# Modeling Cropping Systems Strategies to Optimize Yield, Water and Nutrients

Bruno Basso

Department of Geological Sciences and W.K. Kellogg Biological Station

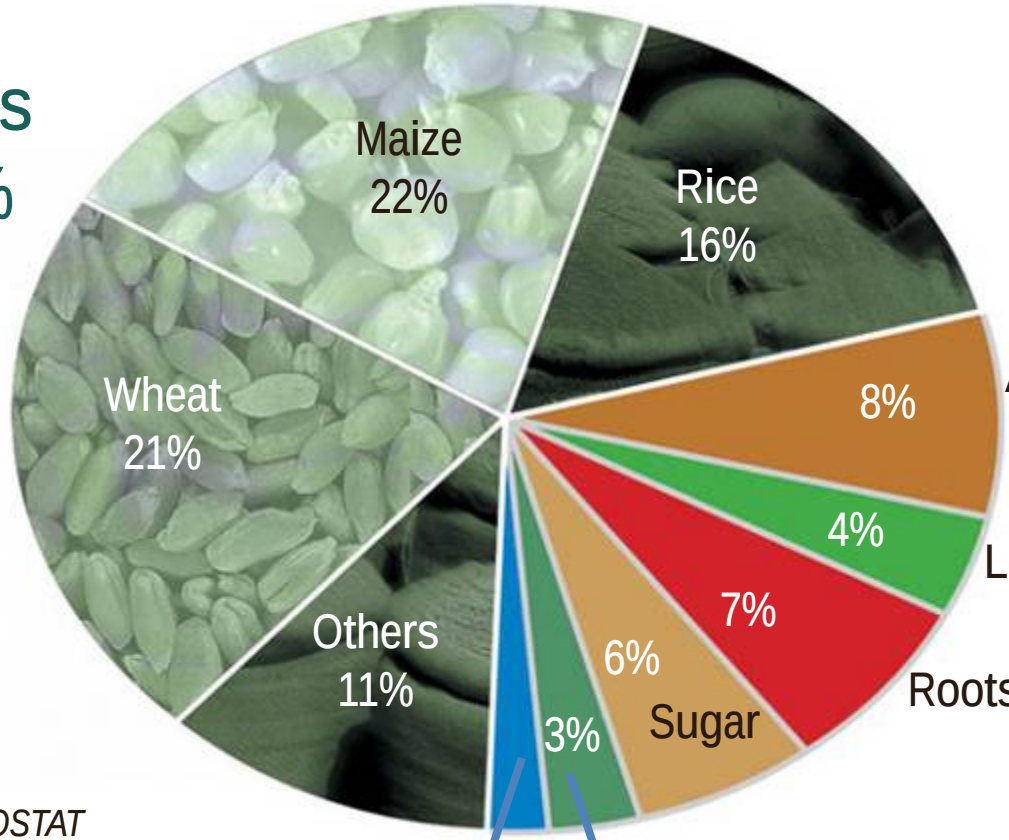
MICHIGAN STATE UNIVERSITY

# 2012 World Food Supply

## 5.5 billion gross tonnes; 2.8 billion tonnes dry weight

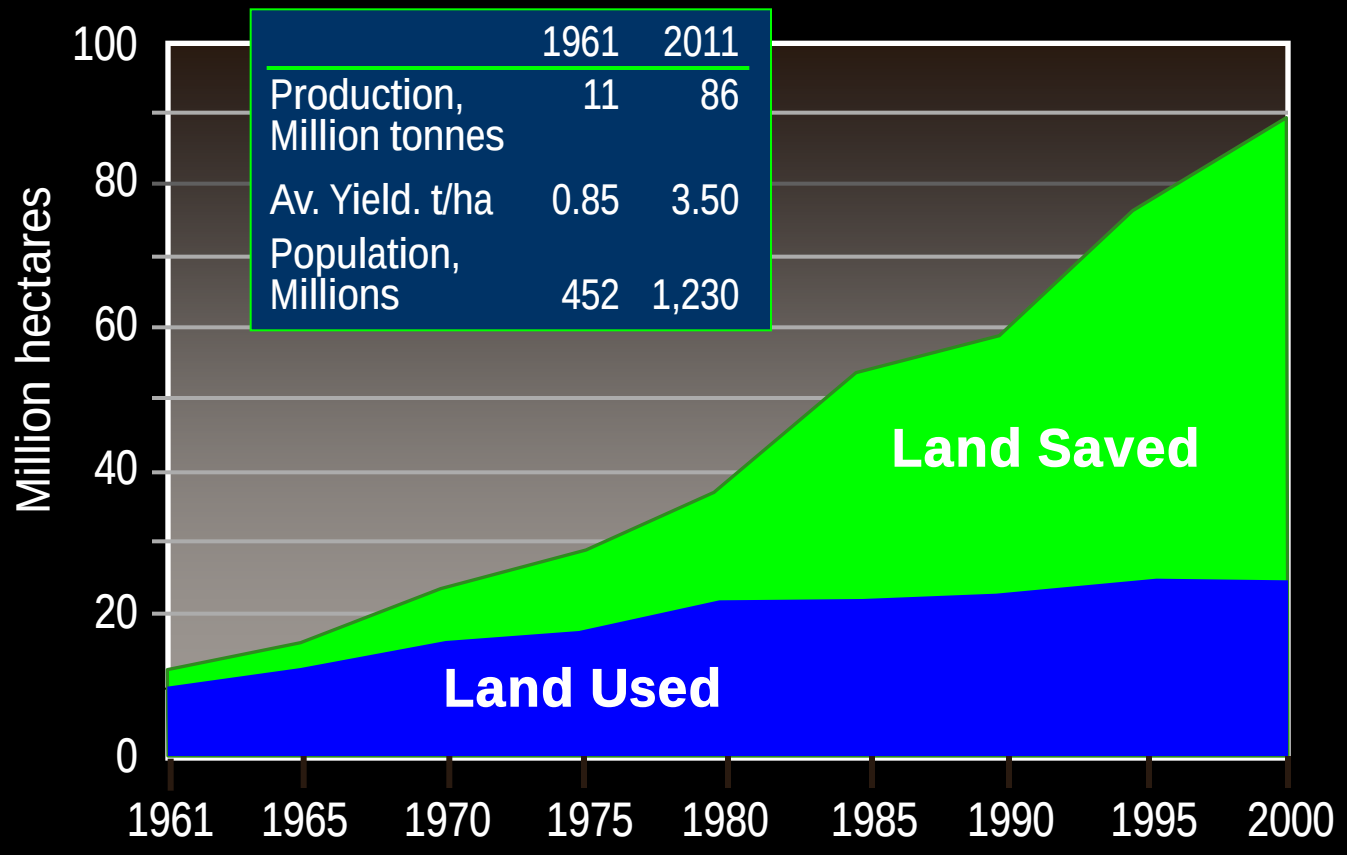
### Edible dry matter, expressed in Kcals

Cereals
70%




*Source: FAO AGROSTAT*

# Indian Wheat Production—Area Saved Through Adoption of High-Yield Technology

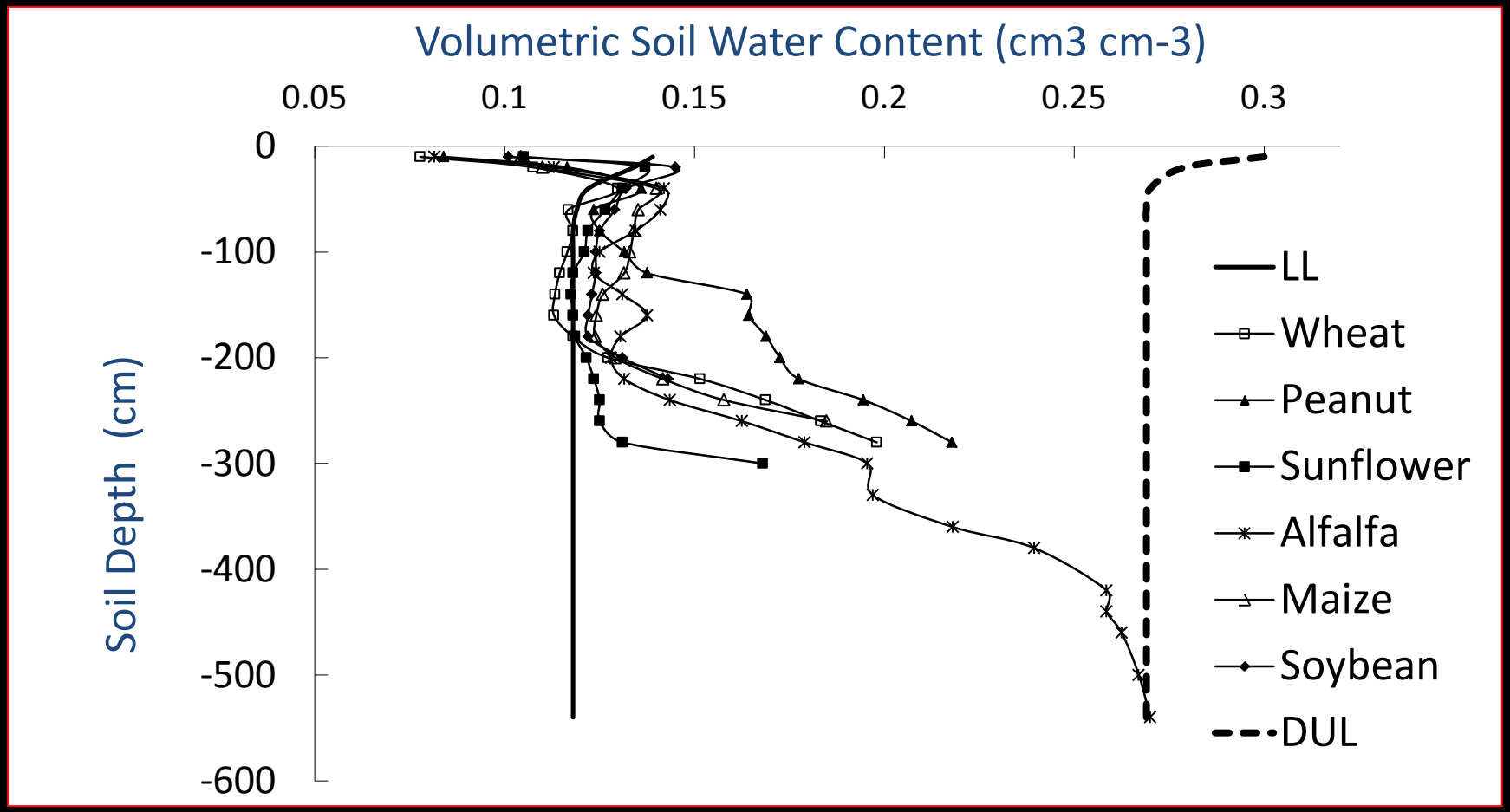



| | 1961 | 2011 |
|---|---|---|
| Production, Million tonnes | 11 | 86 |
| Av. Yield. t/ha | 0.85 | 3.50 |
| Population, Millions | 452 | 1,230 |

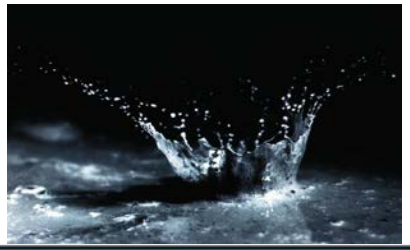
Source: FAOSTAT, 2012

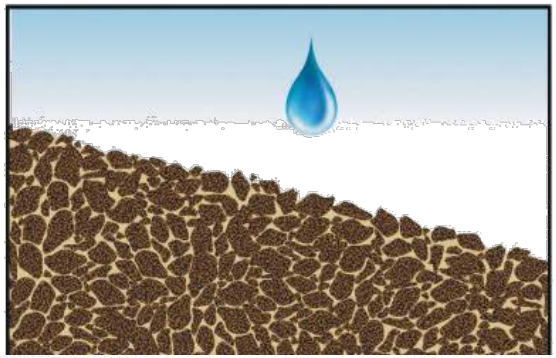
**The accurate response to drought is crucial.**

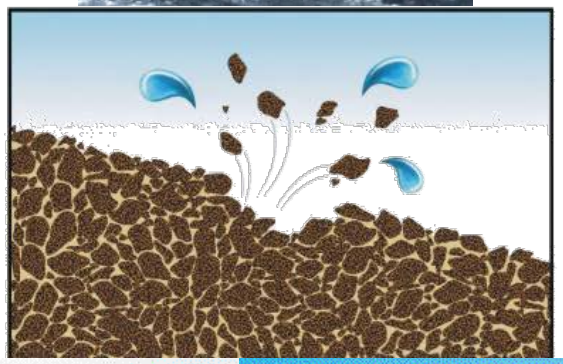
The contribution of the depth below 1 m can be important

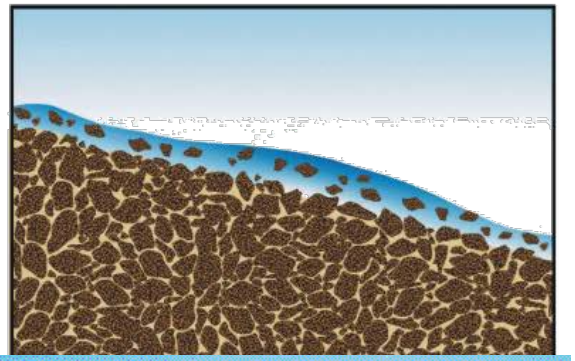



Dardanelli et al. 2004

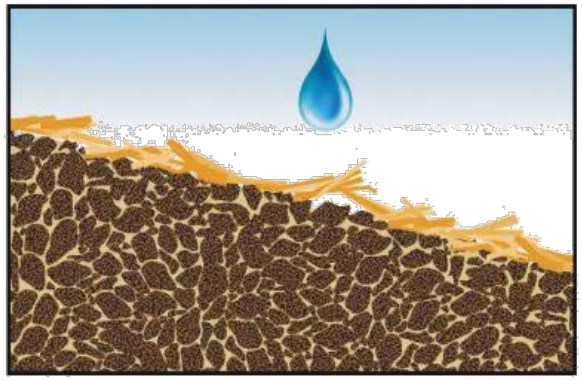


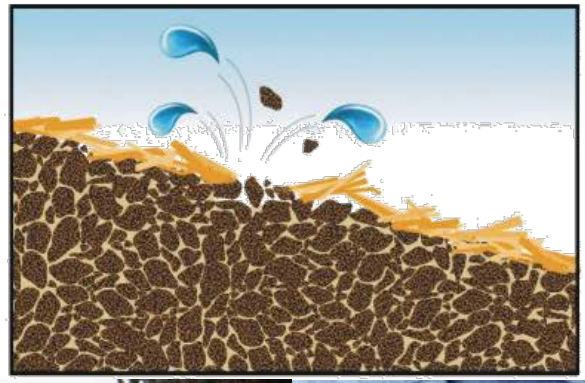


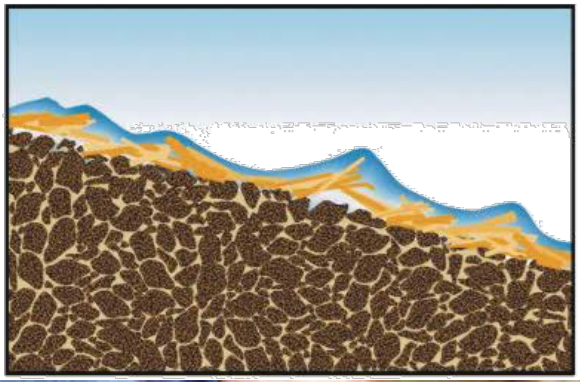




Conventional Inversion Tillage with no surface residues

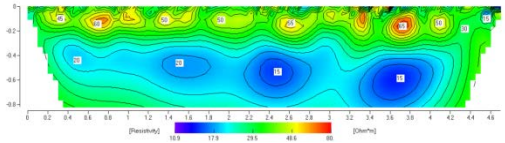


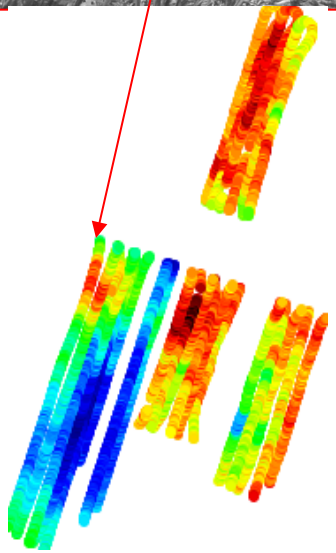




Conservation Tillage with surface residues retained

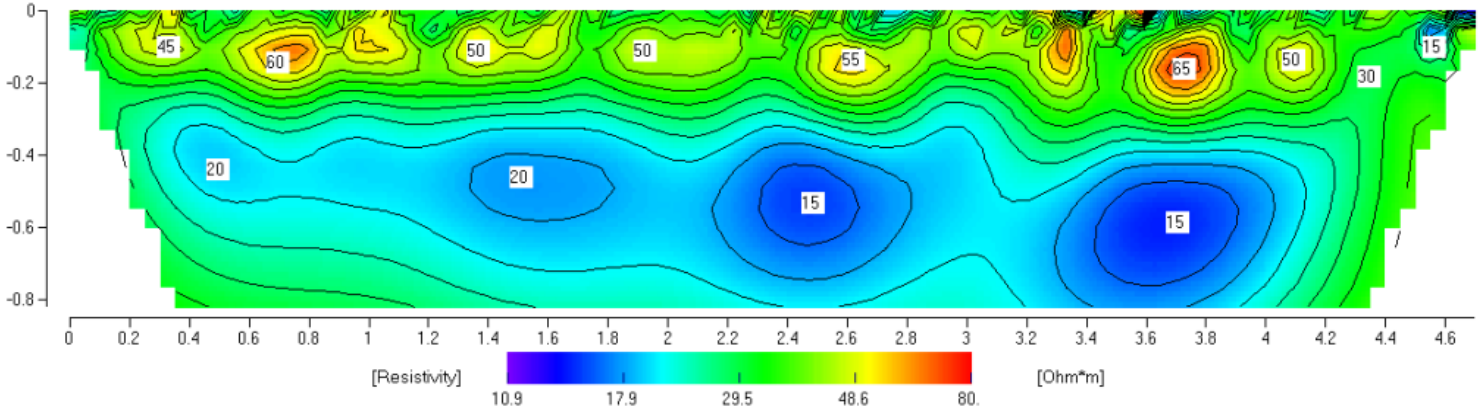
# High-resolution 2-D resistivity tomography



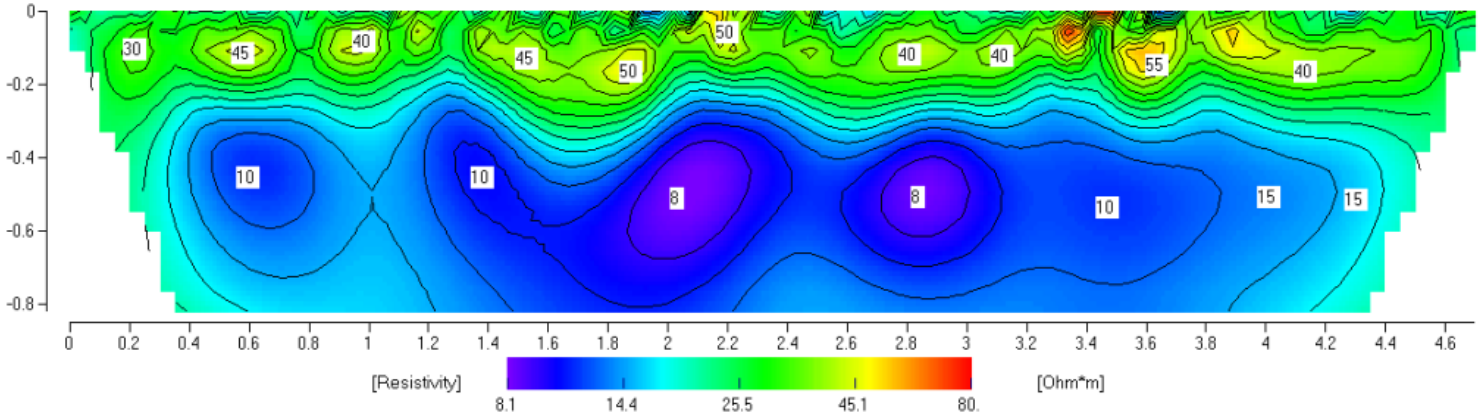


# High-resolution 2-D resistivity tomography

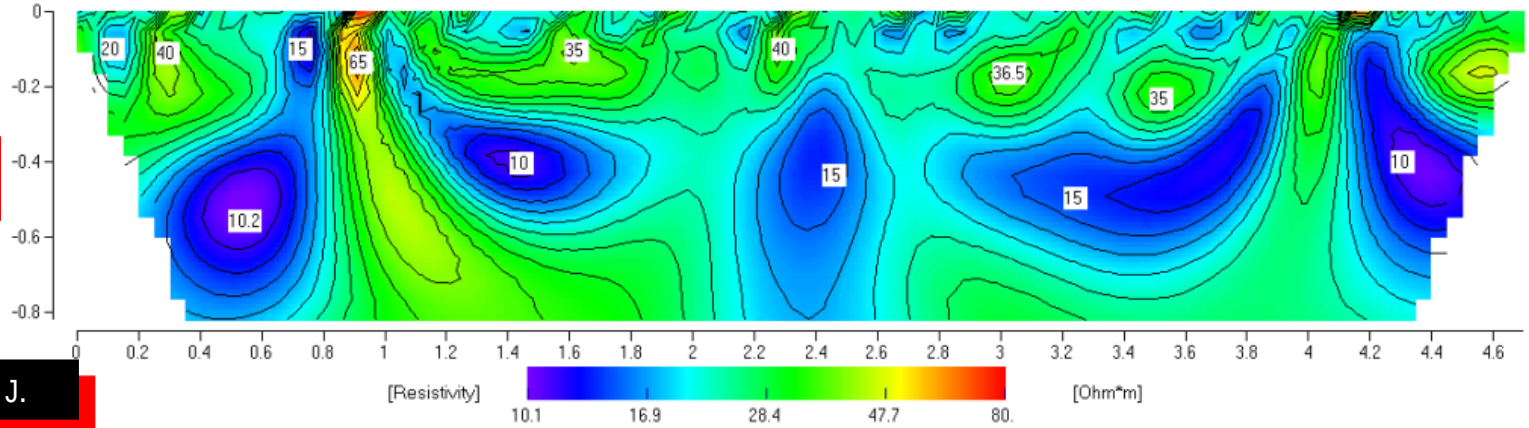
Conventional Tillage




Minimum Tillage

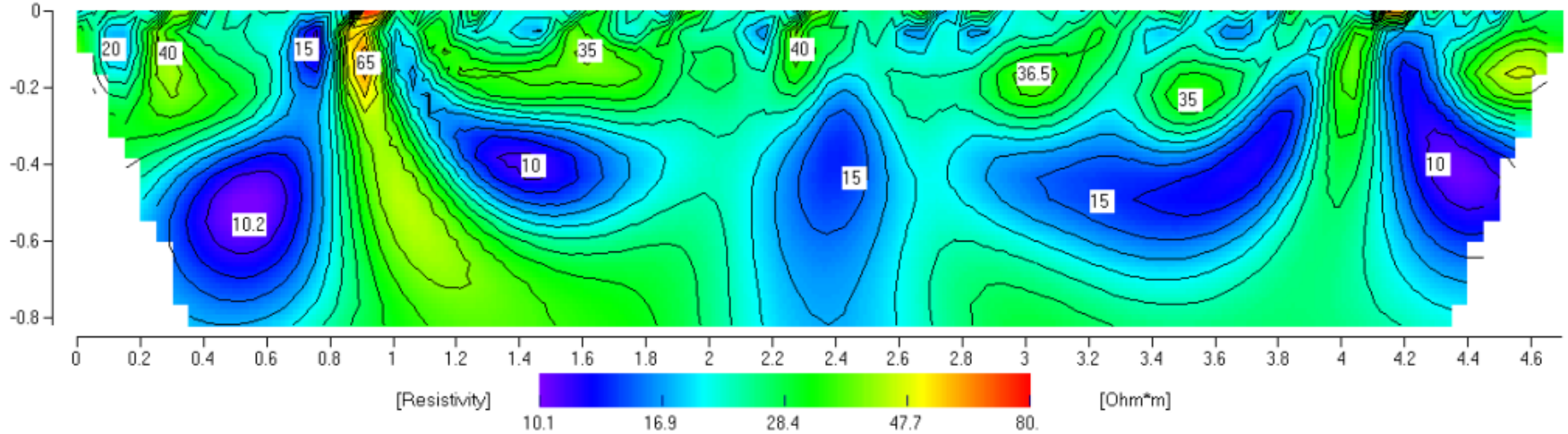



No Tillage

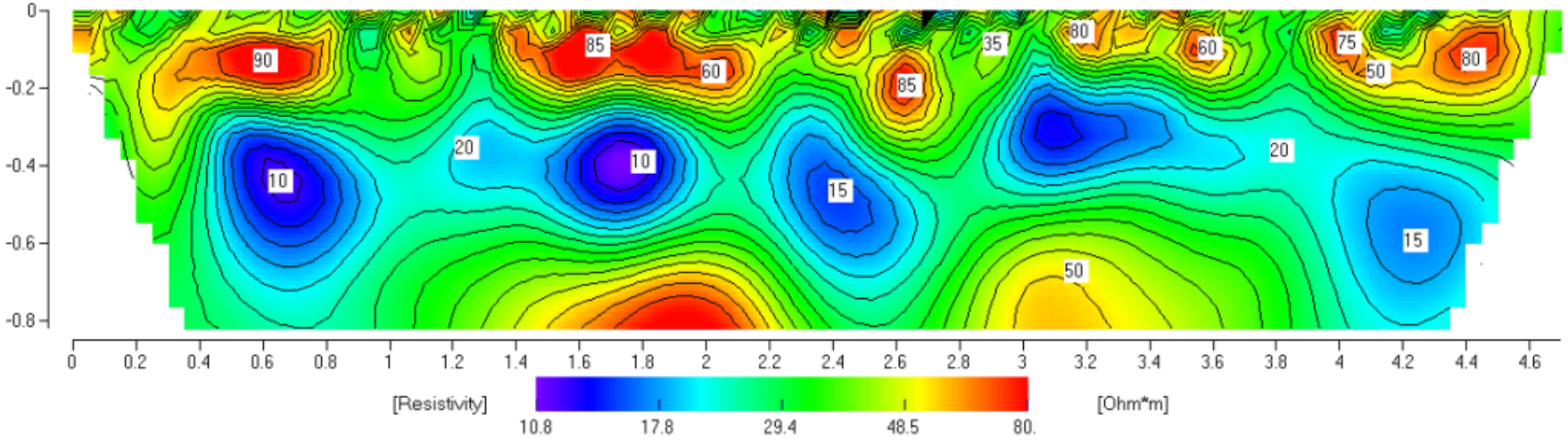



Basso et al., 2010 Agron J.

# No Tillage

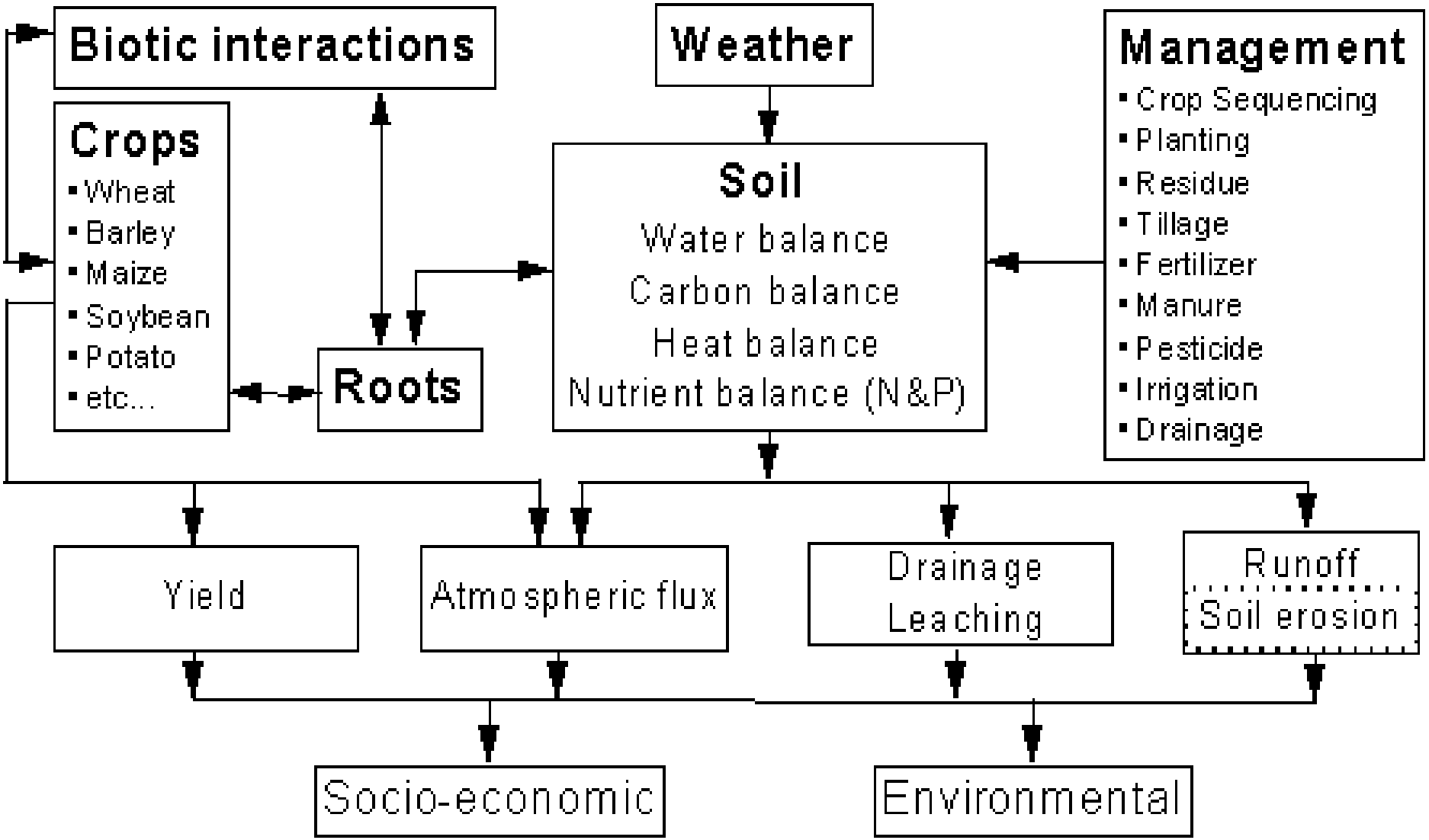



# No Tillage plot right after a tillage event

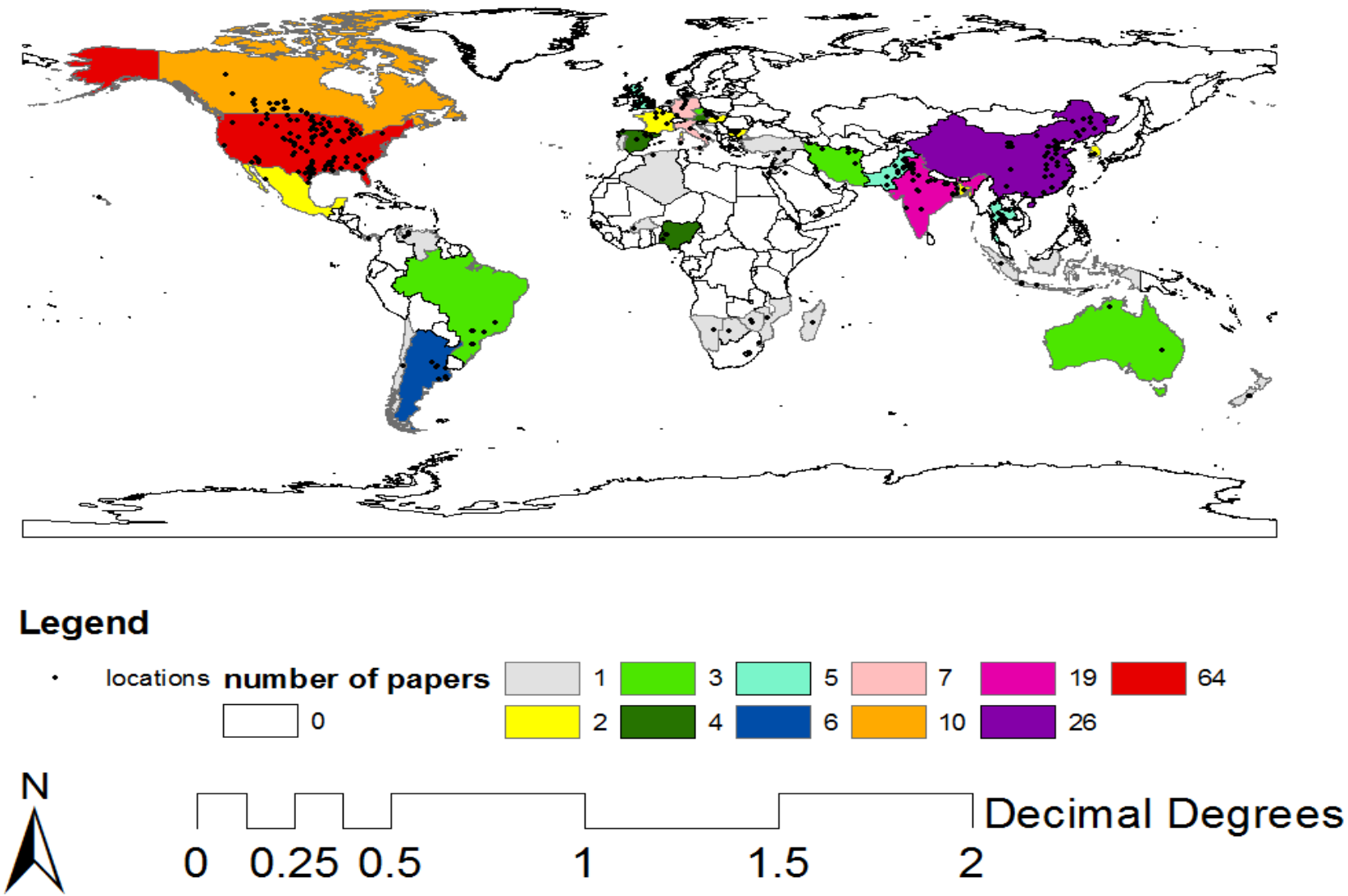



Basso et al., 2010 Agron J.

# SALUS
# (System Approach for Land Use Sustainability)



# Model validation




Basso et al., 2014


# Welcome to SALUS with Simple Interface


- Specify soil and weather data

SALUS SIMPLE

Hello Joshua~ logout

In this screen you can enter soil and weather input

## MANAGEMENT

Step 2/2

### General

How do you till the soil:

Minimum Tillage

What crop are you planting:

Maize

In which month do you plant the crop:

June

How many times do you apply N fertilizer:

2

How much N fertilizer do you apply:

25 (kg/ha)

In which months do you apply N fertilizer:

1st: June

2nd: July

Do you apply manure or compost:

No Yes

If yes how much

2000 (kg/ha)

Do you irrigate the crop:

No Yes

How do you handle crop residues:

Incorporated with tillage

### Problems

Do you have problems of weeds:

No

Do you spray for weeds:

No Yes

Do you have problems of plant diseases:

No

Do you spray for plant diseases:

No Yes

Submit

- Specify management strategies

# Variability

Spatial

Temporal

Static Properties
(soil texture, pH etc..)

Dynamic Prop.
(within the year-
soil water content
nitrates)

Variation
(from year to year)

Agronomic
Management
(timing of tillage/planting;
plant population)

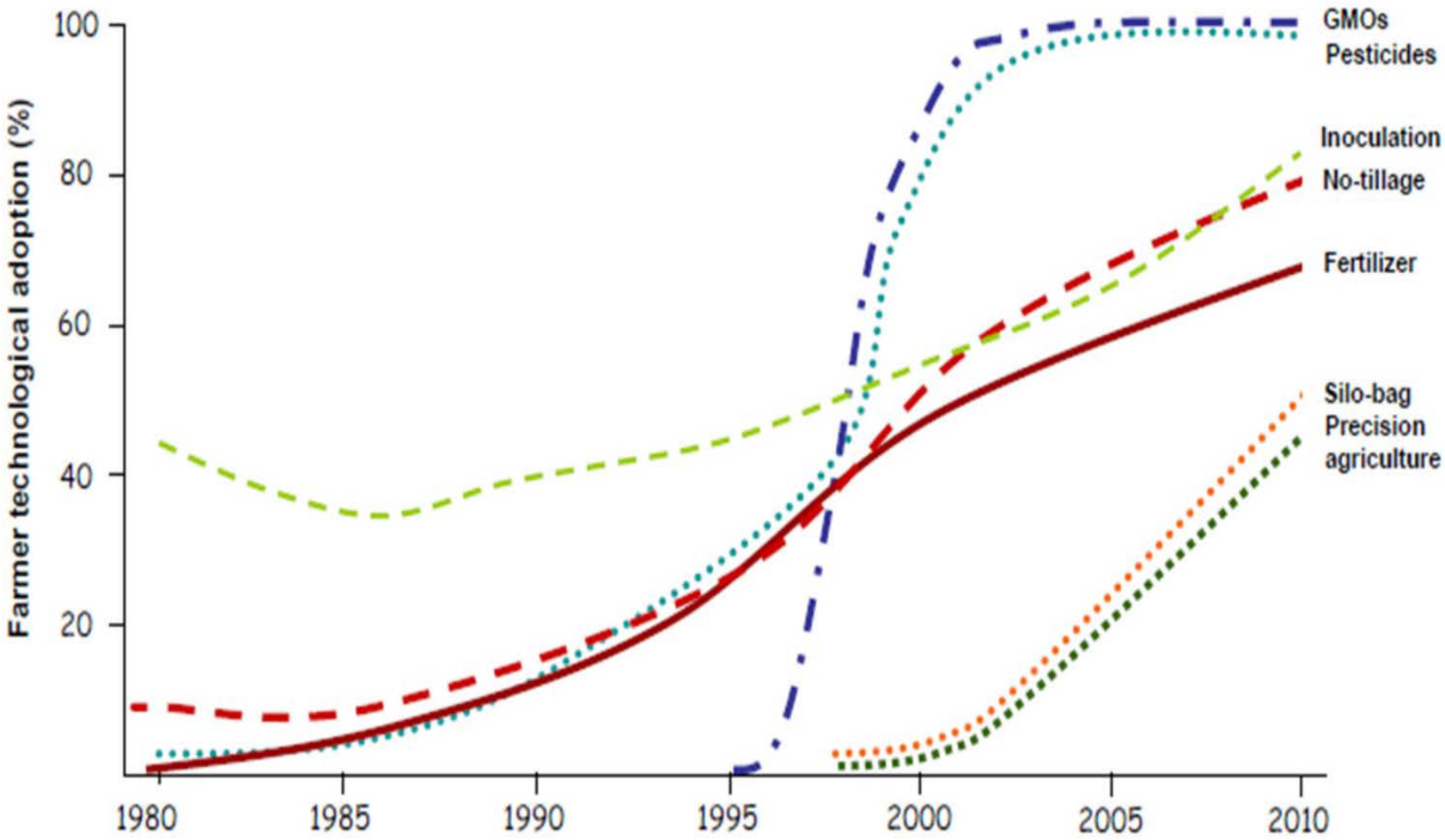
# Precision Agriculture

..is the application of technologies and principles to manage spatial and temporal variability associated with all aspects of agricultural production for the purpose of improving crop performance and environmental quality.

***...applying the Right input***
***in the Right amount***
***at the Right time***
***in the Right place***
***in the Right manner***

Pierre Robert

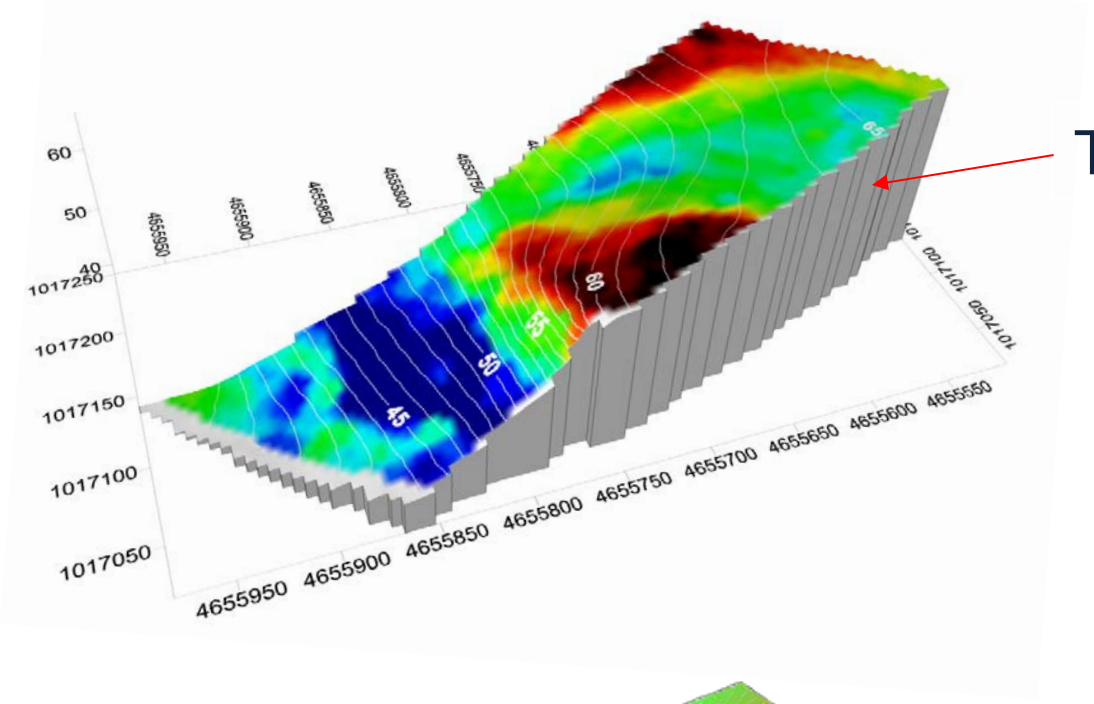
1990 - 2014



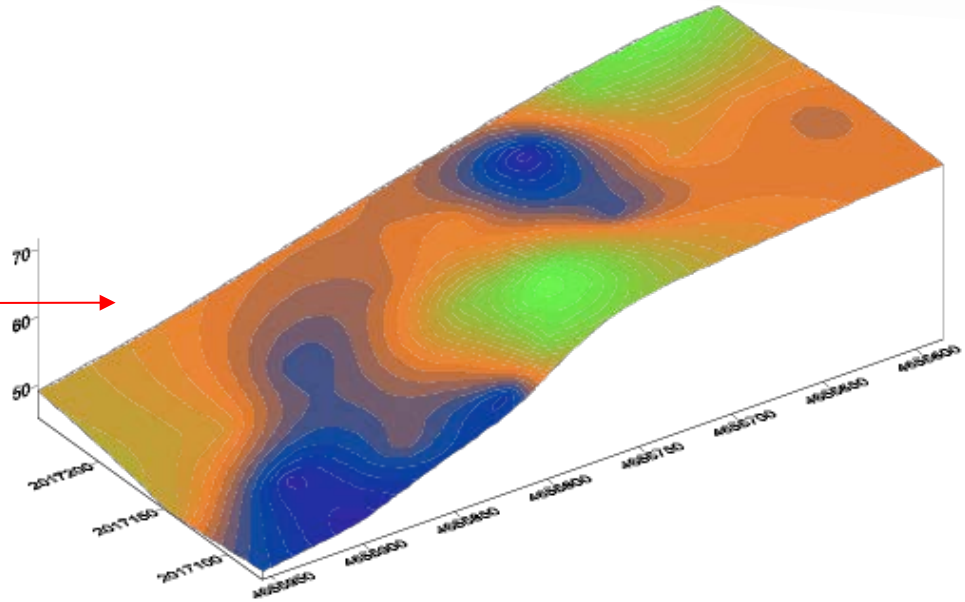

Argentina. Source. INTA Mendes Bragachini Precision Agriculture

# Homogeneous zones

Tomography




Yield

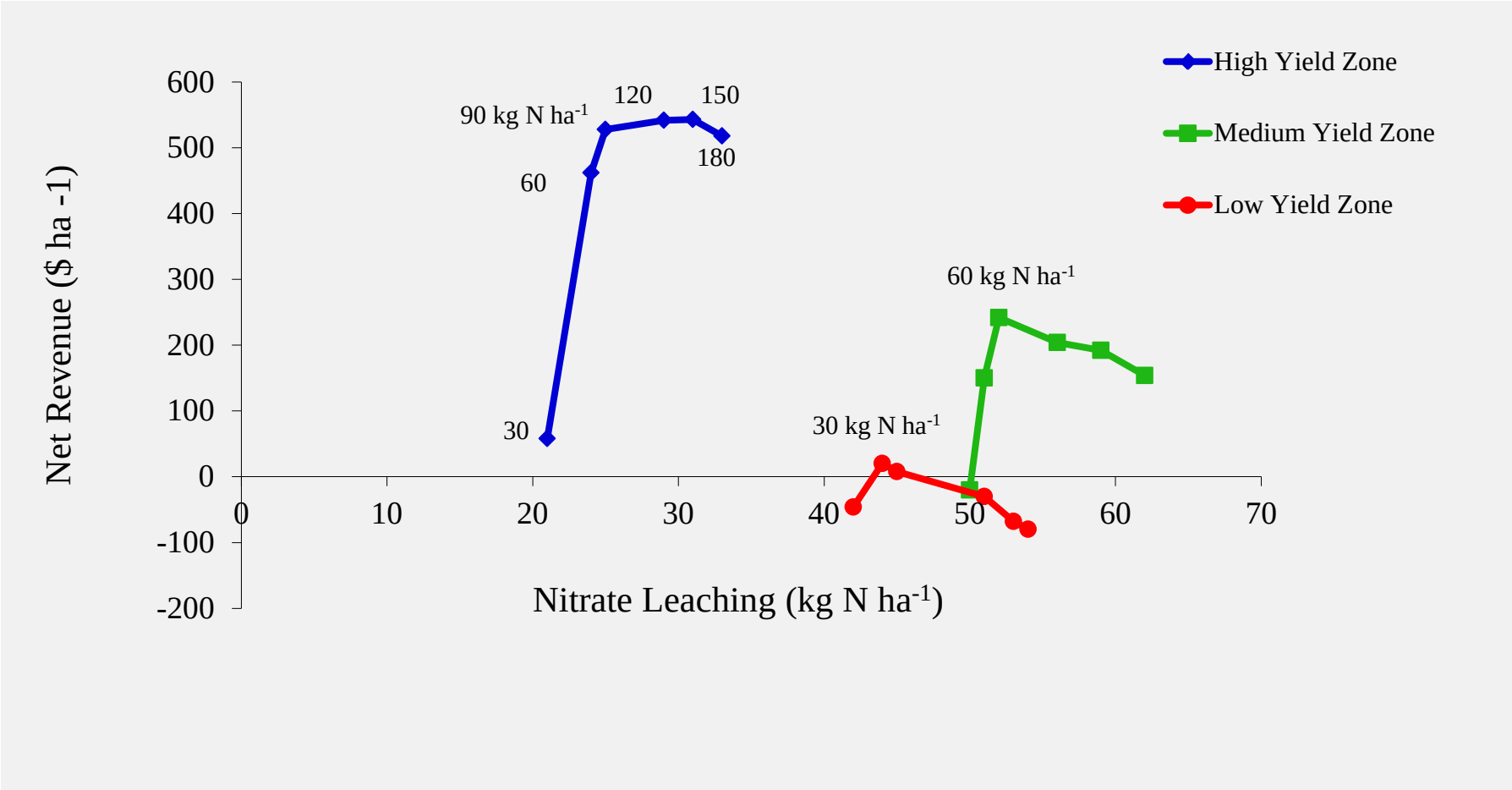



High Yield Zone

Medium Yield Zone

Low Yield Zone

# Strategic and tactical N management using SALUS

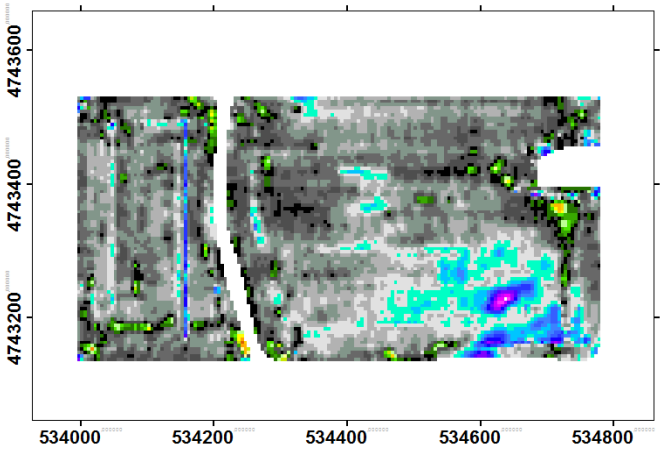



Dual criteria optimization through tested model determines the N rate that minimizes nitrate leaching and increases net revenues for farmers

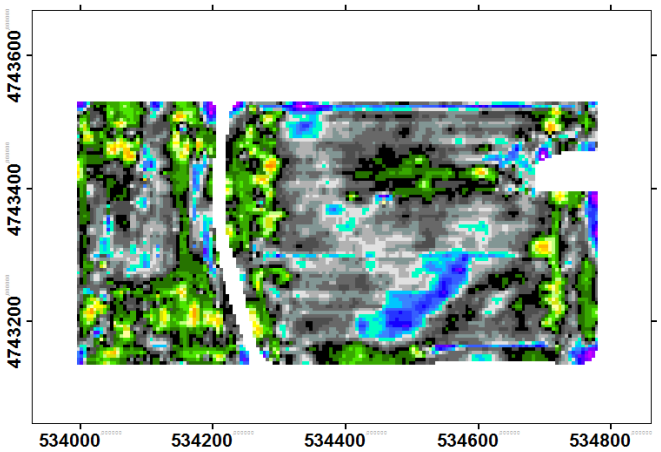
(Basso et al., 2011; Eur J. Agron 35:215–222)

# Yield Maps

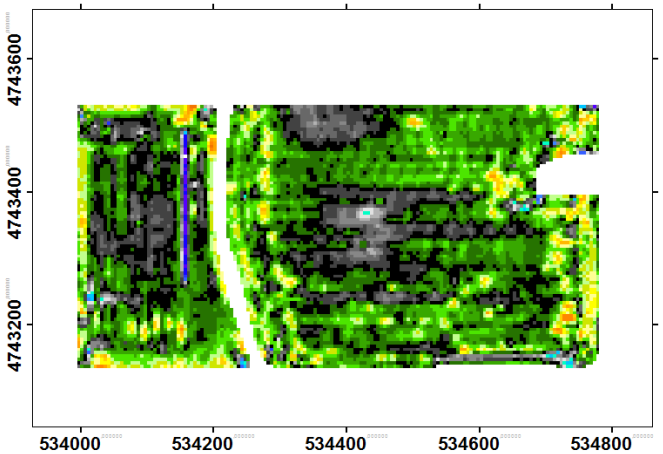
## Yield 2009



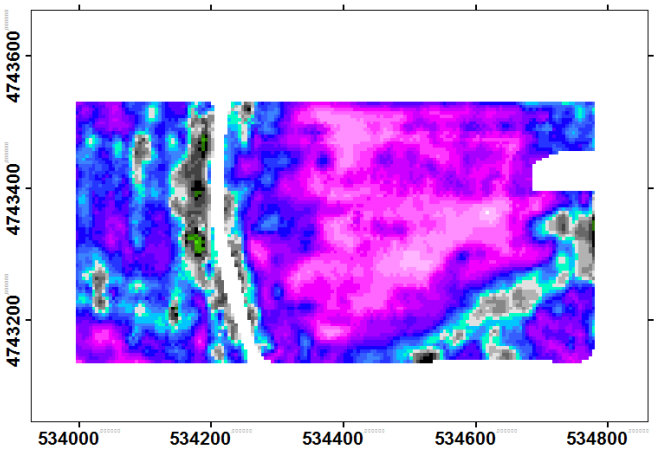

## Yield 2010




## Yield 2011



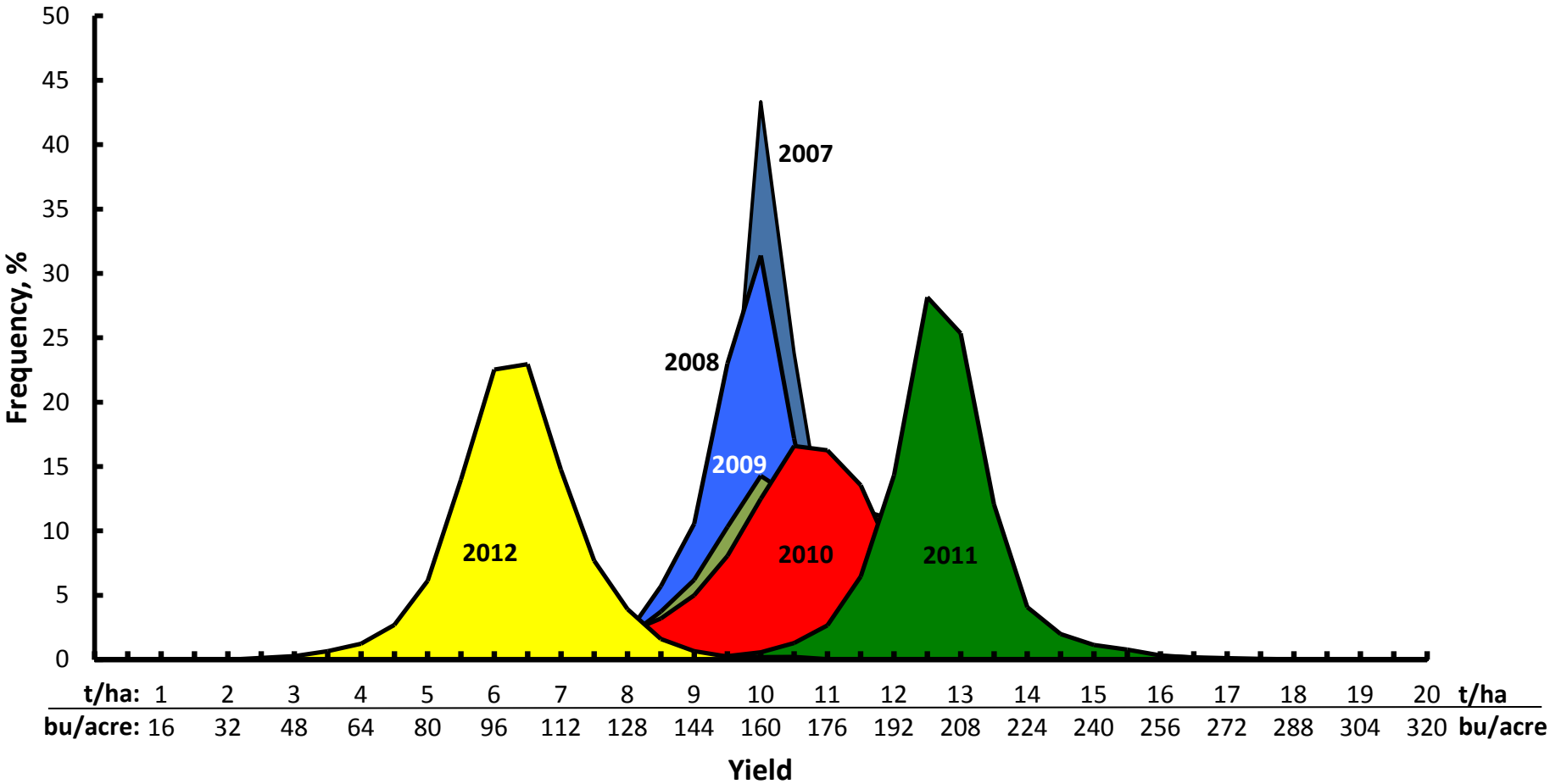

## Yield 2012




**Yield (Kg/ha)**

- 500 - 1000
- 1000,1 - 1500
- 1500,1 - 2000
- 2.000,1 - 2.500
- 2.500,1 - 3.000
- 3.000,1 - 3.500
- 3.500,1 - 4.000
- 4.000,1 - 4.500
- 4.500,1 - 5.000
- 5.000,1 - 5.500
- 5.500,1 - 6.000
- 6.000,1 - 6.500
- 6.500,1 - 7.000
- 7.000,1 - 7.500
- 7.500,1 - 8.000
- 8.000,1 - 8.500
- 8.500,1 - 9.000
- 9.000,1 - 9.500
- 9.500,1 - 10.000
- 10.000,1 - 10.500
- 10.500,1 - 11.000
- 11.000,1 - 11.500
- 11.500,1 - 12.000
- 12.000,1 - 12.500
- 12.500,1 - 13.000
- 13.000,1 - 13.500
- 13.500,1 - 14.000
- 14.000,1 - 14.500
- 14.500,1 - 15.000
- 15.000,1 - 15.500
- 15.500,1 - 16.000
- 16.000,1 - 16.500
- 16.500,1 - 17.000
- 17.000,1 - 17.500
- 17.500,1 - 18.000
- 18.000,1 - 18.500
- 18.500,1 - 19.000
- 19.000,1 - 19.500
- 19.500,1 - 20.000

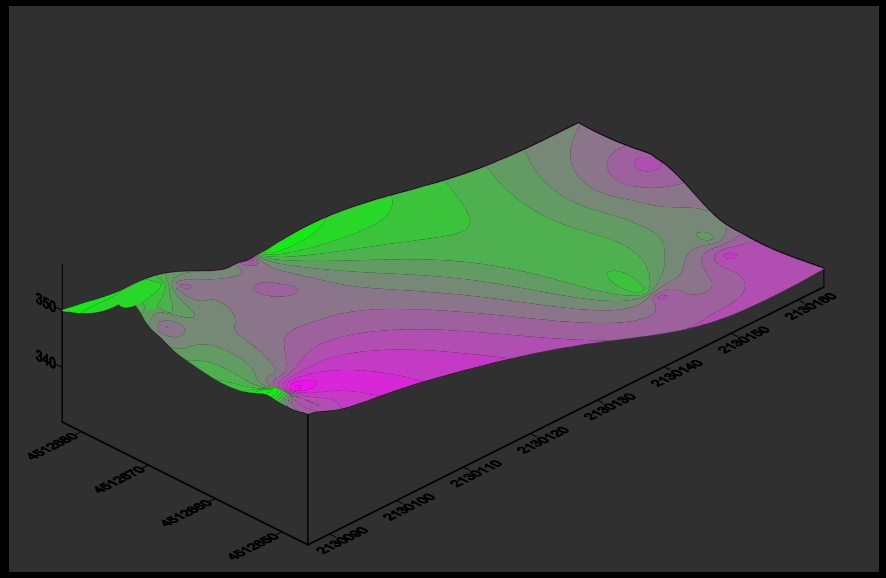
# 6 Years of Yields in a Single Field



# Management Zones Delineation

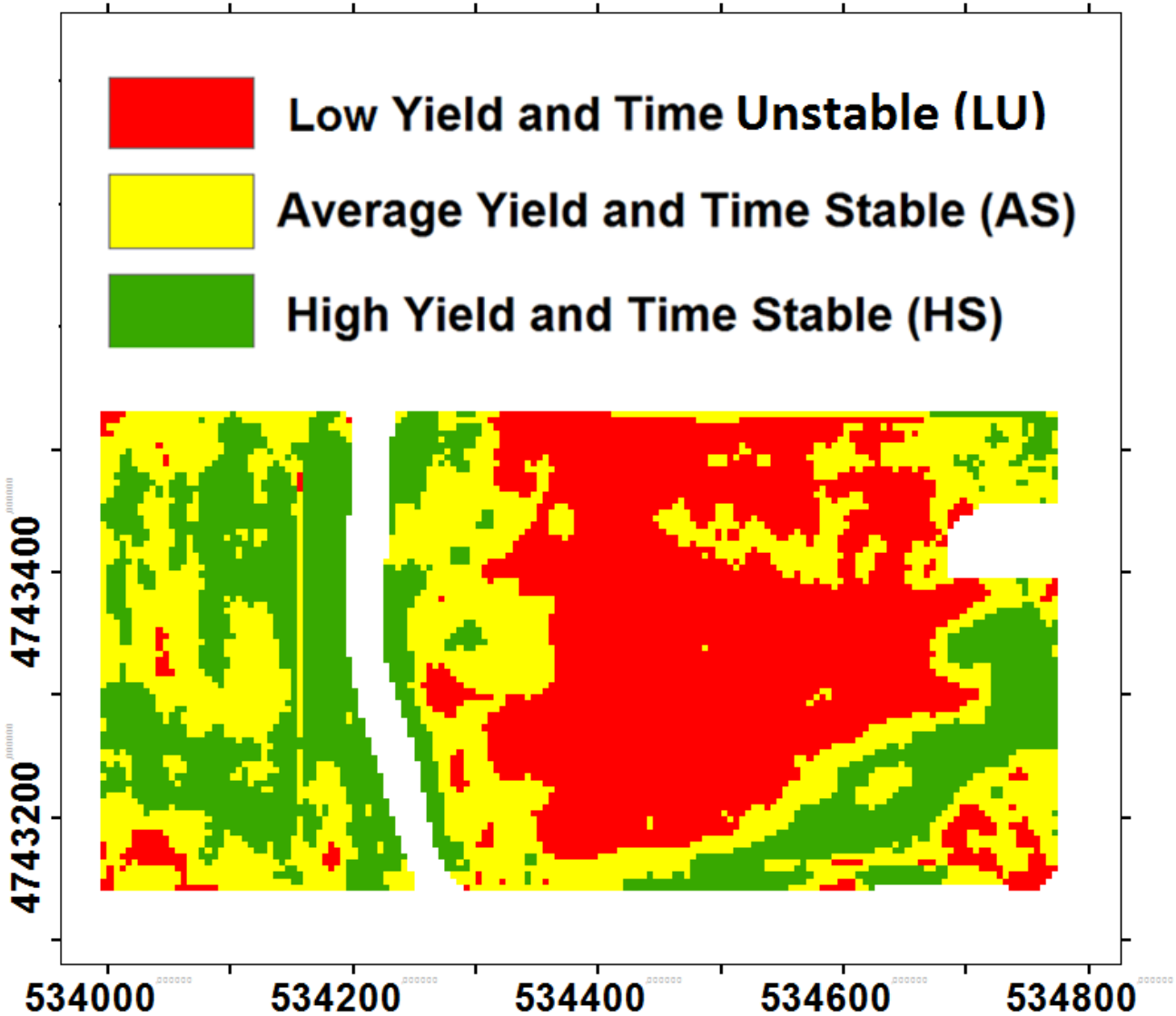
Various authors have proposed criteria for the delineation of management zones based on:

- Topography, landscape position
- Soil Type
- Nutrient levels
- Yield
- EC
- Remote sensing and aerial photos
- Producers experiences

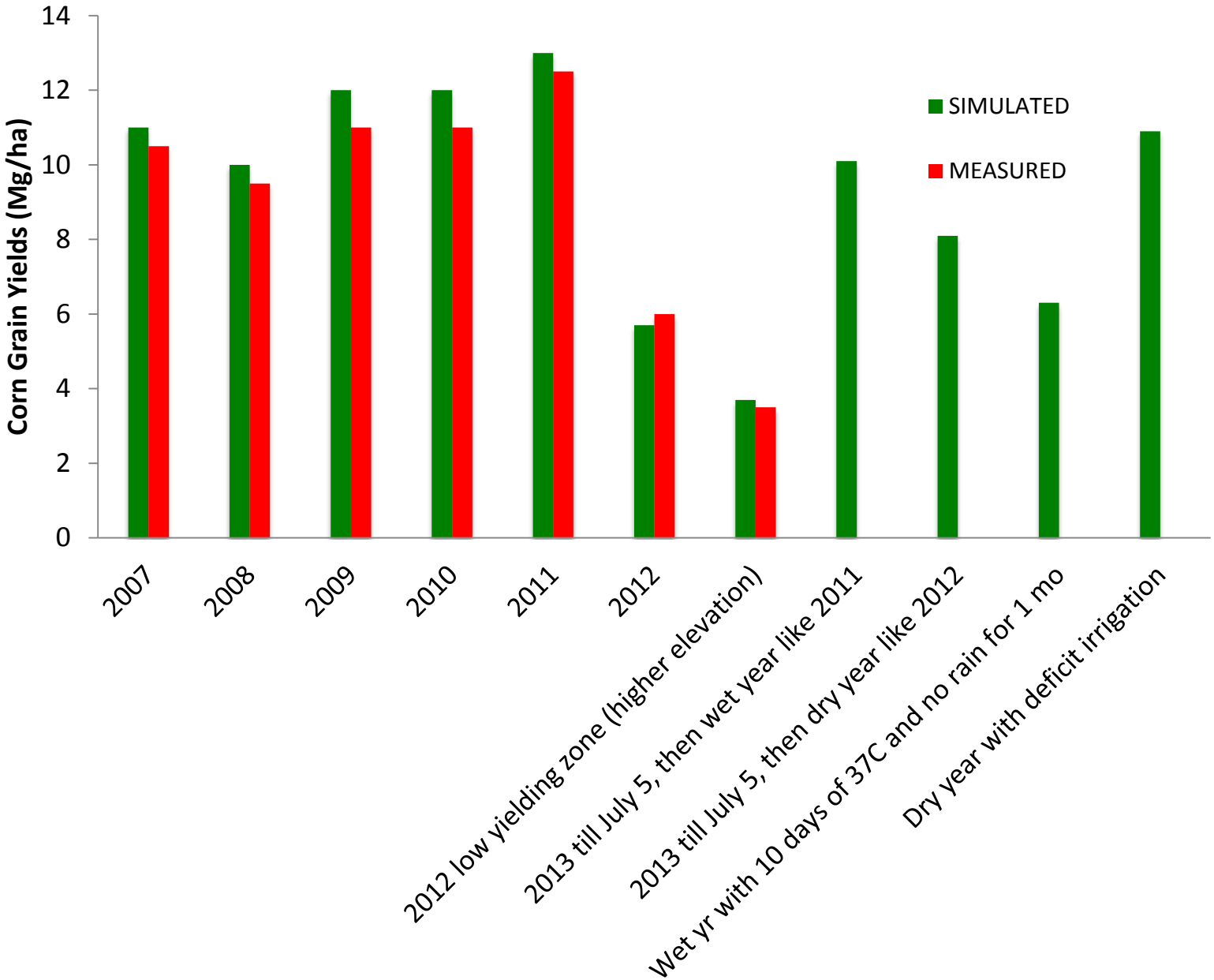


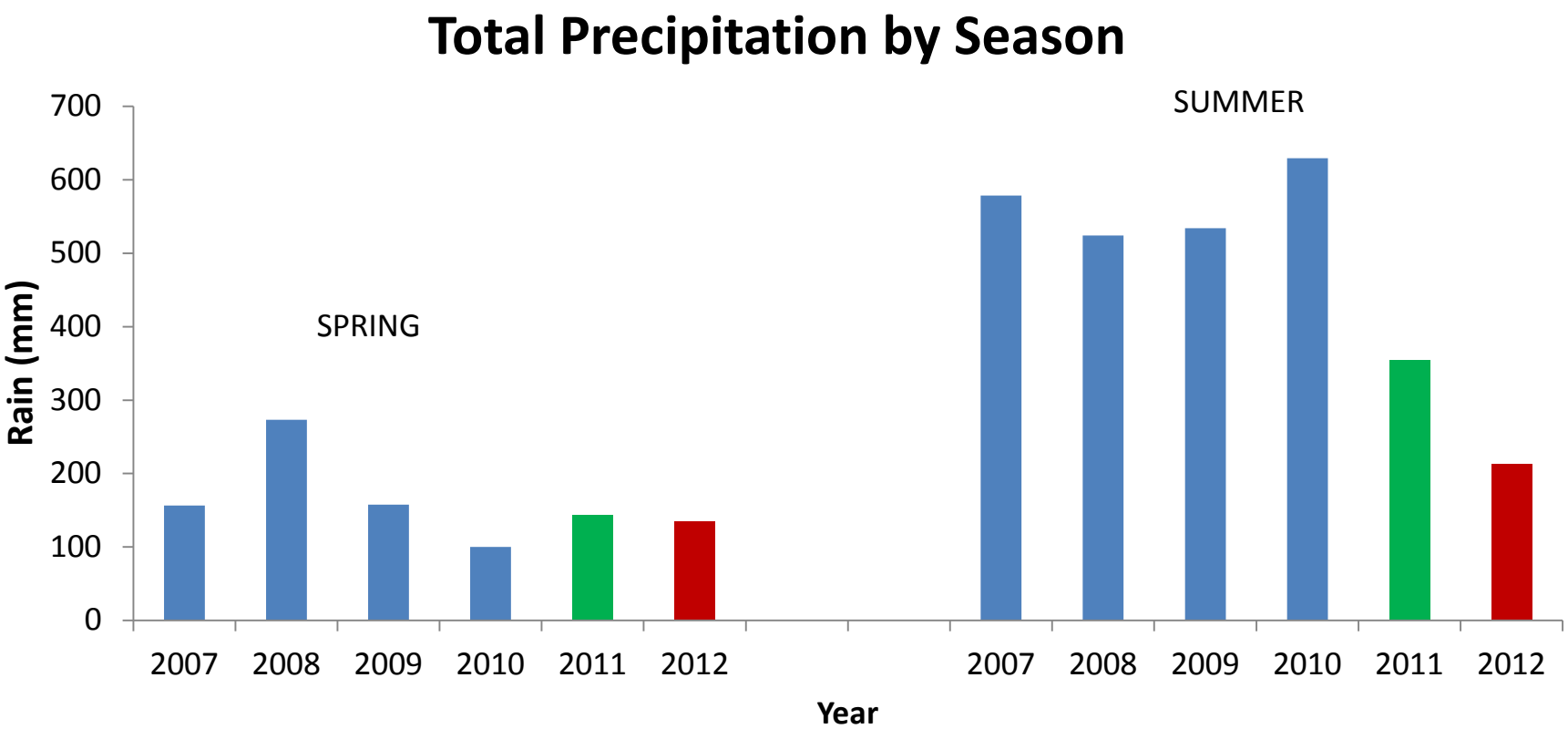

*(Fiez et al.,1994; Ostergaard, 1997; Franzen et al., 2001; Basso et al., 2001; Johnson et al., 2003; Ferguson et al., 2004; Schepers et al., 2004, Chang et al., 2004; Fleming et al.,2004; Inman et al., 2005); Basso et al., 2007,2011)*

# Stability Map



# SALUS Simulations

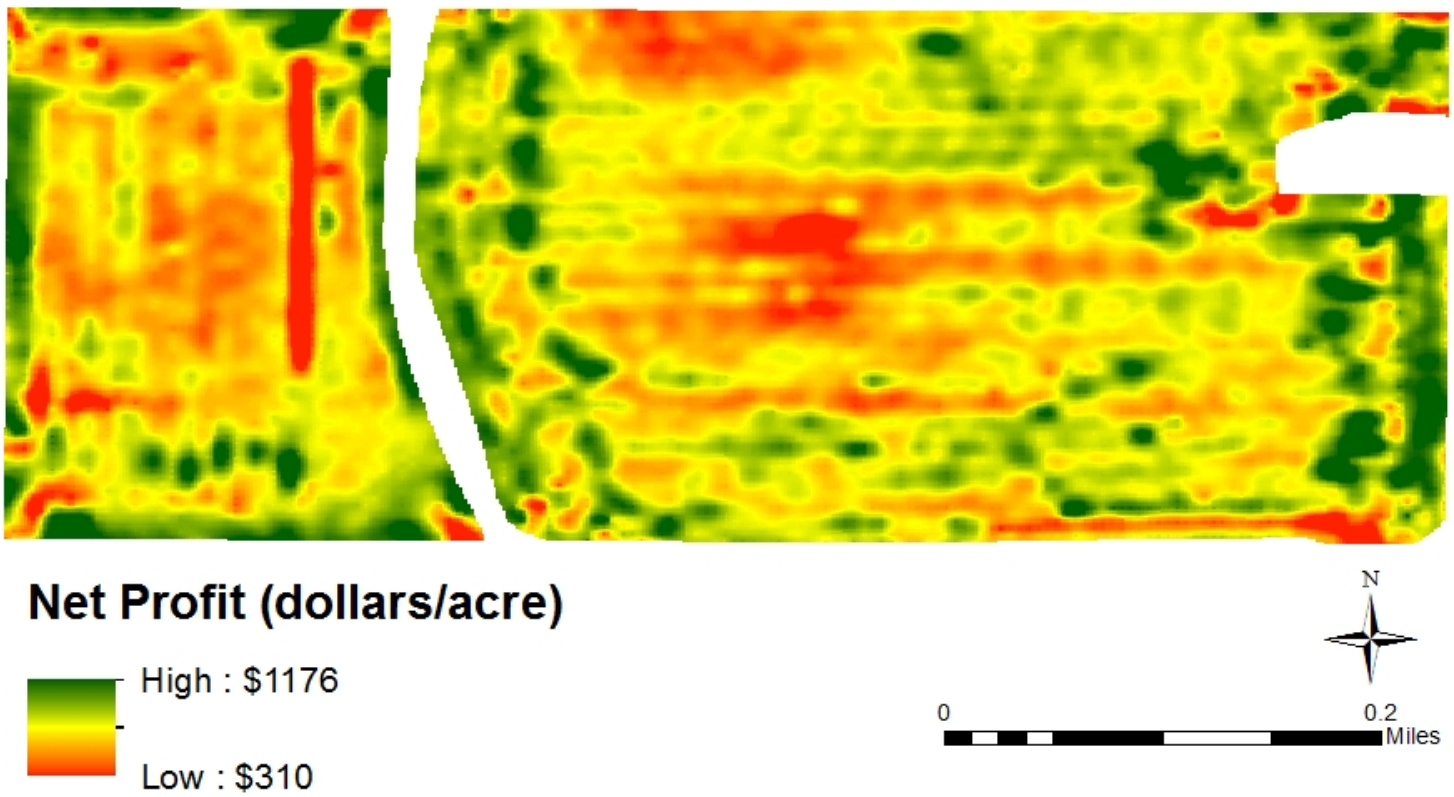





Basso and Ritchie, 2014 Nature Climate Change

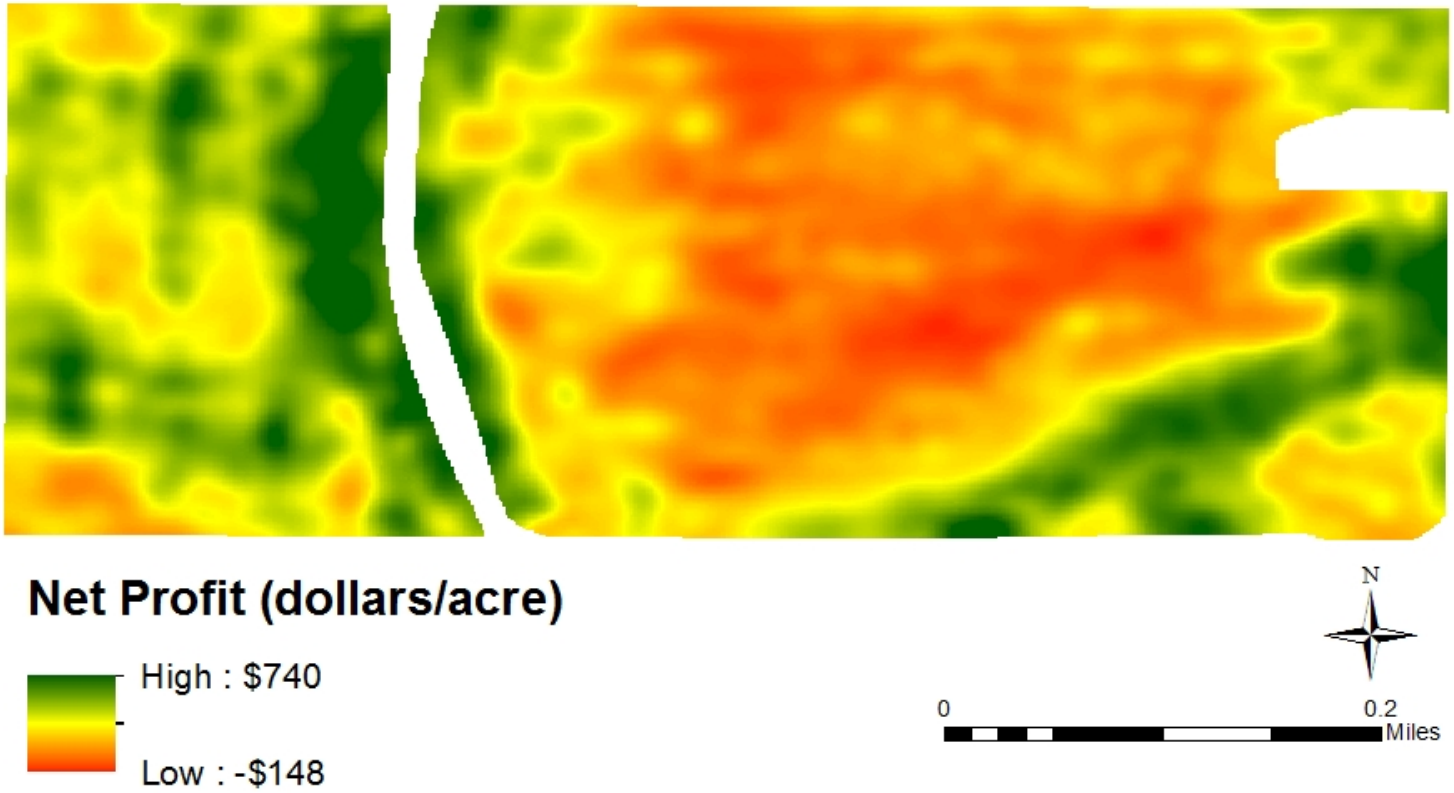
# SALUS Profit Zones: 2011

Green: Profit  Red: Lower Profit  Avg: $740/acre



# SALUS Profit Zones: 2012

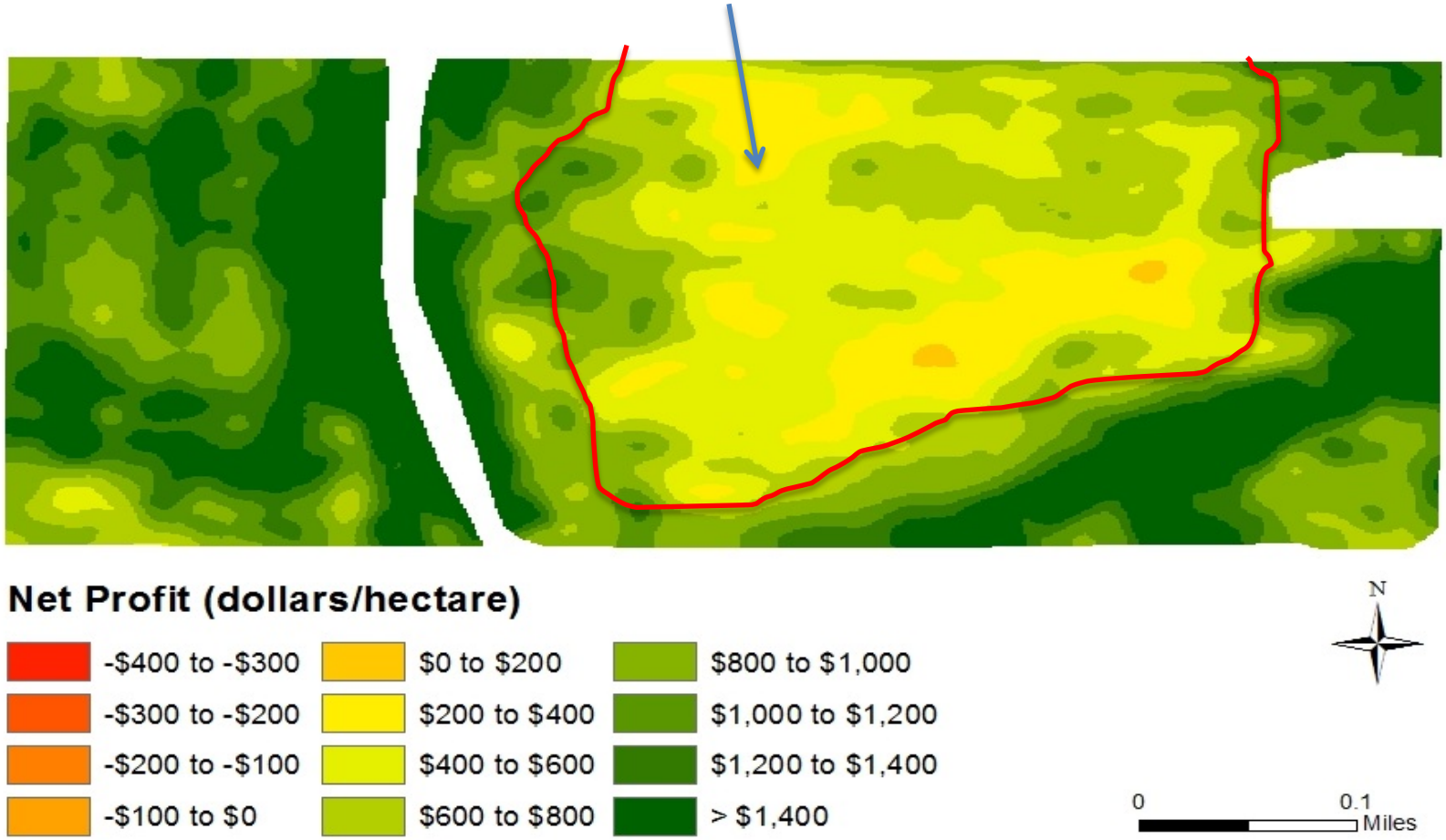
Green: Profit  Red: Loss  Avg: $194/acre



# SALUS Profit Zones: 2012

Green: Profit  Red: Loss  Avg: $428/acres

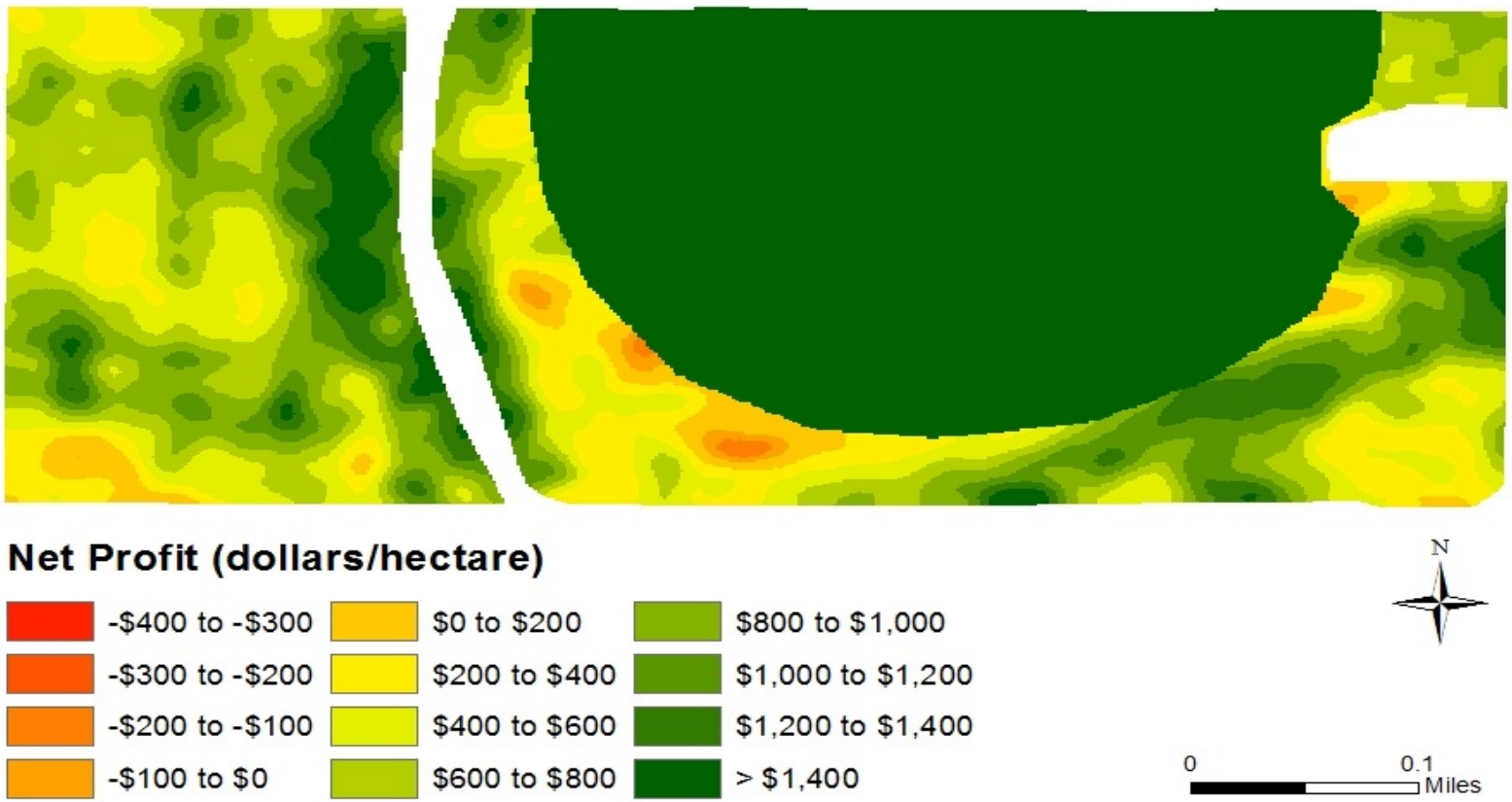
2012, Only 30 # N/ac



# SALUS Profit Zones: 2012

Green: Profit  Red: Loss  Avg: $980/acres

## 2012, Irrigated 200 # N/ac



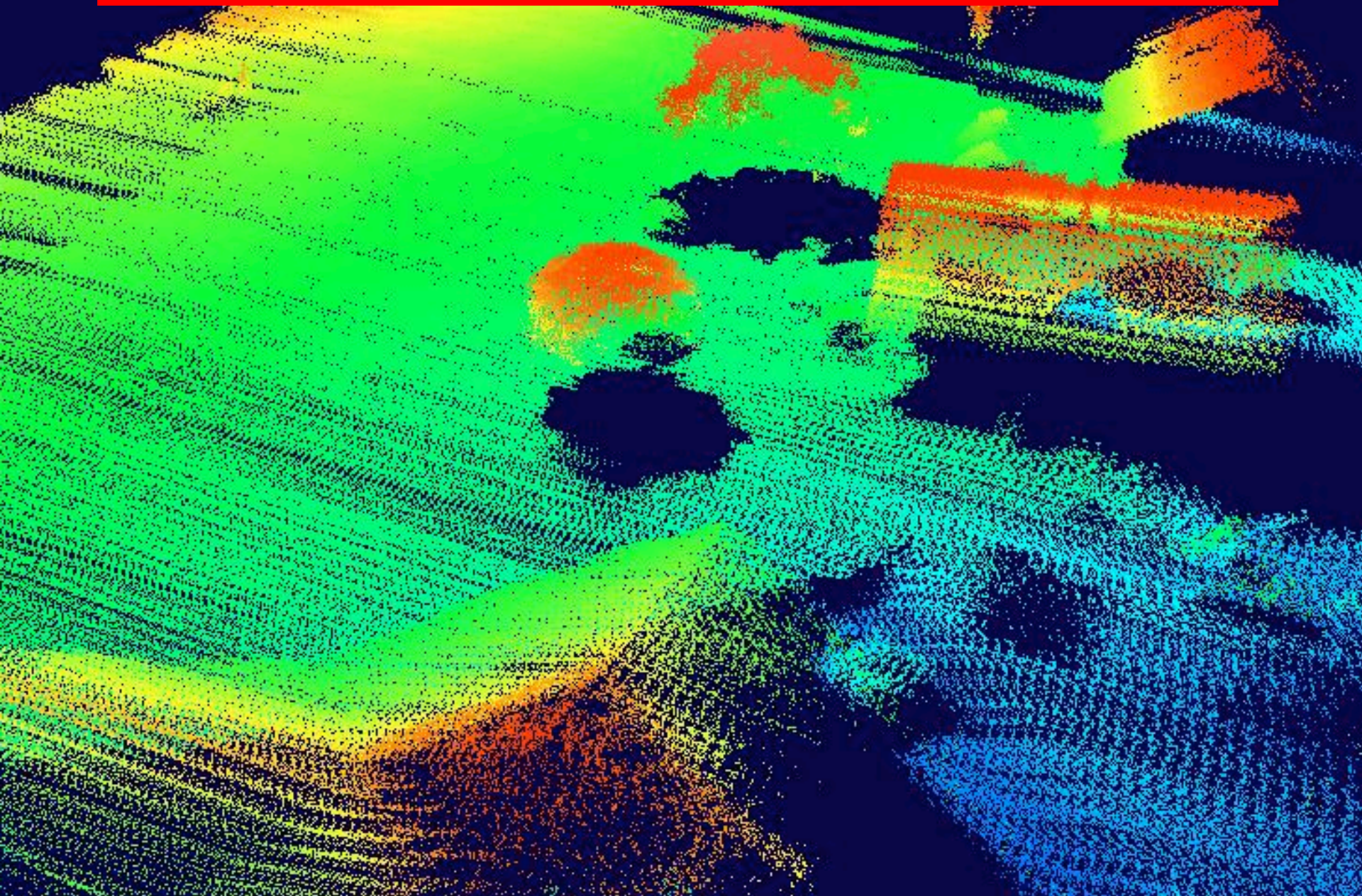
UAV model: mdr4-1000 – microdrones.com

**md4-1000 is equipped with RGB digital video-camera, thermal camera, hyperspectral, laser scanner.**

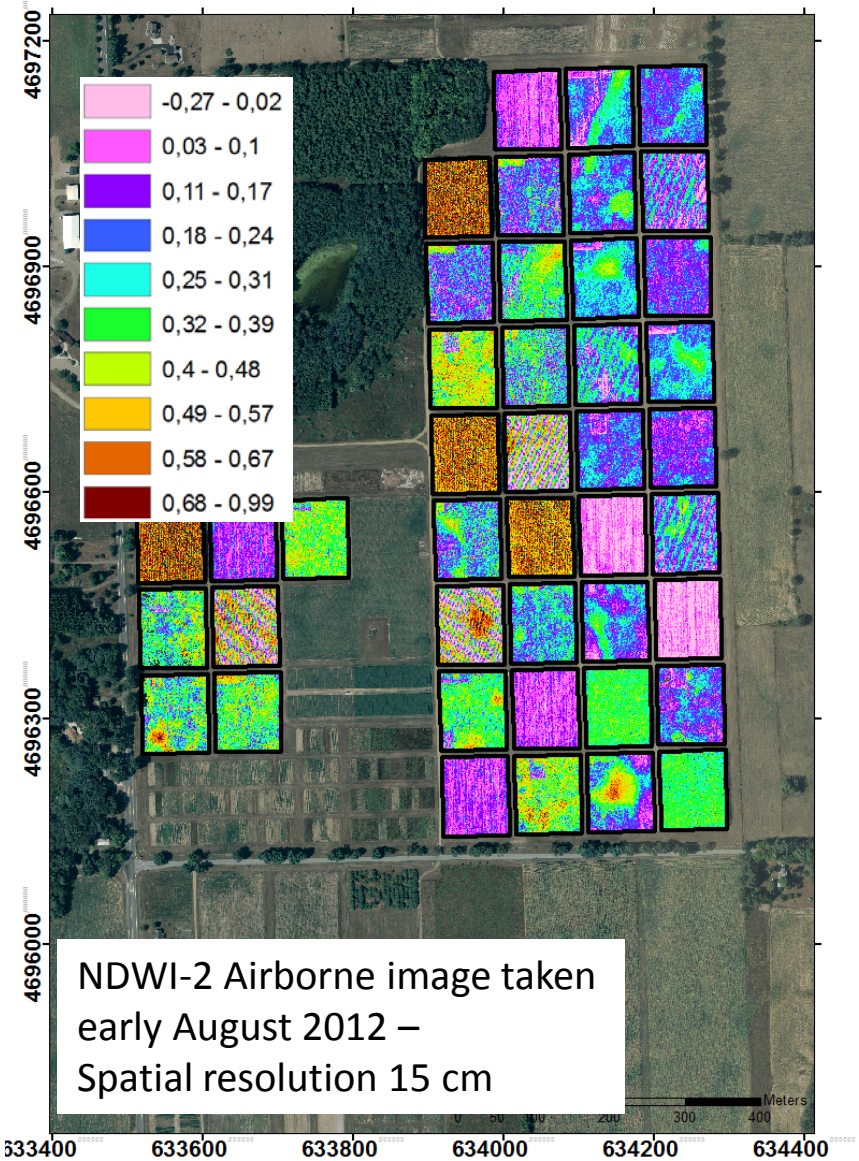
**Spatial resolution < 1 cm (1-7cm)**
**Payload 1.5 kg, Flying time 30-45 minutes with 1 battery**

# Laser scanner imagery from UAV

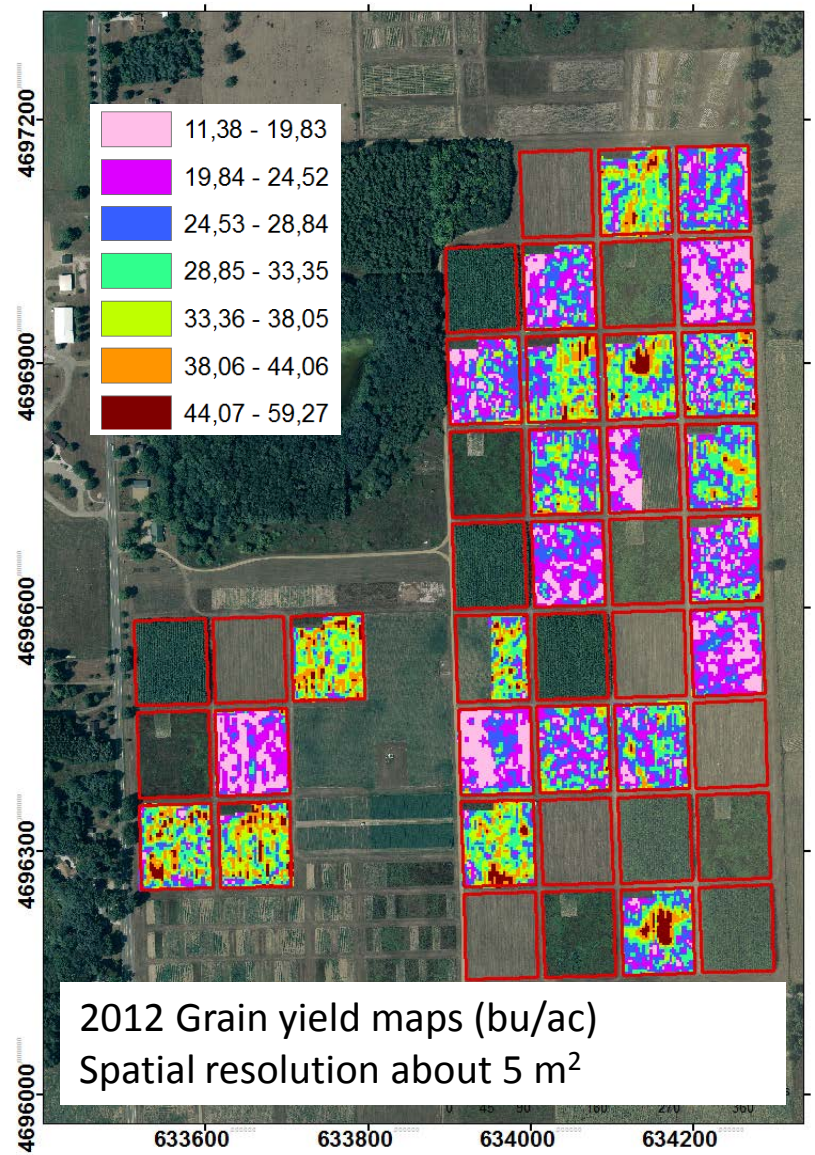
(microdrone md-1000)



# The 2012 drought provided an opportunity to study spatial variability of rooting depth and yield

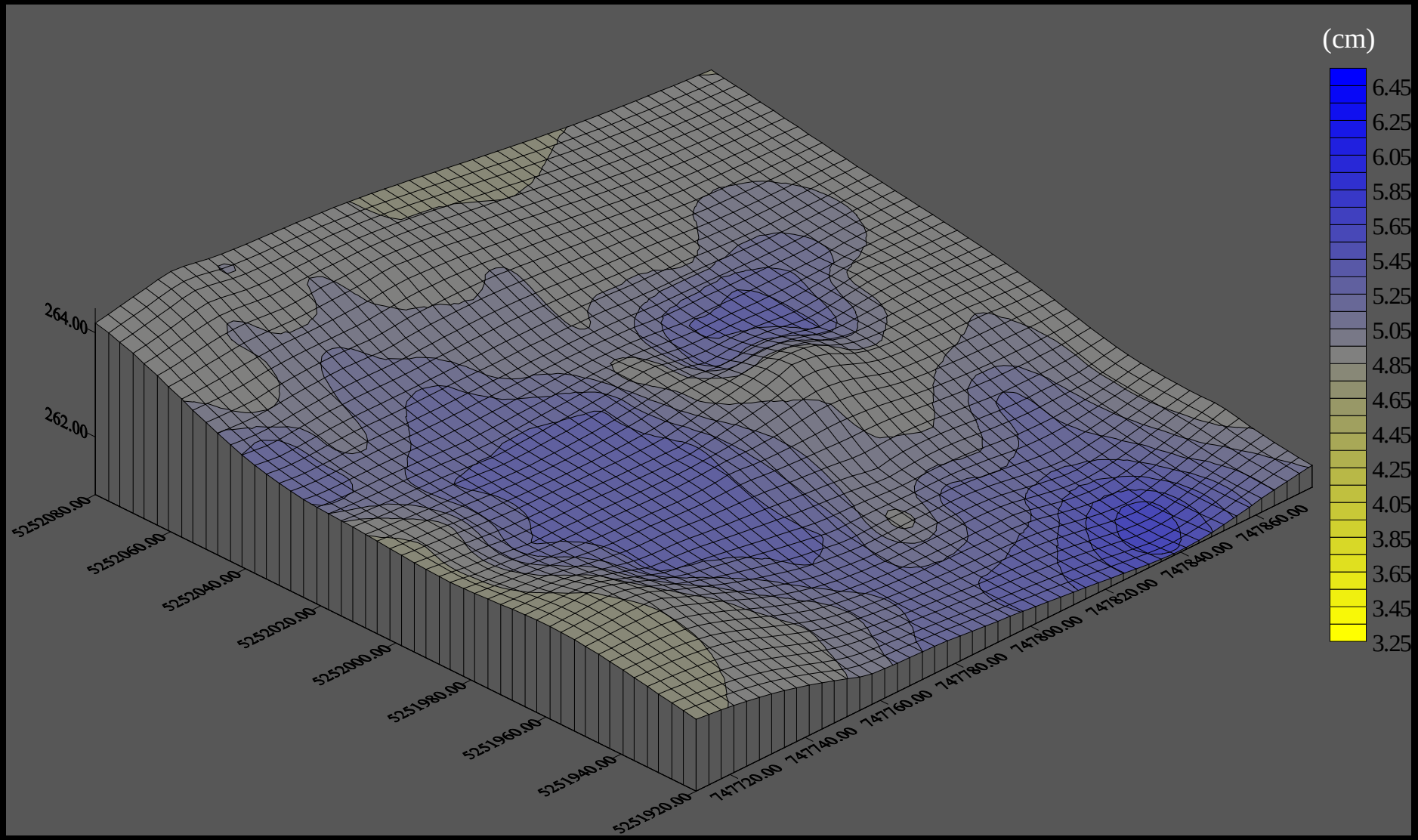



Normalized Difference Water Index 2
NDWI2 =(Green-NIR)/(Green+NIR)
Vegetation Index used to detect water content in plants




Yield Mapping for different crops

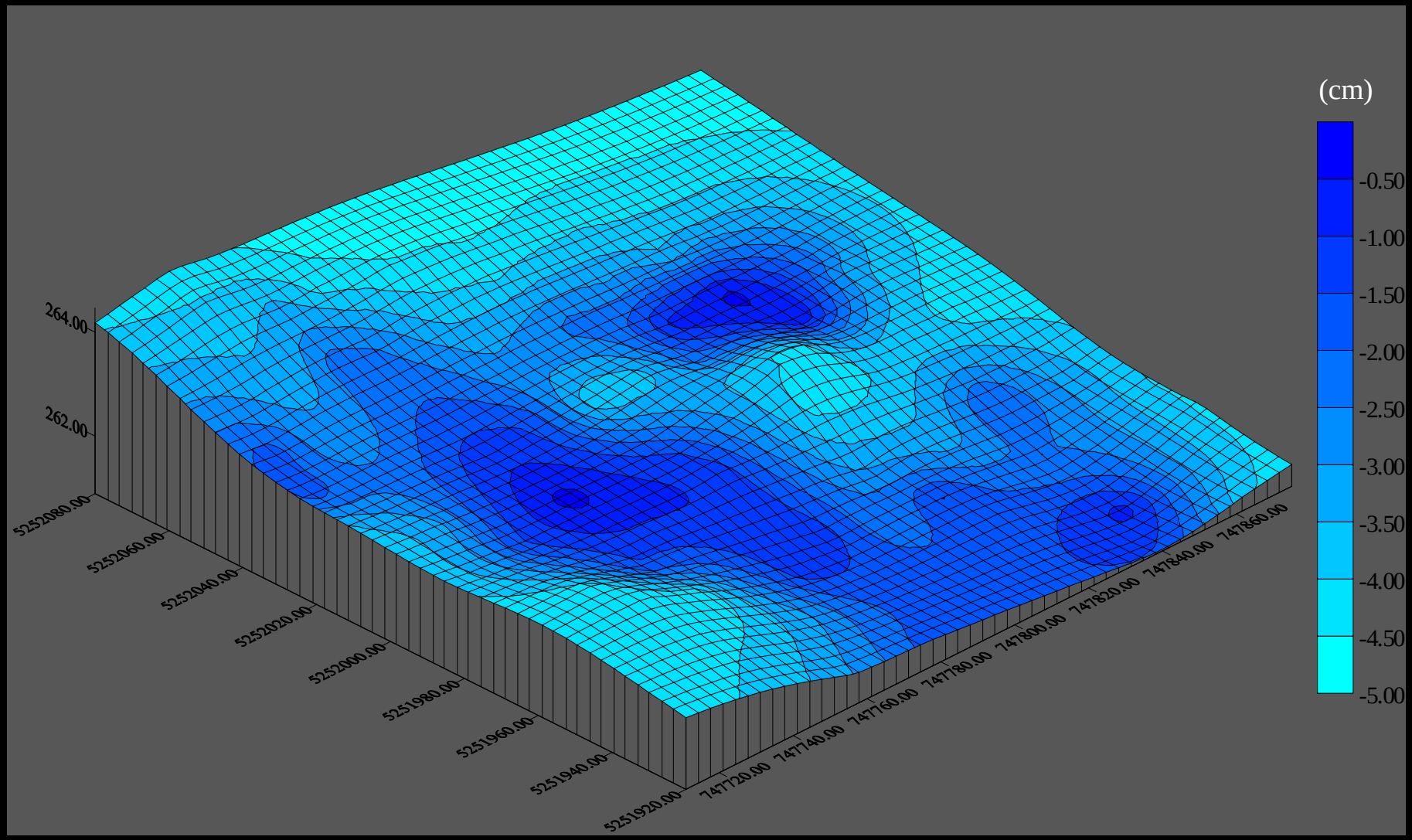
# Accounting for spatially connected processes




SALUS-TERRAE

Soil water content 0-30 cm

# Net surface flow (Runon-Runoff)




SALUS-TERRAE

# Conclusions

Site-specific management strategies may be able to optimize production, but their potential benefits are highly dependent on the accuracy of the assessment of such variability

Process-based crop models can play a significant role in the development of alternatives for obtaining sustainable crop production systems. They can quantify the effects of management practices, genetics, soil and weather on yield, crop quality and environmental impact over space and time.

SALUS model showed to be a valuable tool that would help farmers reduce their economic risk and environmental impact related to N.