# Meeting sustainable intensification goals in agriculture

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XIII Conferencia Internacional de Arroz para América Latina y el Caribe

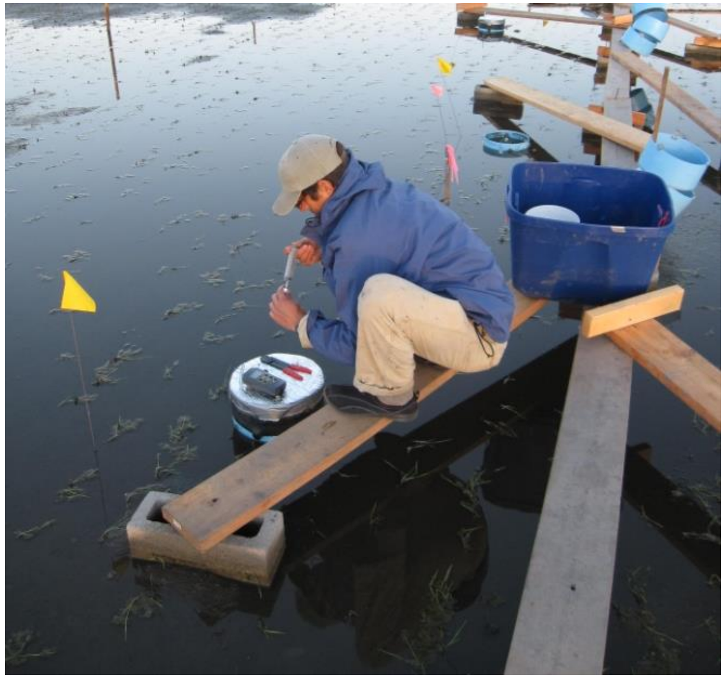
"Alianzas para la sostenibilidad de la producción arrocera"

Mayo 15 al 18, 2018 – Piura, Perú

# Outline

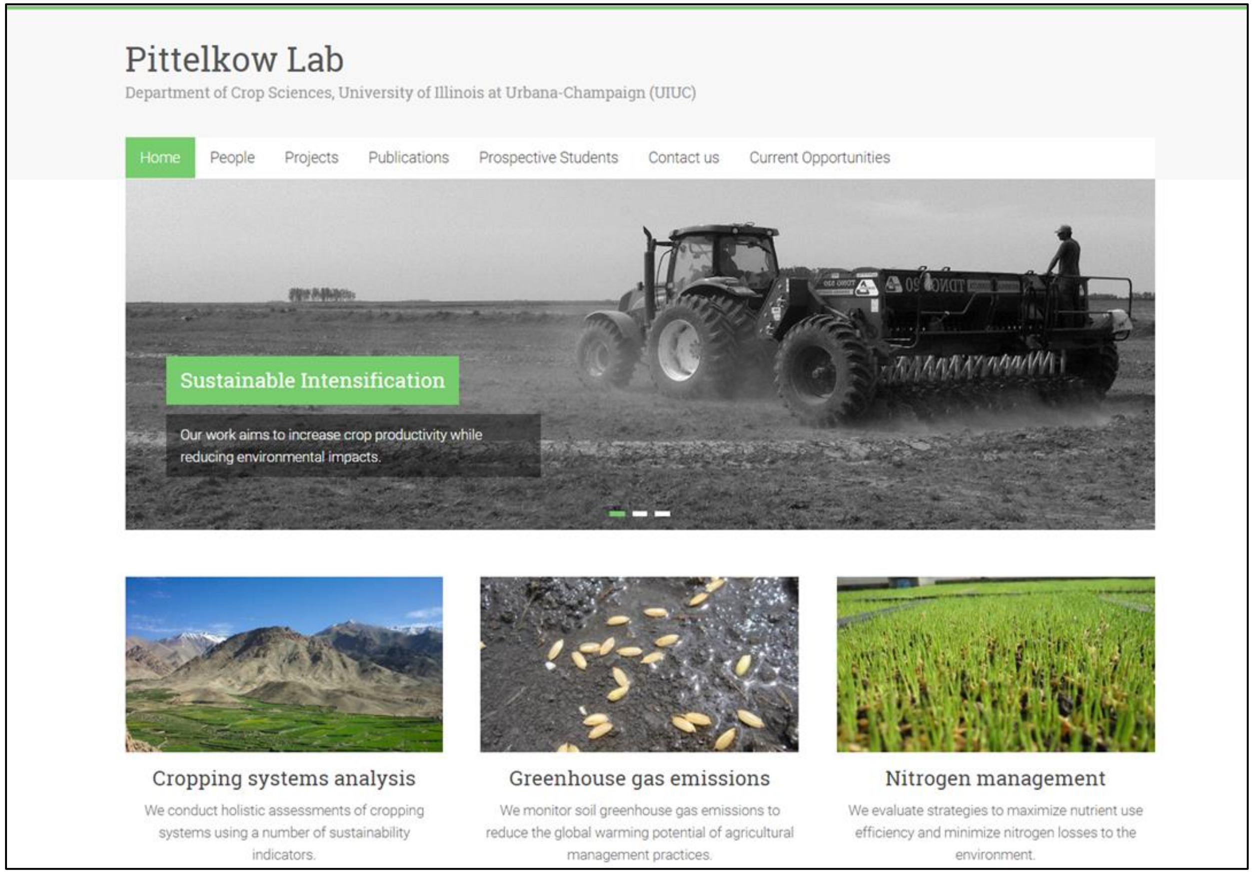
- Background
- Global context for Sustainable Intensification (SI)
- Research example: Rice in Uruguay
- Opportunities for accelerating SI efforts
- Example platforms and tools

# Graduate school

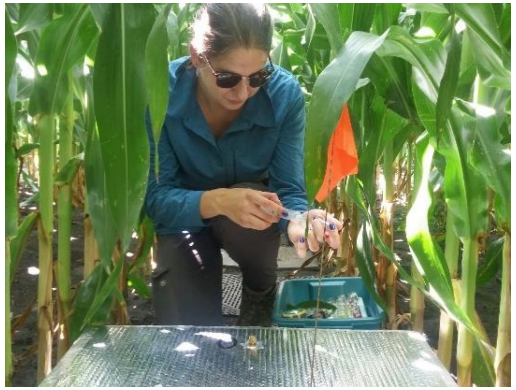


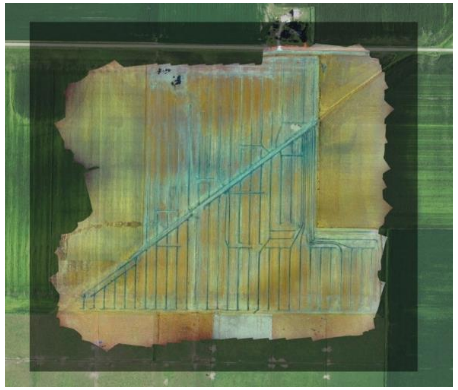
# IRRI

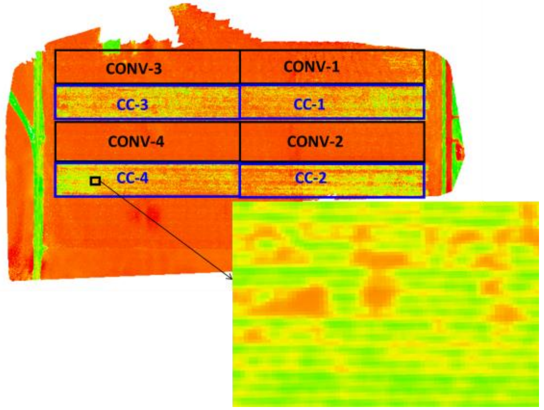

# University of Illinois

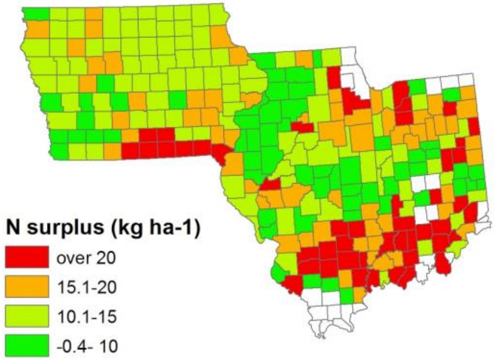



## US Midwest: sustainable N management







# Goals for this presentation

- Bring in an outside perspective
- Share experiences with SI research/metrics as an agronomist
- Discuss alliances/partnerships for impact

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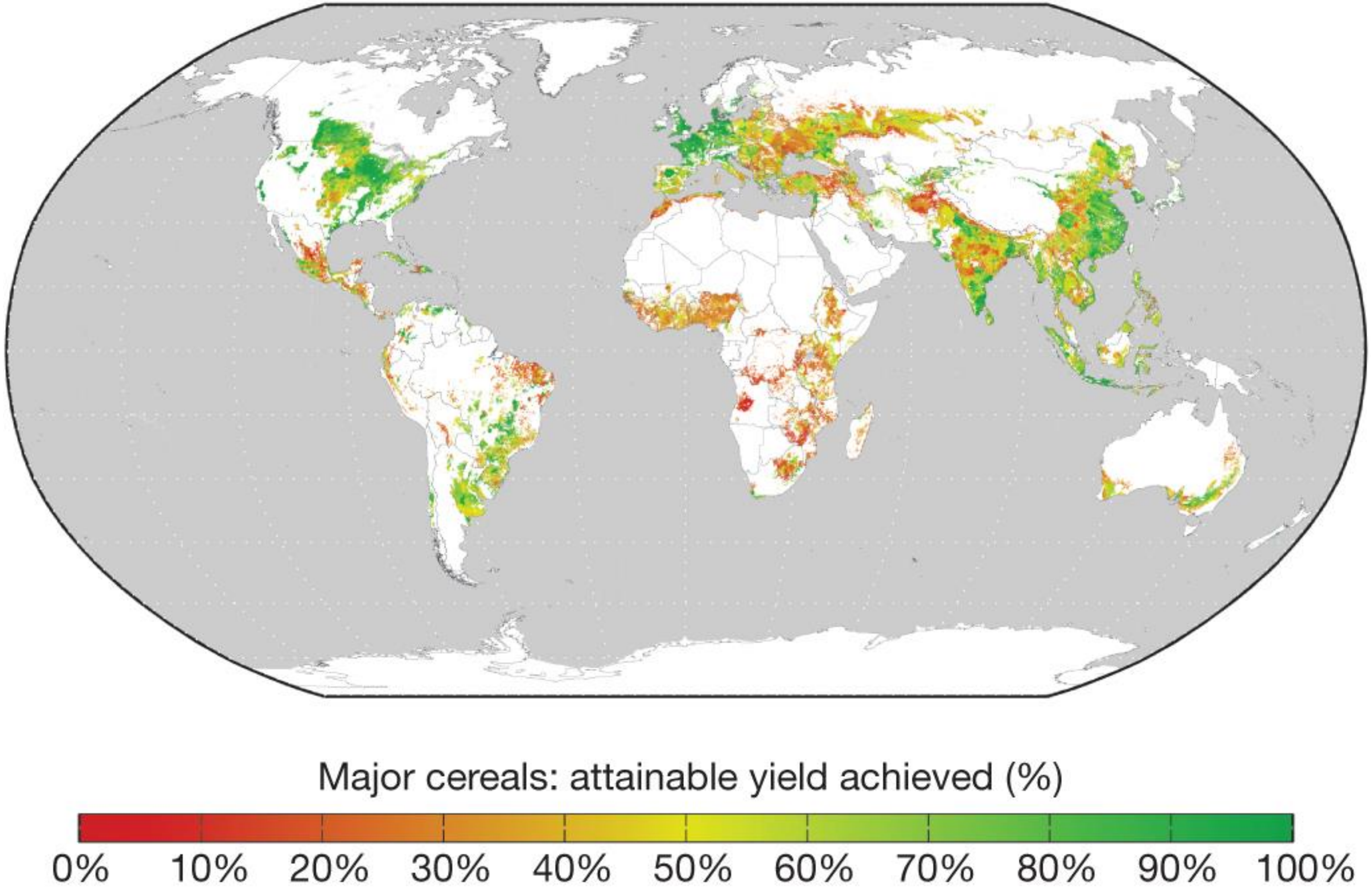
# Yield gaps for rice, wheat, and maize

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Mueller et al. 2013 Nature

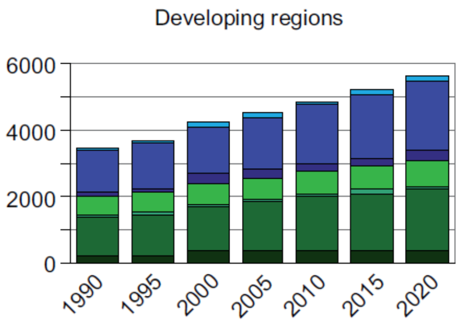
# Environmental concerns

Energy consumption

Water resources

Nutrient pollution

Greenhouse gas emissions and climate change




Smith et al. 2007 IPCC; Foley et al. 2011 Nature;
Tilman et al. 2012 PNAS; Vermeulen et al. 2012 Annu. Rev. Environ. Resour.

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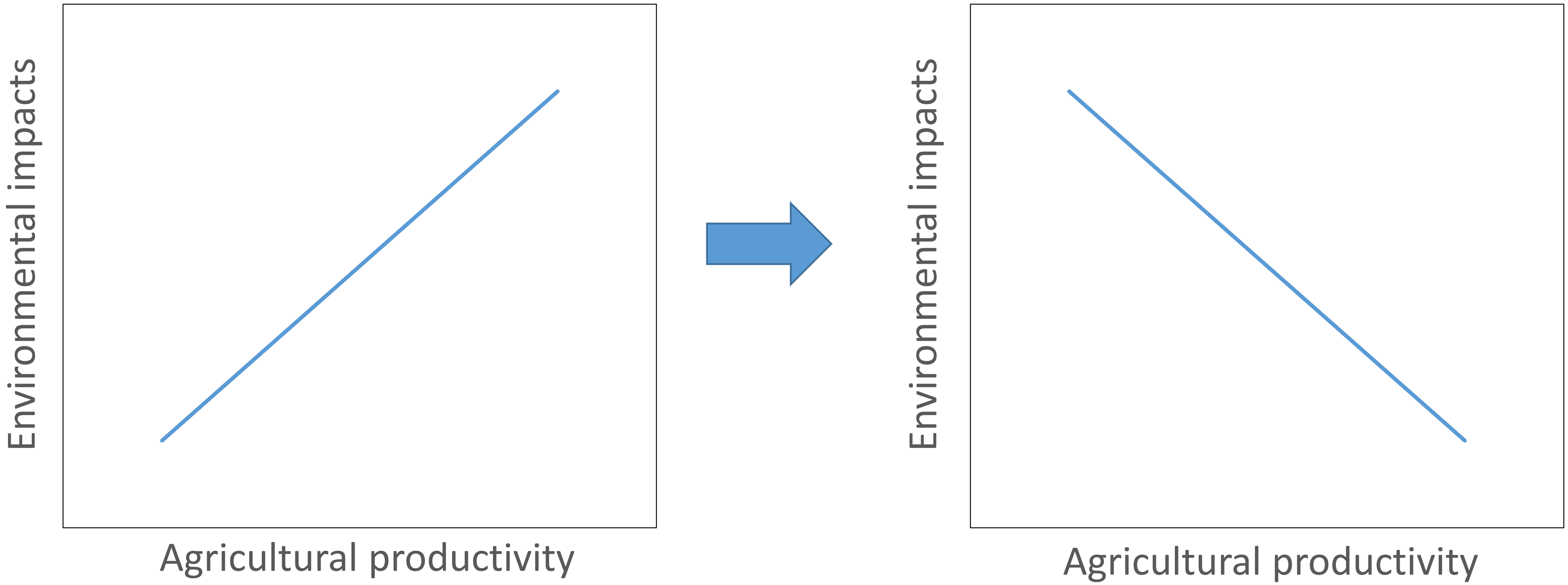
# The challenge: sustainable intensification

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y el Caribe

# Premises underlying SI

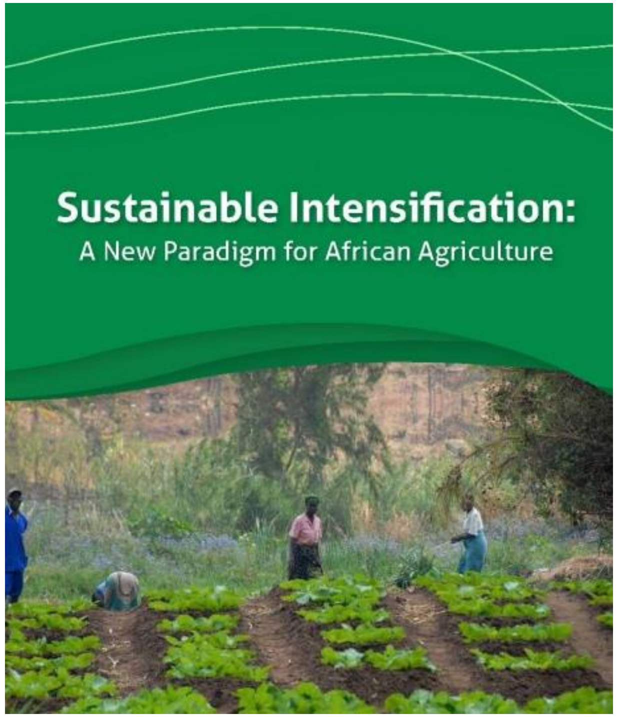
1) Increased production
2) Higher yields per unit area to avoid the environmental costs of agricultural expansion
3) Equal emphasis on food security and environmental sustainability
4) Denotes a goal but does not specify how it should be attained

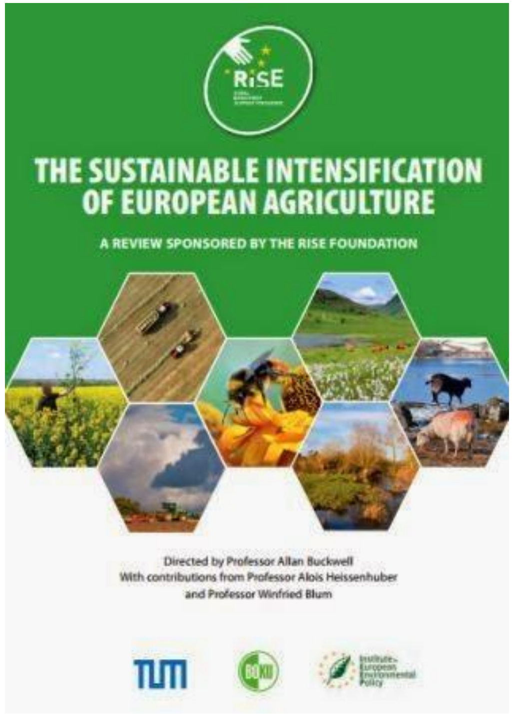
*The missing elements? Social equity, human health and well-being*



Garnett et al. 2013 Science

# Progress?

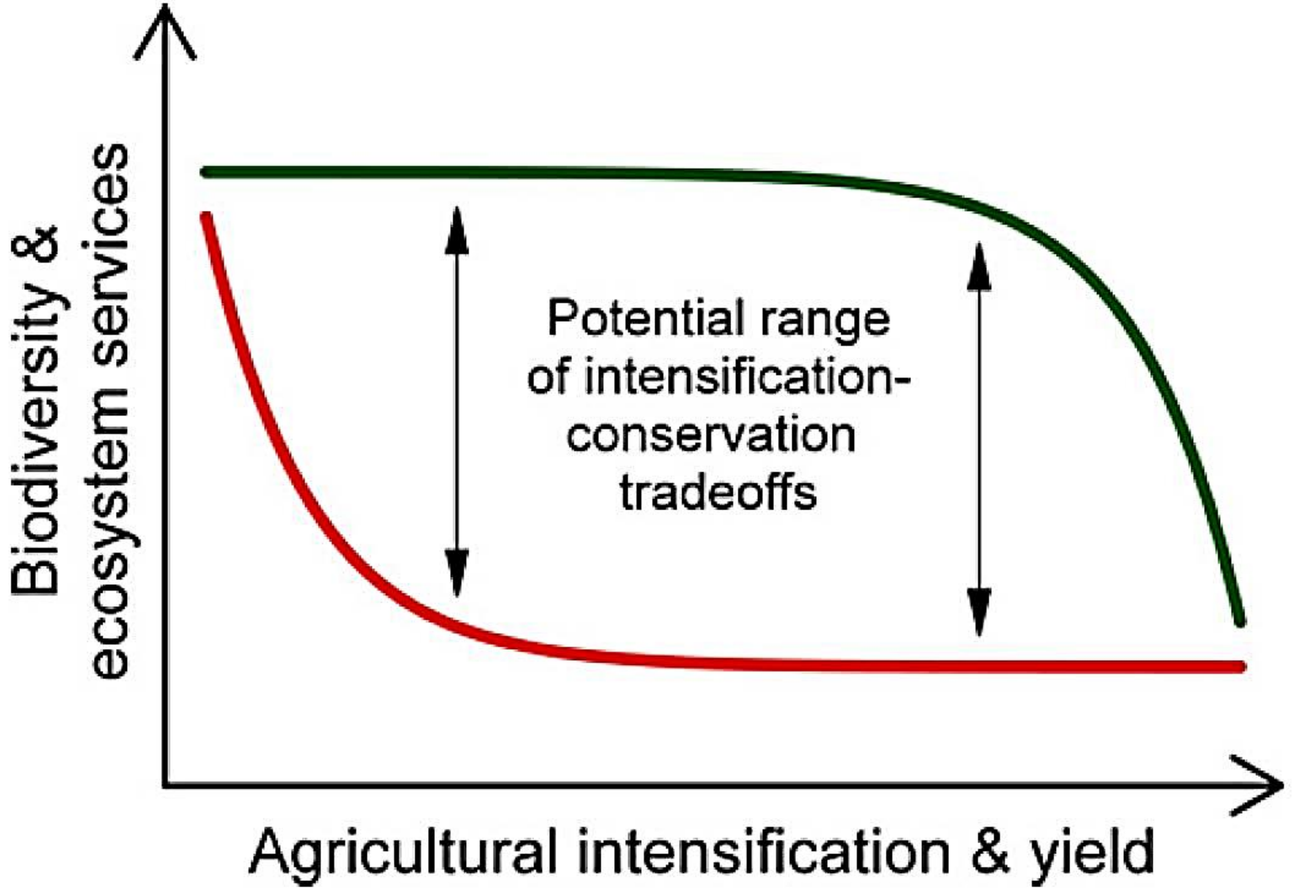




Despite much emphasis at international scales, there are limited large-scale examples evaluating whether it is possible to achieve these often conflicting goals

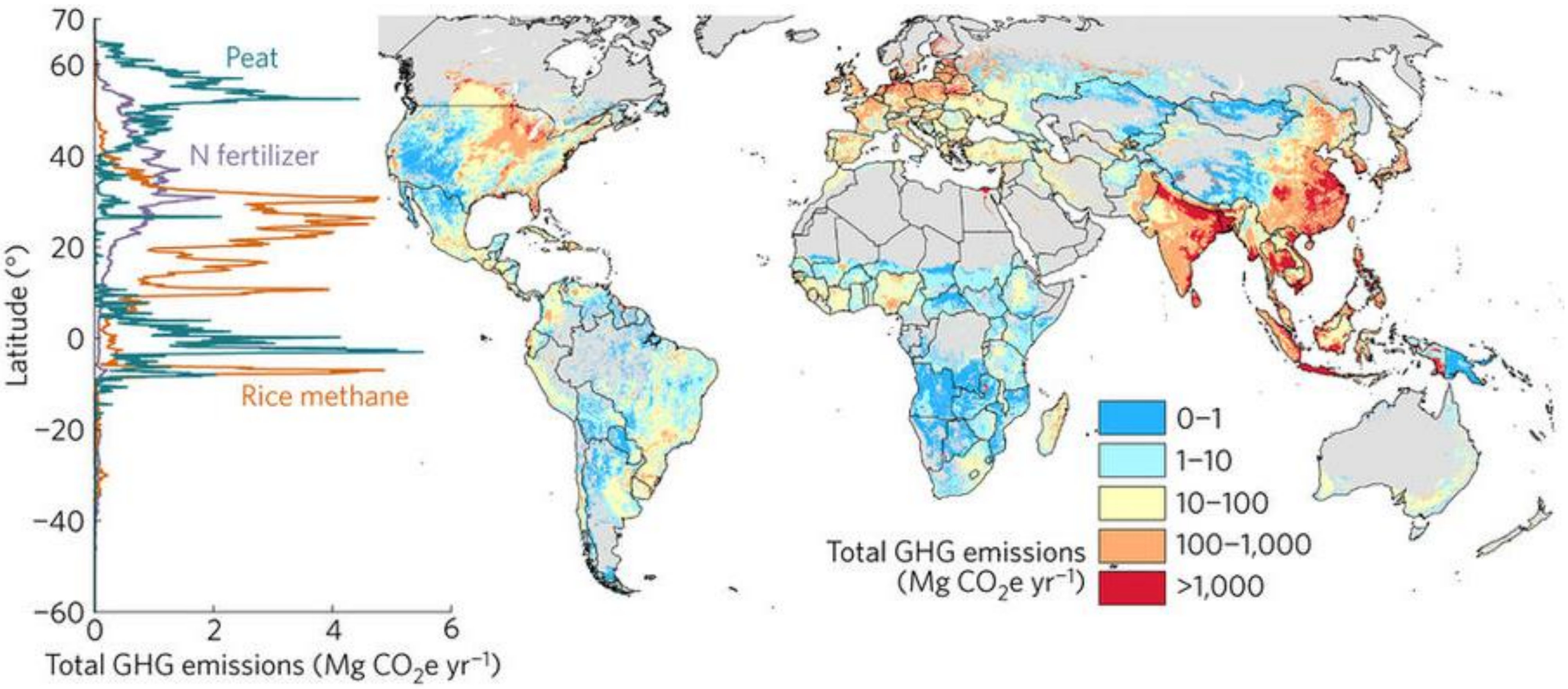
# The reality: systems are complex




- C footprint
- Energy consumption
- Water use efficiency
- Soil quality
- GHG emissions
- Nutrient losses
- Water quality

Tscharntke et al. 2012 Biol. Conserv.

# Leverage points: GHG emissions

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Carlson et al. 2017 Nature Climate Change

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- **Research example: Rice in Uruguay**
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# Rice systems in Uruguay

INIA: Álvaro Roel, Gonzalo Zorrilla, José Terra, Sara Riccetto, Ignacio Macedo, Camila Bonilla


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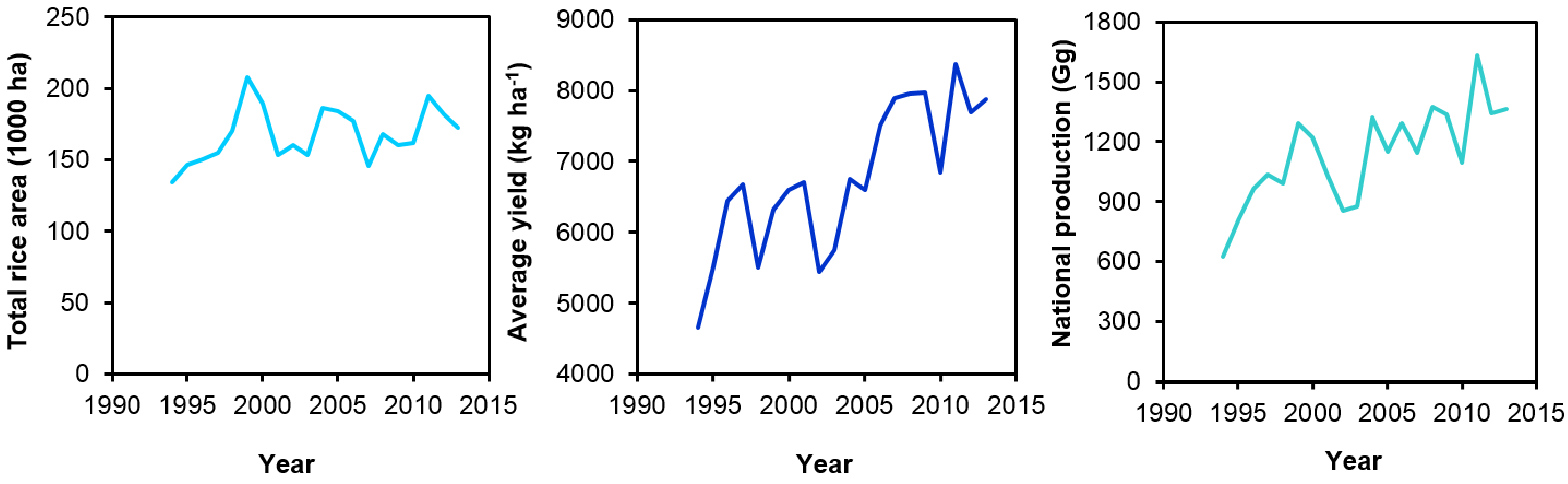
FULBRIGHT URUGUAY

# Increased production

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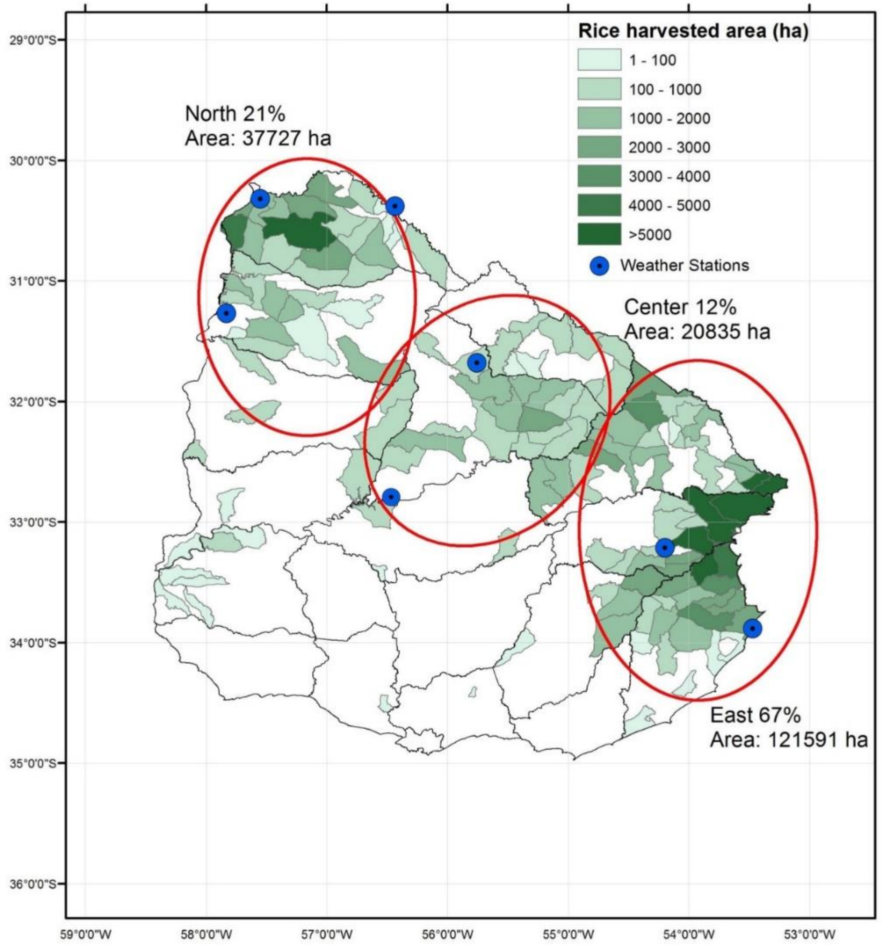
Pittelkow et al. 2016 Global Food Security

# National assessment




1) Estimate the sustainability impacts of rice intensification

2) Evaluate synergies and tradeoffs among indicators

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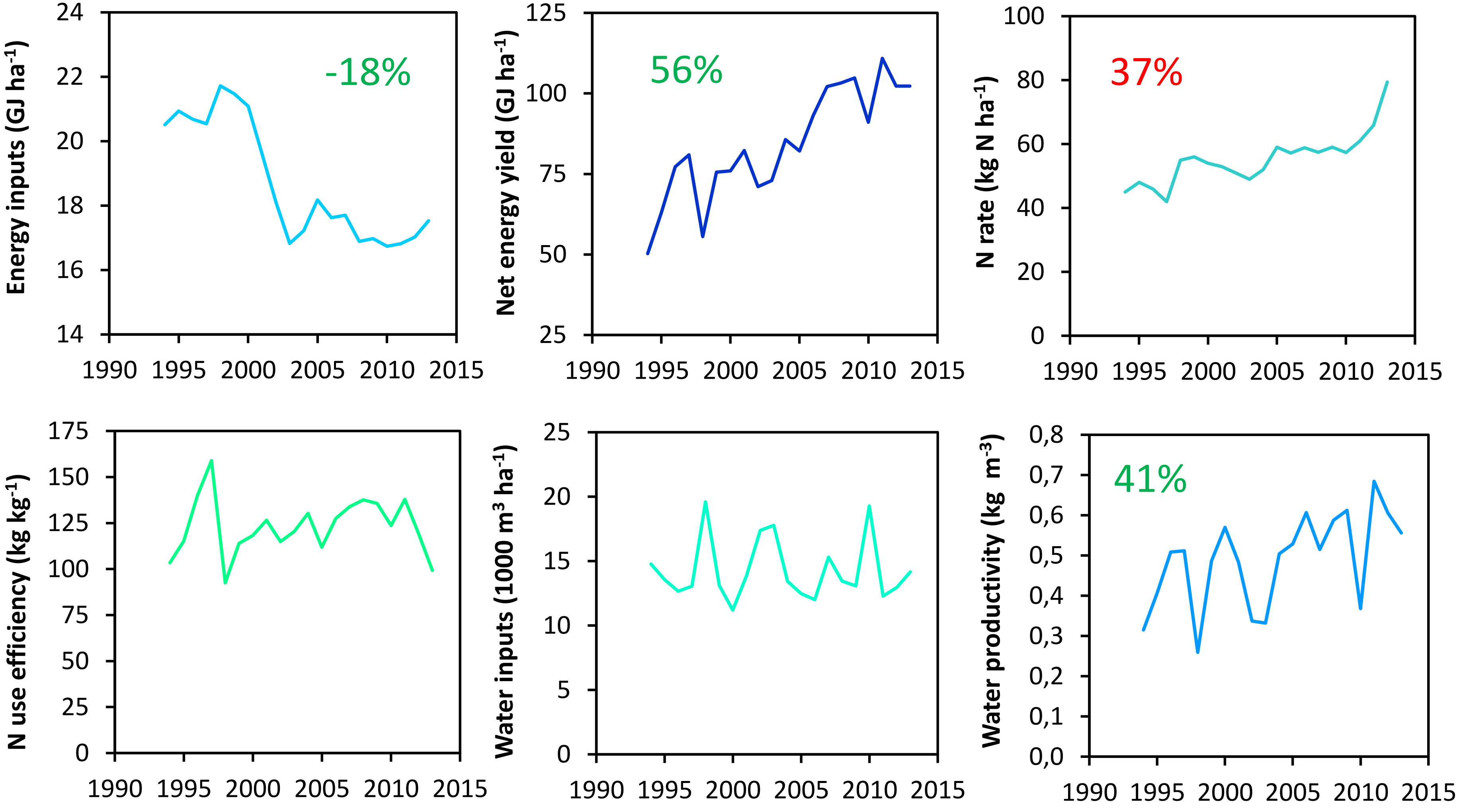
Pittelkow et al. 2016 Global Food Security

# Methods

| Sustainability indicators | |
|---|---|
| Yields | Water productivity |
| Net energy yield | Agrochemical contamination risk |
| Nitrogen use efficiency | Carbon footprint |

- Twenty year study period (1993-2013)
- National statistics (DIEA)
- INIA-rice industry working group statistics
- Reported information, conversion factors, or empirical data from the literature

# Resource use efficiencies

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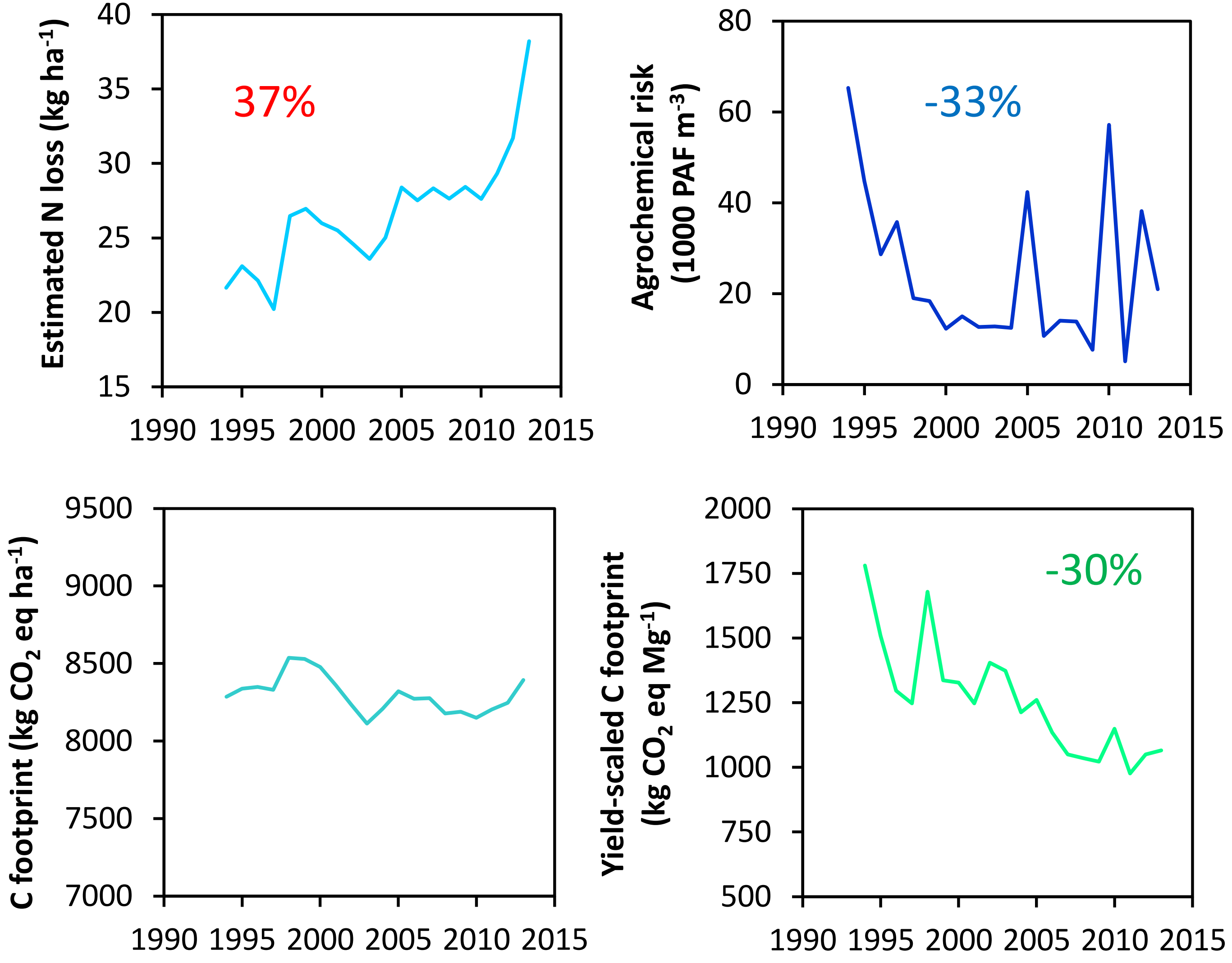
Pittelkow et al. 2016 Global Food Security

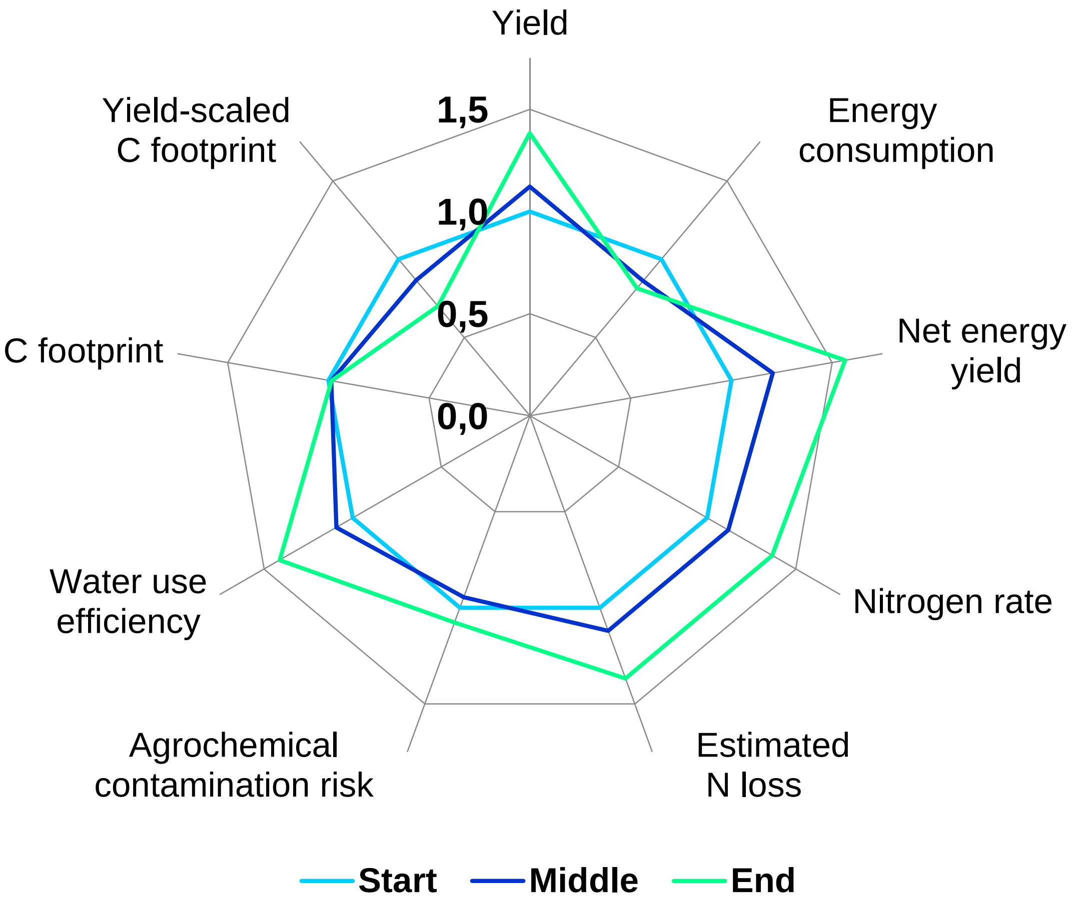
# Environmental indicators






Pittelkow et al. 2016 Global Food Security

# Integrating metrics




- Increased energy efficiency while decreasing yield-scaled C footprint
- Concerns: N losses, agrochemical contamination risk, $CH_4$ emissions

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Pittelkow et al. 2016 Global Food Security

# Next steps

- Ongoing work with INIA and PhD student (Meng-Chun Tseng)
- Breaking the yield ceiling project with on-farm trials
- Participatory research design
- Explore environmental costs associated with future yield increases

# Treatments and preliminary results

| | Treatment | Yield<br>Mt ha$^{-1}$ |
|---|---|---|
| 1 | HYFP | 11.62 |
| 2 | + Improved Cultivar | 1.5%# |
| 3 | + Seed Technology | -0.8% |
| 4 | + Fertilization | 0.9% |
| 5 | + Micronutrient | -0.3% |
| 6 | + Plant Protection | -1.0% |
| 7 | BMPP | 12.10 |
| 8 | - Improved Cultivar | **-4.3%** |
| 9 | - Seed Technology | 2.3% |
| 10 | - Fertilization | -2.0% |
| 11 | - Micronutrient | 1.2% |
| 12 | - Plant Protection | 2.7% |

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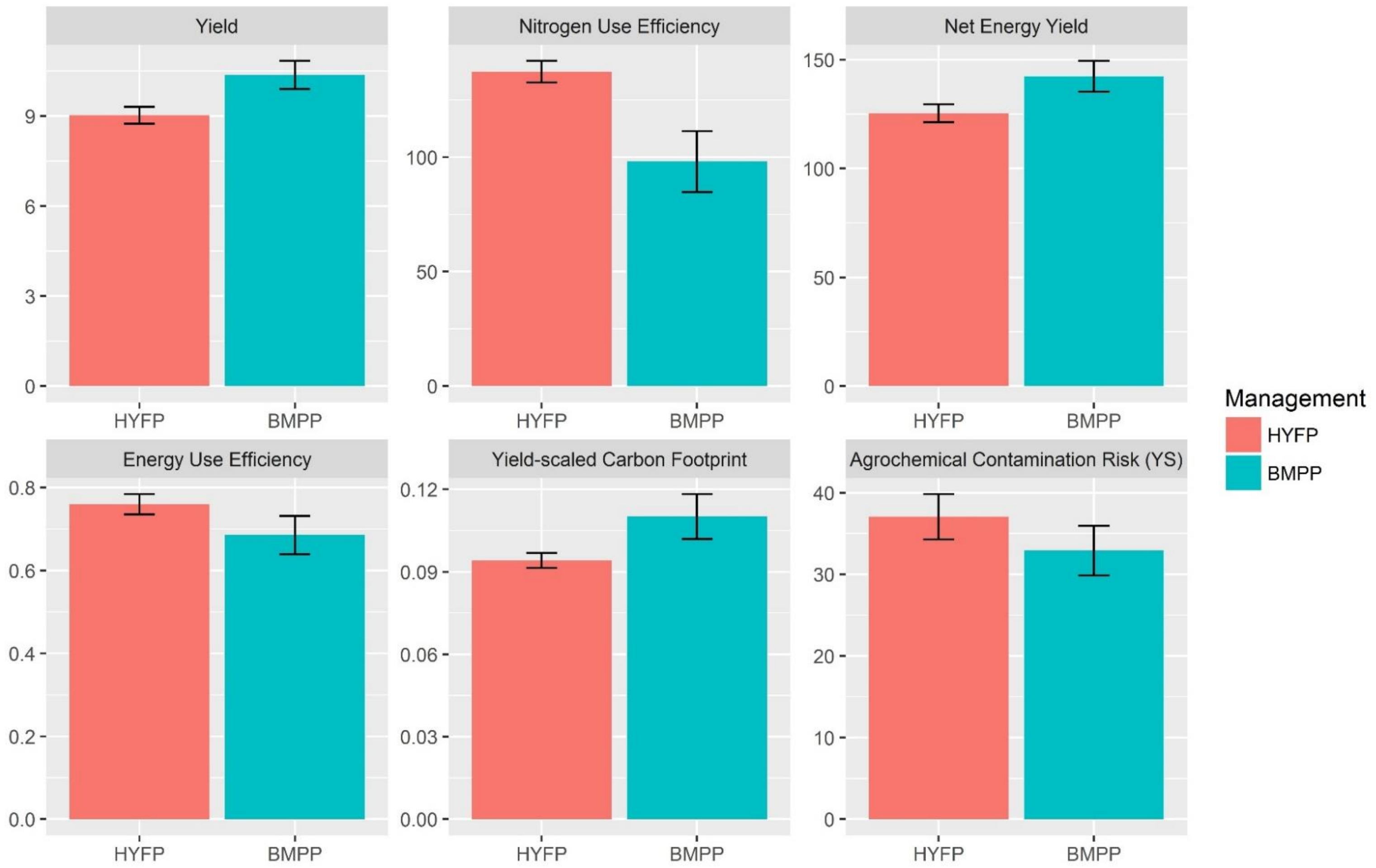
INIA and Meng-Chun Tseng – PhD student

# Treatments and preliminary results

| | Treatment | Yield<br>Mt ha$^{-1}$ | NUE<br>kg yield kg applied N$^{-1}$ | Net energy yield<br>GJ ha$^{-1}$ | Energy use efficiency<br>kg yield MJ$^{-1}$ | Yield-scaled C footprint<br>kg CO2e kg yield$^{-1}$ | Yield-scaled agrochemical contamination risk<br>PAF m$^3$ kg yield$^{-1}$ |
|---|---|---|---|---|---|---|---|
| 1 | HYFP | 11.62 | 167.55 | 165.27 | 0.973 | 0.075 | 29.75 |
| 2 | + Improved Cultivar | 1.5%[#] | 1.5% | 2.3% | 2.2% | -1.8% | -1.8% |
| 3 | + Seed Technology | -0.8% | -0.8% | -0.1% | 4.0% | -3.0% | **-21.8%** |
| 4 | + Fertilization | 0.9% | **-18.9%** | 0.1% | **-10.4%** | **15.3%** | -1.3% |
| 5 | + Micronutrient | -0.3% | -1.2% | 0.4% | 0.0% | 0.1% | -0.7% |
| 6 | + Plant Protection | -1.0% | -1.2% | -1.4% | -1.2% | 1.0% | 1.1% |
| 7 | BMPP | 12.10 | 147.59 | 171.06 | 0.93 | 0.081 | 25.36 |
| 8 | - Improved Cultivar | **-4.3%** | -3.9% | -3.7% | -1.3% | 1.9% | **-8.9%** |
| 9 | - Seed Technology | 2.3% | 2.1% | 2.7% | 0.6% | -1.3% | **9.6%** |
| 10 | - Fertilization | -2.0% | **14.6%** | -0.6% | **8.4%** | **-10.0%** | 0.2% |
| 11 | - Micronutrient | 1.2% | -4.3% | 1.6% | -0.6% | 0.3% | -3.1% |
| 12 | - Plant Protection | 2.7% | 3.1% | 2.7% | 2.6% | -2.9% | -4.1% |

# On-farm validation

15% p = 0.01 | -29% p = 0.04 | 14% p = 0.03




-11% p < 0.01

INIA and Meng-Chun Tseng – PhD student

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# Reflections


- Outcomes can change drastically depending on indicators included
- Little data available for comparison with other regions
- Once yield ceiling is approached, SI appears to become more difficult

# Questions raised

- Acceptable levels of accuracy?
- How to define system boundaries in space or time (e.g. rotations)?
- Need for robust baseline data to improve estimates (e.g. long-term field trials)

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# Key opportunities for SI at a global scale

1. Benchmark system performance
2. Explore thresholds for efficiency and set targets
3. Develop methods to account for tradeoffs (but keep it simple)

nature — Vol 466|29 July 2010

OPINION

## Monitoring the world's agriculture

To feed the world without further damaging the planet, **Jeffrey Sachs** and 24 food-system experts call for a global data collection and dissemination network to track the myriad impacts of different farming practices.

Agriculture must be transformed. Although global food production is increasing, today's farming systems undermine the well-being of communities in many ways. For instance, farming has destroyed huge regions of natural habitat and caused an untold loss of ecosystem services, and it is responsible for about 30% of greenhouse-gas emissions[1,2]. Already, about 1 billion people are undernourished. Yet to feed the global population expected by 2050, more than 1 billion hectares of wild land will need to be converted to farmland if current approaches continue to be used[3].

A key step towards making agriculture sustainable is evaluating the effects of different farming systems around the world. Historically, agricultural strategies have been assessed on the basis of a narrow range of criteria, such as profitability or yields. In the future, the monitoring of agricultural systems should address environmental sustainability, food security (people's access to food and the quality of that food), human health, and economic and social well-being.

We propose establishing a global network to monitor the effects of agriculture on the environment, across major ecological and climatic zones, worldwide. This would involve stakeholders — policy-makers, farmers, consumers, corporations, non-governmental organizations, and research and educational institutions — coming together to develop a set of metrics that quantify the social, economic and environmental outcomes of various agricultural strategies. A network of monitoring organizations would then collect the appropriate information, and the resultant, freely available data could inform agricultural management, policy and research priorities.

**SUMMARY**
- Agriculture is assessed at different scales, using inconsistent methods and narrow criteria
- A common set of metrics must be collected at comparable scales
- The resultant, freely available data should inform farming practices worldwide

### Comparing apples and oranges

The current monitoring of agricultural systems captures only certain effects of farming, by focusing on narrow criteria. Several examples illustrate the need to monitor multiple variables. In the United States, recent investment in the biofuel ethanol has reduced imports of petroleum[4]. But it has also required expensive subsidies, reduced supplies of food and feed grains, spurred deforestation in other regions and perhaps even increased greenhouse-gas emissions overall[5].

Similarly, many consumers, farmers and policy-makers praise organic farming as an ecologically friendly system, but they should consider the additional land and livestock needed to produce 'green manures', the economic cost of producing food in this way and the net effect on greenhouse-gas emissions[6]. In addition, farming genetically modified crops is widely thought to entail certain risks, but these should be assessed alongside the potential benefits, such as reduced pesticide use and higher crop yields[7,8].

A further problem with the current system is that the data collected are rarely comparable across ecological zones because of inconsistencies in methodologies or in the spatial scale at which observations are made[1,2,9]. Agronomists, for example, tend to measure yields from fields that generally range from less than 1 hectare to 200 hectares, whereas landscape ecologists may monitor the way habitats are interconnected over geographical areas of many thousands of hectares. Moreover, some farming systems, such as traditional pastoralist systems, are often under-represented in monitoring efforts[10,11].

To facilitate cross-site comparisons and global modelling, data should be collected for

LEFT TO RIGHT: G. STEINMETZ/CORBIS; A. DELOSSY AND M.D. DE LOSSY/CULTURA/CORBIS

558



Sachs et al. 2010

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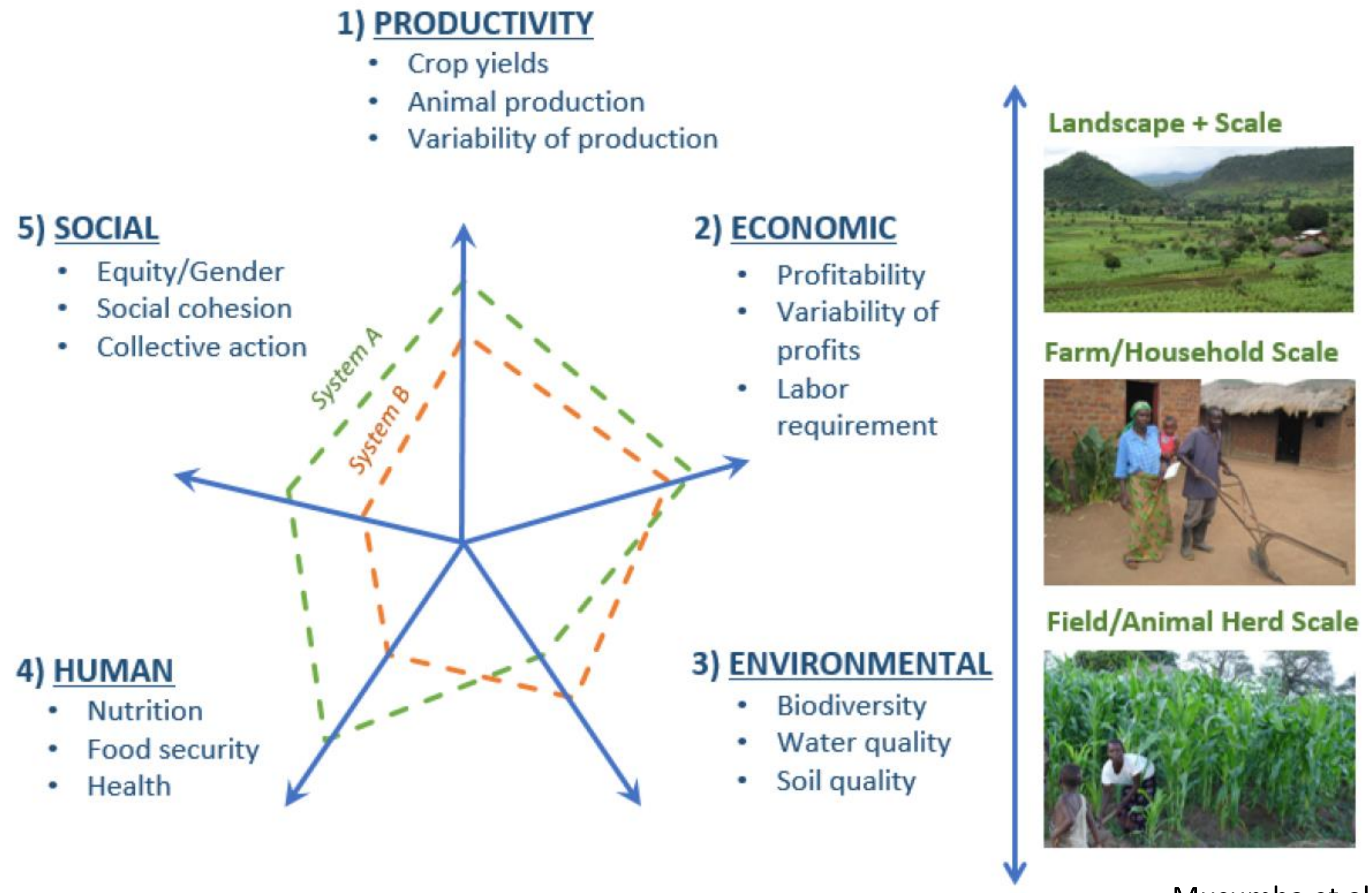
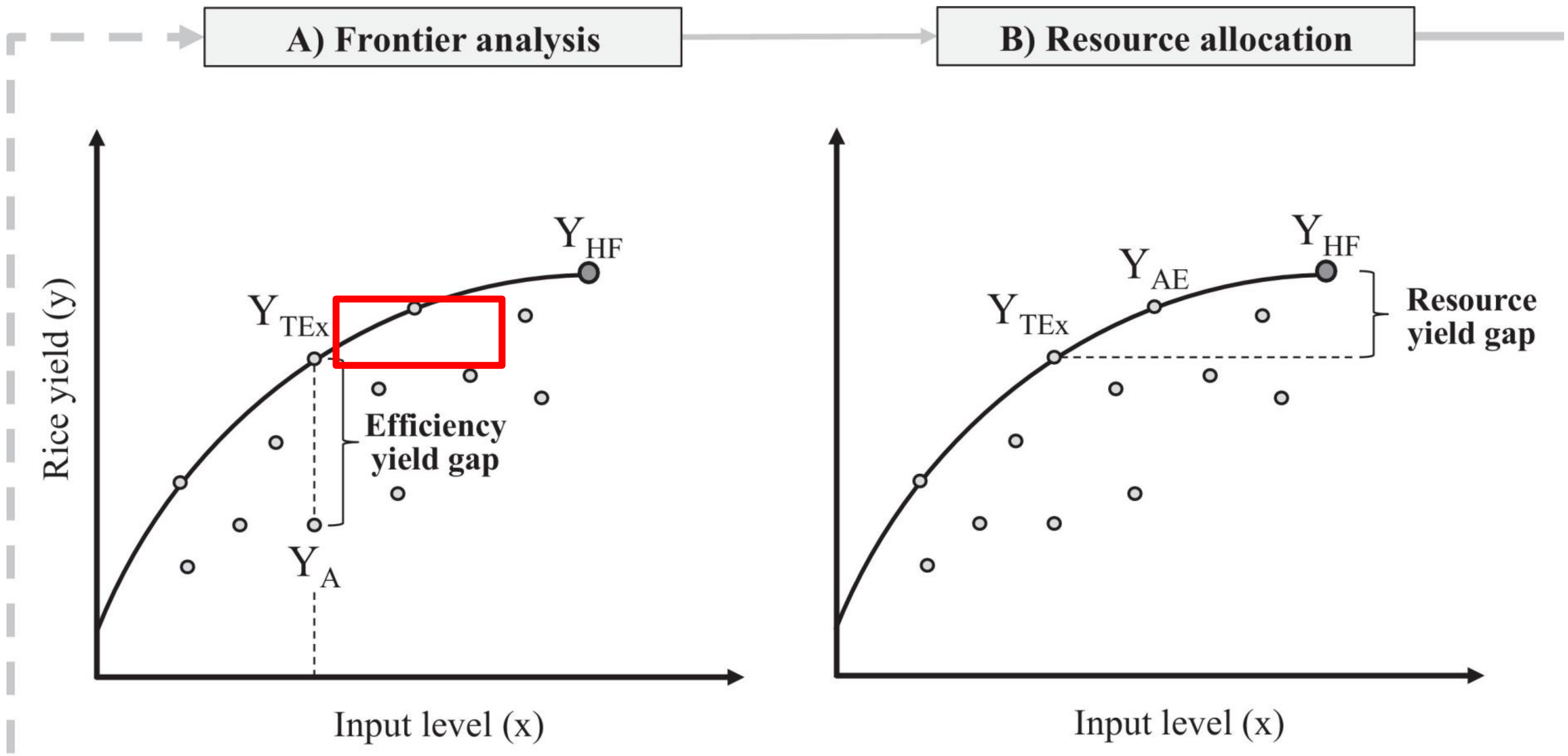
# 1. Benchmark system performance




Musumba et al. 2017

# 2. Setting targets

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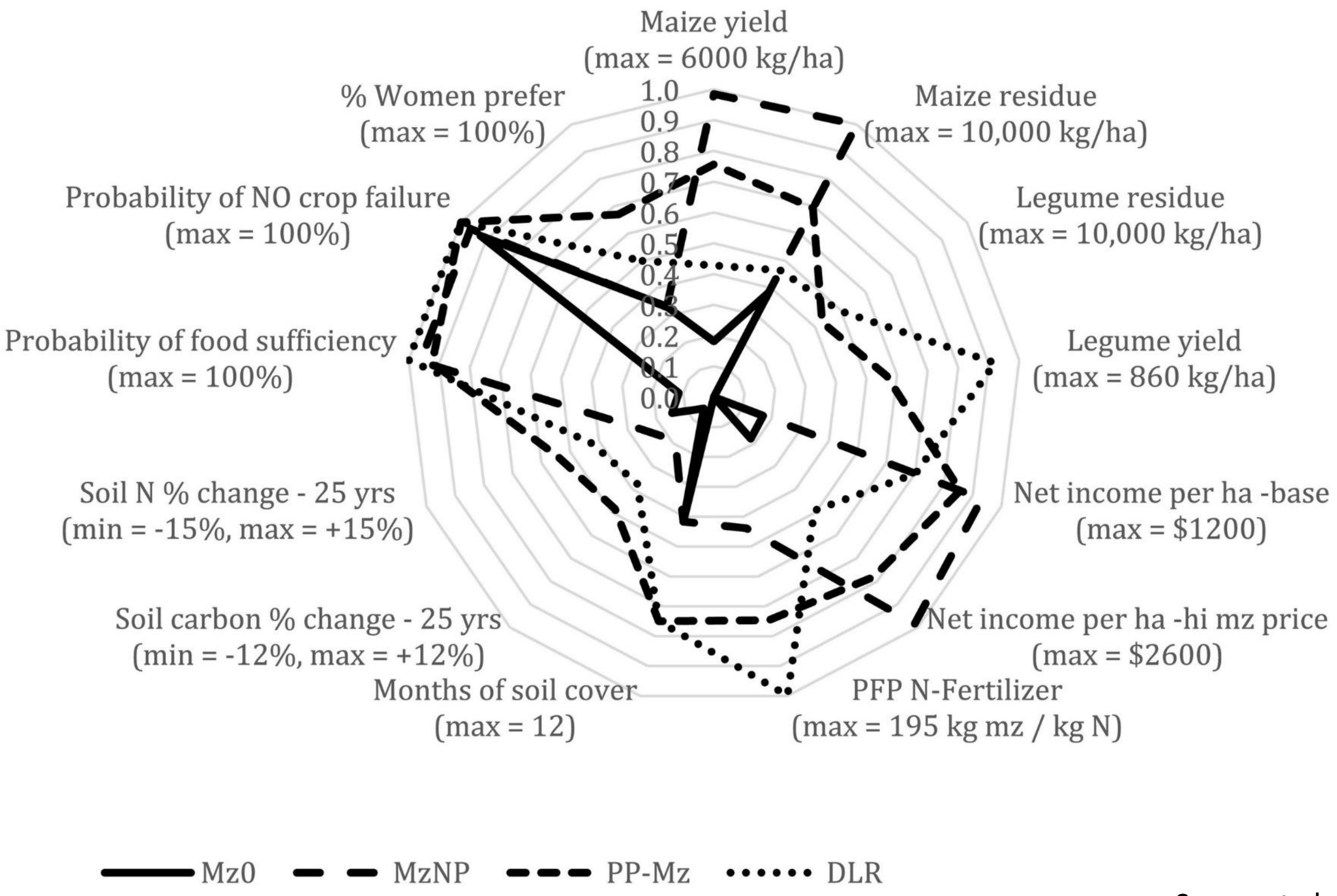
Silva et al. 2017 Europ. J. Agronomy

# 3. Simple tools for assessing tradeoffs

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Snapp et al. 2018 Agric. Systems

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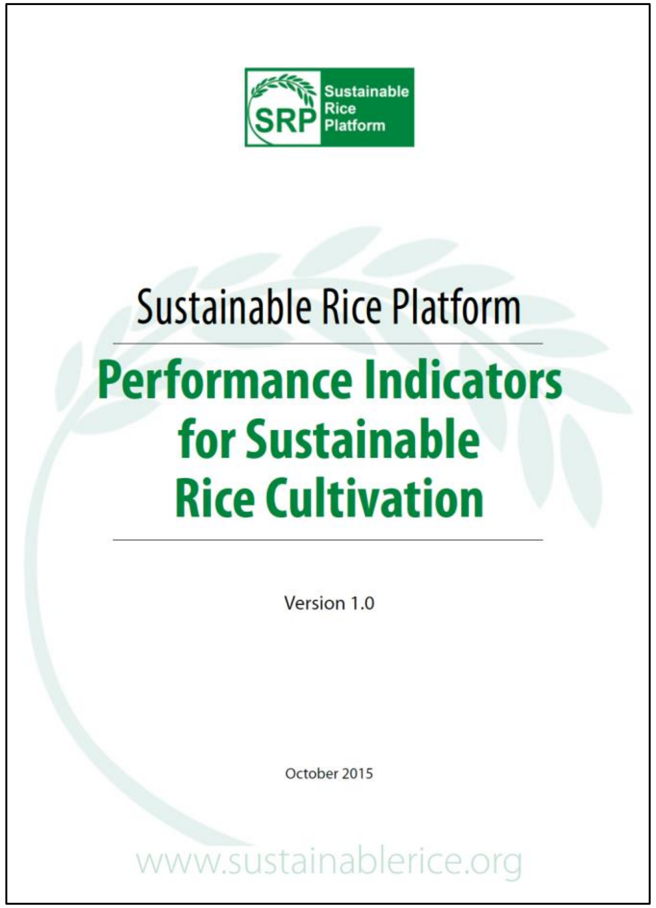
# Alliances to support SI progress

- Harmonized frameworks for evaluation
- Effective monitoring systems to track progress
- Multi-disciplinary from the start
- Some incentive for farmer participation

# Sustainable Rice Platform


Sustainable Rice Platform

Sustainable Rice Platform

Performance Indicators for Sustainable Rice Cultivation

Version 1.0

October 2015

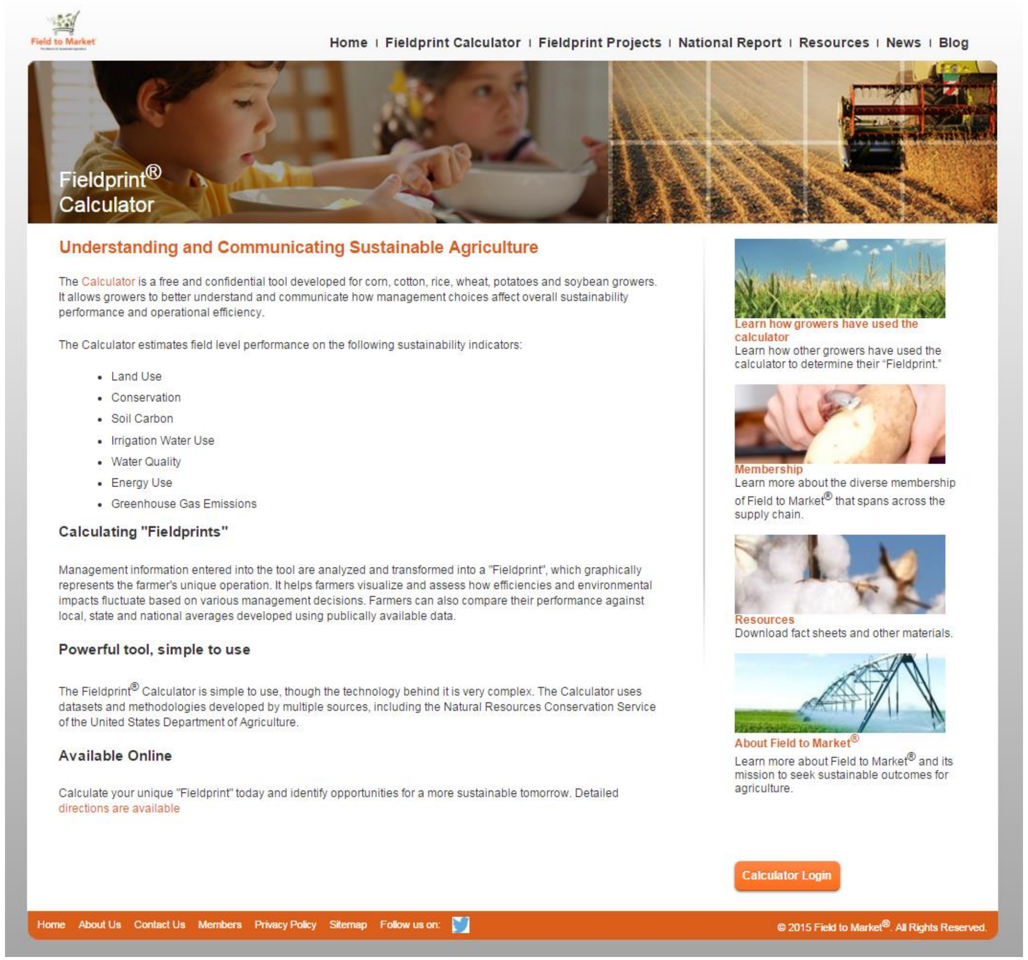
www.sustainablerice.org

- Global initiative for rice-based systems
- Key developers include food retailers
- Simple set of indicators to measure efficiency across diverse systems and environments

# Indicators

| Name of Indicator | Measurement | Source |
|---|---|---|
| **SRP Guiding Principle: Improved Livelihoods** | | |
| 1. Profitability: net income from rice | USD/ha/crop cycle | Farm records |
| | USD/ha/year | Household survey |
| 2. Labor productivity | kg paddy rice/no. of days | Farm records |
| | USD net income from rice/no. of days | Household survey |
| 3. Productivity: grain yield | kg paddy/ha | Farm records |
| | | Household survey |
| **SRP Guiding Principle: Consumer Needs** | | |
| 4. Food safety | kg safe milled rice/kg milled rice × 100 | Laboratory test |
| **SRP Guiding Principle: Resource-Use Efficiency** | | |
| 5. Water-use efficiency: total water productivity | kg paddy/L (rainfall + irrigation) | Farm records |
| | | Household survey |
| 6. Nutrient-use efficiency: N | kg paddy/kg elemental N | Farm records |
| | kg elemental N removal/kg elemental N input | Household survey |
| 7. Nutrient-use efficiency: P | kg paddy/kg elemental P | Farm records |
| | kg elemental P removal/kg elemental P input | Household survey |
| 8. Pesticide-use efficiency | Balanced scorecard | Farm records |
| | | Household survey |
| **SRP Guiding Principle: Climate Change Mitigation** | | |
| 9. Greenhouse gas emissions | Mg/$CO_2$ eq/ha | Farm records |
| | | Household survey |
| **SRP Guiding Principle: Labor Conditions** | | |
| 10. Health and safety | Balanced scorecard | Household survey |
| 11. Child labor | Balanced scorecard | Household survey |
| **SRP Guiding Principle: Social Development** | | |
| 12. Women's empowerment | Balanced scorecard | Household survey |

# Fieldprint® Calculator, USA





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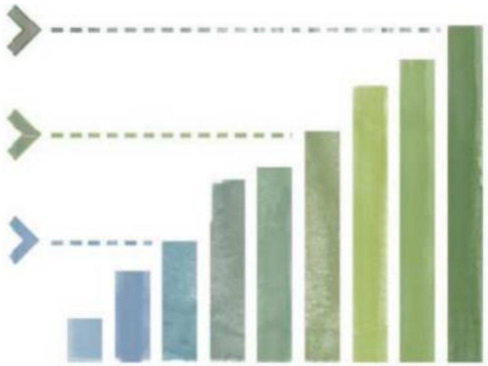
fieldtomarket.org

# Goals of calculator

**Benchmarking**

Sustainability Performance



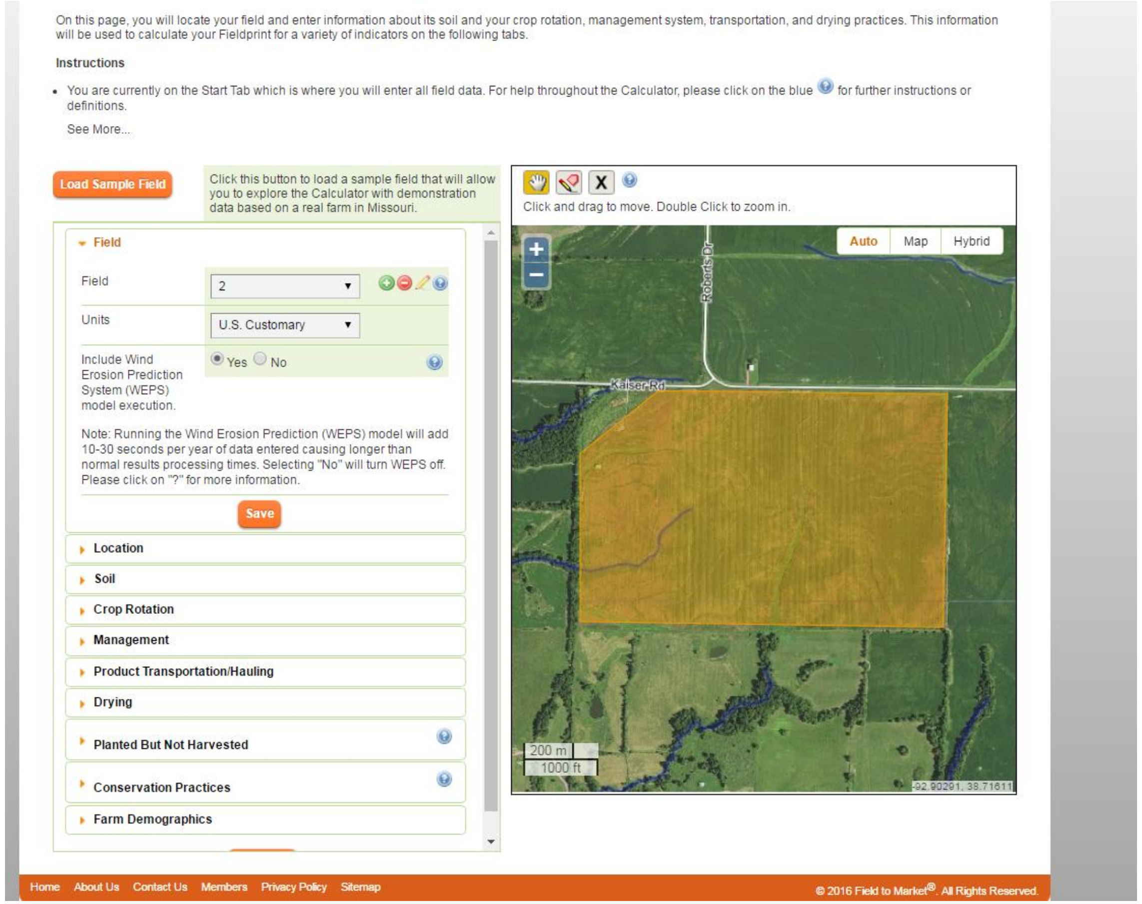
**Catalyzing**

Continuous Improvement

**Enabling**

Sustainability Claims

# Goals of calculator





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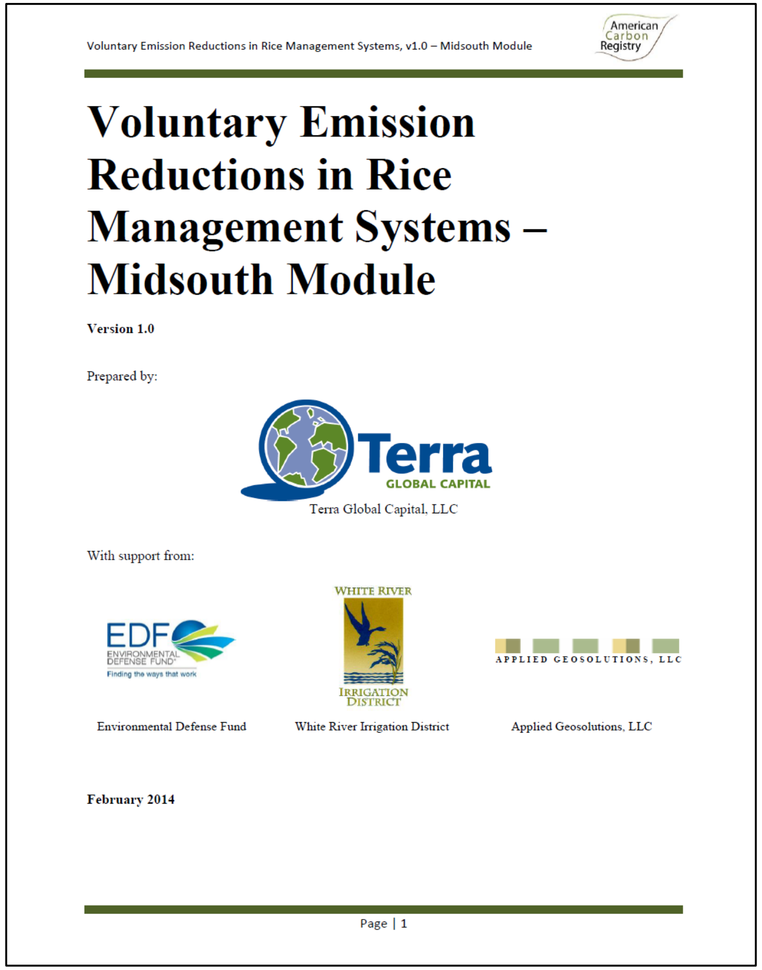
fieldtomarket.org

# Carbon offset protocols (USA)


Voluntary Emission Reductions in Rice Management Systems, v1.0 – Midsouth Module

American Carbon Registry

**Voluntary Emission Reductions in Rice Management Systems – Midsouth Module**

**Version 1.0**

Prepared by:

Terra GLOBAL CAPITAL

Terra Global Capital, LLC

With support from:

EDF ENVIRONMENTAL DEFENSE FUND Finding the ways that work

WHITE RIVER IRRIGATION DISTRICT

APPLIED GEOSOLUTIONS, LLC

Environmental Defense Fund | White River Irrigation District | Applied Geosolutions, LLC

**February 2014**

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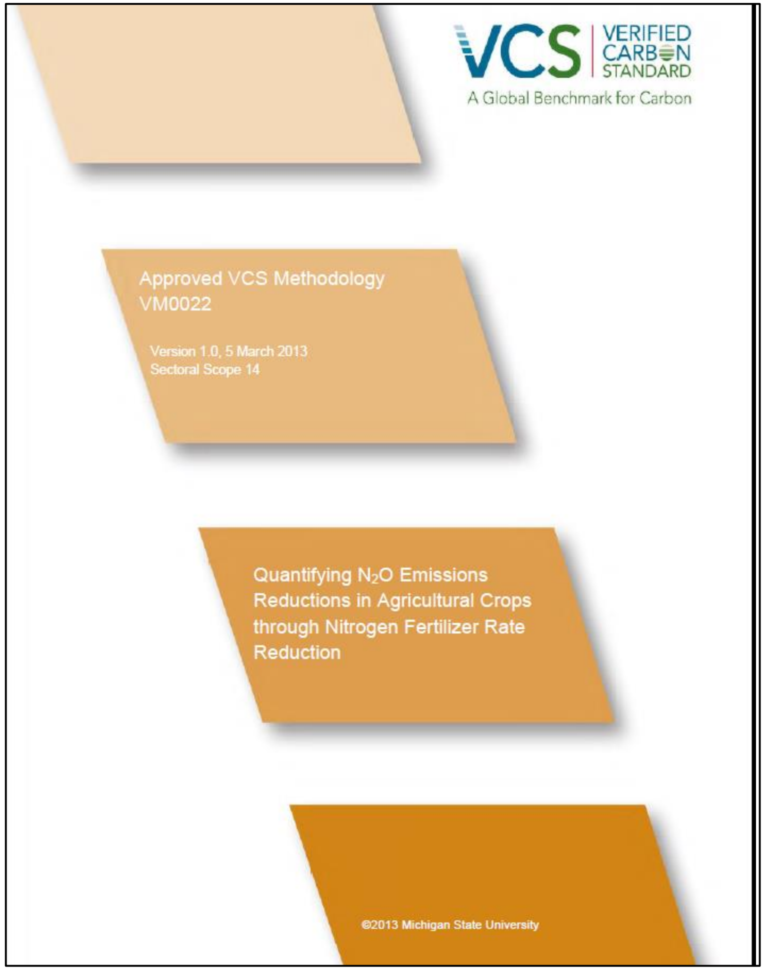
VCS VERIFIED CARBON STANDARD

A Global Benchmark for Carbon

Approved VCS Methodology VM0022

Version 1.0, 5 March 2013

Sectoral Scope 14

Quantifying $N_2O$ Emissions Reductions in Agricultural Crops through Nitrogen Fertilizer Rate Reduction

©2013 Michigan State University

# Conclusions

- Baseline knowledge of key indicators and tradeoffs is low
- Realistic expectations for SI may depending on existing yield gaps
- Environmental indicators will need continuous improvement

- The imperative of SI is common knowledge
- Next generation is being trained to tackle these issues
- Successful examples and frameworks for evaluation exist

# Questions?