Modeling Cropping Systems Strategies to Optimize Yield, Water and Nutrients

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2012 World Food Supply

5.5 billion gross tonnes; 2.8 billion tonnes dry weight

Edible dry matter, expressed in Kcals

Cereals 70%

Maize 22%
Wheat 21%
Rice 16%
Others 11%

Animal & fish products 8%
Legumes, oilseeds 4%
Roots & tubers 7%
Sugar 6%
Vegetables & melons 3%
Fruits 2%

Source: FAO AGROSTAT
Indian Wheat Production—Area Saved Through Adoption of High-Yield Technology

- **Production, Million tonnes**
  - 1961: 11
  - 2011: 86

- **Av. Yield. t/ha**
  - 1961: 0.85
  - 2011: 3.50

- **Population, Millions**
  - 1961: 452
  - 2011: 1,230

Source: FAOSTAT, 2012
The accurate response to drought is crucial. The contribution of the depth below 1 m can be important.
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 plot right after a tillage event

Basso et al., 2010 Agron J.
SALUS
(System Approach for Land Use Sustainability)
Model validation

Legend

- locations
- number of papers

Basso et al., 2014
Welcome to the SALUS model-simple interface. SALUS is a computer simulation crop model designed to improve crop production and reduce environmental impact. In this web page users by answering a set of simple questions (i.e. soil type, planting details, fertilizer, irrigation, etc.) can simulate the effect of a management strategy on crop yield, nitrate leaching and carbon sequestration.
• Specify soil and weather data
• Specify management strategies
Variability

Spatial

Static Properties
(soil texture, pH etc.)

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

Temporal

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
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)
6 Years of Yields in a Single Field

Yield

Frequency, %

0 5 10 15 20 25 30 35 40 45 50

2007 2008 2009 2010 2011 2012

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20

0 5 10 15 20 25 30 35 40 45 50

Yield

t/ha: 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20

bu/acre: 16 32 48 64 80 96 112 128 144 160 176 192 208 224 240 256 272 288 304 320

bu/acre
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

- **Low Yield and Time Unstable (LU)**
- **Average Yield and Time Stable (AS)**
- **High Yield and Time Stable (HS)**
SALUS Simulations

Corn Grain Yields (Mg/ha)

- 2007
- 2008
- 2009
- 2010
- 2011
- 2012
- SIMULATED
- MEASURED

- 2012 low yielding zone (higher elevation)
- 2013 till July 5, then wet year like 2011
- 2013 till July 5, then dry year like 2012
- Wet yr with 10 days of 37°C and no rain for 1 mo
- Dry year with deficit irrigation
Total Precipitation by Season

Basso and Ritchie, 2014 Nature Climate Change
SALUS Profit Zones: 2011

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

Net Profit (dollars/acre)

High: $1176
Low: $310
SALUS Profit Zones: 2012

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

Net Profit (dollars/acre)

- High: $740
- Low: -$148
SALUS Profit Zones: 2012

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

2012, Only 30 # N/ac

Net Profit (dollars/hectare)

- $400 to -$300
- $300 to -$200
- $200 to -$100
- $100 to $0
- $0 to $200
- $200 to $400
- $400 to $600
- $600 to $800
- $800 to $1,000
- $1,000 to $1,200
- $1,200 to $1,400
- > $1,400

0 0.1 Miles
SALUS Profit Zones: 2012
Green: Profit  Red: Loss  Avg: $980/ acres

2012, Irrigated 200 # N/ac

Net Profit (dollars/hectare)

- $400 to - $300
- $300 to - $200
- $200 to $400
- $400 to $600
- $600 to $800
- $800 to $1,000
- $1,000 to $1,200
- $1,200 to $1,400
- > $1,400
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

2012 Grain yield maps (bu/ac)
Spatial resolution about 5 m²

NDWI-2 Airborne image taken early August 2012 – Spatial resolution 15 cm

Yield Mapping for different crops
Accounting for spatially connected processes

Soil water content 0-30 cm

SALUS-TERRAE
Net surface flow (Runon-Runoff)
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.