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Improving Crop Yield and Nutrient Use Efficiency in China

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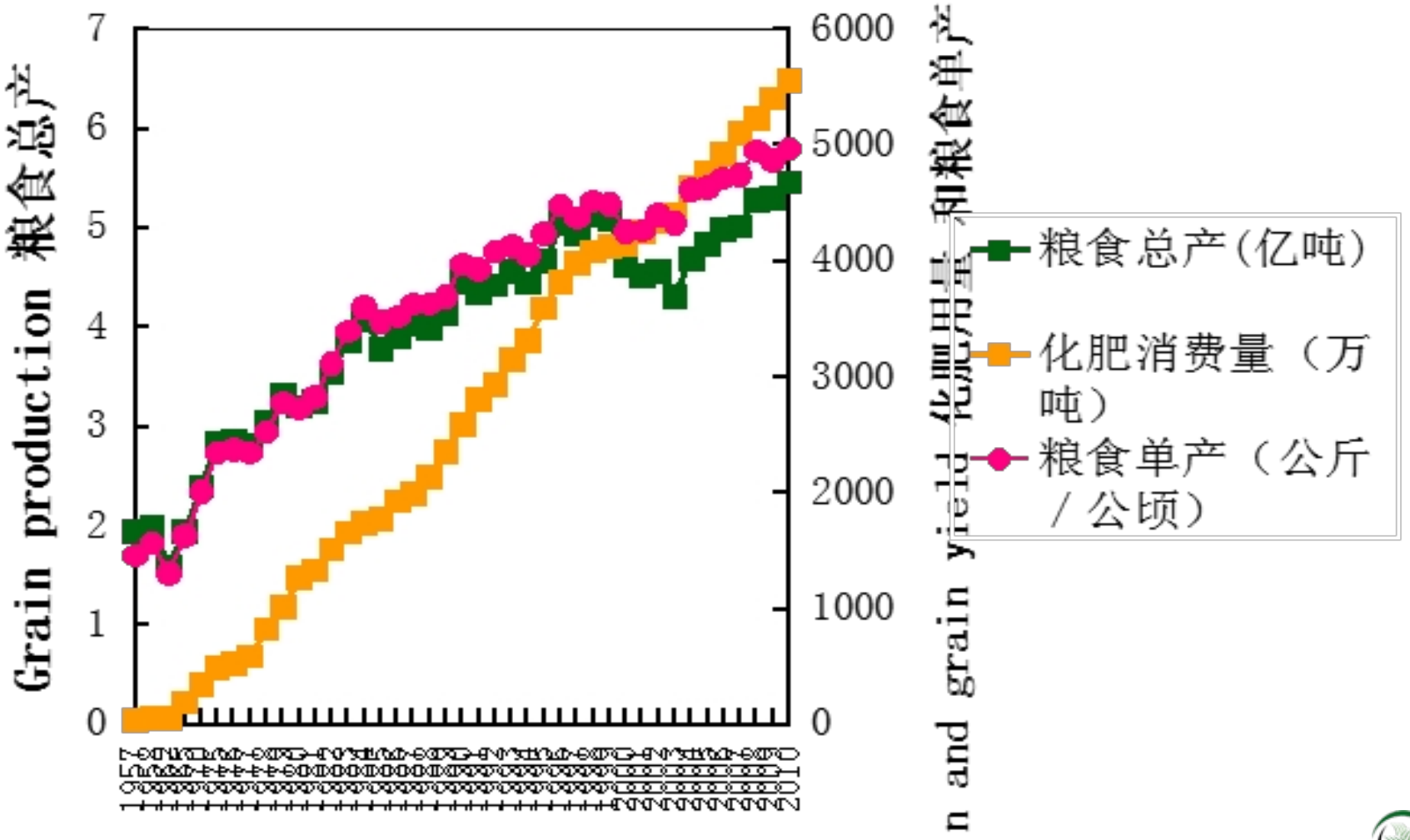
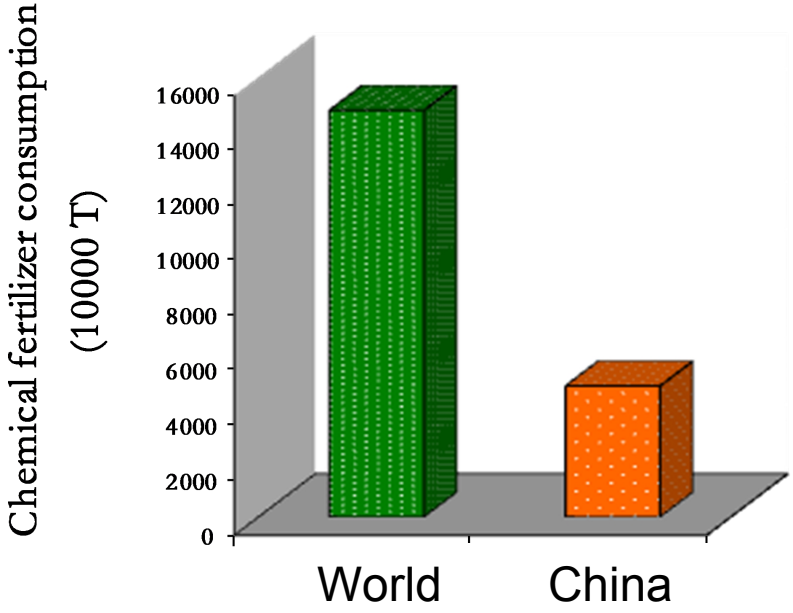
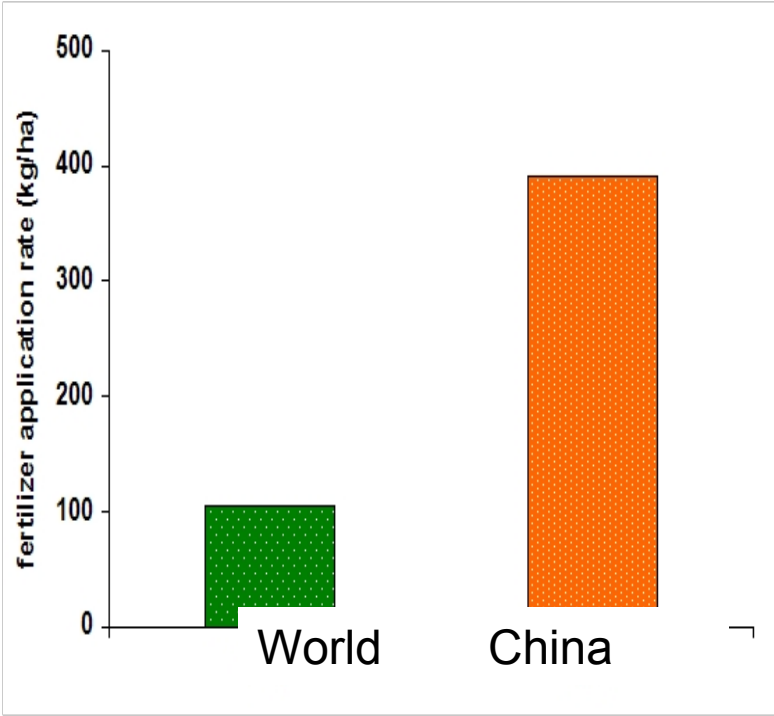
Chemical Fertilizer is the most important guarantee for food security



China is the first fertilizer consumption country

With 9% of world arable land, China consumes about 1/3 of world fertilizer, resulting in high fertilizer application rate (3.7 times of world average level) and low nutrient use efficiency





Low N fertilizer use efficiency

Country	Crops	RE (%)	AE (kg/kg)
China[1]	**Wheat**	**38**	**10**
China[2]	**Maize**	**32**	**10**
China[2]	**Rice**	**27**	**12**
US[3]	**Cereals**	**52**	**20**
World average[3]	**Cereals**	**55**	**21**

1 Liu et al., Agron. J.103: 1452-1463 (2011)
2 IPNI unpublished
3 Ladha et al., 2005, Advances in Agronomy, 87:85–156 (2005)

- Dobermann et al (2007) indicated that AE_N and RE_N was10-30 and 30-50% in developing countries, and could be reached to >25 and 50-80% under well management condition.

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Over fertilization has brought about environmental problems

news feature

Nature, 2003, 425: 894-895

Fertilized to death

Vast quantities of nitrogen being poured onto farmers' fields are wreaking havoc with our forests. Nicola Nosengo investigates.

Dotted throughout forests around the world, yellowed leaves and thinning crowns suggest that some trees are dying an early death. But the culprit may come as something of a surprise. It isn't just pollution spewed from car fumes, or damage from insects proliferating thanks to global warming. Our forests are facing a quieter villain. They're being plagued by the very stuff that has provided people with food for the past hundred years — fertilizer.

The use of fertilizer changed dramatically in the twentieth century. In the late 1890s, people struggled to get enough fertilizer for their fields — the main sources were bird

Nature, 2004, 427:99

correspondence

Cooperation needed to increase fertilizer efficiency

Better use of nitrogen could provide more food and reduce the environmental impact.

Sir — Your News Feature "Fertilized to death" (*Nature* **425**, 894–895; 2003) deals with an extremely important issue: reactive nitrogen and the need to increase the efficiency of nitrogen fertilizers. James Galloway's work, as well as that of the IVL Swedish Environmental Research Institute, has pointed to significant environmental problems with excess reactive nitrogen.

Although environmental concerns about excess nitrogen are worth highlighting, the need to produce more food, more efficiently, in many parts of the world is even more urgent. Energy expert Vaclav Smil estimates that approximately 40% of the world's dietary protein supply in the mid-1990s originated from fertilizer nitrogen (V. Smil *Enriching the Earth* 156–161, MIT Press; 2001). Agronomists and soil scientists throughout the world are working to make nitrogen use in farming more efficient for both food production and environmental reasons.

Although cutting back on fertilizer use might be a method to reduce the total load of reactive nitrogen in developed countries with excess food production capacity, it is not an acceptable solution in countries with malnourished people. The effect of increased food costs on people with low incomes in developed countries must also be considered. Efficiency improvements can help reduce nitrogen-fertilizer consumption if populations stabilize, and reduce its impact on the environment.

Ecologists, agronomists, environmental groups and industry must join to increase nitrogen-fertilizer efficiency for the benefit of everyone. Publications such as *Nature* should lead the way in building interdisciplinary support for this worthy goal.

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Nutrient management strategies

- SOIL BASED:
  - Rely mainly on soil testing, traditional, destructive, and more static

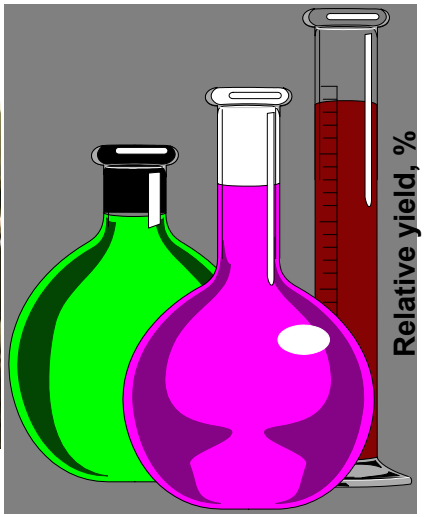
- PLANT BASED:
  - Rely mainly on plants as indicators, new, non-destructive, and more dynamic

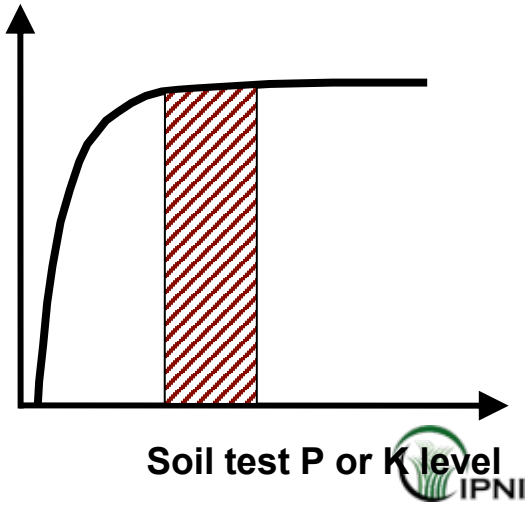
Soil testing process

- Soil sampling
- Extraction and chemical analysis
- Correlation and calibration
- Fertilizer recommendation philosophy

15-20 samples per area tested, clean equipment and containers, proper sample handling, delivery to the lab.

Do the chemical methods used by soil testing labs best suit their local soils?



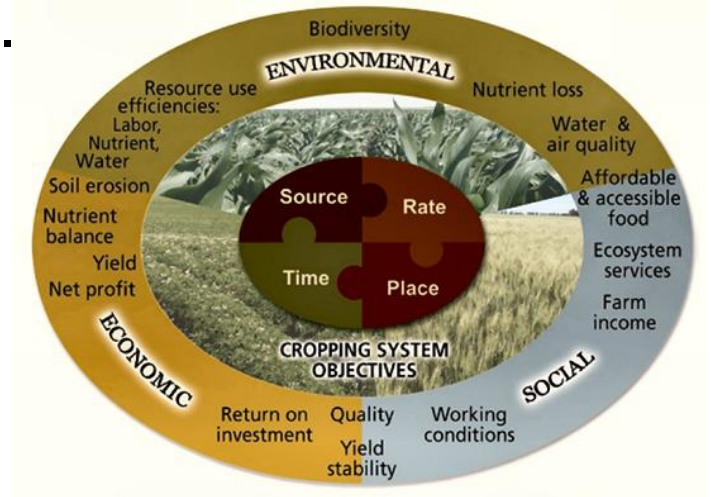


Plant based nutrient management -Nutrient Expert™

- An approach for “feeding” crops with nutrients as and when needed. It advocates:

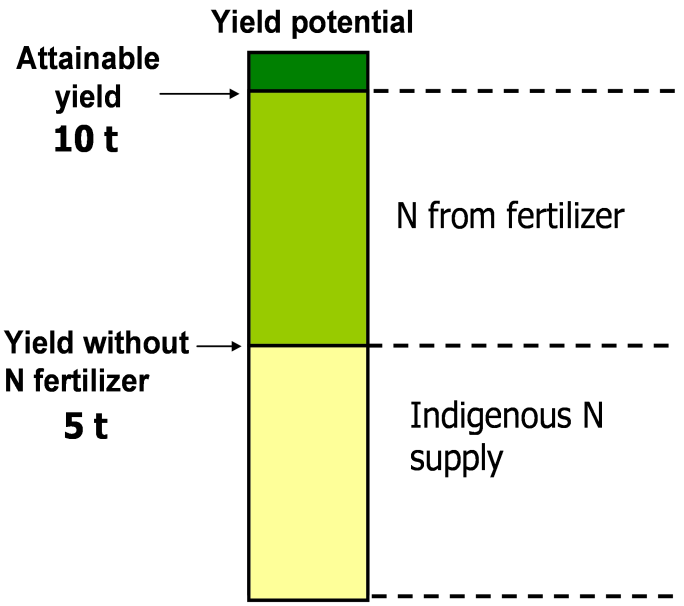
- Optimal use of existing indigenous nutrient sources (e.g. crop residue, manure)

- Manage nutrient with 4R strategy
  - Apply fertilizer with the right source at the right rate, right time and right place



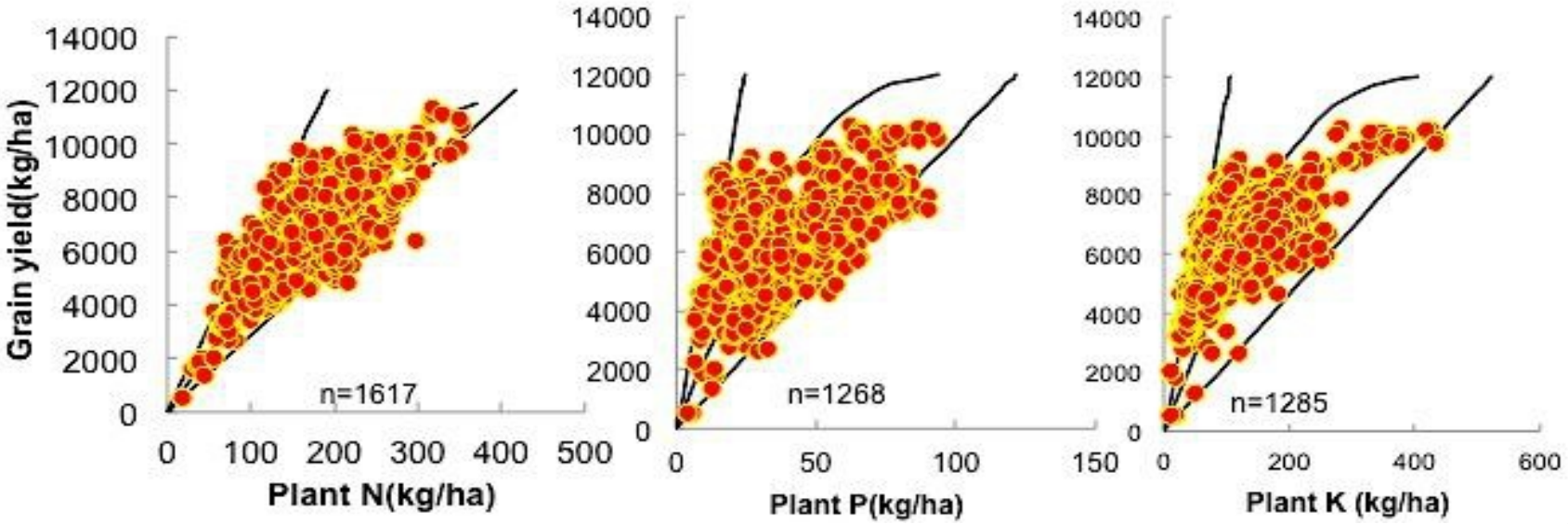
Estimating fertilizer nutrient requirements
The SSNM approach

- Identify a yield target (i.e. attainable yield)
  - Yield achieved with best management practices where nutrients were not limiting
- Estimate indigenous nutrient supply
  - Can be determined through use of nutrient omission plots
- Estimate amount of nutrient to be supplied as fertilizer



Estimating nutrient requirements
The QUEFTS model

- The Quantitative Evaluation of the Fertility of Tropical Soils (QUEFTS) model to use to determine more generic relationship between grain yield and crop nutrient requirements
- The QUEFTS model can simulate optimal nutrient requirement to avoid imbalanced fertilization (example below-wheat)



Chuan et al. Field Crops Research, 2013, 146:196-104

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Nutrient uptake requirements for cereal crops as predicted using QUEFTS – China data

Crop	Reciprocal internal efficiency (kg nutrient/1000 kg grain)		
	N	P	K
Rice [1]	17.7	3.9	17.8
Summer maize [2]	22.5	4.4	15.9
Spring maize [2]	16.9	3.5	15.3
Wheat [3]	22.8	4.4	19.0

[1] IPNI China. Unpublished data
[2] Xu et al. 2013. Field Crops Research
[3] Chuan et al. 2013. Field Crops Research

Fertilizer recommendation principles for Nutrient Expert™

- Fertilizer recommendation method in *Nutrient Expert* is based on yield response and agronomic efficiency (AE)

- The determination of fertilizer N requirements from *Nutrient Expert* has been modified to use a target agronomic efficiency and an estimation of yield response to applied N

- The determination of fertilizer P and K requirements considers the internal nutrient efficiency combined with estimates of attainable yield, nutrient balances, and yield responses from added nutrient within specific fields

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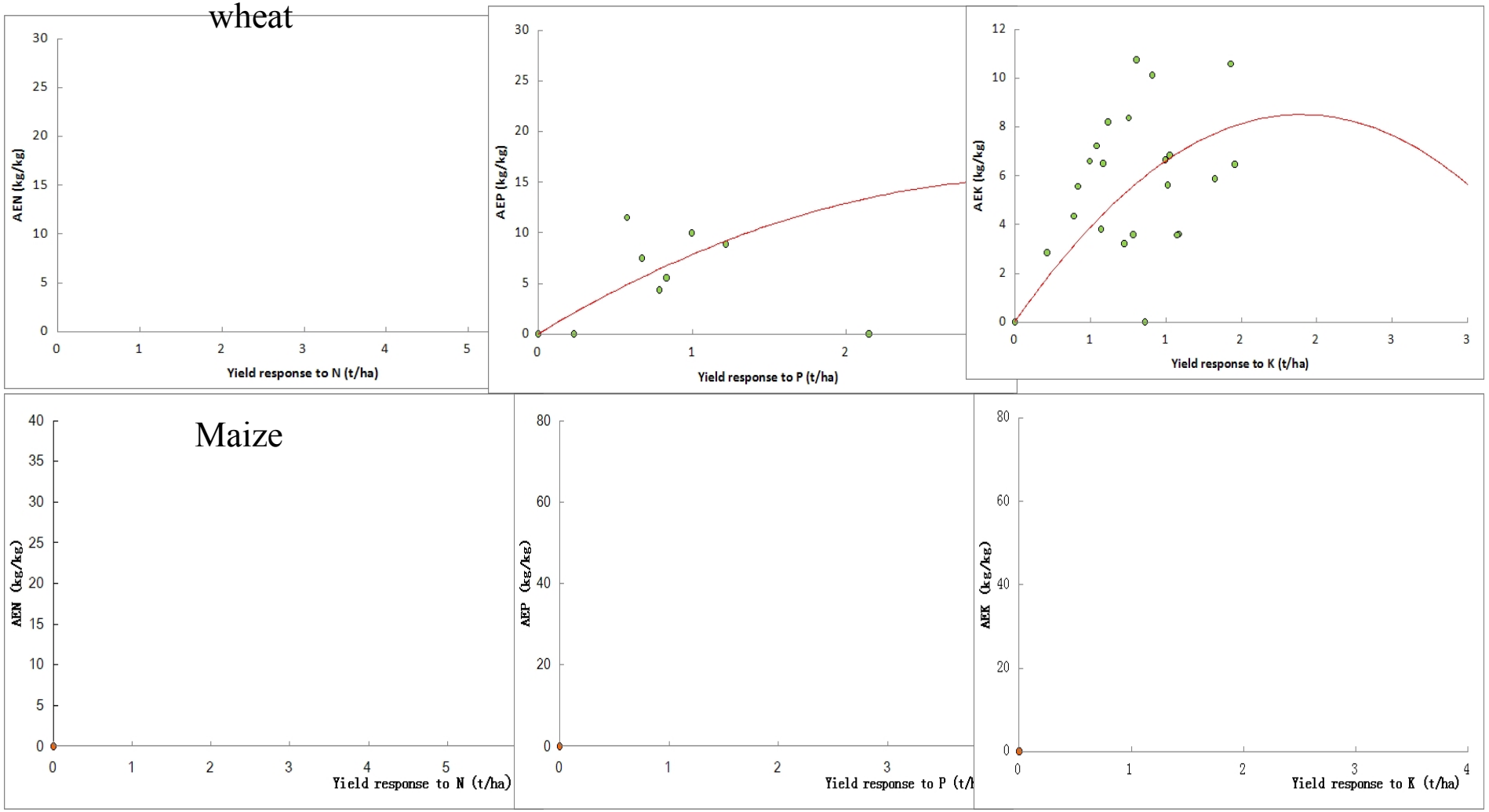
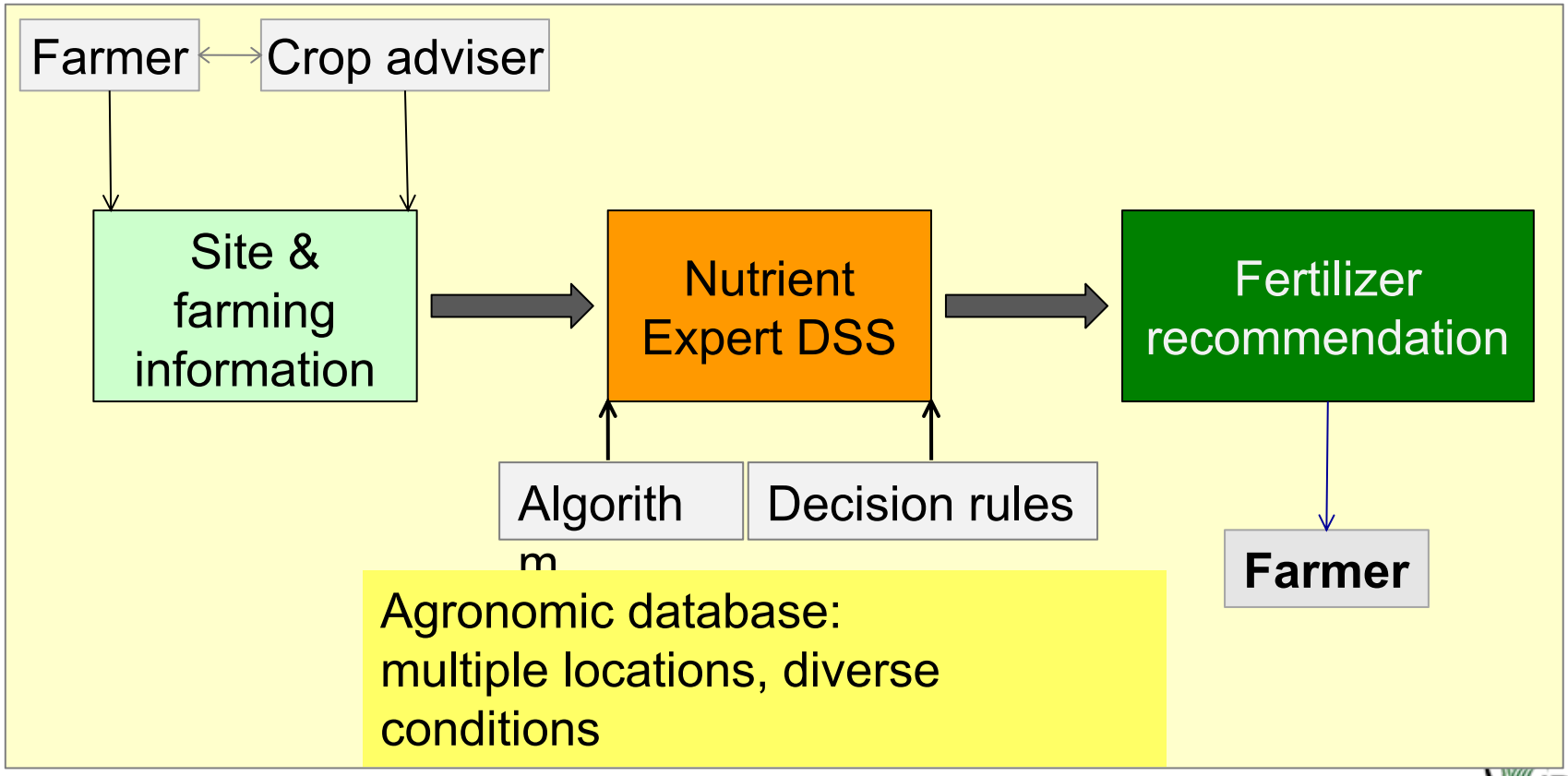
Relationship between AE and yield response



Chuan et al. Field Crops Research, 2013, 140:1-8

Nutrient Expert: Simplifying implementation of SSNM

Nutrient Expert provides SSNM-based fertilizer guidelines for a location using only site information that can be easily provided by a farmer or crop adviser



Nutrient Expert: Simplifying implementation of SSNM

- Nutrient Expert cuts through the complexities of SSNM by using
  - a systematic approach to capture important farming data
  - a simple interface (easy-to-answer questions)
- Nutrient Expert allows crop advisors to develop fertilizer guidelines for a location using only site information that can be easily provided by a farmer or local extension worker
  - The available site information using decision rules developed from trial data → no need to collect experimental data for every field
  - Users can draw information from their own experience, farmers' knowledge of the local region and farmers' practices

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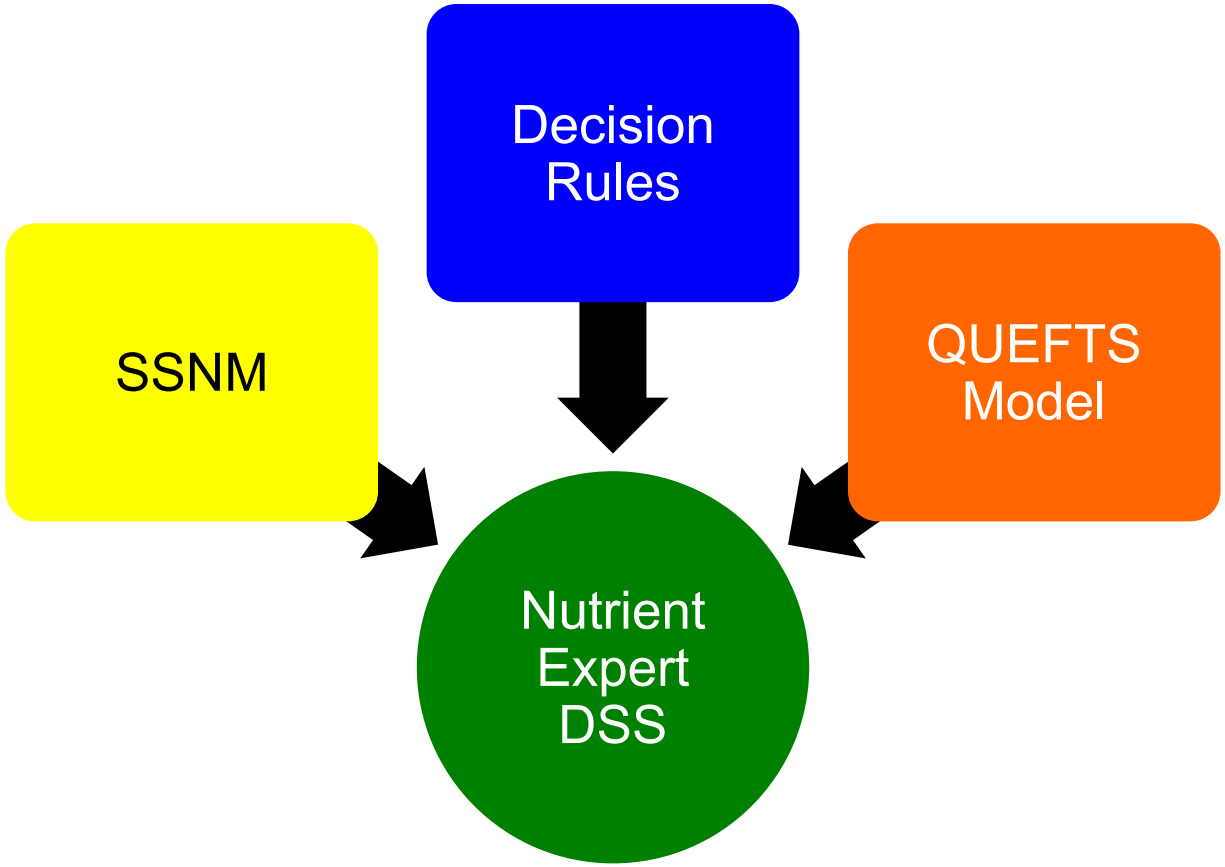
The Process of Developing a DSS



Nutrient Expert[R] for maize in China

Nutrient Expert[R] for wheat in China

Field validation results of Nutrient Expert for Hybrid Maize

China (2010-2012): Farmers' current yield level ≈ attainable yield

Year	Treatment	n	Grain yield (t/ha)	Fertilizer rate (kg/ha)			Gross profit
				N	P_2O_5	K_2O	(US$/ha)
2010	FP	138	8.6	225	53	40	2364
	Soil test	127	8.8	195	47	69	2454
	NE	**138**	**8.7**	**138**	**50**	**63**	**2433**
2011	FP	185	10.0	222	64	44	2978
	Soil test	90	10.5	215	65	86	3039
	NE	**185**	**10.6**	**161**	**49**	**61**	**3097**
2012	FP	138	10.6	235	67	59	3285
	Soil test	109	11.1	204	60	72	3485
	NE	**138**	**10.9**	**167**	**63**	**74**	**3477**

Data source: IPNI China unpublished

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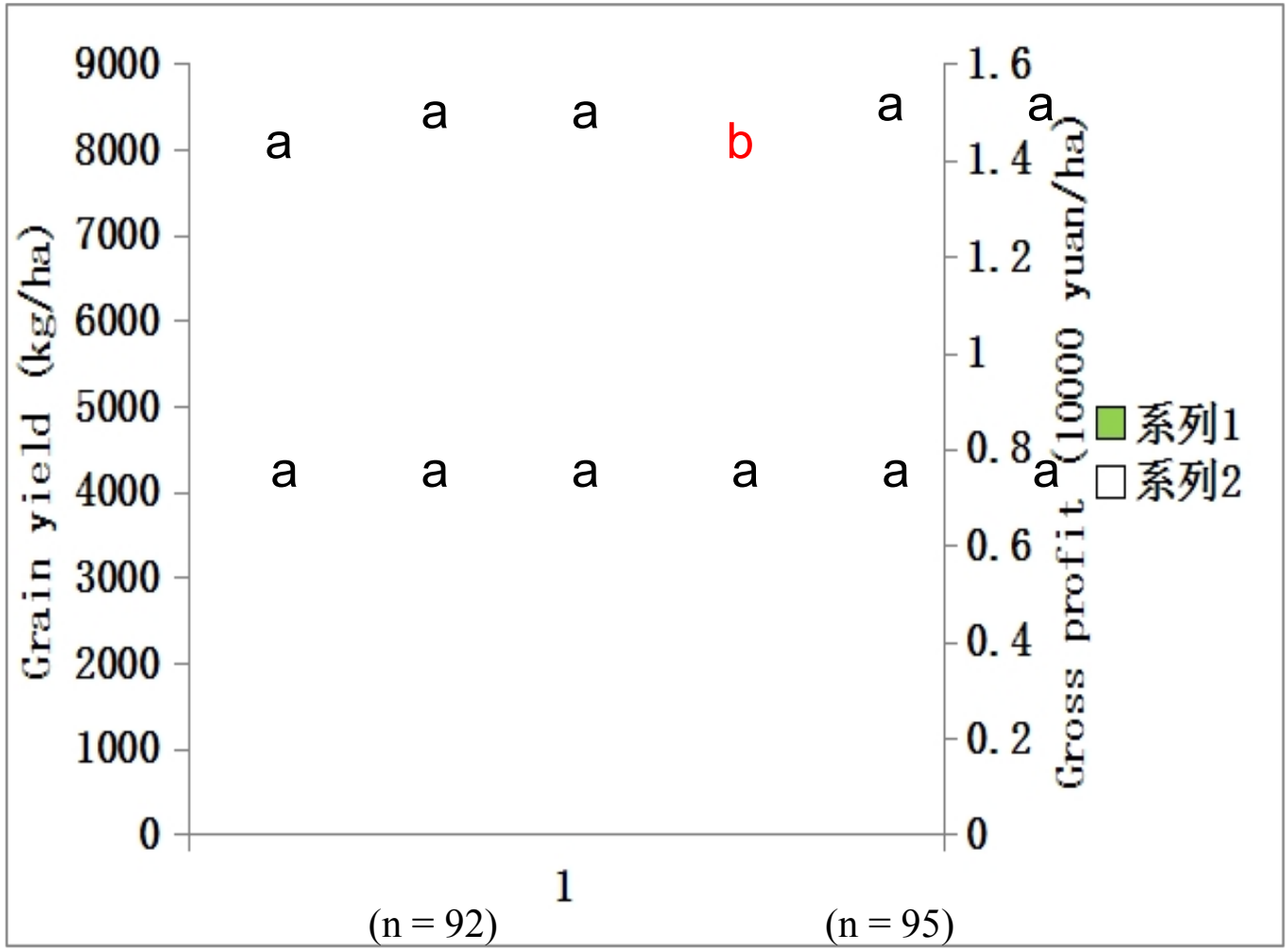
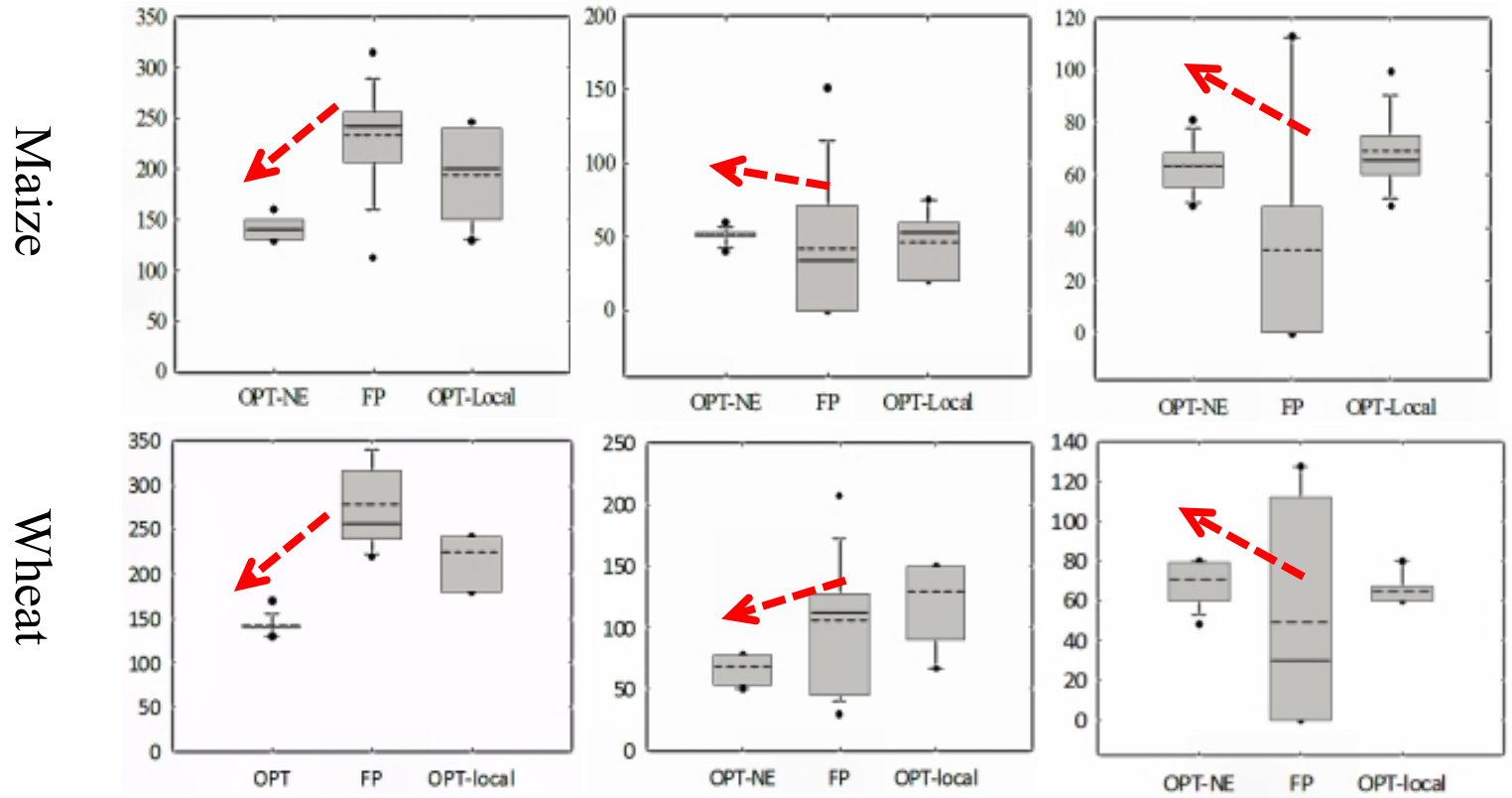
China: Nutrient Expert maintained high yields and economic benefits in wheat



FP: farmer's fertilizer practice; **Local**: local recommendation; **NE**: Nutrient Expert

Nutrient Expert reduced N rate, and balanced P and K



- Summer maize: N saved by -24~131 kg N/ha, averagely 94 kg/ha(40.1%)
- Winter wheat: N saved by 95-177kg N/ha ， averagely 135kg/ha (48.3%)

Nutrient Expert improved fertilizer N use efficiency in maize and wheat in China

Nutrient Expert for Maize

	AEN (kg/kg)		REN (%)	
Spring maize (n = 145)				
NE	**15.8**	**a**	**34.2**	**a**
FP	10.2	b	23.8	b
Summer maize (n = 263)				
NE	**10.3**	**a**	**28.0**	**a**
FP	7.2	b	17.8	b

Source: IPNI (unpublished)

Nutrient Expert for Wheat

	AEN (kg/kg)		REN (%)	
2011 (n = 92)				
NE	**8.4**	**a**	**32.5**	**a**
Local	6.6	b	26.6	b
FP	4.5	c	18.3	c
2012 (n = 95)				
NE	**6.8**	**a**	**22.5**	**a**
Local	5.3	b	19.8	ab
FP	4.8	c	17.0	b

Source: Chuan et al. 2013. Field Crops Res. 140:1-8

AEN: agronomic efficiency of N (kg yield increase/kg applied N)
REN: apparent recovery efficiency of N (increase in N uptake/applied N)

Field validation effect of Nutrient Expert

From 2010-2012, 461 maize and 187 wheat field validation has been successfully conducted. From 2013, the technology has been transferred to large scale and southern China

Nutrient Expert – successful in other countries

- South Asia: India
- Africa
- Southeast Asia
- Russia
- US

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Plan to other crops

- Rice based cropping system
  - One season rice
  - Rice-wheat/rapeseed
  - Rice-rice
- Soybean based cropping system

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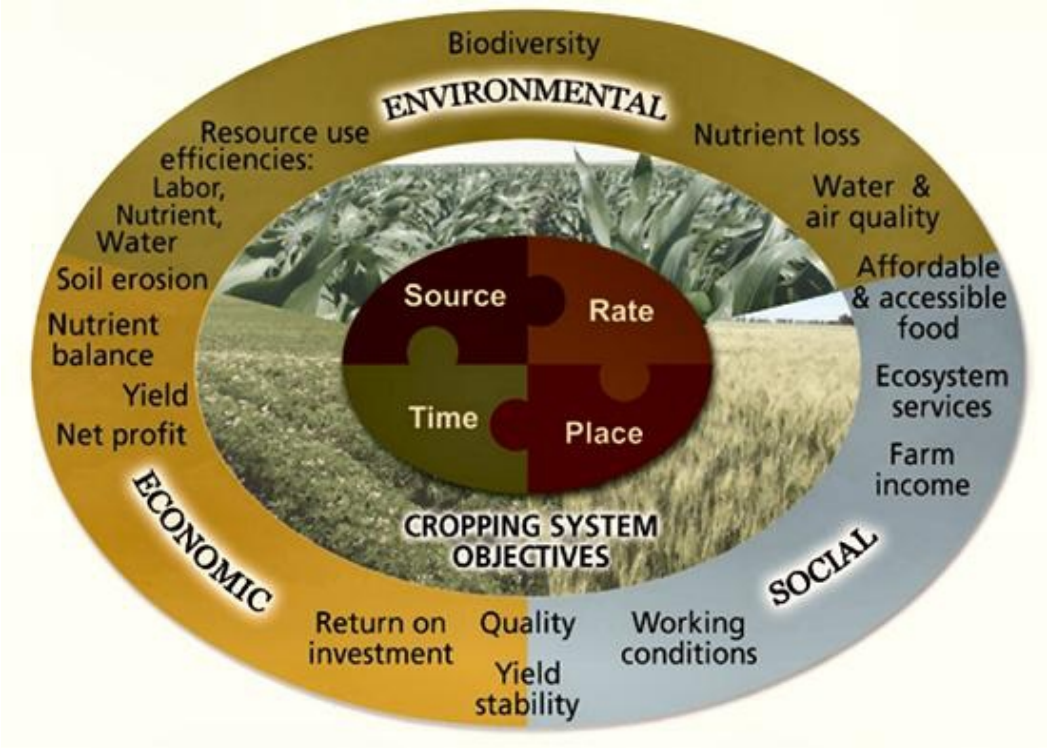
Summary

- Over fertilization is one of the main reasons for low nutrient use efficiency in China
- Nutrient Expert can improve both grain yield and nutrient efficiency for wheat and maize
- Nutrient Expert based fertilizer recommendation is a promising method in small holder farmers when soil testing is not available or not timely
- Nutrient use efficiency can be improved further with integrated with other agronomic practices

More cooperation needed

- Fertilization practice needs to work together with water management, tillage, and all other farming practices, to develop a scientific package for a sustained cropping system.



Questions and comments ?

Acknowledgement: IPNI, MOST, MOA, NSFC

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