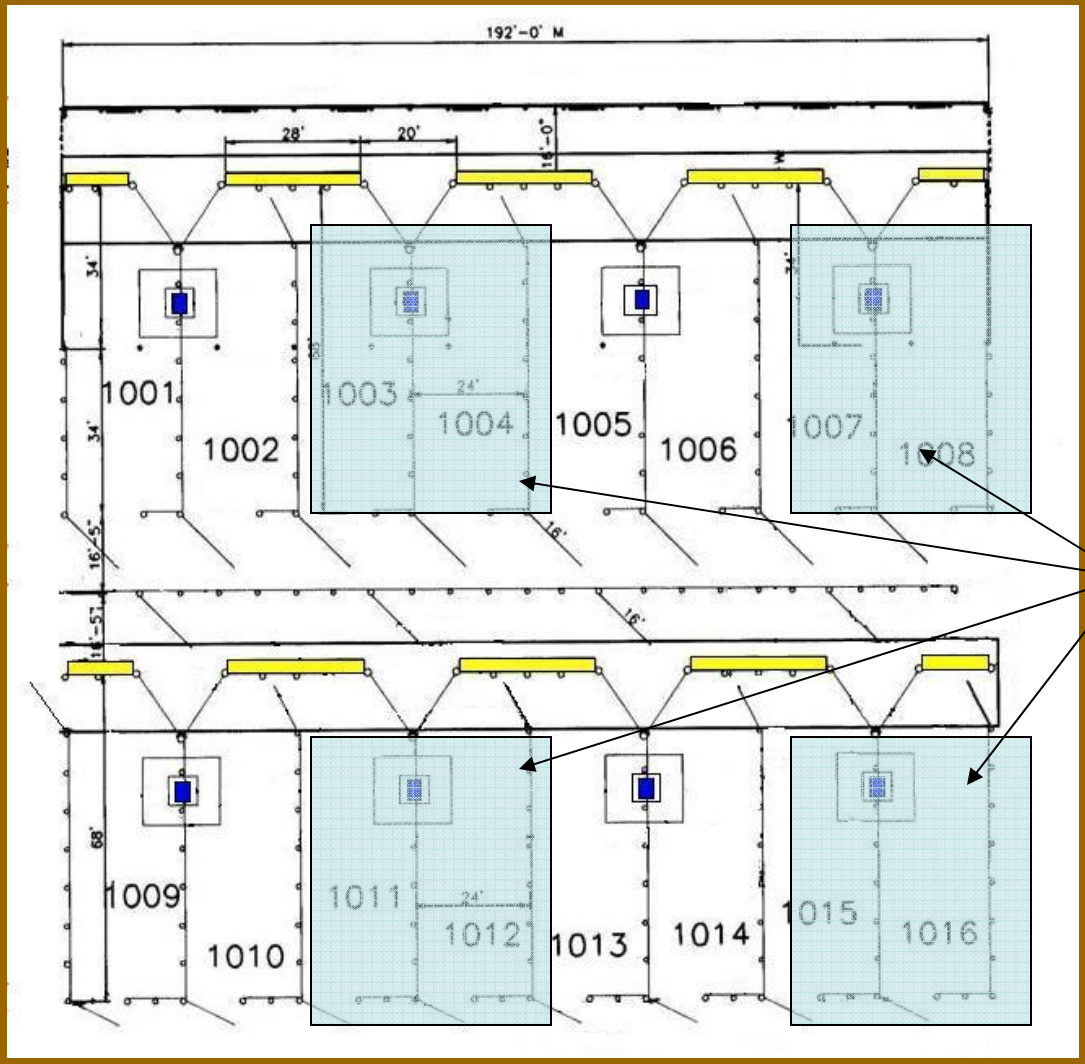
- Compare pond ash surfaced pens with soil surface pens for reducing the soil content of the pen scrapings



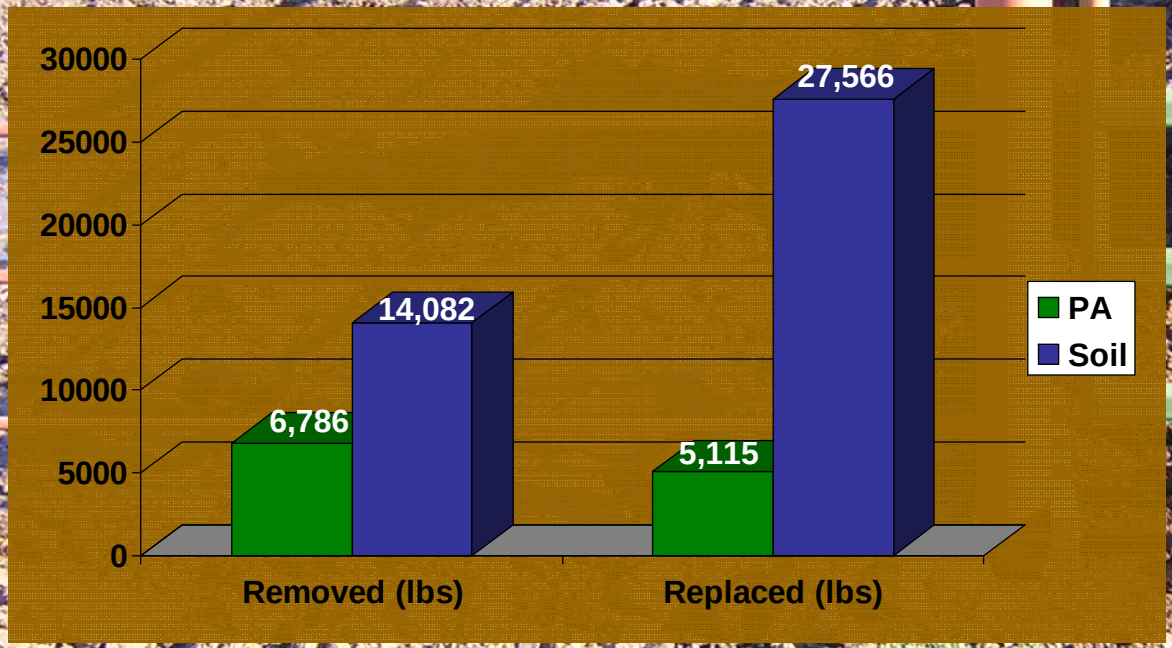
Feedlot Surface Material

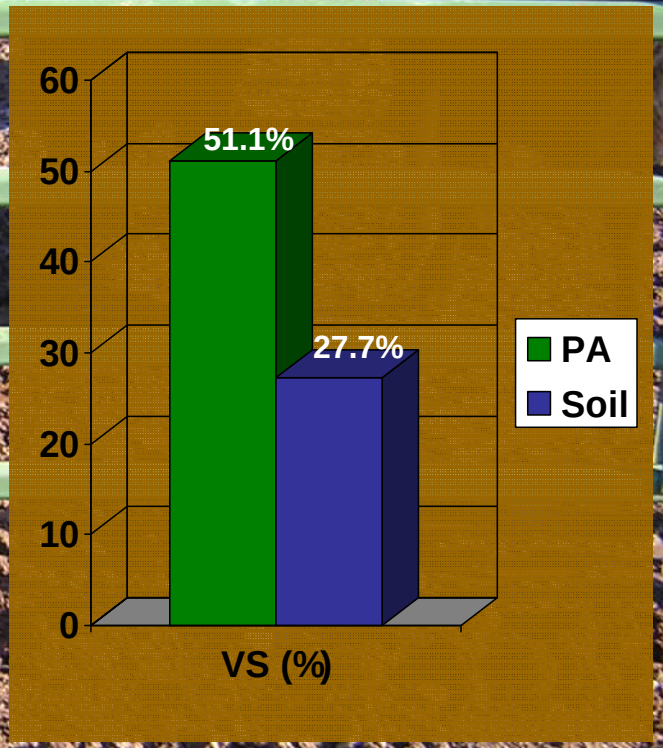
- 64 MARC III heifers
- 8 pens
- 8 animal per pen
- 19 m^2/head
- 85 days
- Pens 1011, 1012, 1015, 1016 had 18 inch thick pond ash surface
- Standard finish ration

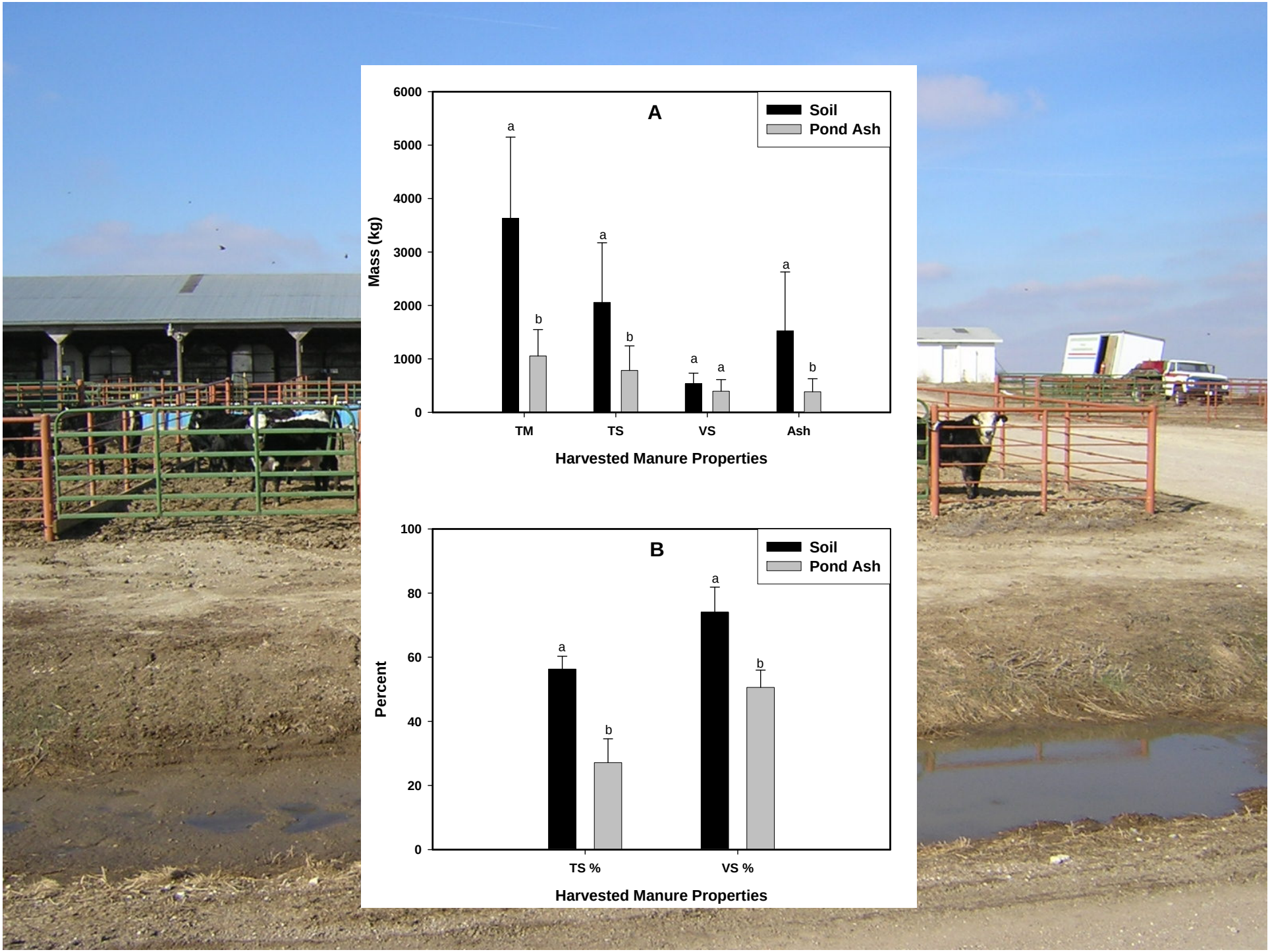
Feedlot Surface Material



Pen Surface Materials






A
Soil
Pond Ash
Mass (kg)
6000
5000
4000
3000
2000
1000
0
a
b
a
b
a
a
a
b
TM
TS
VS
Ash
Harvested Manure Properties
B
Soil
Pond Ash
Percent
100
80
60
40
20
0
a
b
a
b
TS %
VS %
Harvested Manure Properties

Feedlot Surface Material

Summary

- The total mass of VS removed from all pens was not different
- 70% reduction in total mass removed
- The VS% from the PA pens was nearly twice as high as SS pens
- 14 times more material (scrapings removed and fill dirt replace) for the SS pen when compared to PA pens


Questions
09.29.2004

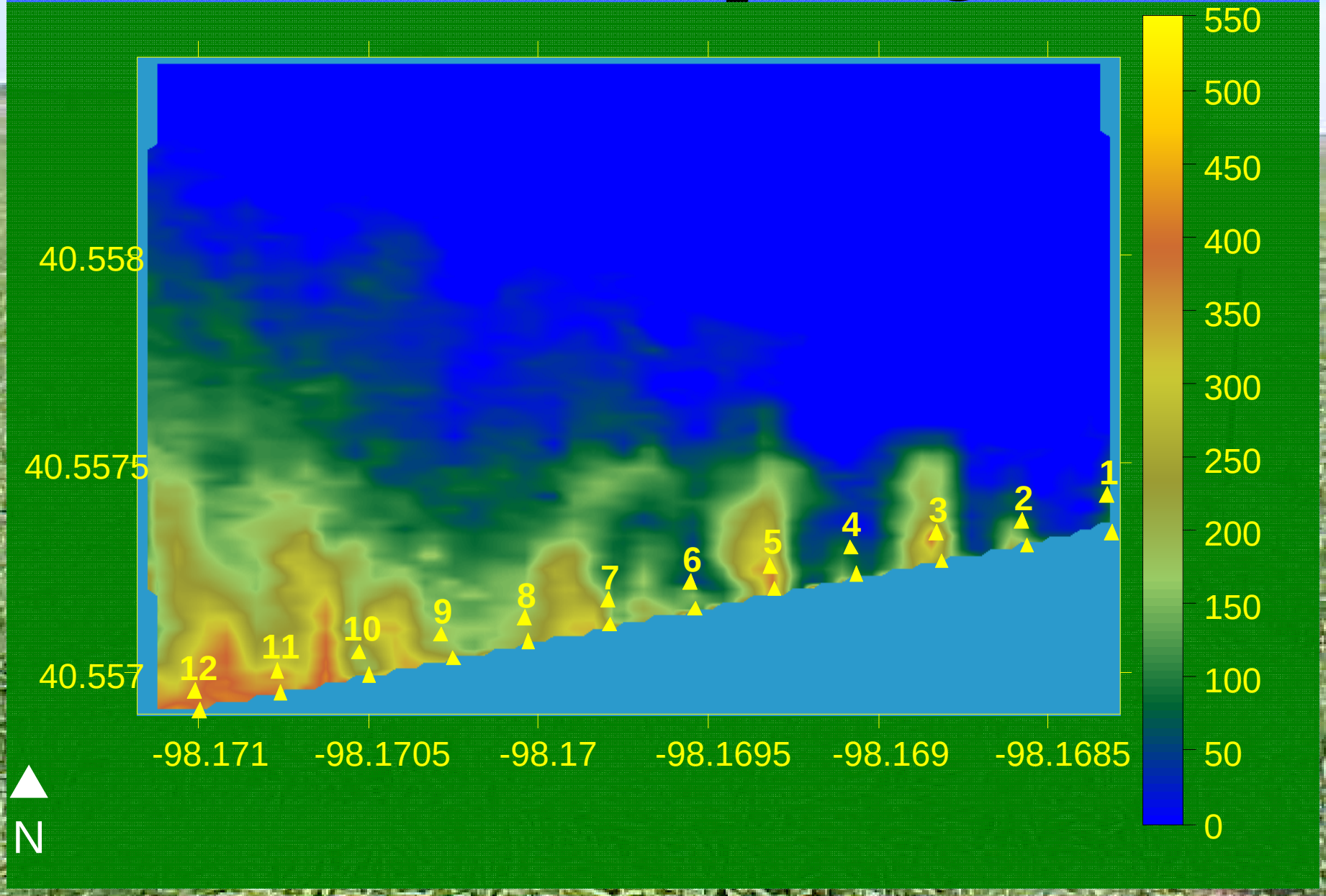
Management Changes

- Discharge inlets were modified in Spring of 2006

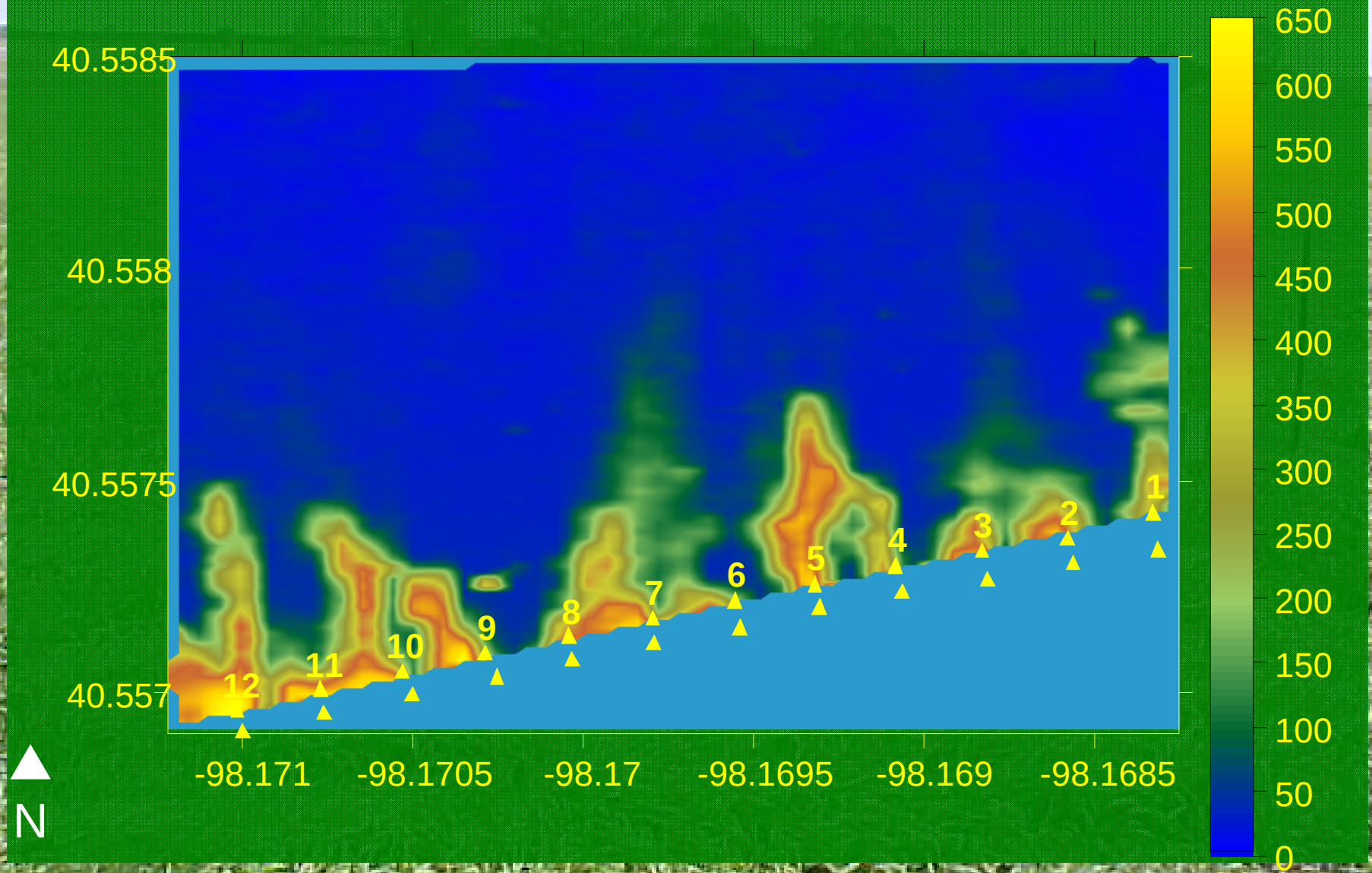
Original Inlet Design

New Inlet Design

Cl^- Prediction Map - August 2005



Cl^- Pred. Map - November 2006



Feedlot Surface Material

Trtmt	Total Mass	Total Solids	Volatile Solids	Ash	Fill
	kg	kg	kg	kg	kg
Soil	3631	2059	535.5	1523	11026
Pond Ash	1055	783.7	396.6	387.1	0
P-value	0.0083	0.026	0.22	0.025	