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Global Potential for Adaptively Managing Nitrogen Using Active Sensors

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Are Sensors Relevant in Developing-World Agriculture?

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Cook et al., 2003

“We question this assertion and postulate that the basic purpose of precision agriculture – to provide spatial information to reduce uncertainty – far from being a luxury, and could be viewed as essential to accelerate change in the developing world…”

“The need for [site-specific] information is actually greater [in the developing world], principally because of stronger imperative for change and lack of conventional support.”

The Nutrient Expert decision support tool

- Nutrient Expert is a computer-based decision support tool for crop advisers. It uses the principles of site-specific nutrient management (SSNM).

- SSNM aims to supply a crop's nutrient requirements tailored to a specific field or growing environment.
  - accounts for indigenous nutrient sources
  - applies fertilizer at optimal rates and at critical growth stages → 4Rs (right source, right rate, right time, right place)

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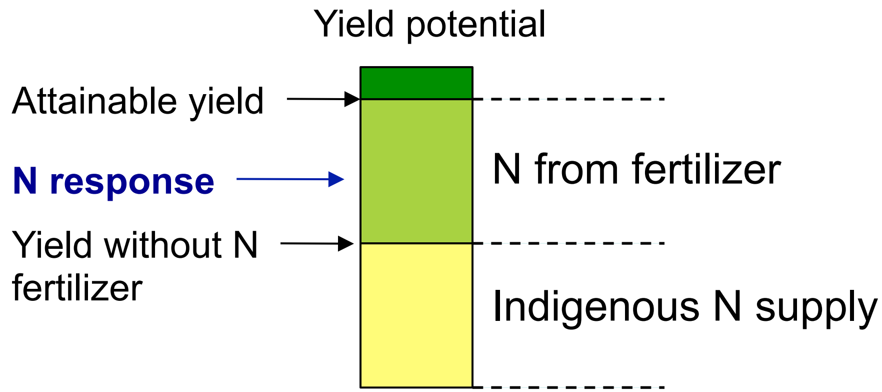
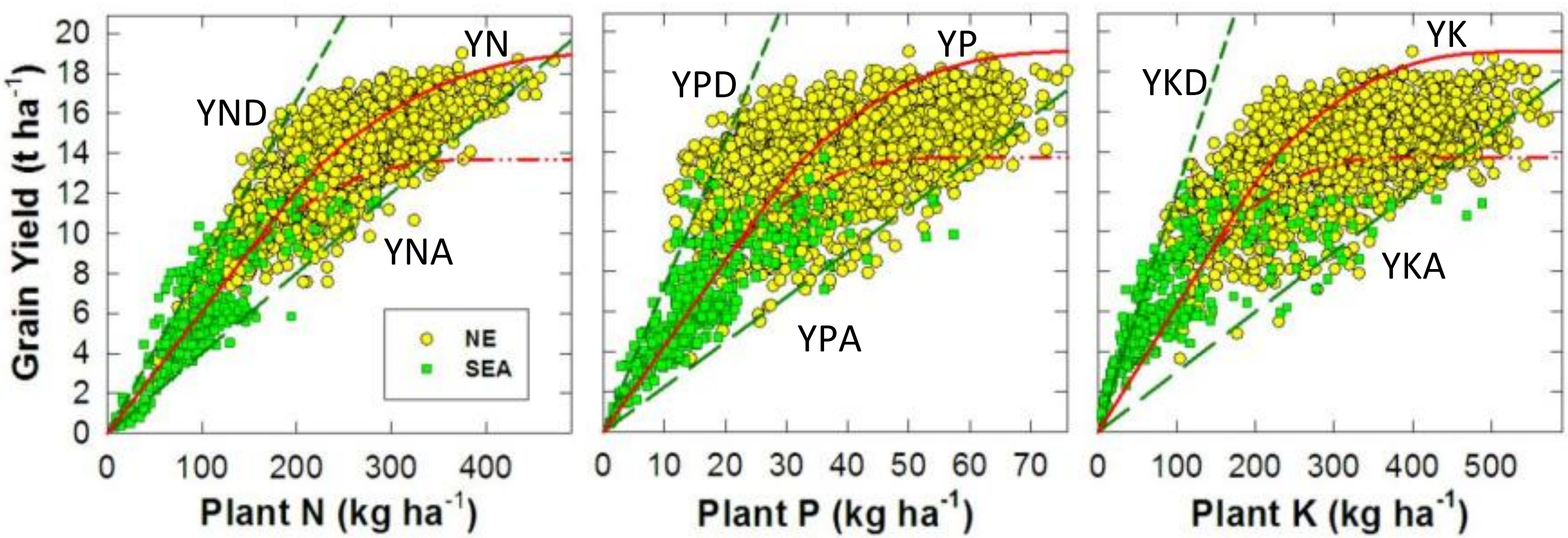
Estimating fertilizer requirement

- Estimate attainable yield
- Determine yield response to fertilizer application



- Estimate nutrient uptake requirement from the relationship between grain yield and balanced uptake of nutrients at harvest

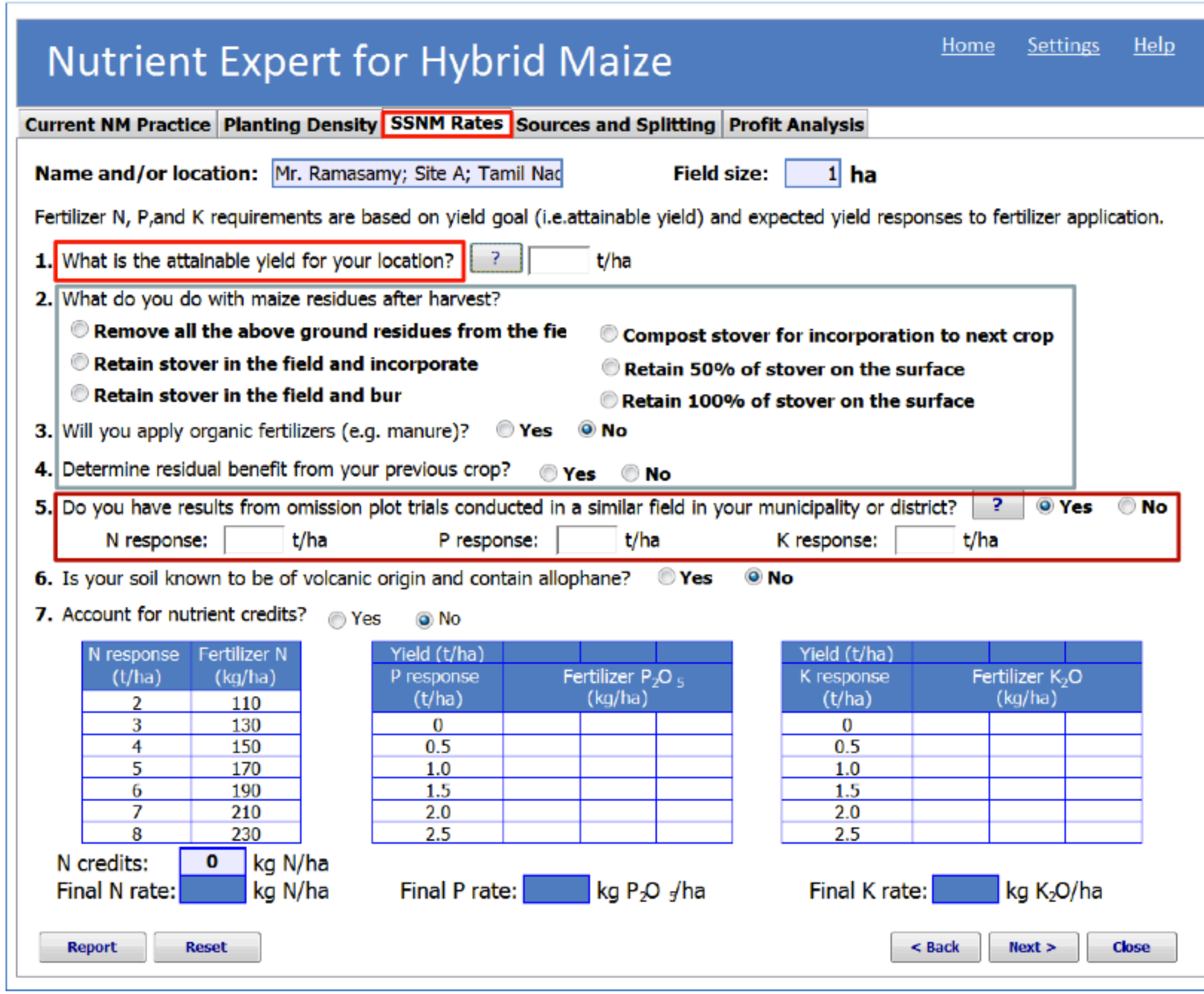


Nutrient Expert is developed through collaboration with local experts and stakeholders

- Collaboration with target users and stakeholders through consultation meetings
  - Collection of locally-available agronomic data and information
  - Field testing, evaluation, and refinement of the software
  - Building confidence in the concept with collaborators

Nutrient Expert recommendation:

- Tailored to location-specific conditions
- Consistent with 4Rs:
  - right source
  - right rate
  - right time
  - right place
- Option to tailor recommendation based on farmer's resource availability



Nutrient Expert for Hybrid Maize

Name and/or location Mr. Ramasamy; Site A; Tamil Nadu **Growing season** kharif **Field size:** 1 ha

Current yield 7.0 ton (18% MC) 6.8 t/ha (15.5% MC) **Growing environment** Irrigated maize

Recommended alternative practice for hybrid mai

Yield goal: 8.2 ton (18% MC) 8.0 t/ha (15.5% MC)

Planting density: 71,429 plants/ha **Distance between rows:** 70 cm **Distance between plants** 20 cm

VE V3 V6-V8 V10 or later V14-VT R6

Growth stage	Days after	Soil moisture	Fertilizer sources	Weight of full bag (kg)	Amount
Basal	0	sufficent	Urea	50	2
			Single Super Phosphate	50	3.5
			Muriate of Potash	50	1
V6	25-30	sufficent	Urea	50	2.5
V10	35-40	sufficient	Urea	50	2

Other sources of nutrients

Crop residue (rice): low

Organic fertilizer: 3.5 t

N: 26 kg

P_2O_5: 7 kg

K_2O: 18 kg

Right rate

Right time

Right source

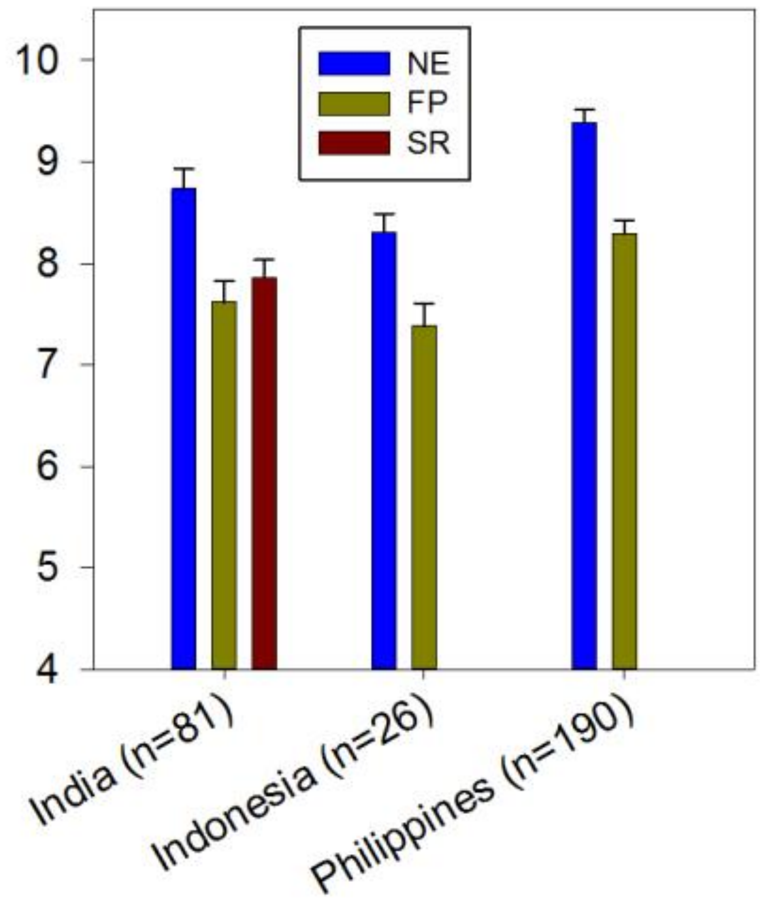
Fertilizer rates are adjusted to field siz

Deficient Nutrient	Recommendation to correct deficiency
Sulfur	Apply 30-60 kg/ha elemental sulfur or 227-375 kg/ha gypsum as basal.
Zinc	Apply 25-30 kg/ha zinc sulfate as basal.

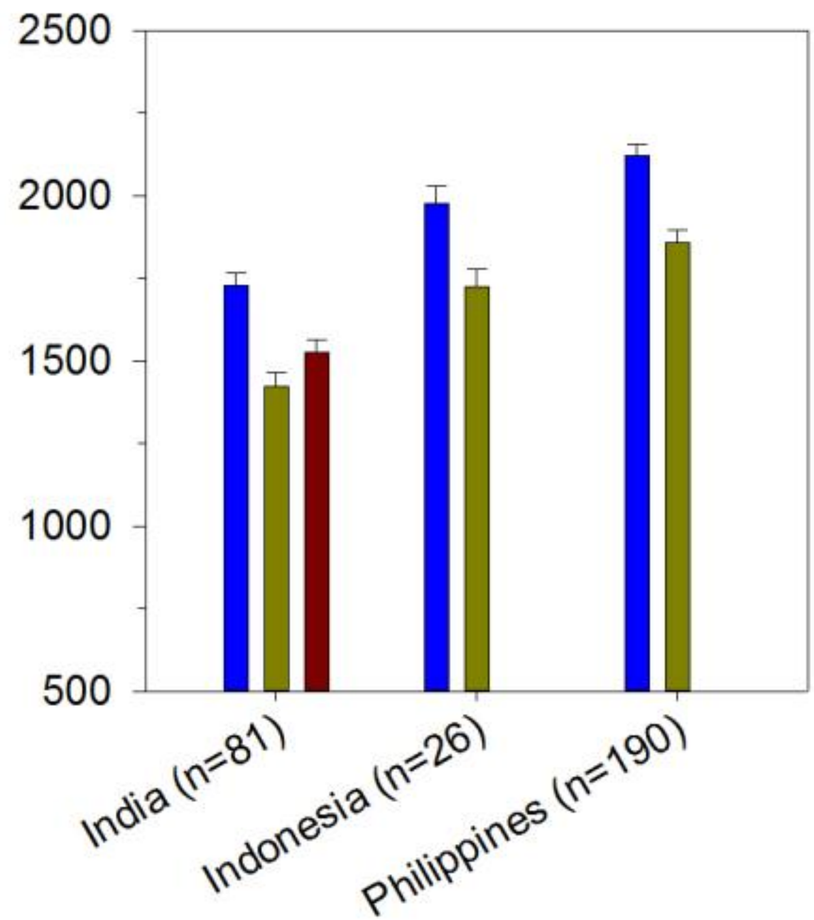
Field validation results of Nutrient Expert for maize

India, Indonesia, Philippines (2010-2013):
Farmers' current yield level < attainable yield

Grain yield (t/ha)



GRF (USD/ha)



GRF = gross returns above seed and fertilizer costs

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NE for maize performance across 22 sites in Indonesia

Parameter	Unit	FFP	NE	Difference (NE – FFP)
Grain yield	t/ha	7.51	8.40	**0.89** ***
Fertilizer N	kg/ha	173	160	-12.30 ns
Fertilizer P_2O_5	kg/ha	43	33	-10.04 *
Fertilizer K_2O	kg/ha	28	41	13.15 **
Fertilizer cost	USD/ha	126	126	0.08 ns
Gross return above seed & fertilizer	USD/ha	1761	2032	**270.94** ***

***, **, *: significant at <0.001, 0.01, and 0.05 level; ns = not significant

Data from 22 farmers' fields in five locations under irrigated (rice-rice-maize) and favorable rainfed (maize-maize) environments, 2010-2011

Seed cost: USD 5.08/kg; Price of maize grain: USD 0.27/kg; Price of fertilizer: actual local prices; USD 1 = IDR 8850

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NE for maize performance across 24 sites in the Philippines

Parameter	Unit	FFP	NE	Difference (NE – FFP)
Grain yield	t/ha	7.49	9.16	**1.67** ***
Fertilizer N	kg/ha	114	132	18 ns
Fertilizer P_2O_5	kg/ha	26	36	10 ***
Fertilizer K_2O	kg/ha	18	35	17 ***
Fertilizer cost	USD/ha	176	241	65 ***
Gross return above seed & fertilizer	USD/ha	1730	2126	**395** ***

***, **, *: significant at <0.001, 0.01, and 0.05 level; ns = not significant

Data from 24 farmers' fields in six regions under favorable rainfed (maize-maize, rice-maize) environments, dry season 2010-2011

Price of seeds, fertilizer, and maize grain are based on actual local prices; USD 1 = Php 43

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FFP vs SSNM (NE) in Iloilo, Philippines

NE for maize performance across 27 sites in India

Andhra Pradesh (n = 27)

Parameter	Unit	FP	NE	NE – FP	
Grain yield	kg/ha	8568	9699	**1131**	***
Fertilizer N	kg/ha	288	203	-85	**
Fertilizer P_2O_5	kg/ha	153	54	-99	***
Fertilizer K_2O	kg/ha	68	74	6	ns
Fertilizer cost	INR/ha	9509	5459	-4050	**
GRF[1]	INR/ha	76167	91770	**15603**	***

***, **, *: significant at <0.001, 0.01, and 0.05 level; ns = not significant

[1] GRF = gross return above fertilizer cost

Prices (in INR/kg): maize = 10.00; N = 11.40; P_2O_5 = 32.20; K_2O = 18.80

Field validation results of Nutrient Expert for maize in China (2010-2012)

Year	Treatment	n	Grain yield (t/ha)	Fertilizer rate (kg/ha)		
				N	P_2O_5	K_2O
2010	FP	138	8.6	225	53	40
	Soil test	127	8.8	195	47	69
	NE	**138**	**8.7**	**138**	**50**	**63**
2011	FP	185	10.0	222	64	44
	Soil test	90	10.5	215	65	86
	NE	**185**	**10.6**	**161**	**49**	**61**
2012	FP	138	10.6	235	67	59
	Soil test	109	11.1	204	60	72
	NE	**138**	**10.9**	**167**	**63**	**74**

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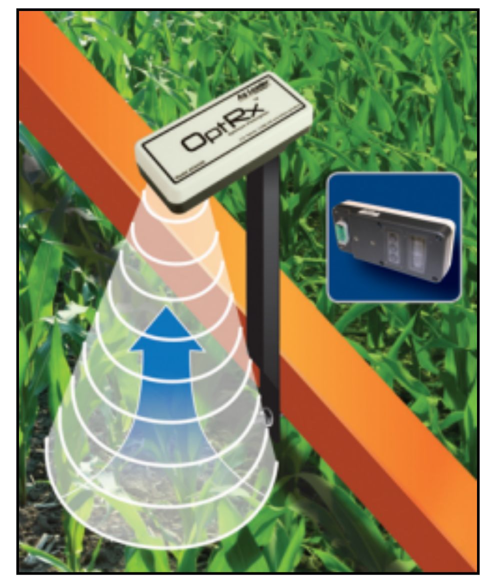
Estimating fertilizer requirement for Nutrient Expert

- Estimate attainable yield
- Determine yield response to fertilizer application
- Estimate nutrient uptake requirement
- Estimate site-specific nutrient use efficiency



Developing a Sensor-Based Program

1. Calibration
2. Validation
3. Development
4. Training

Sensor Based N Rate Calculator, Rice 2009

DATA ENTRY	
Max yield, bu/ac	320
Planting Date	23-Apr-09
Sensing Date	29-Jun-09
NDVI, N Rich Strip	0.78
NDVI, Farmer's practice	0.767
NUE expected	0.5
RESULTS	
Response Index	1.19
Days, planting to sensing	66
Potential yield (0-N), bu/ac	223
Potential yield (+ N), bu/ac	266
Fertilizer N, lb N/ac	46

Note:

NRS (Nitrogen Rich Strip) - Reference Strip
FP (Farmer's Practice)
NDVI (normalized difference vegetation index)

Max yield set to 2 times the average yield in the area
Rough rice: 45 lbs/bu
Rice grain N = 1.2%

PROCEDURE:

1. Farmer is asked to Establish the Maximum Yield Achievable, For that Year (YPMAX)
2. Sense the N Rich Strip (NRS)
3. Sense a strip parallel to the NRS (Farmer's Practice or FP)
4. Determine how many days from planting to sensing
5. Compute INSEY (NDVI/days from planting to sensing)
6. Predict yield
7. Predict grain N uptake in FP
8. Predict grain N uptake in FP based on RI
9. N rate = (grain N uptake in FP based on RI - grain N uptake in FP)/expected NUE

Contributors: Brenda Tubana, Dustin Harrell, and Timothy Walker

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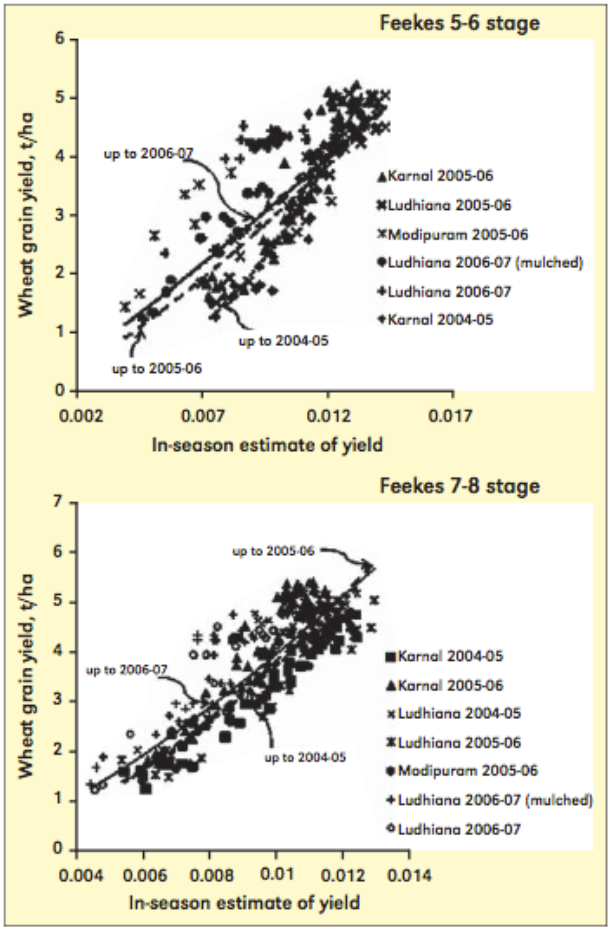
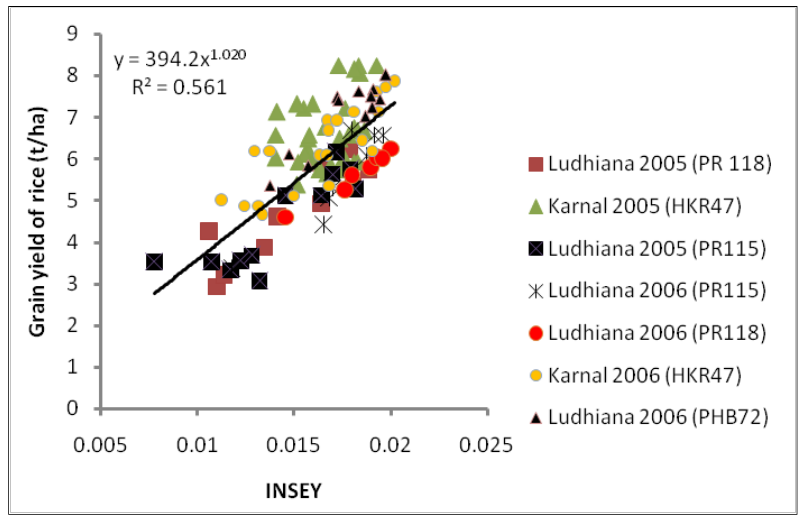
Calibration

- Establish sensor-based model for predicting grain yield potential





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Validation

- Evaluate the performance of sensor-based N decision tool against the commonly applied flat N rate

N management in rice: application of GreenSeeker optical sensor-guided fertilizer in India

Fertilizer N application (kg N/ha)				Grain yield (t/ha)			
Basal	21DAT	42 DAT (GS guided)*	Total	2006	2007	2008	2008
				PR118	PR118	PAU201	PHB71
0	0	0	0	3.85	4.05	4.16	3.42
40	40	40	120	6.19	5.01	6.86	6.16
30	30	32	92	5.63			
30	30	23	83		4.74		
30	30	48	108			6.59	
30	30	49	109				6.09
L.S.D. (p=0.05)				0.774	0.337	0.488	0.488

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Sensor Calibration and Validation Research

- Li et al., 2009
- Bijay-Singh et al., 2011
- Cao et al., 2012

Wheat

- Yao et al., 2012
- Xue et al., 2013

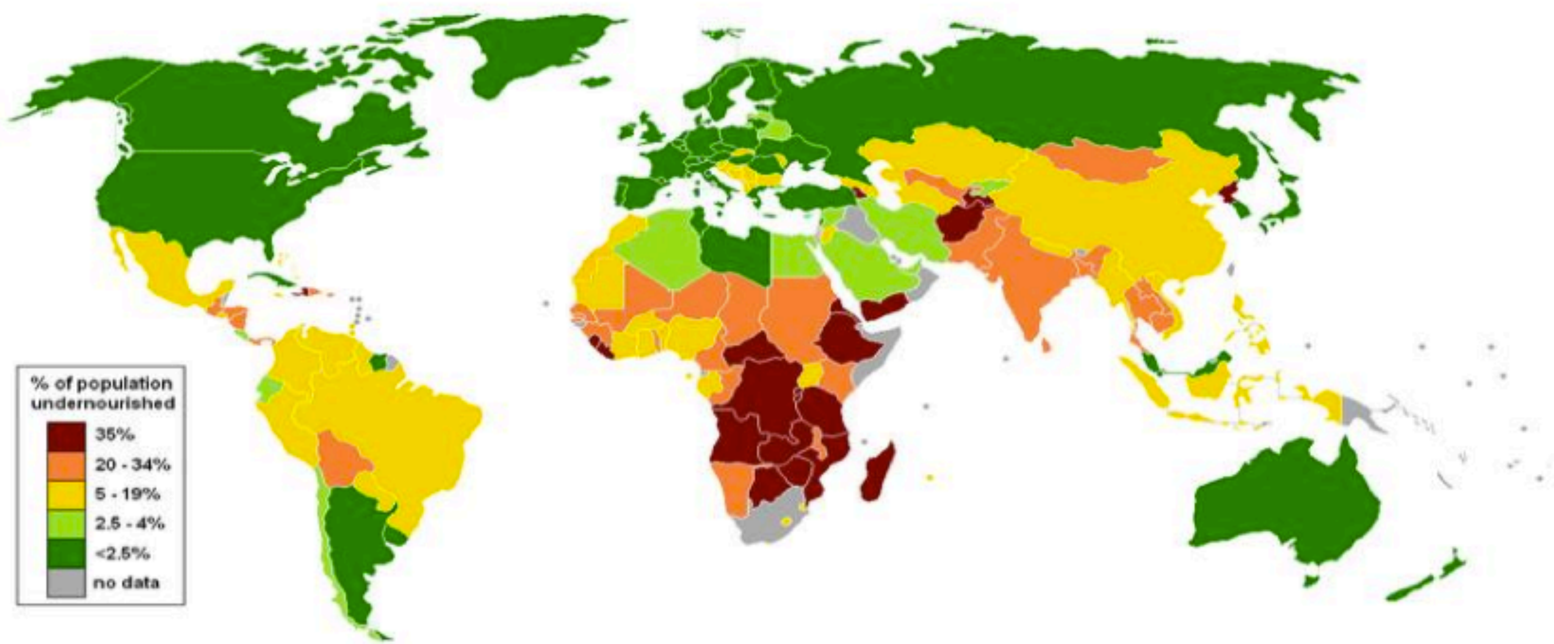
Rice

Development and Training

Challenges and Opportunities

- Cost / Profit potential
  - Handheld sensors
- Delivery mechanism for rate recommendations
  - Mobile device technology
- Continued research / extension support
  - Incomplete follow-through
- Technical support
  - Equipment operation, data collection, rate calculation
- Can be incorporated into existing SSNM strategies
- Logistics in small-holder system
  - Ownership of equipment
  - Reference strips

Global Population and Food Security



- Population increases are placing greater pressure on the food security of certain regions of the world
- Potential food security challenges are going to affect all world residents, regardless of their location.

Application of precision agriculture technologies will be essential for sustainable access to food for a global population

Global food security will be dependent on how well we adapt the principles of precision agriculture for the small holder systems of Asia

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