SCI BioResources Group / Syngenta

Sustainable Intensification: Growth from research and technology

Jealott's Hill Research Centre, UK, Tuesday 30th October 2012

Optimized fertilizer use efficiency for crop nutrition and GHG reduction

Kevin Moran

Formerly Yara and Phosyn plc

Content

- Mind the Gap!
- Crop nutrition foundations
- Climate smart agriculture
- What is Nutrient Use Efficiency (NUE)?
- Optimizing NUE to reduce GHG's
- 4R Nutrient Stewardship
- Systems and Technologies for NUE improvement
- Closing the Gap!

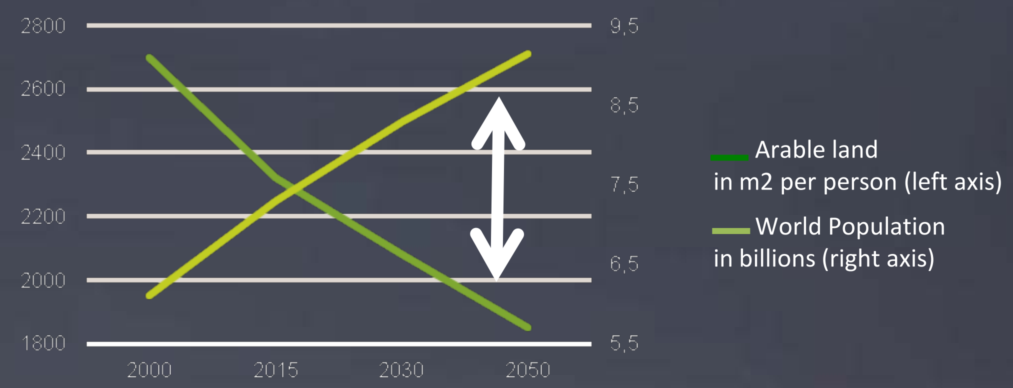
MIND THE GAP

(Yara, 2011)

THE GAP : Feed more people

from less resources

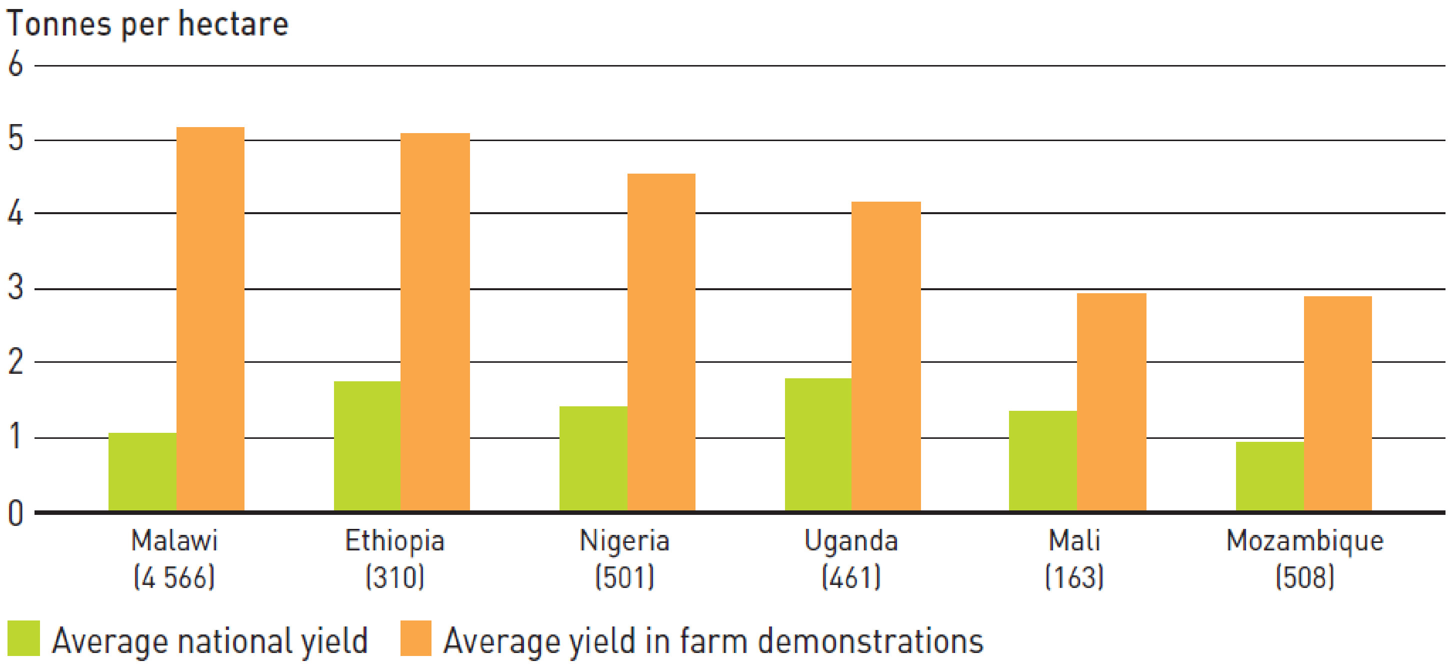
Feeding 9.15 billion people at higher consumption levels by 2050 will require a 70% increase in food production, demanding higher yields



Source: UN Medium variant scenario. FAO (2003): World Agriculture: towards 2015/2030.

(Yara, 2011)

Yield gaps in African agriculture



Notes: Number of plots in parentheses. Open pollinated improved varieties in all cases except Nigeria, which uses hybrids. Data are for 2001 for Ethiopia, Mozambique, Nigeria and Uganda; 2002 for Malawi; and an average of 2001, 2002 and 2004 for Mali.

Source: World Bank. 2007. World Development Report 2008: Agriculture for Development. *Washington, DC.*

Essential Fertilizer Nutrients for Crops

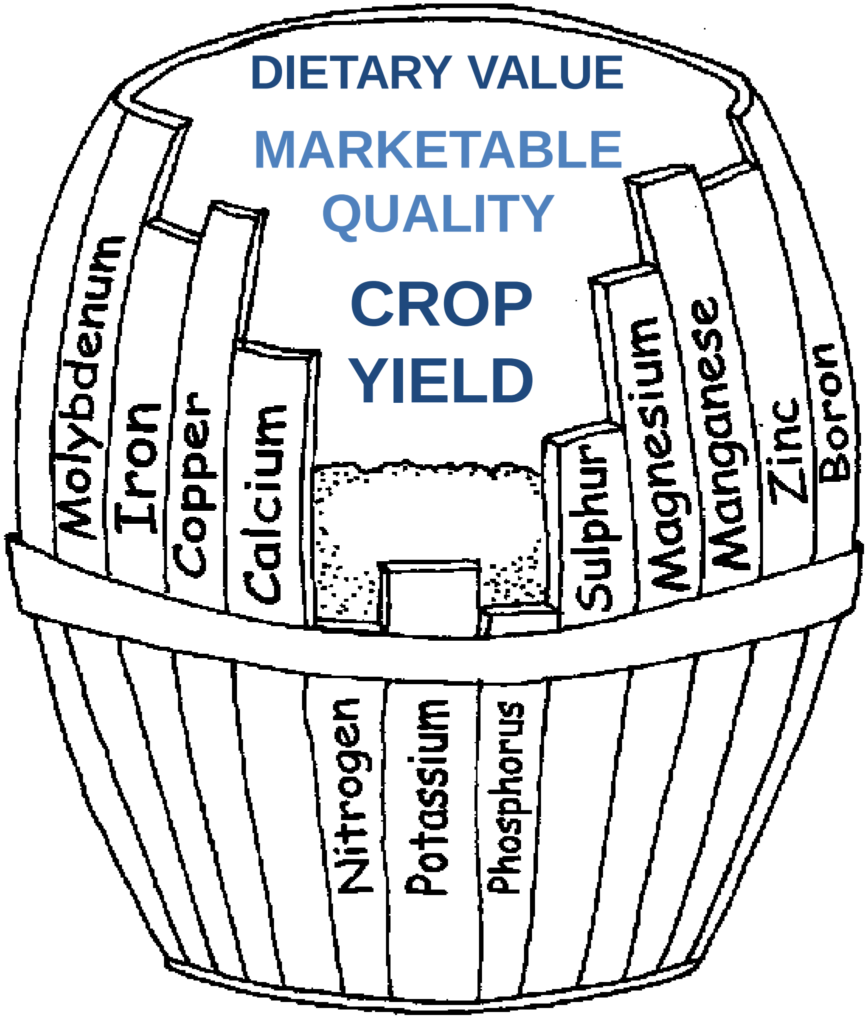
PRIMARY NUTRIENTS	SECONDARY NUTRIENTS	MICRONUTRIENTS
Nitrogen (N) **Phosphorus** (P) **Potassium** (K)	**Calcium** (Ca) **Magnesium** (Mg) **Sulphur** (S)	**Boron** (B) **Copper** (Cu) **Iron** (Fe) **Manganese** (Mn) **Molybdenum** (Mo) **Zinc** (Zn)
100's Kg/Ha	**10's Kg/Ha**	**1's Kg/Ha**

1,000,000 atoms of N ← **impairs the biochemical advantages of (Katyal, 2004)** ← **Deficiency of 1 atom of Mo**

Adequate and balanced fertilization with all nutrients is essential to achieve optimum yield, crop quality and nutrient density

Justus von Liebig's "Law of the Minimum" published in 1843

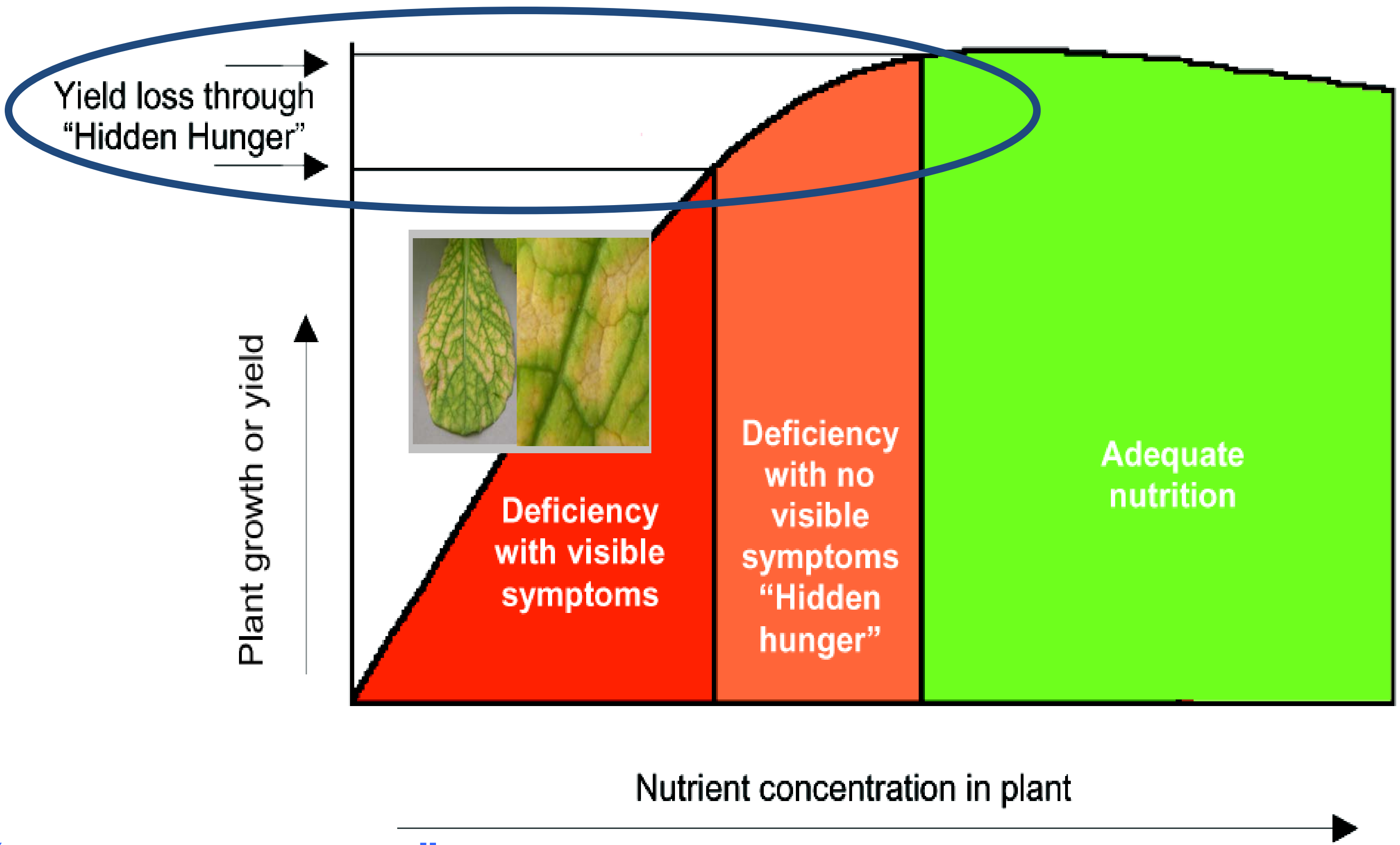
"If one plant nutrient is deficient, plant growth is limited, even if all other vital nutrients are adequate…plant growth is improved by increasing the amount of the deficient nutrient"



"Although this 'law of minimum' was already detected in 1843, a shortfall of specific nutrients is still the major reason - with limited water supply - for low crop yields and poor quality throughout World Agriculture"

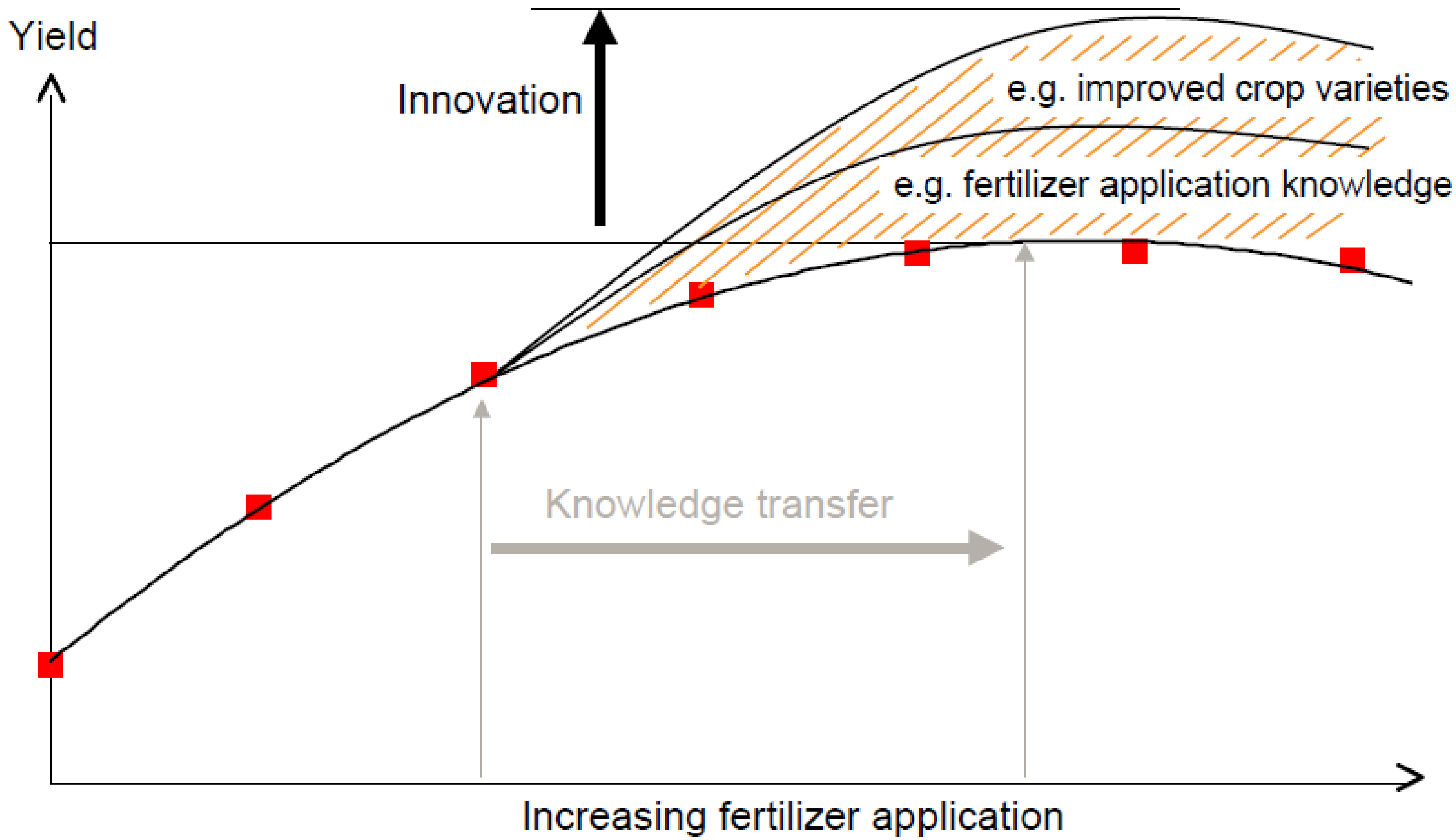
Dr Joachim Lammel, Director, Yara Hanninghof Research Centre, Germany (2005)

The Classic Nutrient Response Curve



The “Hidden Hunger” zone is where fertilizer optimization will most significantly affect crop yield and quality

Challenges for future research and technology



From "Barrel" to "Global" Scale

Agriculture Production and Resource Use

	1960	2000	2030-2040
Food production (Mt $x10^9$)	1.8	3.5	5.5
Population (billions)	3	6	8 (/10)
Irrigated land (% of arable)	10	18	20
Cultivated land (hectares $x10^9$)	1.3	1.5	1.8
Water-stressed countries	20	28	52
N fertilizer use (Tg/10^{12}g)	10	88	120
P fertilizer use (Tg/10^{12}g)	9	40	55-60

Pereira, 2003

Challenges for future research and technology

Agriculture must improve its way of working. “Business as usual” is not sufficient.

The future of crop nutrition management in agriculture must involve:

- Increasing Nutrient Use Efficiency (NUE);
- Improvements in water management and use efficiency (WUE);
- Minimal environmental impact.

Which requires innovation and knowledge transfer in:

- Improved crop and application strategies to further optimize NUE;
- Which can also assist in improving WUE;
- Reducing GHG emissions from fertilizer production and application;
- Knowledge and technology transfer to the developing world.

"Climate-smart agriculture is needed"

EXCELLENCE IN SCIENCE

Events Diary | royalsociety.tv | Scientific Meetings | Maps | Summer Science Exhibition | more

Reducing greenhouse gas emissions from agriculture

Starts: 9.00am on 28 February 2011
Finishes: 5.00pm on 01 March 2011
Venue: The Royal Society, London

Meeting the challenges of food security and climate change

Audio recordings of the presentations are now available

Organised by Professor Sir David Read FRS and Professor Sam Evans with Professor Richard Bardgett, Professor Sir David Baulcombe FRS, Professor Gareth Edwards-Jones, Professor Graham Farquhar FRS, Professor Maggie Gill, Dr Murray Lark, Dr Sinclair Mayne, Professor Pete Smith and Dr Jeremy Woods.

Supported by Department for Environment, Food and Rural Affairs; Agriculture and Horticulture Development Board; Biotechnology and Biological Sciences Research Council; Biosciences Knowledge Transfer Network; Environmental Sustainability Knowledge Transfer Network; Living With Environmental Change; National Farmers Union; Natural Environment Research Council; Technology Strategy Board

Monday 28 February 2011

9.00 Welcome by Dr Peter Cotgreave, Director, Public Affairs, Royal Society and **Professor Sir David Read FRS**

Session 1

9.05 Chair Dr Miles Parker, Department for Environment, Food and Rural Affairs (Defra), UK

9.10 Introduction
Professor Sir John Beddington CMG FRS, Chief Scientific Advisor to HM Government, UK

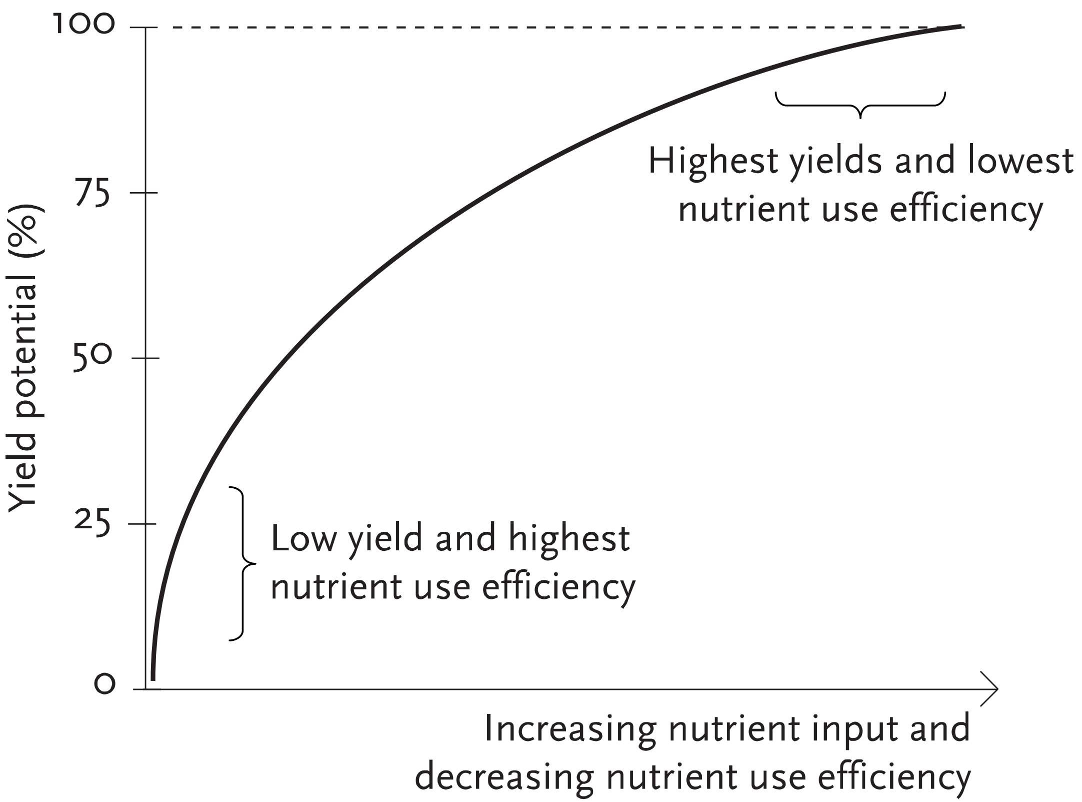
UPCOMING: Achieving food and environmental security – new approaches to close the gap
The Royal Society, London.
Scientific discussion meeting organised by Professor Guy Poppy, Professor Paul Jepson, Professor John Pickett CBE FRS and Dr Michael Birkett. December 3rd and 4th 2012.

*"The need to tackle climate change while producing more food to feed the world's growing population means that **'climate-smart' agriculture** is the only way forward."*

Professor Sir John Beddington quoted in *Nature* following the Conference

What is meant by Nutrient Use Efficiency (NUE)?

Simply put, the degree to which a crop responds to applied nutrient on the response curve:



There are many ways that NUE can be calculated; these are the two most common:

(1) Output-input ratio:

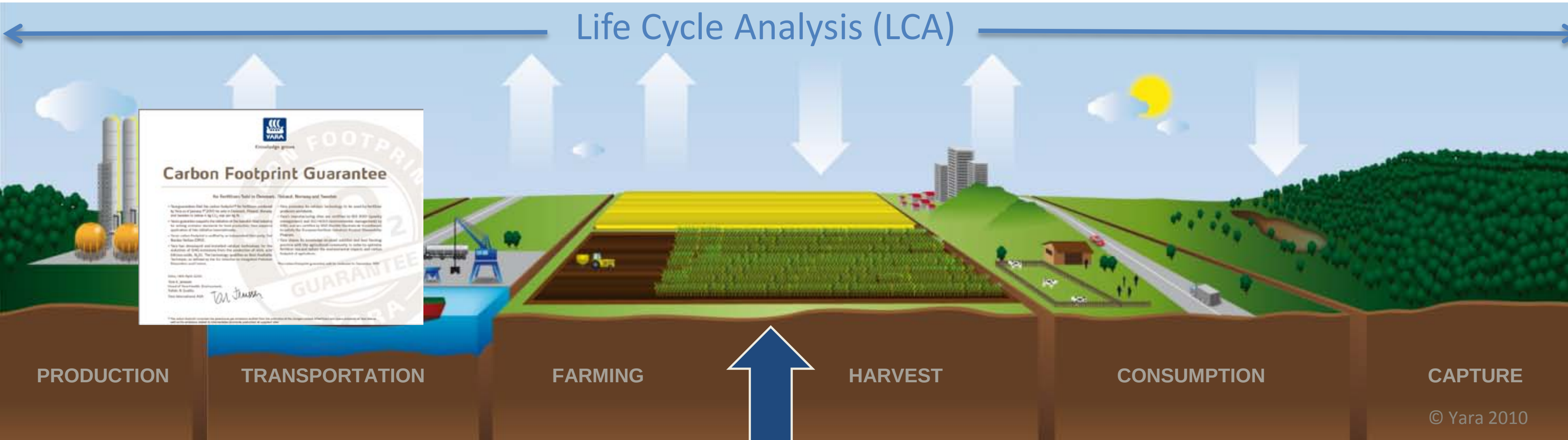
$$\frac{208 \text{ kg N/ha}}{236 \text{ kg N/ha}} \times 100 = 88\%$$

(2) Partial factor productivity from applied nitrogen:

$$\frac{11000 \text{ kg grain/ha}}{236 \text{ kg N/ha}} = 47 \text{ kg grain/kg N}$$

-> kg grain yield per kg N applied

Important to take the whole production chain into account when considering the NUE challenge for N and other nutrients



Optimizing Nutrient Use Efficiency (NUE)

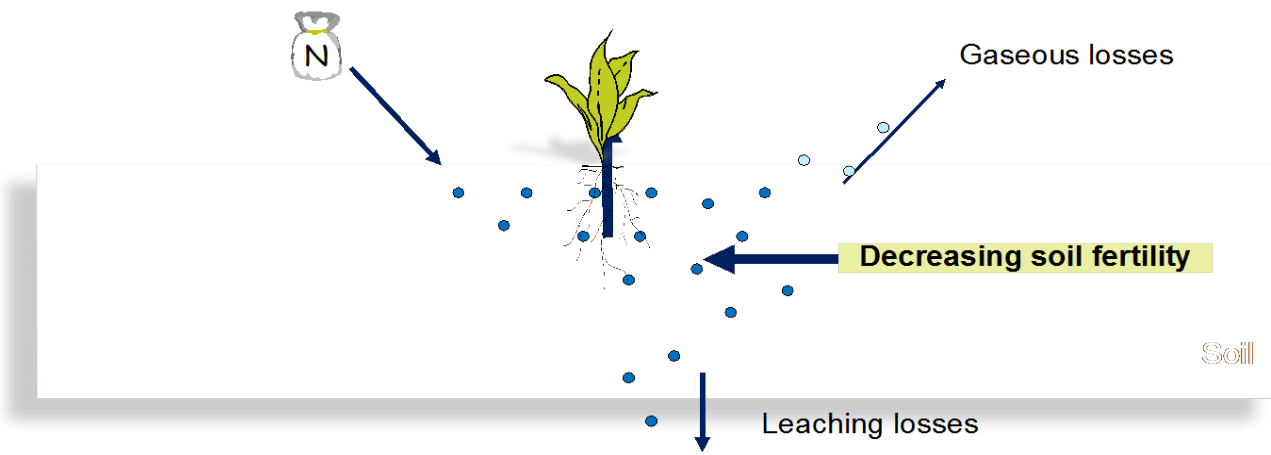
Increases Resource & Energy Use Efficiencies

Increases Food & Biomass Production and Carbon Capture

Reduces Nutrient Leakage into Ecosystems

If the crop N removal exceeds the N input, the soil N reserves are depleted = soil mining

- NUE should not permanently exceed 100%



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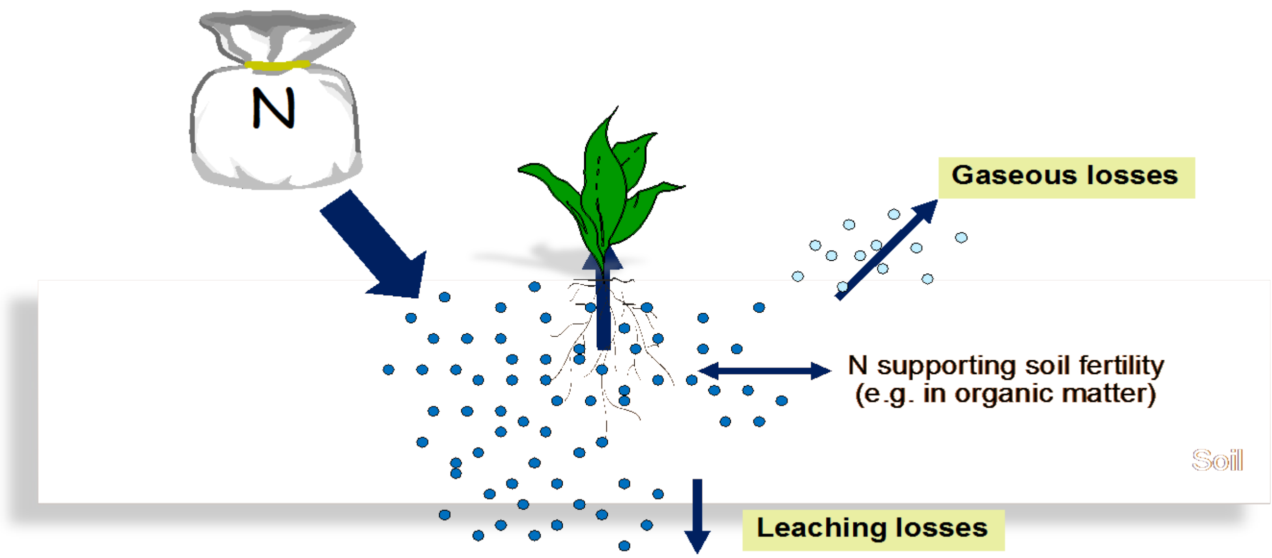
(Brentrup et al, 2012)

If the N fertilizer input exceeds crop demand, the risk for N losses to air and water increases

- NUE should not remain under 70%



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(Brentrup et al, 2012)

Effects of different NUE's using output/input ratio method

NUE (%)	Interpretation
>100	Soil mining [1]
90 – 100	Risk of soil mining [2]
70 – 90	Balanced in- and outputs [3]
< 70	Risk of high N losses [4]

(1) Soil mining = N removal exceeds N input -> declining soil fertility and yield **= unsustainable**

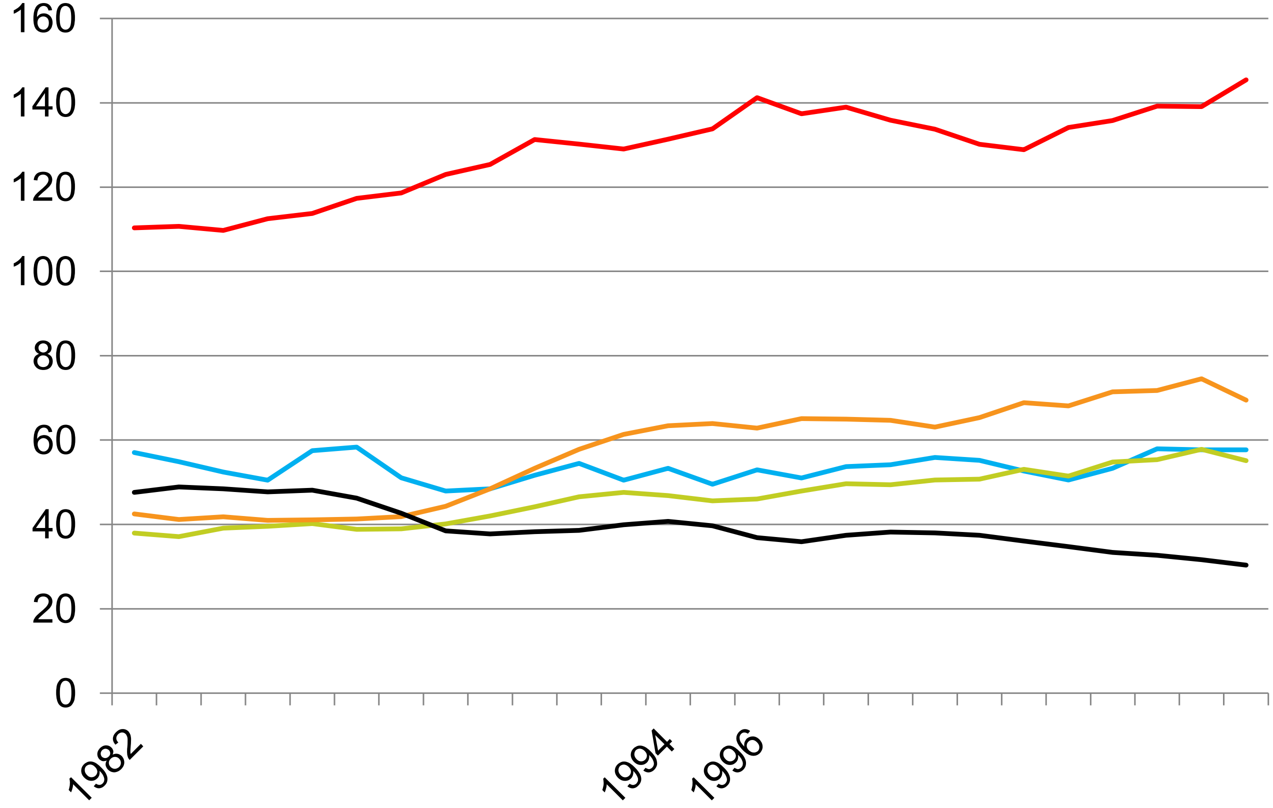
(2) Risk of soil mining = additional N requirement for soil fertility and unavoidable losses is not met by N input

(3) Balanced in- and outputs = N fertilizer input meets crop & soil demand and compensates for unavoidable N losses **= sustainable**

(4) Risk of high N losses = N fertilizer input exceeds total crop demand -> increased risk of leaching

(Brentrup et al, 2012)

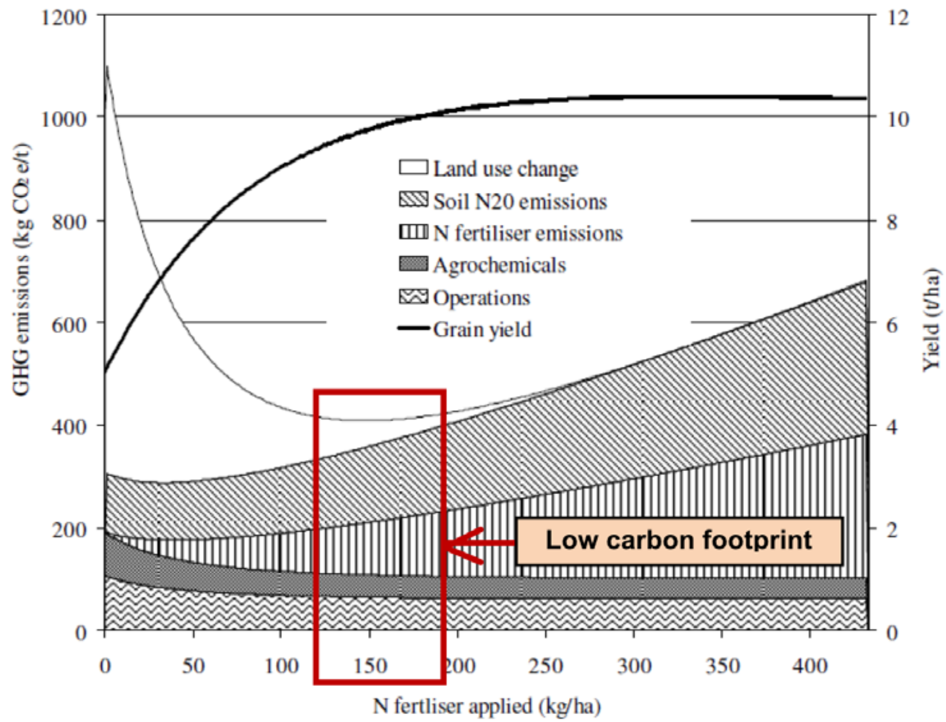
NUE over recent decades in different regions



(Sources: IFA, FAO and Yara, 2012)

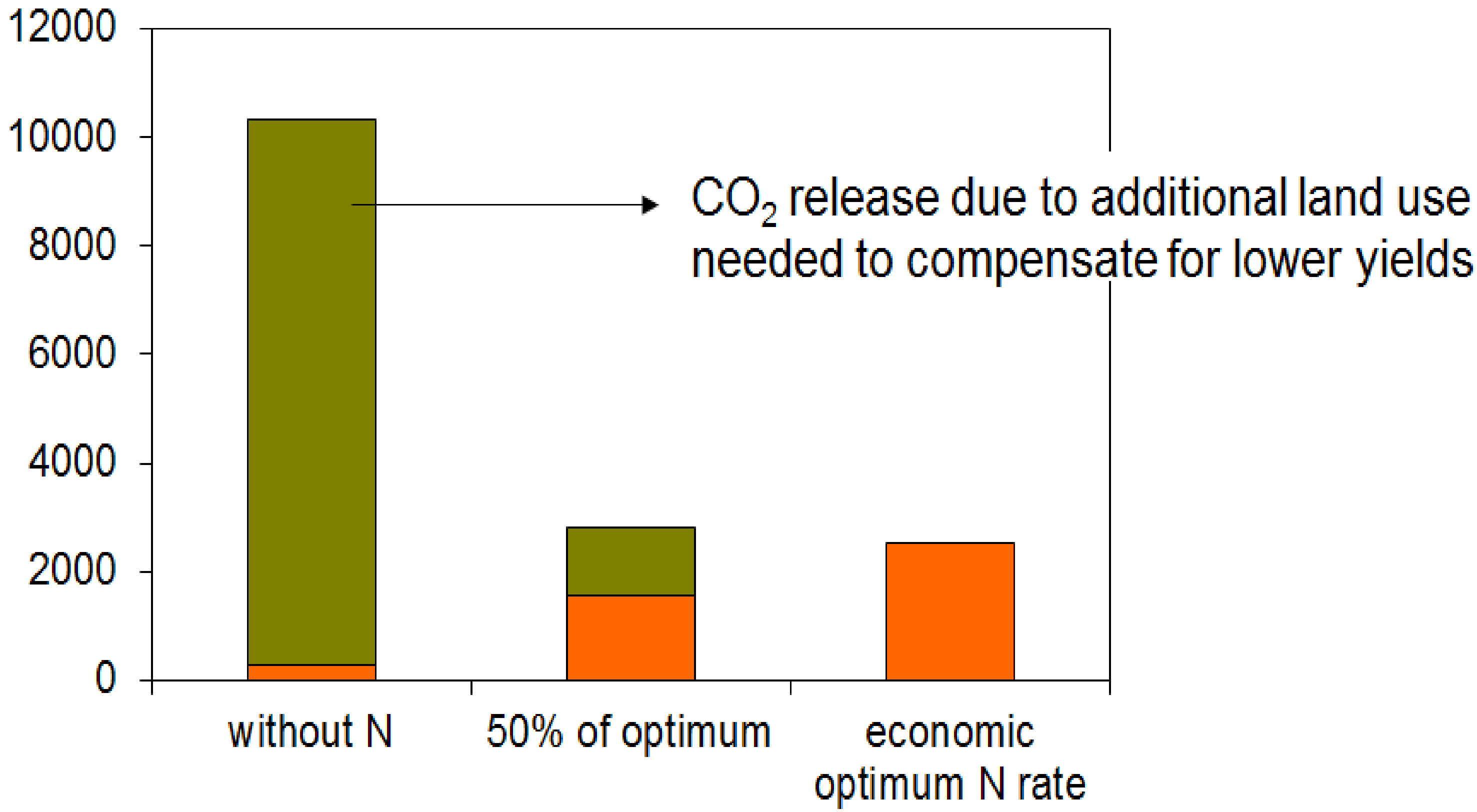
Optimised NUE minimizes overall GHG emissions in production systems

Relationship between N fertilizer and wheat yield (bold line) and the effects of N rate on the estimated GHG emissions per tonne of wheat (top fine line; shaded areas show contributions plotted cumulatively) after accounting for the conversion of grass land to arable land in the United Kingdom



(Kindred et al., 2008)

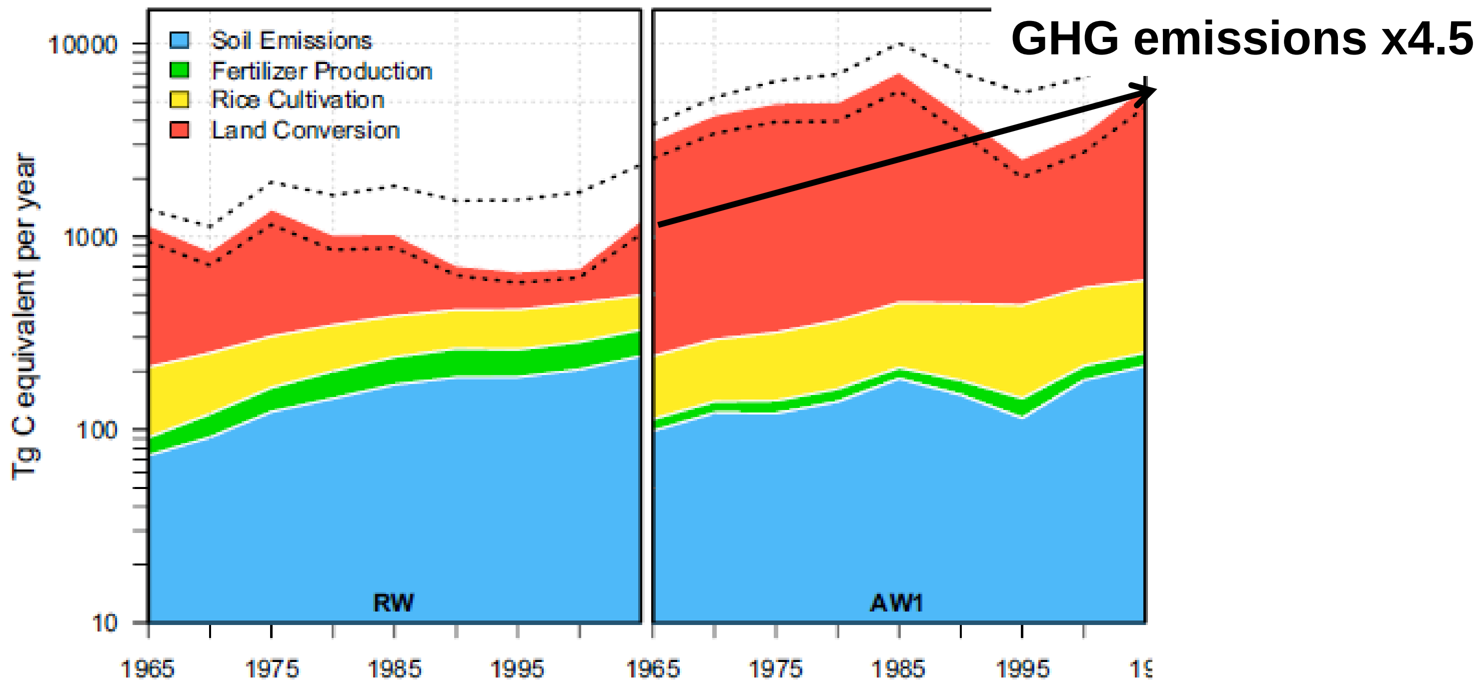
Optimum NUE increases production per hectare and negates additional land use requirement



Yield: 2.07 t/ha 7.11 t/ha 9.25 t/ha

(Brentrup and Palliere, 2006)

Analysis of data since 1965 confirms that intensive agriculture ‘reduced’ GHG emissions



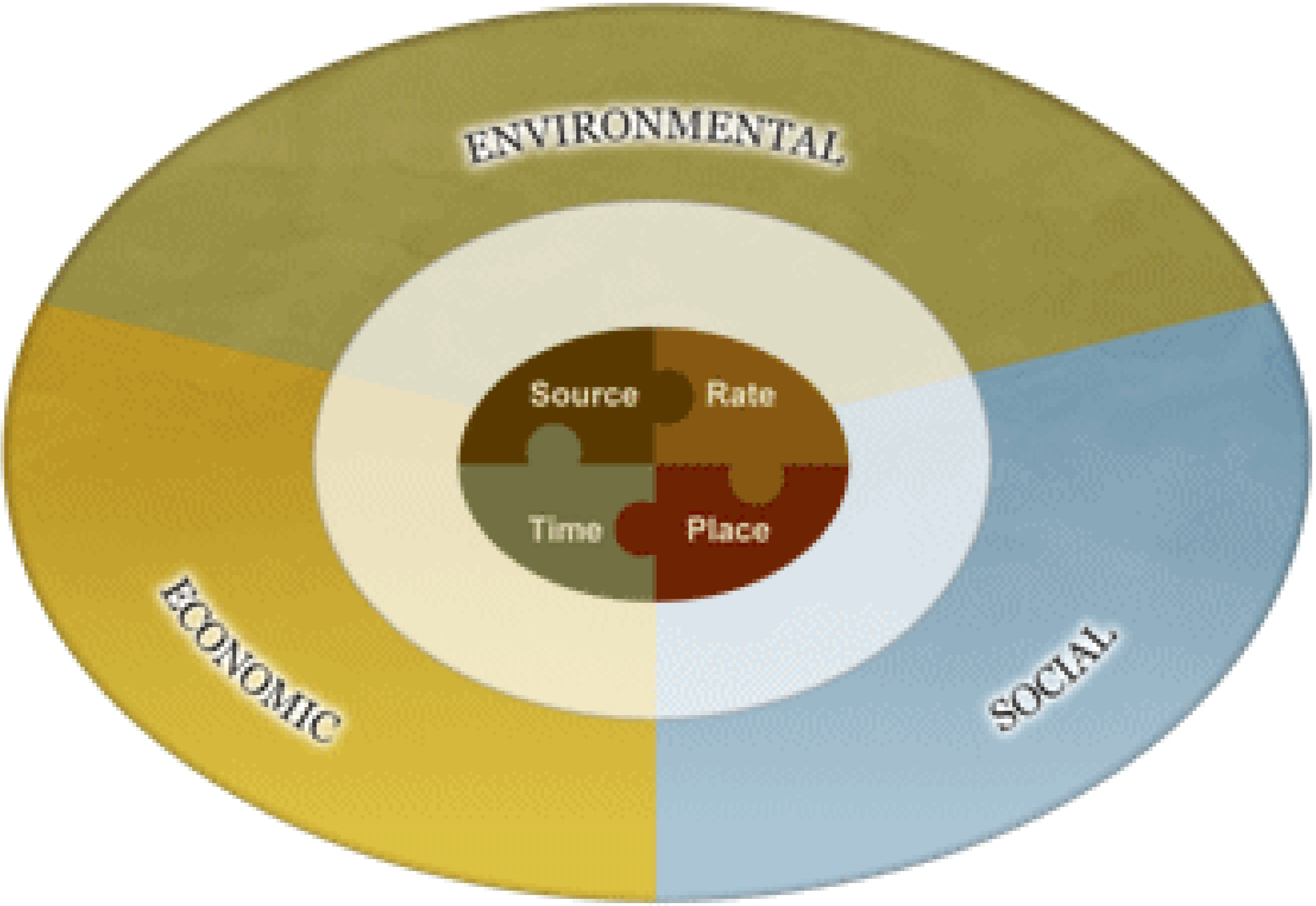
Main findings from the study by Burney et al. *(2010):*

- *While GHG emissions from factors such as fertilizer production and application have increased, the net effect of higher yields has avoided emissions of up to 590 Gt CO_2-eq between 1961 and 2005, or 13.4 Gt CO_2-eq per year.*
- *Investments in yield improvements compares favorably with other commonly proposed mitigation strategies. Further yield improvements should therefore be prominent among efforts to reduce future GHG emissions.*

Systems and Technologies for NUE improvement

- 4R Nutrient Stewardship & Fertilizer Best Management Practices (FBMP's);
- Balanced Fertilizer Practices;
- Controlled Release and Stabilized Fertilizer Technologies;
- Fertigation: also improved Water Use Efficiency (WUE);
- Improved or alternative application/delivery systems: Precision Agriculture;
- Crop and soil analysis and monitoring;
- Consumer market co-operation;
- Fertilizing crops to improve human health.

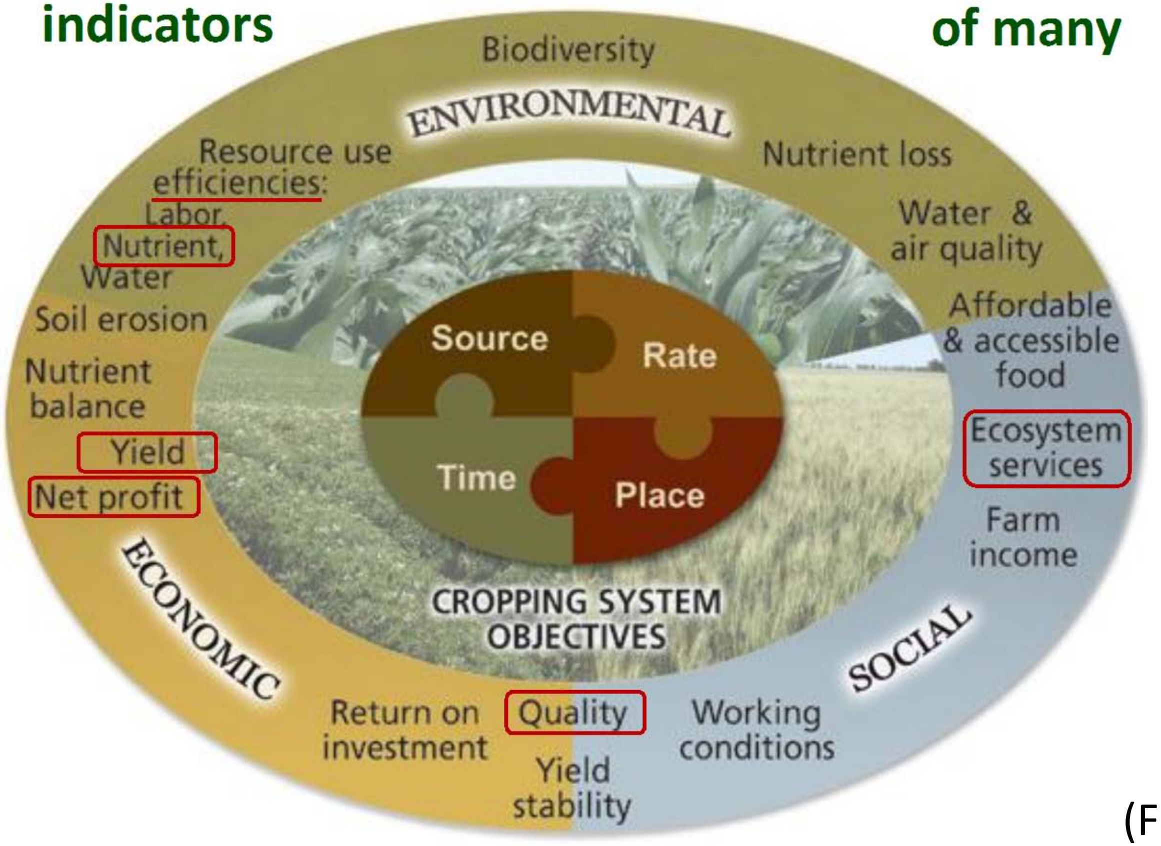
4R Nutrient Stewardship



4R Nutrient Stewardship incorporating NUE and Fertilizer Best Management Practices (FBMP's)

Performance indicators

NUE is one of many

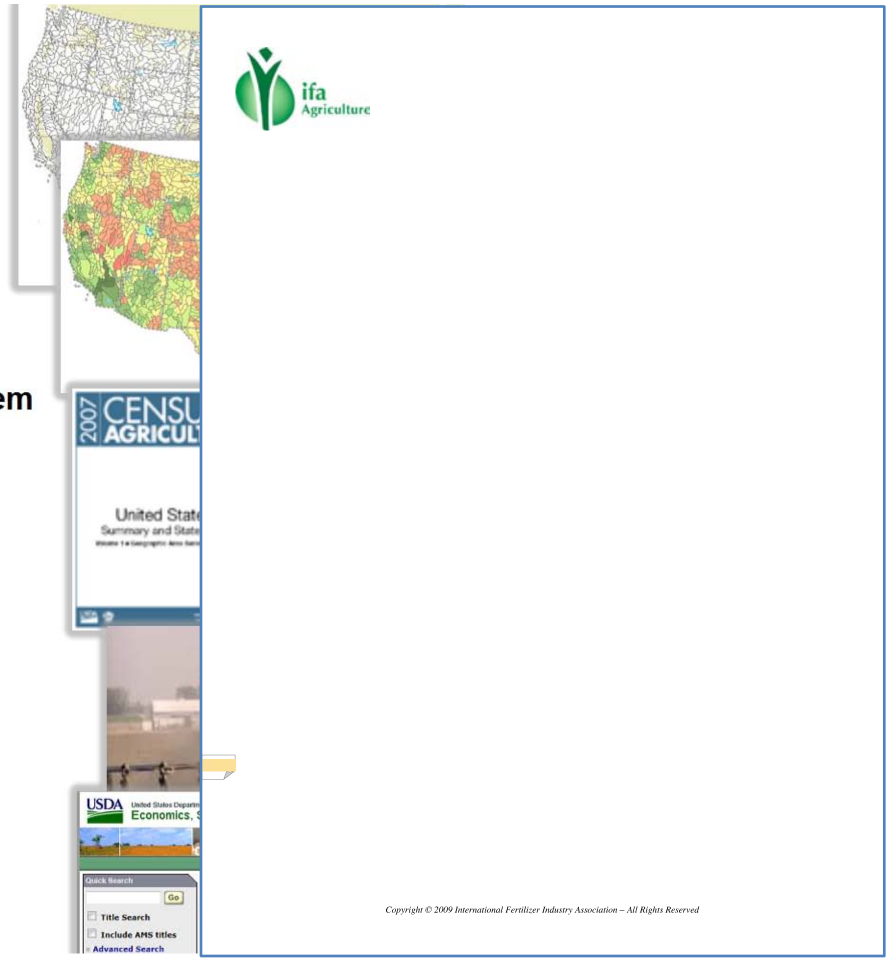


(Fixen, 2012)

Systems supporting 4R and FBMP's global implementation

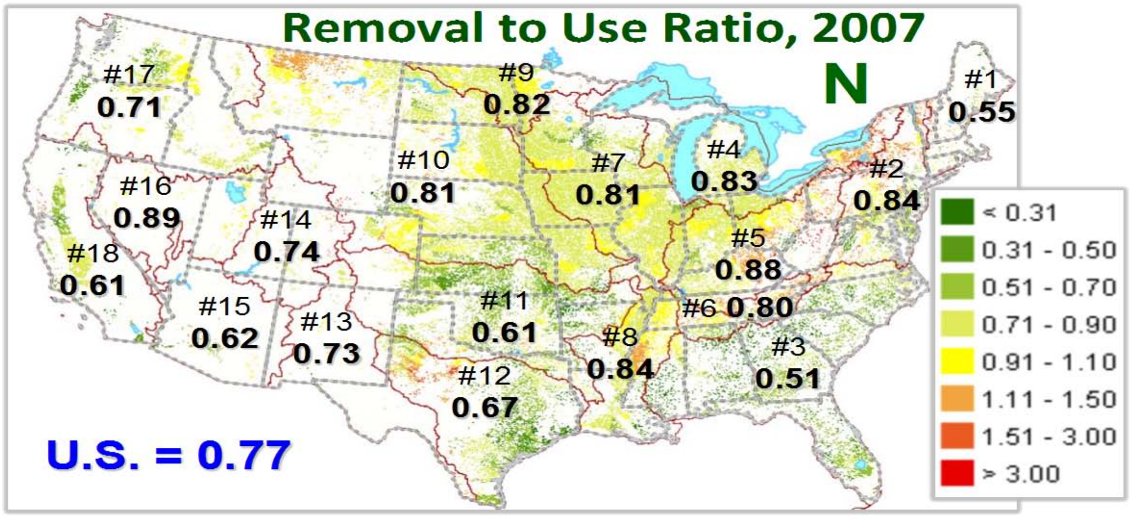
IPNI
INTERNATIONAL
PLANT NUTRITION
INSTITUTE

NuGIS
Nutrient Use Geographic Information System



(Fixen, 2012)

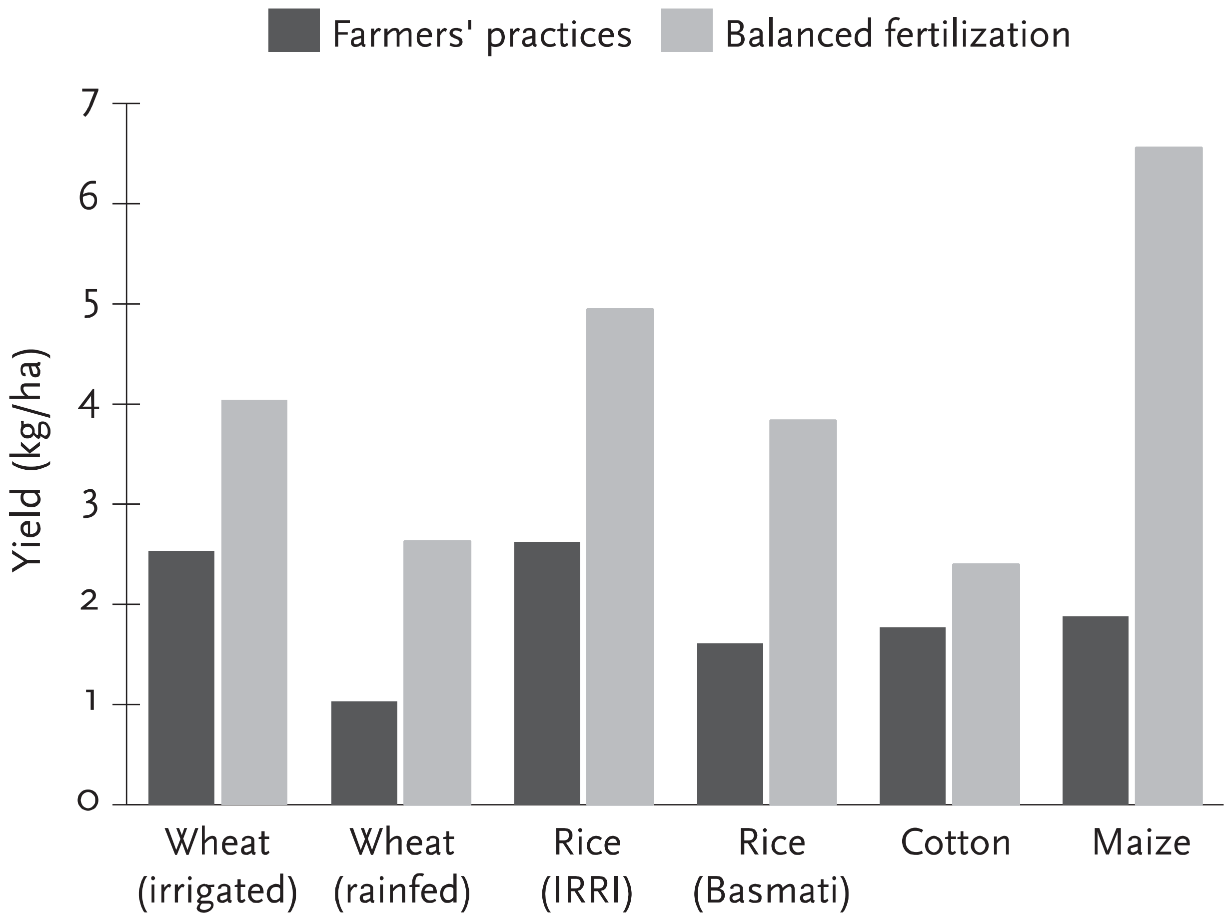
NuGIS use in measuring NUE in USA



NuGIS, 1/12/2012

(Fixen, 2012)

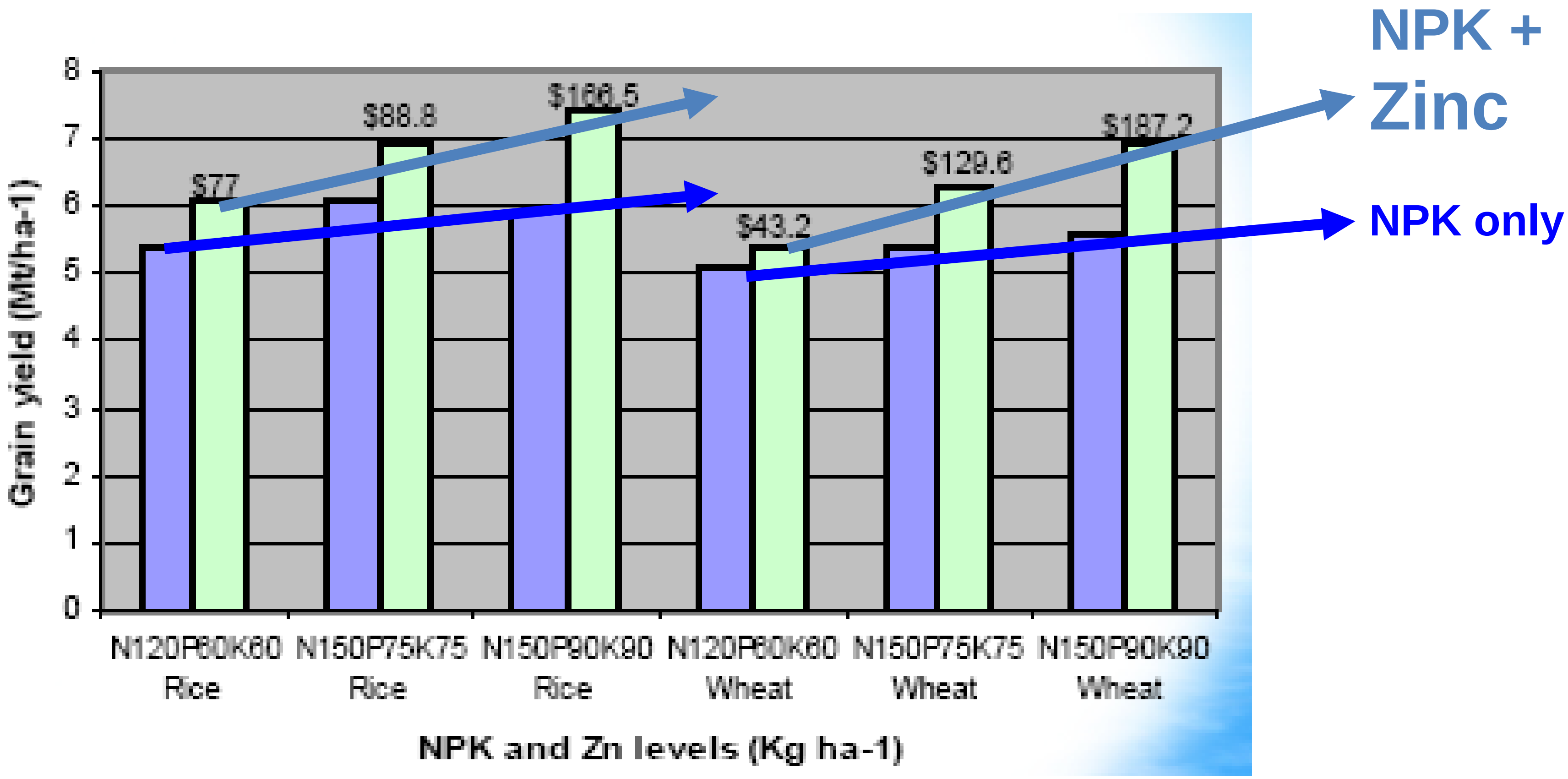
Balancing N applications with P in Indian Cropping Systems



(IFA, 2007)

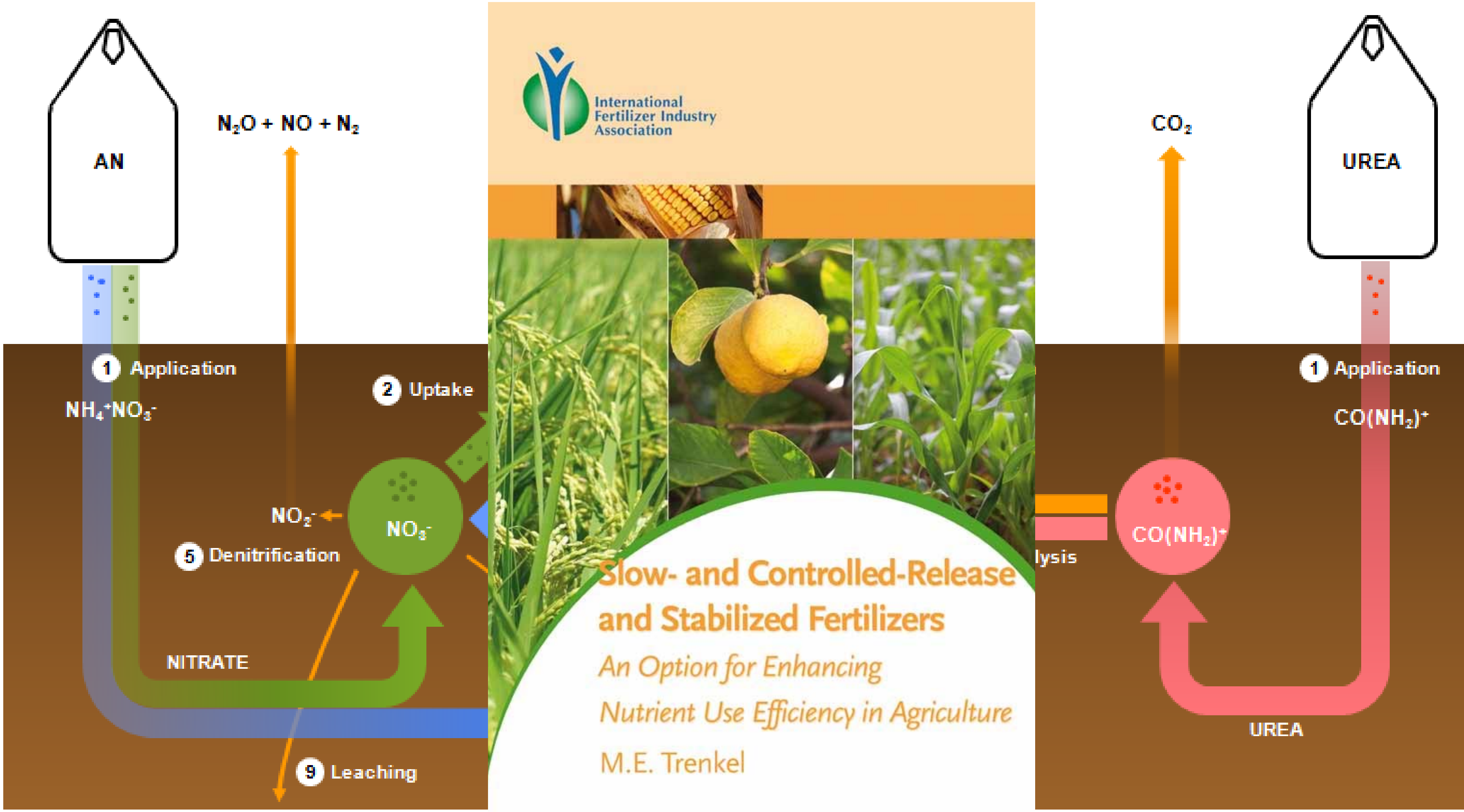
30% increase over national average represents additional 11.7 Mt for selected crops

Improved Nutrient Use Efficiency of NPK applications with Micronutrient Input…



…in rice/wheat systems in Bangladesh (Phillips, 2006)

Soil interactions associated with AN and Urea



More high value, irrigated crops in future

Changes in land use China 1949-1996

	1949		1996		Change	
	Million ha	%	Million ha	%	In area million ha	%
Cultivated land	97.8	10.1	130.0	13.7	+32.2	+33
Orchards/plantations	1.1	0.1	10.0	1.1	+8.9	+840
Forest	125.0	13.2	227.6	23.9	+102.7	+82
Pasture	391.9	41.2	266.1	28.0	-125.9	-32
Settlements, industry/mining	4.7	0.5	24.1	2.5	+19.3	+40
Transport	2.0	0.2	5.5	0.6	+3.5	+173
Water area	22.5	2.4	42.3	4.5	+19.8	+88
Unused land	305.5	32.1	245.1	25.8	-60.5	-20
Total area	950.7	100.0	950.7	100.0		

Hartemink, 2006

More high value, irrigated crops in future

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Food production (Mt $x10^9$)	1.8	3.5	5.5
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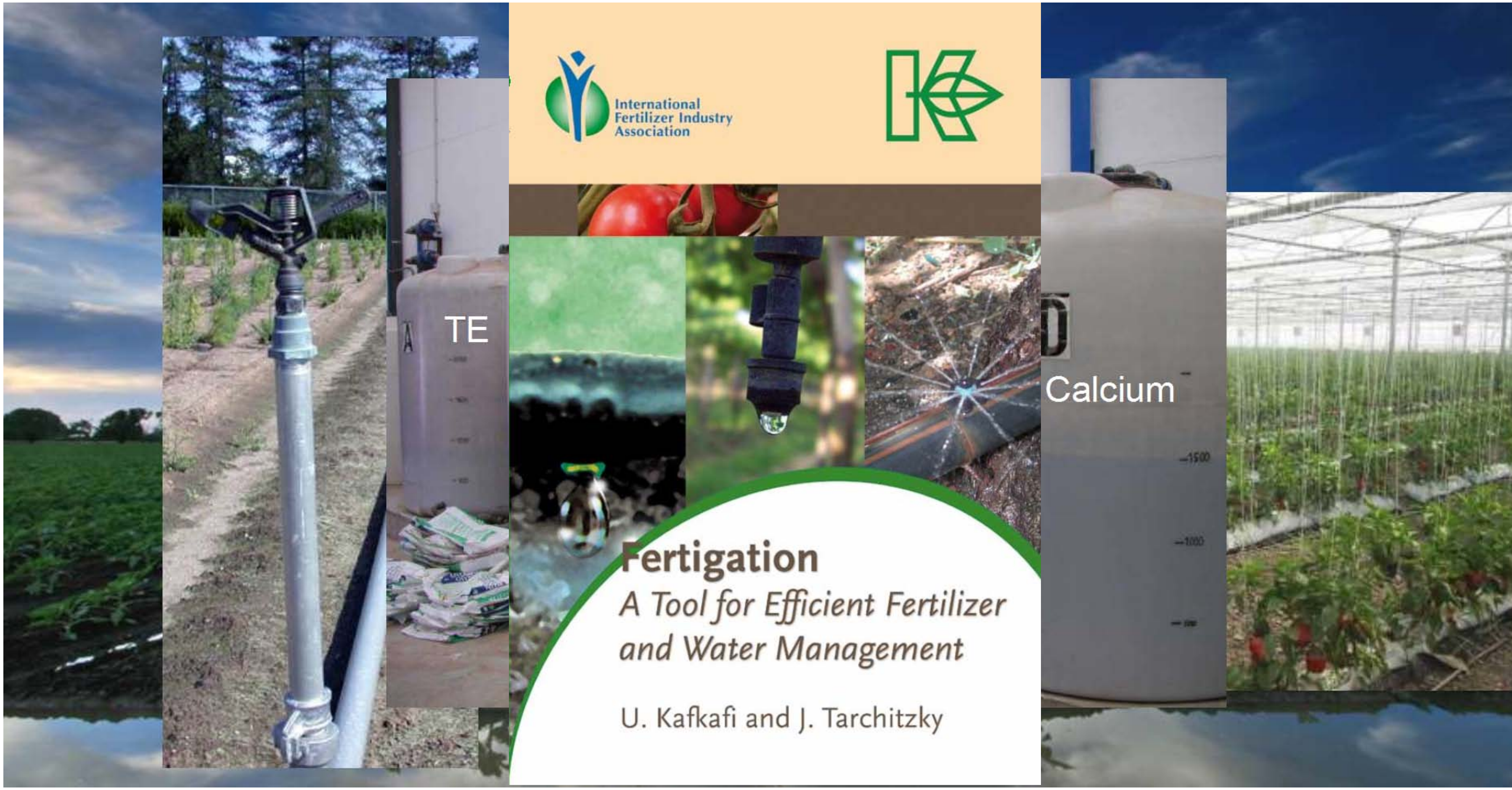
Pereira, 2003

Technology challenges in fertigation



(Jaeger, 2010)

Primary nutrient delivery systems

Spreading

Drilling
(No-till shown here*)

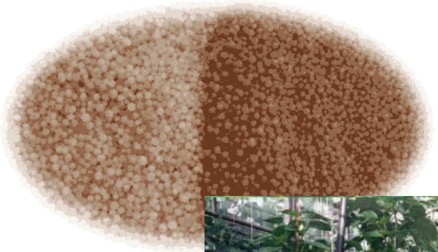
(*Technology changes compared with traditional ploughing)

Alternative nutrient delivery systems

- Foliar application……

- Seed treatment / coating………………

- Fertilizer impregnation…..



- Fertigation……………………………….

Precision agriculture / crop monitoring

Fertilizers Europe members have launched tools to support Good Agricultural Practices

Fertilizer planners and crop monitoring tools are introduced to calculate the right nutrient requirement for each crop and each field

=> these tools helped to improve nutrient use efficiency

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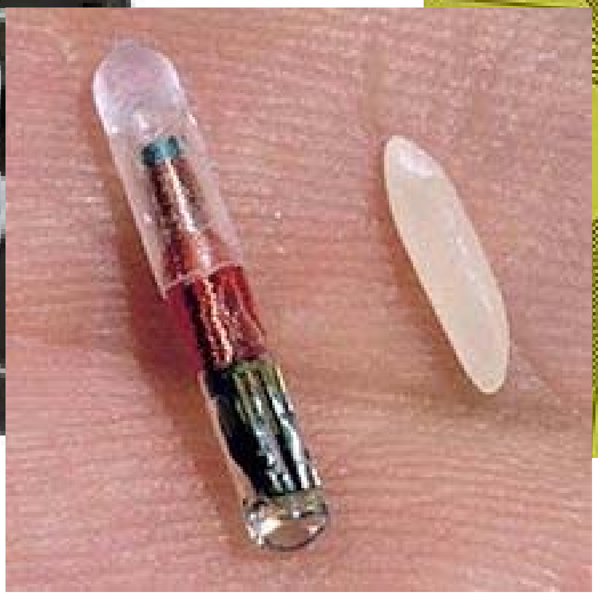
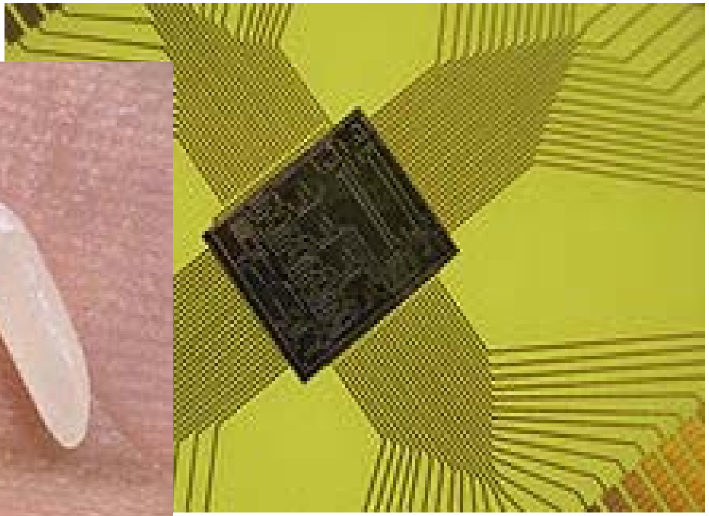
Future of Crop & Monitoring

Carbon nanotube based ion selective electrodes (www.cleangrow.com)

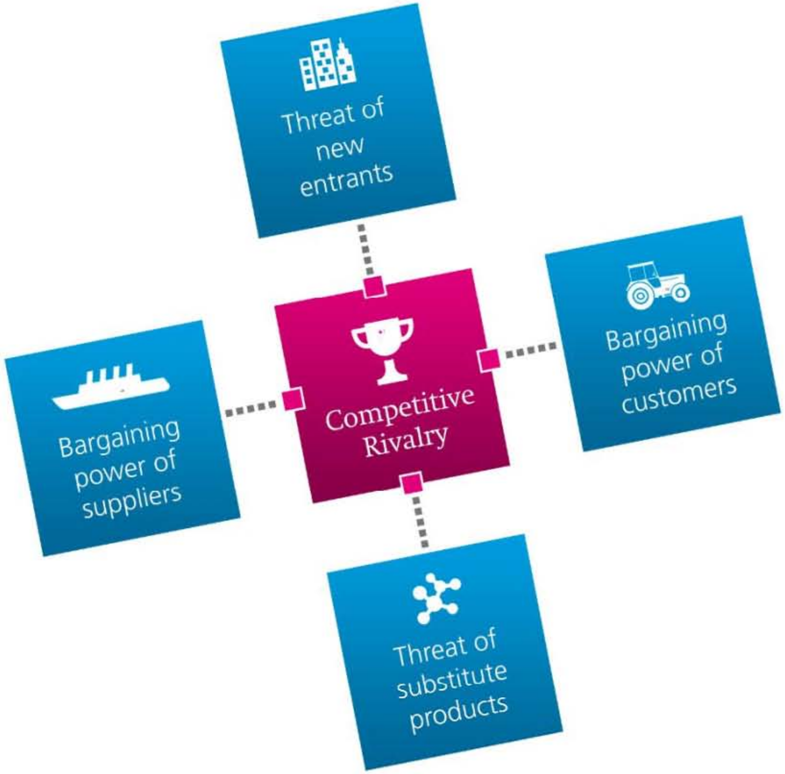


RFID's?



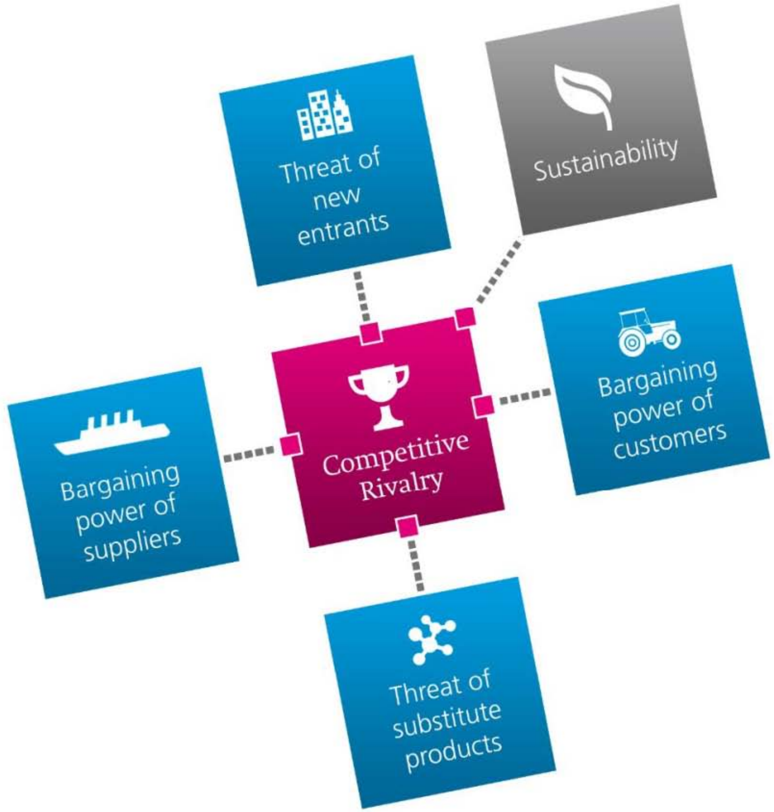
Micro-electro-mechanical systems chip
"Lab On a Chip (LOC)"

Competitive challenges for the fertilizer industry



(van Doorn, 2012)

Competitive challenges for the fertilizer industry



(van Doorn, 2012)

Achieving Sustainability in Fertilizer Production

Integrated super sites

Achieving Sustainability in Fertilizer Production

Minimizing CO_2 emissions

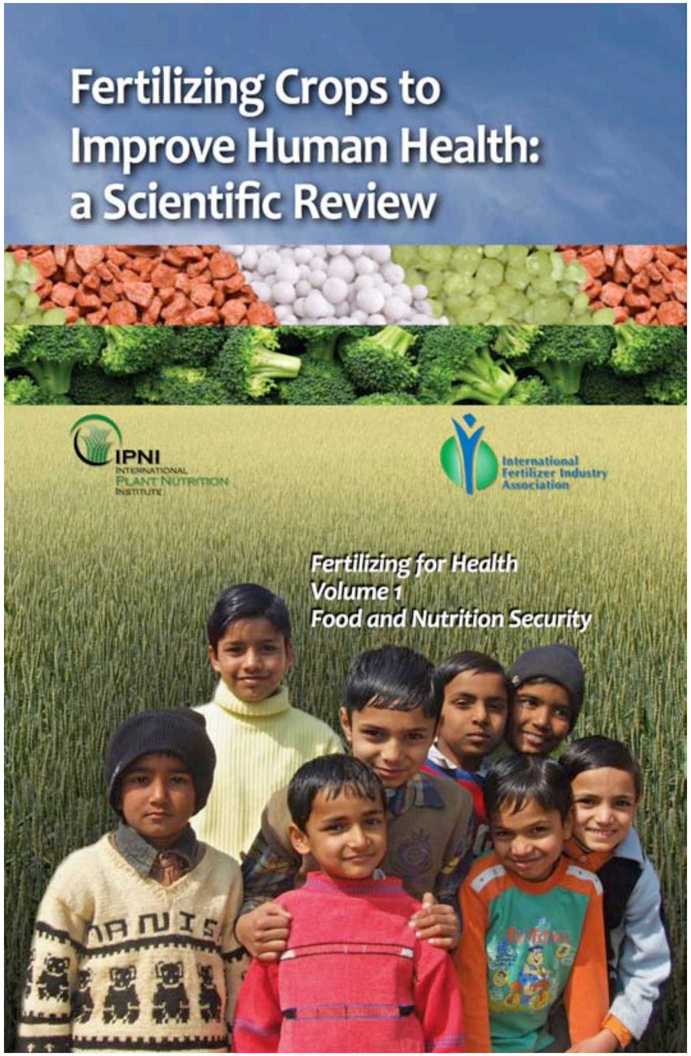
Consumer market cooperation

(van Doorn, 2012)

Reducing carbon footprint with PepsiCo

- Fertilizer = 58% of CO_2 emissions in orange juice production
- PepsiCo-Tropicana: Wants to reduce overall carbon footprint for orange juice production
- YaraLiva Tropicote can decrease carbon footprint of orange juice production by 50%
- Five years trial project started February 2010 in Florida
- Partnership between PepsiCo, SMR, Yara and University of Florida

Direct and indirect benefits to human health and well-being from improved NUE



Fertilizing Crops to Improve Human Health: a Scientific Review

By Tom W. Bruulsema, Patrick Heffer, Ross Welch, Ismail Cakmak, and Kevin Moran[1]

A large proportion of humanity depends for its sustenance on the food production increases brought about through the application of fertilizers to crops. Fertilizer contributes to both the quantity and quality of the food produced. Used in the right way— applying the right source at the right rate, time and place— and on the right crops, it contributes immensely to the health…and well being of humanity.

Since 1948, the World Health Organization has defined human health as "a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity." Reflection on this definition leads one to realize that responsibility for human health extends well beyond the critically important domain of medical science to include many other disciplines. The awarding of the 1970 Nobel Peace Prize to Dr. Norman Borlaug indicates a high level of recognition of the linkage of agricultural sciences to this definition of human health.

The increasing use of fertilizer in agricultural crops has boosted production per unit area, increasing the total supply of food as well as contributing to the quality of food and its content of essential trace elements. Increased production of the crops most responsive to fertilizer has also changed the mix of crops produced

For abbreviations and symbols used commonly throughout this book see page v.

1 T. Bruulsema is Director, Northeast North America Program, International Plant Nutrition Institute; Guelph, Ontario, Canada; e-mail: Tom.Bruulsema@ipni.net

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R. Welch is with the Robert W. Holley Center for Agricultural and Health at Cornell University, Ithaca, New York, U.S.; email: rmw1@cornell.edu

I. Cakmak is a Professor at Sabanci University, Istanbul, Turkey; e-mail: cakmak@sabanciuniv.edu

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Putting agriculture on the WEF agenda

- Yara has been playing a key role in bringing agriculture higher on the agenda of the World Economic Forum

- With the New Vision for Agriculture, the aim is to take giant steps forward every decade:
  - Increase food production by 20%
  - While emitting 20% less
  - Reducing rural poverty by 20%

Agriculture provides much more than food, and can fulfill the world's most basic social needs

Closing the gap

Improving Nutrient Use Efficiency

Resources
Greater efficiency
Better land use strategies
New and smart water solutions
Improved energy efficiency

Food
Improving Yields
Sustainable solutions for agriculture
Cropland productivity
Knowledge sharing

Environment
Reducing footprint
Reduced emissions from production
Environmental solutions
Climate smart agriculture

(Yara, 2011)

First meeting of IFA Working Group on 'Research & Innovation' on 12th December in Paris – prime focus topic is R&D for NUE!

THANKYOU