Precision Agriculture for Food Security and Sustainable Development in China

Yuxin Miao
China Agricultural University
Chinese Agriculture: Success at High Costs

Grain Yield (100 Mt) / Planting Area (100 MHa)

Grain Demand

Grain Yield

Irrigation Area

Chemical Fertilizer

Pesticide

Plastic Mulch

Planting area

(Zhang, F., 2014)
Challenges of Chinese Agriculture

Decreasing Nitrogen Use Efficiency

Zhang et al., 2015. Nature
Challenges of Chinese Agriculture

Water Pollution

Strokal et al., 2016. Environmental Research Letters
Challenges of Chinese Agriculture

Water Pollution

China’s area lake eutrophication reached 8700 km² (2007)
Challenges of Chinese Agriculture

Air Pollution

Air pollution in Beijing

Liu et al., 2013. Nature
Leverage Points of Sustainable Development

- **United States**
  - 8% irrigation* consumption
  - 11% excess nitrogen
  - 4% excess phosphorus
  - 13% N2O emissions

- **Brazil**
  - 34% tropical deforestation

- **Pakistan**
  - 15% irrigation* consumption

- **China**
  - 13% irrigation* consumption
  - 33% excess nitrogen
  - 36% excess phosphorus
  - 28% N2O emissions

- **India**
  - 36% irrigation* consumption
  - 19% excess nitrogen
  - 26% excess phosphorus

- **Indonesia**
  - 17% tropical deforestation

*West et al., 2014. Science*
Challenges of Chinese Agriculture

Food Security

Per Capita Food Consumption (kg/person) in China since 1980

China’s Policy: Achieve food self-sufficiency in staples (wheat and rice) against increasing population and consumption patterns

Challenges of Chinese Agriculture

Food Security

Sustainable Intensification

Sustainable Development
7.8 billion RMB has been invested to cover all agricultural areas (totally 2498 counties). The technology has been used for over 9 million ha cropland.
Increasing both NUE and Yield

Zhang et al., 2015. Nature
Sustainable Intensification of Agriculture

2011
Integrated soil–crop system management for food security
Xin-Ping Chen1,2, Zhen-Ling Cui1,3, Peter M. Vitousek1,3, Kenneth G. Cassman4, Pamela A. Matson4, Jin-Shun Bai5, Qing-Feng Meng6, Peng Hou6, Shan-Chao Yue7, Volker Römheld8, and Fu-Suo Zhang9,10
PNAS | April 19, 2011 | vol. 108 | no. 16 | 6399–6404

2013

Increased yield by 97%
Doubled NUE in maize
(66 field experiments)

MORE FOR LESS
Using farm designs informed by modelling, Chinese agricultural researchers are increasing yields in experimental plots and in farm studies while reducing the amount of resources.

2014

doi:10.1038/nature13609

Producing more grain with lower environmental costs
Xinping Chen1, Zhenling Cui1, Mingsheng Yan1, Peter Vitousek1, Ming Zhao1, Wenyi Ma1, Zhenbiao Wang3, Weijian Zhang1, Xianyu Yuan1, Jianzhuang Yang1, Xiping Deng1, Qing Cao1, Qing Zhang1, Shuwei Liu3, Jun Zan4, Shiqing Li5, Yuqiang Ye2, Zhaohui Wang2, Ranhao Huang2, Qiuyan Tang2, Yixiang Sun2, Xianlong Peng2, Ping Zhang2, Mingrong He2, Yunji Zhu2, Jiqiang Xue2, Guangliang Wang2, Liang Wu2, Ning An1, Liuming Wu1, Lin Ma1, Weifeng Zhuang1 & Fu-Suo Zhang9

Yield >30%
GHG >40%

China's scientists are using a variety of approaches to boost crop yields and limit environmental damage, say Fu-Suo Zhang, Xinping Chen and Peter Vitousek.
Large Scale Sustainable Intensification of Agriculture?
Spatial and temporal optimization of key factors influencing crop yield, profitability and environmental footprint.

Precision Agriculture for Smallholder Farmers?

Precision Agriculture: Supporting Global Food Security

By Steve Phillips

regulator and defoliant applications, and estimating disease and insect stress and damage spatially throughout the field.

One of the misconceptions about PA is that it is only an option for the large-scale, high-profitability farming systems found in developed nations. In reality, spatial and temporal variability exists in smallholder systems and allowing these factors to contribute to the mismanagement of resources creates an even greater risk to these producers. The ability to incorporate spatial and temporal information into the decision-making process in the developing world is of tremendous value, possibly even more so than in developed nations. Several precision nutrient management strategies exist and are being used successfully in smallholder systems including leaf color charts, omission plots, handheld crop sensors, and web-based

Precision Agriculture in China

The First PA Center, 1998, China Agricultural University

National Experiment Station for PA
2002, Beijing

Chinese Academy of Agricultural Sciences
Precision Agriculture Research and Demonstration
Hypothesis

Precision crop management can further increase crop yield and nutrient use efficiency and decrease environmental footprint than regional optimum crop management practices in small scale farming systems, and thus contributing to food security and sustainable development in China.
Different Scales of Farming

Quzhou, Hebei
Small scale (0.3 - 0.5 ha, 70 - 80%)
winter wheat/Summer Maize

Lishu, Jilin
Medium scale (1 - 2 ha, 10 - 20%)
Farmer Cooperatives
Spring Maize

Jiansanjiang, Heilongjiang
Large scale (20-30 ha, 5-10%)
Family Farm
Rice

Quzhou, Hebei
Small scale (0.3-0.5 ha, 70-80%)
winter wheat/Summer Maize
Implications of Scale for Sustainable Intensification of Agriculture

To manage 20 ha

- **Quzhou**: 100 Farmers
  - 40% mechanization
  - WW: 9.9 / 5.7 t/ha: 58%
  - SM: 13.7 / 7.2 t/ha: 53%
  - WW: PFP 54/25 kg/kg: 46%
  - SM: PFP 78/40 kg/kg: 51%

- **Lishu**: 10 Farmers
  - 70% mechanization
  - 15.1 t/ha/9.0 t/ha: 60%
  - PFP: 69/41 kg/kg: 59%

- **Jiansanjiang**: 1 Farmer
  - 95% mechanization
  - 12.0 t/ha/8.5 t/ha: 71%
  - PFP: 100/70-80 kg/kg: 70-80%
Precision Nitrogen Management for Sustainable Development

Zhang et al., 2015. Nature
Regional Optimum N Management of Corn

Increase yield by 13%
Decrease N rate by 21%
Decrease GHG 31%

Wu et al., 2014. PLoS ONE
Regional Optimum N Management of Rice

Increase yield by 7%

Decrease N rate by 21%

Decrease GHG by 11%

Wu et al., 2015. Environmental Research Letters
Regional Optimum N Rate (RONR) in North China Plain

Winter Wheat
180 kg/ha: 60 kg/ha as basal
   120 kg/ha as topdressing at stem elongation

Summer Maize
180 kg/ha: 60 kg/ha as basal
   120 kg/ha as topdressing at V9-V10

Fixed rate and time
In-season N Management

OSU RAMP Calibration Strip Technology

TUM Green Window Approach (GWA) (http://nue.okstate.edu/Index_RI.htm)

Increased Yield: 13%;
RE: 11% → 46%;
Reduced N rate by 69%.

Yue et al., 2015, J. Agric. Sci.
In-season N Management

Soil Nmin-based In-Season N Management Strategy

On average:
reduce N application by 197 kg ha$^{-1}$;

(Chen et al., 2006; Cui et al., 2008; Yue et al., 2013)
GreenSeeker Active Sensor-Based N Management in NCP

Li, et al., 2009, SSSAJ
Evaluating Different Precision N Management Strategies for the Winter Wheat–Summer Maize Cropping System

Cao et al. (In Preparation)
Precision N Management in North China Plain

Cao et al. (In Preparation)
GreenSeeker and Nitrogen Nutrition Index-based Precision N Management Strategy (NNI-PNM)

Regional Optimum N Rate (180kg/ha)

In-season N Status Diagnosis

Early Season N Application (1/3 as basal application)

Increased PFP by 67% and 37% over FP and RONM, respectively

Deficient Optimum Surplus

Side-dressing N Rate Adjustment

Xia, T. 2016.
Increased N PFP by 48%,

No significant difference in yield  

Yao et al., 2012. Agronomy for Sustainable Development
Saturation of GreenSeeker NDVI

Winter Wheat

Rice

Corn

Overcoming the Saturation Effect of NDVI using Crop Circle Sensor

550 + 20nm
730 + 10nm
760WLP

(Cao et al., 2013, Field Crops Research; Cao et al., 2016. Precision Agriculture)
Developing Crop Circle Sensor-based Precision N Management Strategy for Winter Wheat

(Cao et al., 2016. Precision Agriculture; Yue et al., 2012, Agronomy Journal)
Crop Circle Sensor-based Precision N Management Strategy for Winter Wheat

1/3 as Basal N Application

Regional Optimum N Rate

In-season Adjustment

Total N Requirement

N Need

Plant N uptake

Topdressing N Rate

(Cao et al., 2016, Precision Agriculture)
Satellite Remote Sensing-based Rice N Status Diagnosis and Precision Management

(Huang et al., 2015, Remote Sensing)
UAV Remote Sensing-based Crop N Status Diagnosis and Precision Management

450nm (B), 550nm (G), 680nm (R), 720nm (RE), 800nm (NIR), Incident light Sensor (ILS)

Digital Image

NNI Map
Precision Agriculture for Food Security & Sustainable Development?

- Precision Nutrient Management
- Precision Water Management
- Precision Crop Protection

Improved Resource Use Efficiencies → Sustainable Development → Food Security

Gebbers and Adamchuk. 2010. Science 327 (5967), 828-831
Different Scales of Farming

Jiansanjiang, Heilongjiang
Large scale (20-30 ha, 5-10%)
Family Farm
Rice
Large Scale Rice Farming in Jiansanjiang

One household manages an average of 20-30 ha land
Large Scale Rice Farming in Jiansanjiang

95% of field operations are mechanized
Implications of Scale for Sustainable Intensification of Agriculture in Heilongjiang

N PFP
60-70 vs. 30-40 kg kg\(^{-1}\)

Chen et al., 2014, Nature
High Crop Yield and Resource Use Efficiency in Jiansanjiang

[Diagram showing yield and resource use efficiency for different regions such as World, GD, HN, China, HLJ, LN, HARB, and JSJ.]
Integrated Precision Rice Management

Soil Testing

+ Optimizing Transplanting Density

+ Precision N Management

+ Alternate Drying and Wetting

Zhao et al., 2013. Field Crops Research
Active Crop Sensor-based Integrated Precision Rice Management Strategies

PRM 1 (RORM+PNM): Increased yield by 12 and 5% than FP and RORM, respectively.

PRM 2 (HY+PNM): Increased yield by 21% and 14% than FP and RORM, respectively.

PRM (HY+OF+PNM): Increased yield by 23% and 16% than FP and RORM, respectively.

(Based on results of 2011-2015)

(Lu et al., In Preparation)
Crop Sensor-based Integrated Precision Rice Management Strategies

PRM 1 (RORM+PNM): Increased RE by 67 and 16% than FP and RORM, respectively

PRM 2 (HY+PNM): Increased yield by 74% and 21% than FP and RORM, respectively

PRM (HY+OF+PNM): Increased yield by 86% and 29% than FP and RORM, respectively

(Based on results of 2011-2015)
UAV RS-based Precision Rice Management increased 12% and 9% yield, 43% and 10% N PFP than FP and RORM.

(Yield)

1. +9%
2. +3% +8% +12%

(N PFP)

1. +10%
2. +30% +28% +43%

(Lu et al., In Preparation)
Integrated Precision Rice Management System
Adoption of PA in Chinese Agriculture
Why Low Adoption of PA?

1) Small-scale farming

2) Lack of young and well educated farmers
Why Low Adoption of PA?

3) Manual application

4) Lack of suitable machines
Why Low Adoption of PA?

5) Lack of PA service providing systems
Opportunities for PA in China

China’s New Policy: Zero increase in chemical fertilizers and pesticides after 2020

(WF Zhang, PC)
Opportunities for PA in China

The 2016 No. 1 Document of Chinese Government

Support intelligent agriculture and the application of information technology in agriculture

Support the development of cooperatives, and the increase of farming scale

Support agricultural mechanization

Support agricultural service providing systems, and explore and expand test sites for government to buy agricultural services
Opportunities for PA in China

Government investment for big research projects to support zero increase in chemical fertilizers and pesticides

Integrated Technology Research and Development Program for Chemical fertilizer and Pesticide Application Reduction and Efficiency Improvement (2016-2020)

Basic research for chemical fertilizer and pesticide reduction mechanisms and Limit Standards

Key technologies, products and equipments

Technology integration and application

42 projects
Opportunities for PA in China

Precision Agriculture Service Providing Systems

北京爱科农科技有限公司
Beijing ICAN Technology Co. Ltd.

精准农服科技（北京）有限公司
(Vipfarms Limited)
Thanks