Integrated soil-crop system management

---Reducing environmental risk while increasing crop productivity and nutrient use efficiency in China

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Plant Nutrition in CAU

This presentation was made at the IPI-OUAT-IPNI International Symposium, 5-7 November 2009, OUAT, Bhubaneswar, Orissa, India. The Role and Benefits of Potassium in Improving Nutrient Management for Food Production, Quality and Reduced Environmental Damage.

Outline

- Challenges and problems of food production and environmental protection
- Development of Integrated soil-crop system management technology
- Summary and perspective

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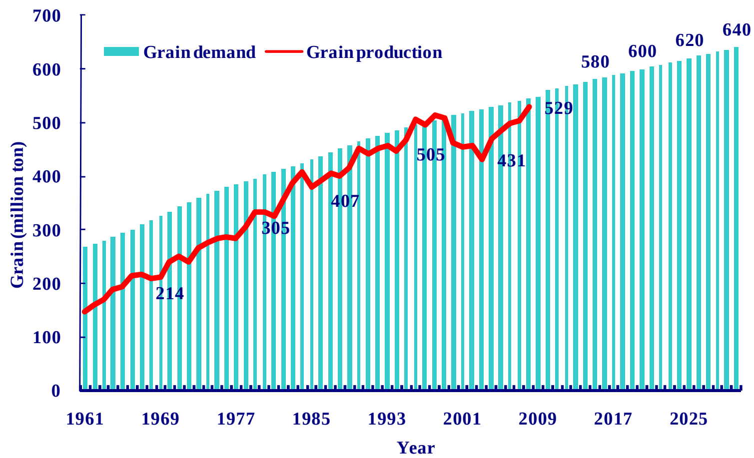
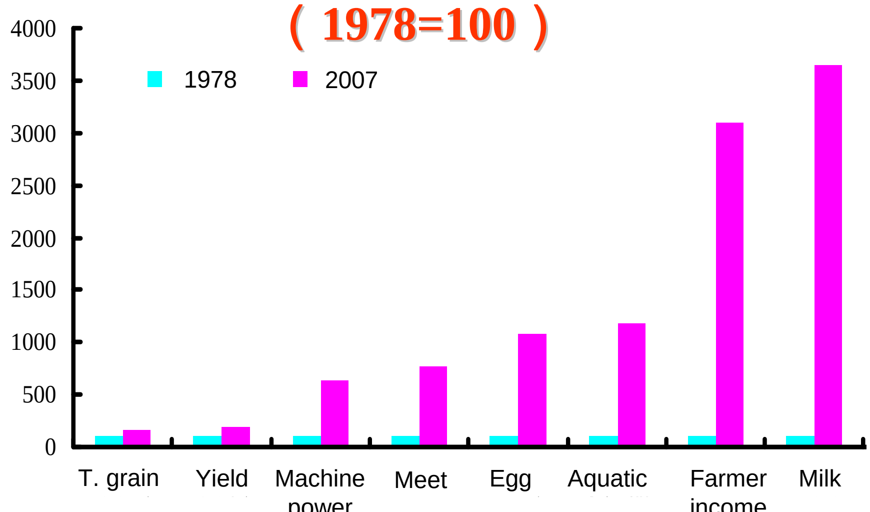
It took nearly 50 yrs to realize the dream of food sufficiency in China with massive inputs



(Data from the Statistic Bureau of China
Demand was estimated by using average grain demand of 400 kg/capita/year)

30 years achievements in agriculture

（1978=100）



数据来源：《中国统计年鉴》和《新中国五十年农业统计资料》

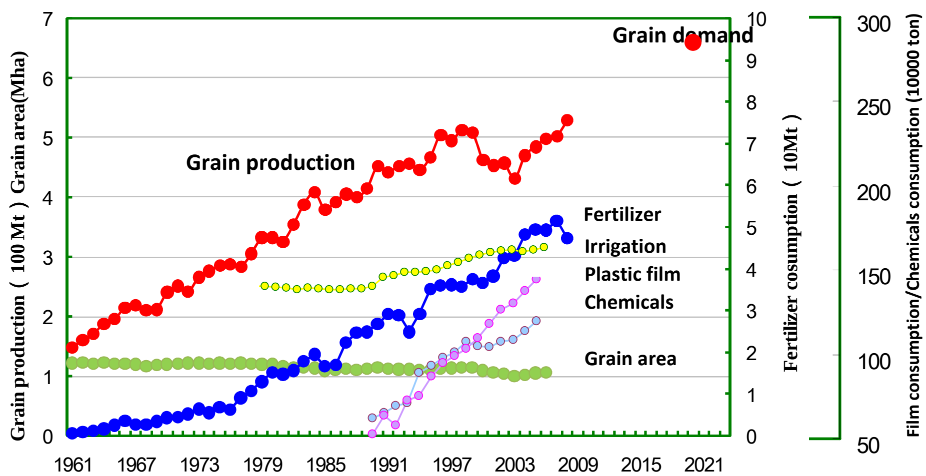
Questions

- **What are major driving forces of China's agriculture in the past?**

-- Institutional reform
-- Agricultural technology
-- Market liberalization
-- …

High input

Grain production and resources input



Grain production has been merely secured by much higher input of resources

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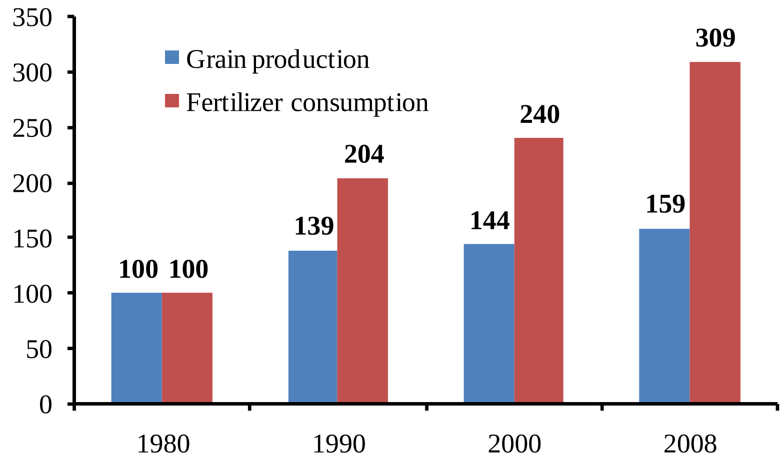
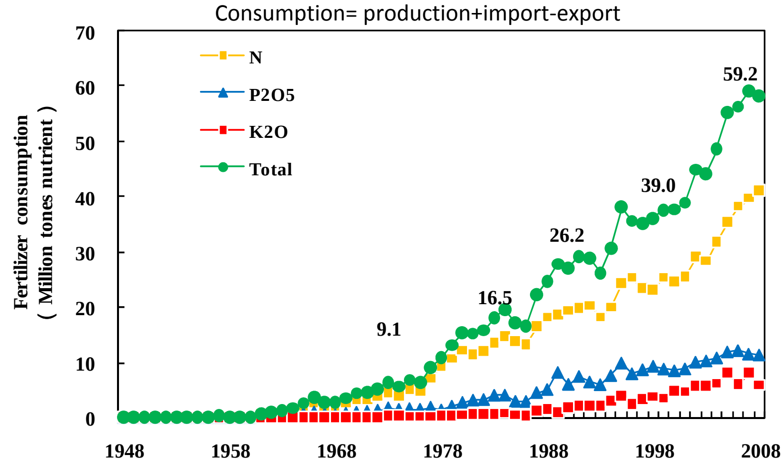
China fertilizer consumption and grain production (1980=100)



China consumed more than 59 million tones of NPK nutrients as inorganic fertilizer in 2007



The trends of fertilizers consumption in China from 1949 to 2007

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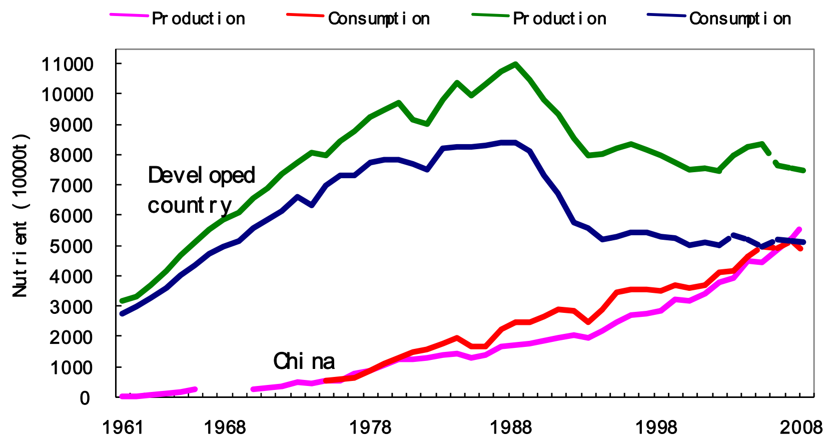
Policies stimulate a rapid expansion of the fertilizer enterprises



(**Forecast** based on the increase rate of recent five years
Data from FAO website and Chinese statistics)

Fertilizer Overuse and Misuse

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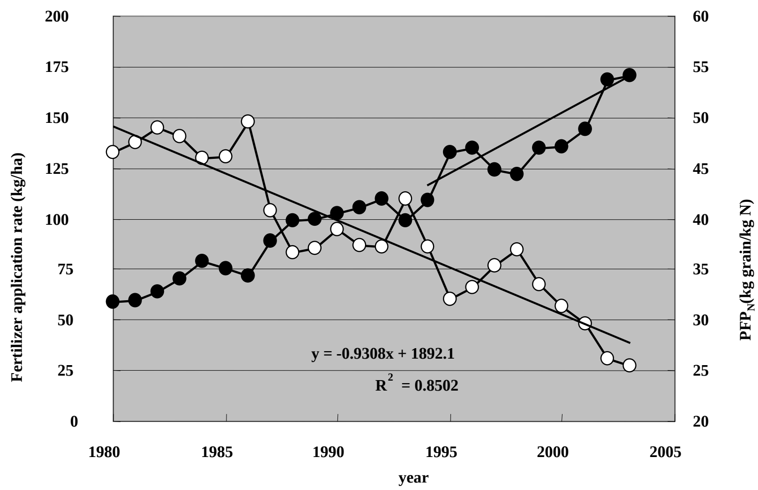
Low nutrient use efficiency (NUE) ---Low PFP

Partial factor productivity: PFP_N = kg harvest product per kg N applied



Substantial decrease in PFPN with increased rate of fertilization

Agronomic efficiency of N fertilizer in rice

Philippine	15-18	kg grain/kg N
China (1958-1963)	15-20	kg grain/kg N
China (1981-1983)	9.1	kg grain/kg N
China (2000-2004)	3-5	kg grain/kg N

(Modified from Cassman et al., 1996; Li, 1991)

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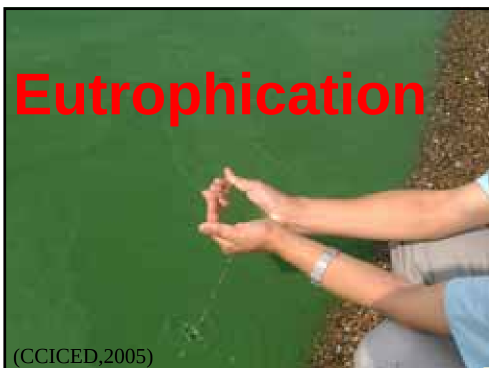
Grain yield and N rate of rice crop

Country	Grain yield* (t ha^{-1})	N rate (kg ha^{-1})
China	6.26	~200
Japan	6.42	70
South Korea	6.79	110

***FAO, 2004**

Eutrophication



(CCICED,2005)

- Four fold increase in N inputs to estuaries since 1980
- Increased N inputs contribute to eutrophication, decreased fish production, and toxic algal bloom (red tides)
- The occurrence of red tides increased from 10/yr in the 1960s to 300/yr now (Norse and Zhu,2004)

Blue alga attacked Tai lake again and Wuxi people are threatened by drink water shortage. Is it too naughty to be solved?

China News, April 16, 2008

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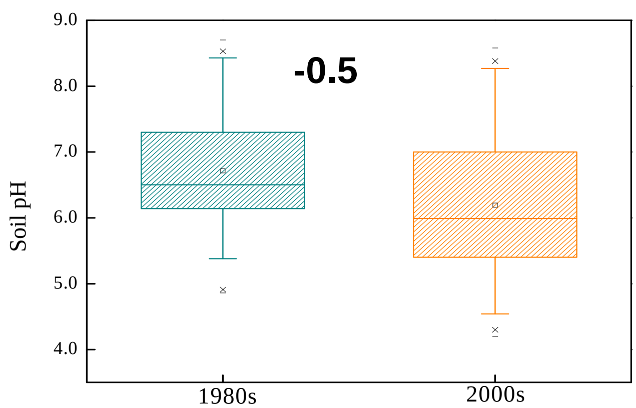
Soil pH changes in major croplands in China



Topsoil pH changes of Chinese agricultural soils between the 1980s and the 2000s.
(Guo et al. 2009. SCIENCE, in review)

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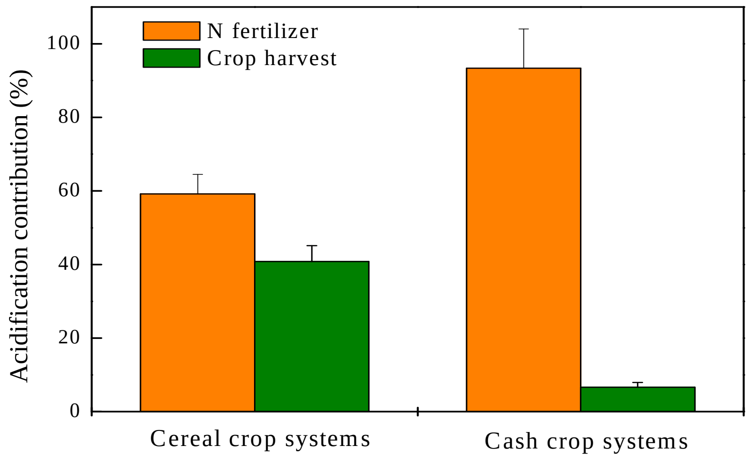
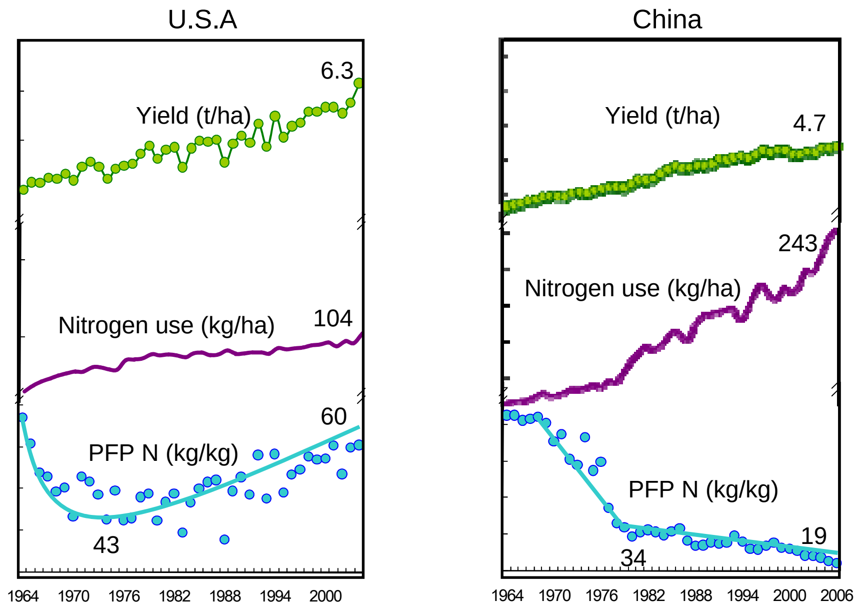


Contributions of main factors to soil acidification in two crop systems

(Guo et al. 2009. SCIENCE, in review)

How to Increase both Crop Yield and NUE Simultaneously?

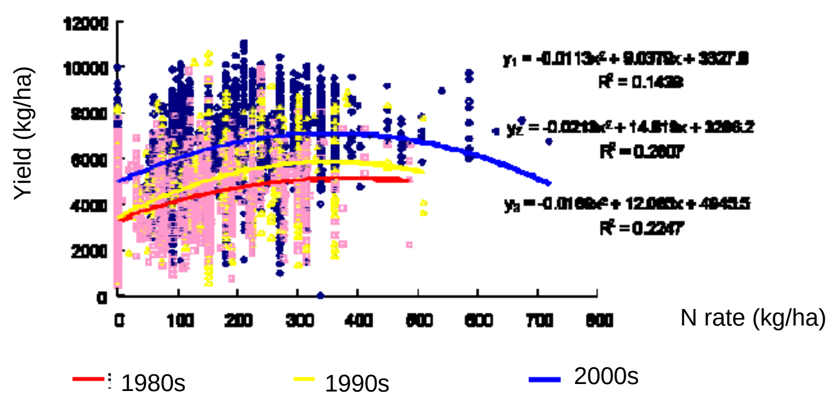


Outline

- Challenges and problems of food production and environmental protection
- **Development of Integrated soil-crop system management technology**
- Summary and perspective

Principles 1: Improve Soil Quality

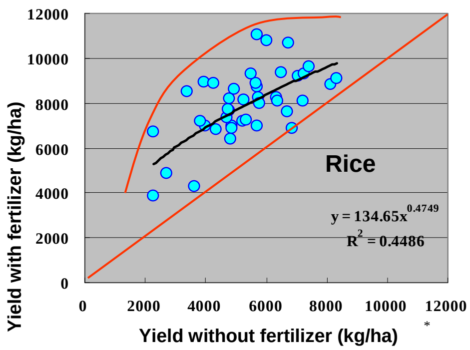
Response of wheat yield to nitrogen fertilizer

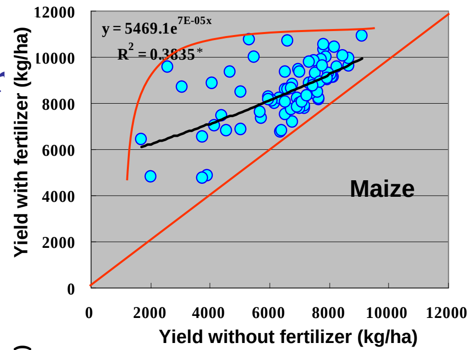


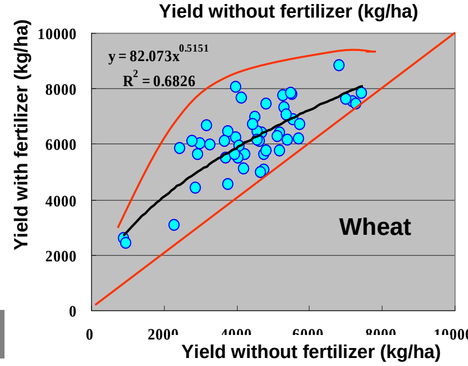
(Zhang et al., unpublished)

The higher yield of non-fertilized soil, the higher of the obtained yield with fertilizer

(Wang et al., unpublished)



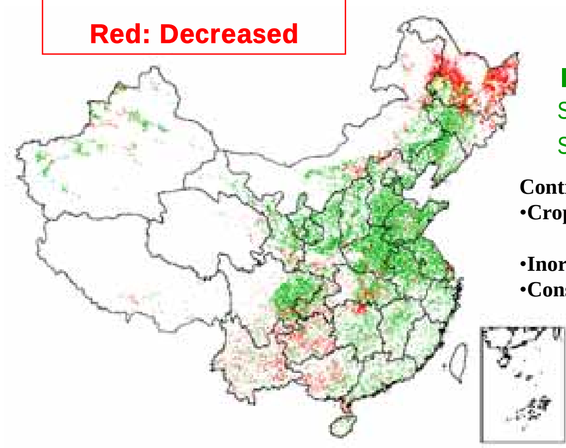




SOC change from 1980-2000 in Chinese cropland

Green : Increased

Red: Decreased



Increase rate:

SOC storage 4.5-6.4%

SOC content 27%

Contributors:

- **Crop residues, organic amendments: 76%**
- **Inorganic fertilizers: 22%**
- **Conservation tillage: 2%**

(Huang et al.,2007)

How to improve soil quality?

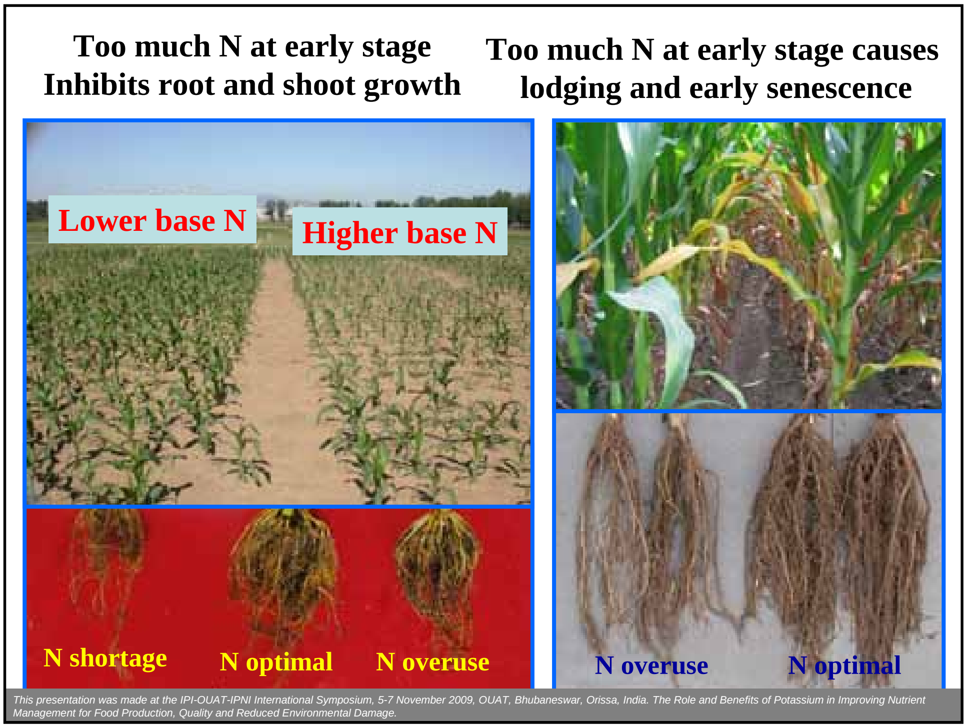
1) Higher yield
   higher C return

2) Return straw
   back into soil

3)Organic manure

Principles 2: Integrated nutrient management (INM)

1) **Match soil supply to crop requirement spatially and temporally**
2) **Take all possible sources of nutrient into consideration!**
3) **Take all possible reducing nutrient loss measures into consideration!**


Too much N at early stage
Inhibits root and shoot growth
Too much N at early stage causes
lodging and early senescence
Lower base N
Higher base N
N shortage
N optimal
N overuse
N overuse
N optimal
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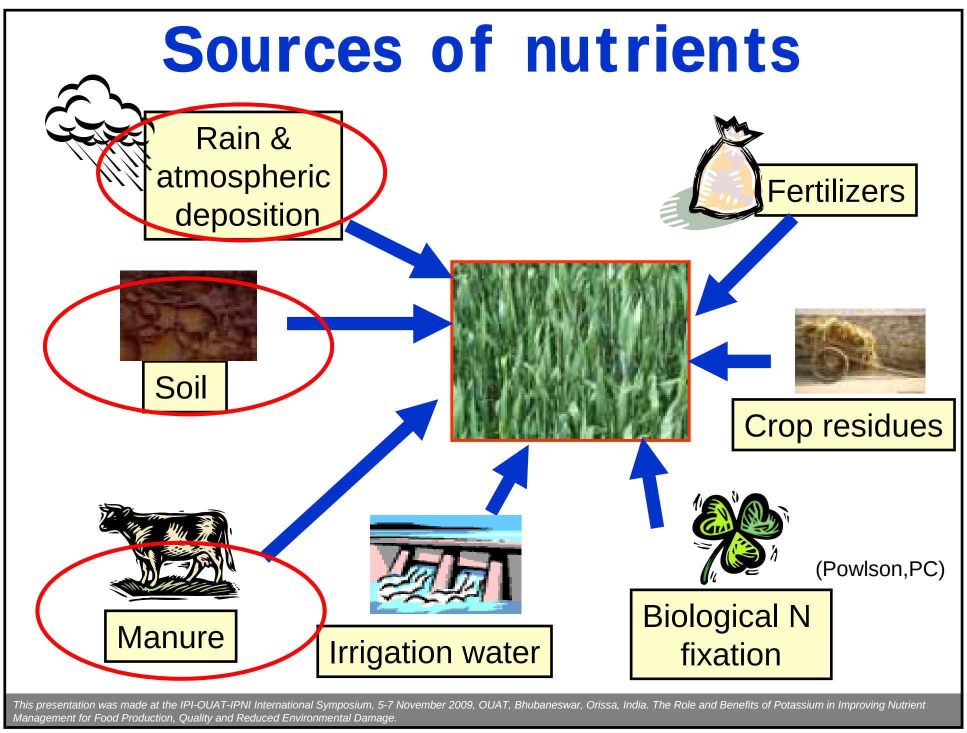
Sources of nutrients
Rain & atmospheric deposition
Fertilizers
Soil
Crop residues
Manure
Irrigation water
Biological N fixation
(Powlson,PC)
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Important N source- wet and dry deposition

Wheat-maize rotation in North China Plain：

Annual input (deposition):

80-90 kg N ha^{-1}

Accounting for crop demand of 20-30%

Rice-wheat along the Yangtze River Basin:

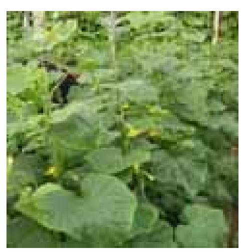
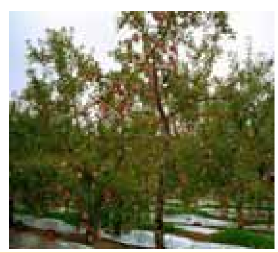
Annual input (deposition + BNF):

103-127 kg N ha^{-1}

Accounting for crop demand of 30-40%

(Liu et al., Xin et al., P.C.)

Large amount of nitrate accumulated in soil

N in 100cm	384(n=140)	1267(n=140)	651(n=206)
Crop demand	280	329	121

100cm

N accumulation as nitrate in 0-100cm soil layer(kg/ha)

in cereal, vegetable and fruit production systems in China

Groundwater

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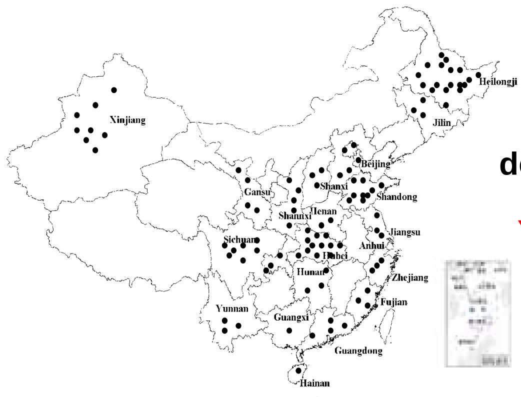
Principles 3: Increase crop yield significantly (> 15%)



saved N by 20-40%,
decrease losses by 10-50%

Yield increase by 8-10%

National dissemination of INM in 12 cropping systems throughout China (4 million ha annually)

Higher yield, higher NUE

Yield (t/ha)	6	14.8
N rate (kg/ha)	300	265
PFP (kg/kg)	20	56

3 main tech: Increased density of plants
Better nutrient and water management
Improved soil quality

(Chen et al., 2008, unpublished)

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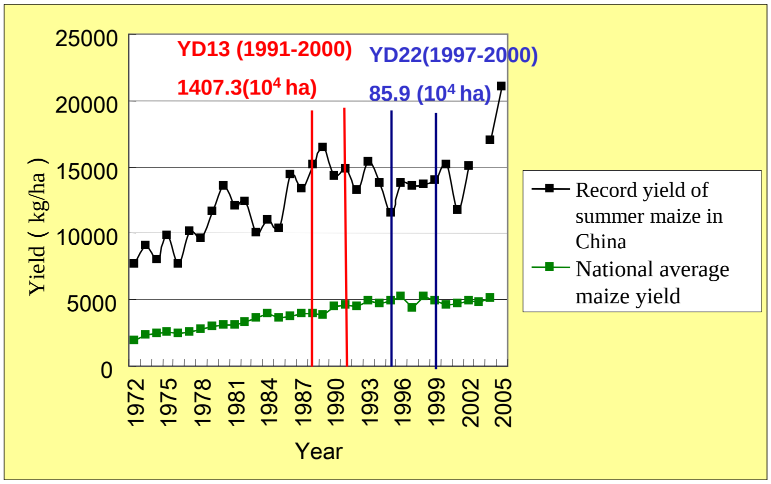
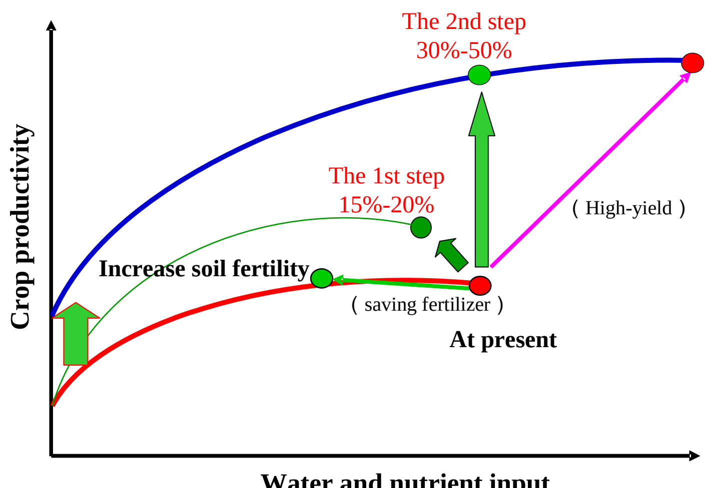
A gap in yield



(Li, 2004; FAO; website:http://www.cornexpert.com, http://www.denghai.com/)

Challenge: How to realize high crop yield, high efficiency of resource use, improving soil fertility and environment quality at the same time.



Outline

- Challenges and problems of food production and environmental protection
- Development of Integrated soil-crop system management technology
- **Summary and perspective**

Technologically, INM and ISSM is a feasible solution for harmonization of nutrient input, crop production and environmental protection.

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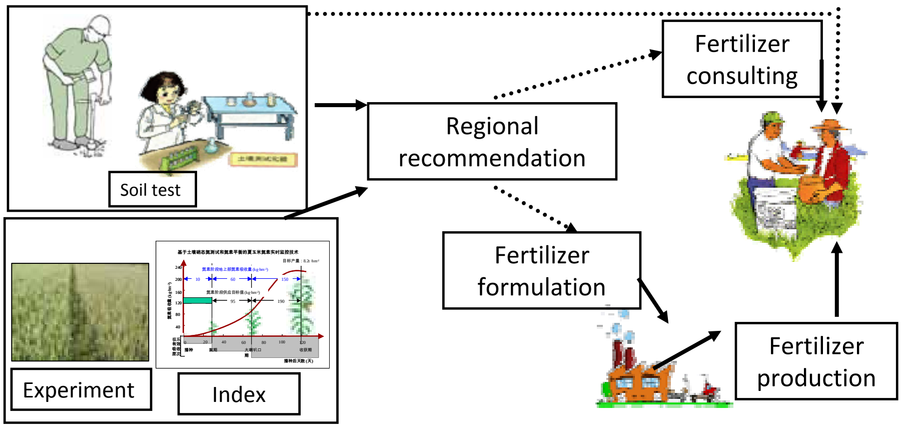
National Soil Testing and Fertilizer Recommendation Project

(totally 4.25 billion RMB in 5 years)

200 Million Yuan covered 200 counties in 2005
500 Million Yuan covered 600 counties in 2006
900 Million Yuan covered 1200 counties in 2007
1150 Million Yuan covered 1861 counties in 2008
1500 Million Yuan covered all agric.counties 2009

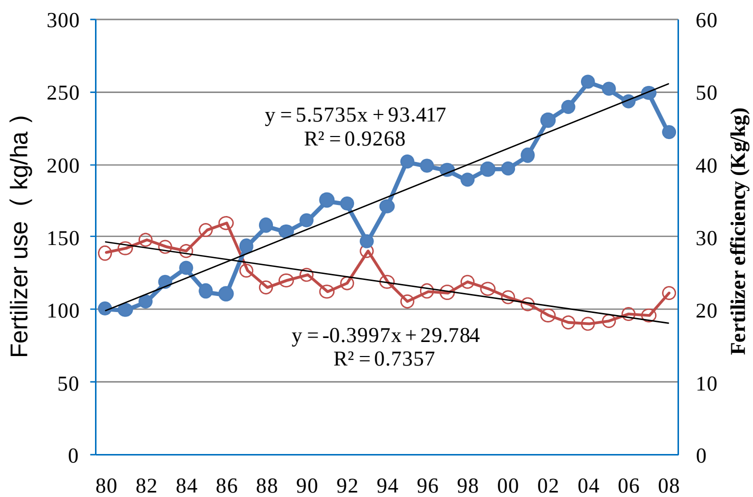
Yield +11%

NUE +10%



Low nutrient use efficiency (NUE) ---Low PFP

Partial factor productivity: PFP = kg harvest product per kg N applied



Turn the trend of substantial decrease in PFP in China

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Reducing environmental risk by improving N management in intensive Chinese agricultural systems

Xiao-Tang Ju[a,1], Guang-Xi Xing[b], Xin-Ping Chen[a], Shao-Lin Zhang[b], Li-Juan Zhang[c], Xue-Jun Liu[a], Zhen-Ling Cui[a], Bin Yin[b], Peter Christie[a,d], Zhao-Liang Zhu[b], and Fu-Suo Zhang[a,1]

Table 2. Different N loss pathways expressed as a percentage (mean ± SD) of N application rate in farmers' N practices (Field Study 3. Lysimeter Study)

Component		Taihu region: Rice	Taihu region: Wheat-south	North China Plain: Wheat-north	North China Plain: Maize
N rate (kg of N per hectare)		300	250	325	263
Recovery rate (%)*		29.6 ± 4.9	18.4 ± 6.3	31.0 ± 3.6	25.5 ± 5.2
Retention rate (%)*		21.7 ± 5.1	28.5 ± 4.6	45.7 ± 5.4	33.9 ± 2.3
Loss pathway	NH_3 volatilization (%)	11.6 ± 4.7	2.1 ± 1.4	19.4 ± 5.2	24.7 ± 5.6
	Leaching out of 1 m soil depth (%)	0.3 ± 0.5	3.4 ± 2.1	2.7 ± 2.6	12.1 ± 8.5
	Denitrification (%)	36.4†	43.5†	0.1 ± 0.04	3.3 ± 1.6

*Measured from corresponding ^{15}N field experiments.
†Calculated by difference method.

Cut down N fertilizer by 30-50% reduces N loss into environment greatly without diminishing crop yield!

Recovery efficiency of K fertilizer and increase of N use efficiency on maize (n=3)

Treatment	Recovery efficiency of K (%): Range	Recovery efficiency of K (%): Mean	Increase of use efficiency of N (%): Range	Increase of use efficiency of N (%): Mean
N1PK0	-	-	-	-
N1PK1	26.7~39.5	33.8	9.4~22.3	14.8
N1PK2	38.3~42.7	40.5	20.7~25.1	22.2
N1PK3	39.2~43.6	38.3	20.7~36.7	29.7
N2PK0	-	-	-	-
N2PK3	29.0~38.2	29.3	12.2~25.1	18.3

* These ... nty, Anhui province ... ,150 and 195 kg K_2O ...

** Recovery efficiency of K (%) = Plant K uptake (K fertilized – K unfertilized)/fertilized K amounts ×100.

*** Increase of use efficiency of N (%) = Plant N uptake (K fertilized – K unfertilized) / fertilized N amounts ×100.

Optimal N-K ratios favored crop growth and enhanced K and N use efficiency.

Xie et al. unpublished data

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Nitrogen recovery efficiency in field grown vegetables in Shandong, China

Treat-ment	Cucumber (%)			Chinese cabbage (%)			
	2000	2001	2002	1999	2000	2001	2002
$N_{300}K_0$*	0.38	2.37	-1.48	-5.43	2.93	-43.94	10.14
$N_{300}K_{300}$	6.40	6.97	1.25	19.87	-0.05	12.34	38.61
$N_{300}K_{600}$	0.51	0.6	1.57	18.87	1.43	27.58	14.35
$N_{600}K_0$	1.56	1.92	-2.36	4.77	1.66	-8.96	5.91
$N_{600}K_{300}$	3.58	5.65	1.80	4.45	2.49	8.56	12.88
$N_{600}K_{600}$	-1.46	-0.1	1.76	6.13	2.96	6.81	10.89

* in kg N and kg K_2O ha^{-1}

(IPI,2005)

POLICYFORUM

AGRICULTURE

Nutrient Imbalances in Agricultural Development

Nutrient additions to intensive agricultural systems range from inadequate to excessive—and both extremes have substantial human and environmental costs.

P. M. Vitousek,[1*] R. Naylor,[2] T. Crews,[3] M. B. David,[4] L. E. Drinkwater,[5] E. Holland,[6] P. J. Johnes,[7] J. Katzenberger,[8] L. A. Martinelli,[9] P. A. Matson,[10] G. Nziguheba,[11] D. Ojima,[12] C. A. Palm,[11] G. P. Robertson,[13] P. A. Sanchez,[11] A. R. Townsend,[14] F. S. Zhang[15]

Inputs and outputs	Nutrient balances by region (kg ha $^{-1}$ year $^{-1}$)					
	Western Kenya		North China		Midwest U.S.A	
	N	P	N	P	N	P
Fertilizer	7	8	588	92	93	14
Biological N fixation					62	
Total agronomic inputs	7	8	588	92	155	14
Removal in grain and/or beans	23	4	361	39	145	23
Removal in other harvested products	36	3				
Total agronomic outputs	59	7	361	39	145	23
Agronomic inputs minus harvest removals	-52	+1	+227	+53	+10	-9

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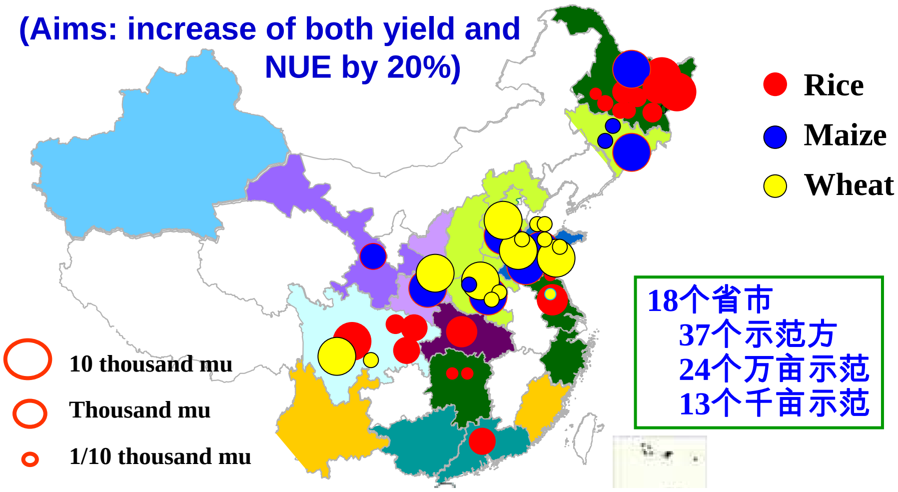
High yield and high NUE Demos in China

(Aims: increase of both yield and NUE by 20%)



NISSM

(**N**etwork on **I**ntegrated **S**oil-Crop **S**ystem **M**anagement)

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Politically, much more reform is needed

Major Decisions on Key Issues of Promoting Rural Reform and Development

The 3rd Plenary Session of CCCP, 12 Oct 2008

To establish resource-saving and environmental friendly agricultural production system

4 WINs: Yield increase
NUE enhancement
Soil quality improvement
Environment protection

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Acknowledgments

IPI, NSFC, MoA , MoE

Thanks

for your attention !

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