Meeting Challenges in Balanced Fertilization

"…the yield of a field cannot be increased by adding more of the same substances"
(Liebig, 1855)

H. Magen and S.K. Bansal

FAI Annual Seminar 2013
December 11-13, The Ashok, New Delhi

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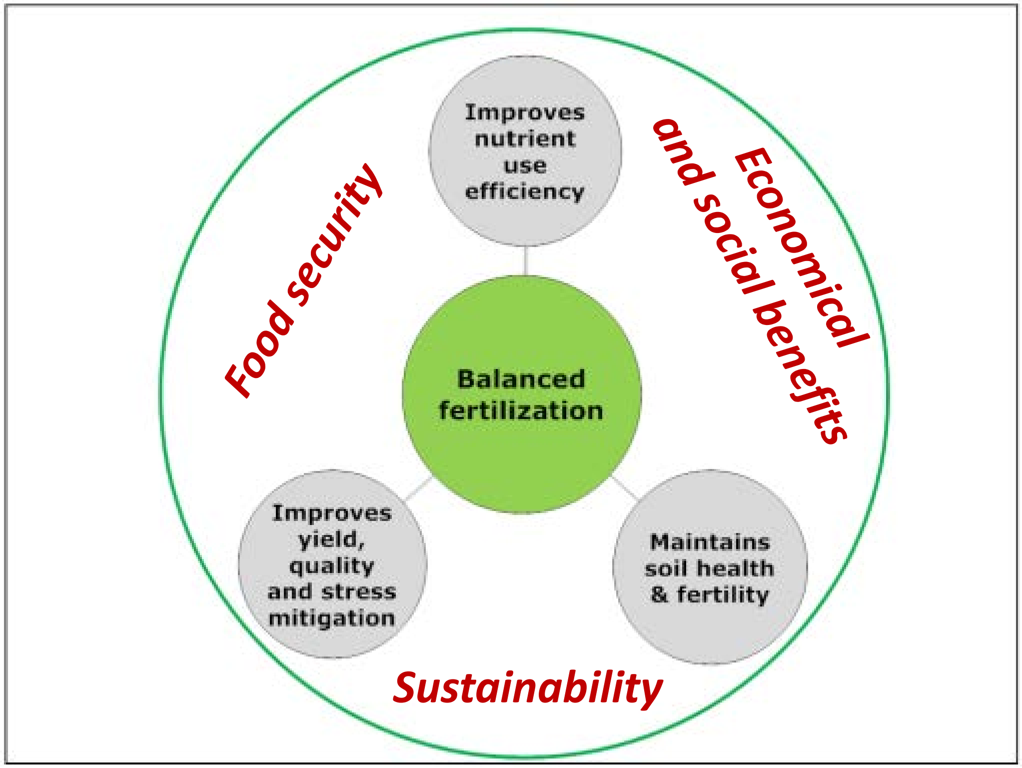
Balanced Fertilization – what is the value?

Balanced fertilization - today's value:

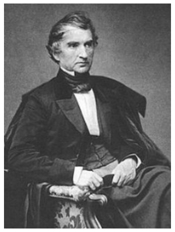
- Improves nutrient use efficiency
- Maintains soil health and fertility
- Improves yield, quality and stress mitigation

Contributing to

- food security
- economical and social development
- Sustainability



SPRENGEL-LIEBIG LAW OF THE MINIMUM



Introduction; BF for improving NUE; BF for improving agricultural productivity ; BF for maintaining soil health and fertility; BF and fertilizer subsidies; Conclusions

Project in Ethiopia, highlands vertisols

Some facts and figures

Demand

- From 2003 to 2050, food consumption in India (g/capita/day) will increase by
  - Cereals – 15%
  - Meat – 84%
  - Milk – 68%
  - Vegetables – 40%
  - Fruit – 42%
  - Potatoes – 81% (Kearney, 2010)

Productivity

- Productivity needs to increase by
  - For Wheat: An average increase of about 7.5% per annum
  - For Pulses: 5.3% per annum (NAAS, 2006).

Resources

- While per capita
  - Arable land will decrease (Swaminathan 2006)
  - Water table in Northern India is falling (Kerr, 2009)

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Some facts and figures

Yield gap

In many parts of India there is a substantial delta between actual productivity and yield potential, while in (few) others, the limit is genetic yield potential (Aggarwal et al., 2000)

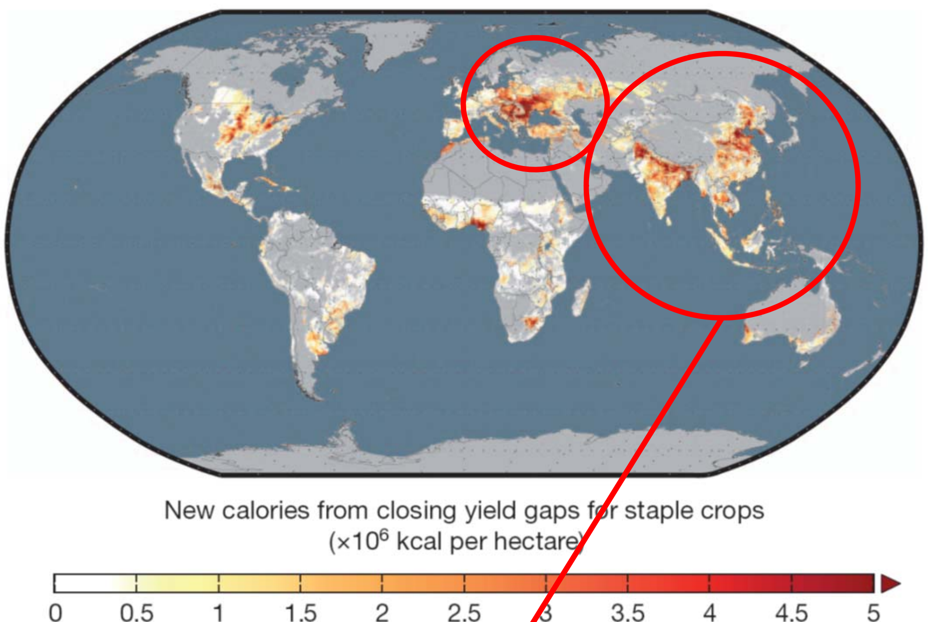
Response to fertilizers

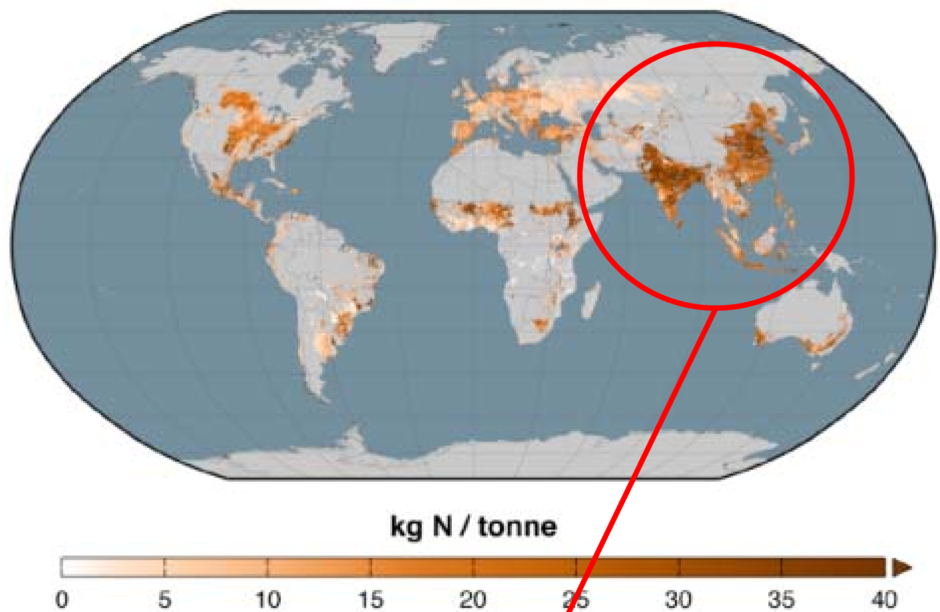
There is a reduction in crop response to fertilizer application, specially when balanced fertilization is not practiced (NAAS, 2006)

Closing global yield gaps – and seeking nutrient use efficiency

New calories from closing yield gaps for staple crops

The cost of production (kg N tonne)





Where potential awaits utilization

…and where N use efficiency is low

Source: Foley et al., 3 4 0 | NATURE|VOL 478 | 20 OCTOBER 2 0 1 1

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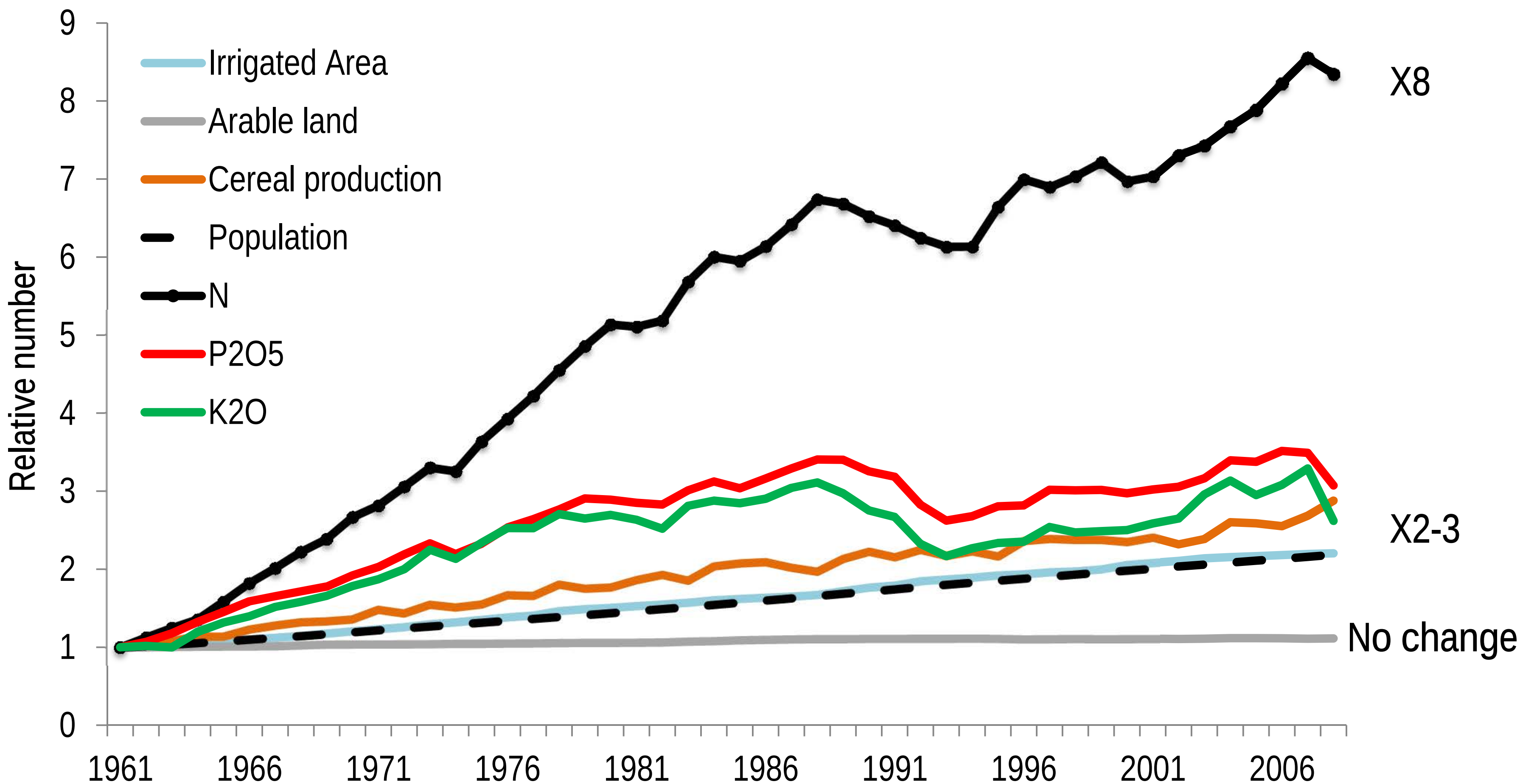
Global relative growth 1961-2008
The `Ncentury`



Source: FAOSTAT and IFA

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Introduction; BF for improving NUE; BF for improving agricultural productivity ; BF for maintaining soil health and fertility; BF and fertilizer subsidies; Conclusions

-K

+K

Omitting K; lettuce. Courtesy U. Yermiyahu, Gilat, Israel.

Nitrogen-use efficiency, the next green revolution

(The Economist Nov 13 2009)

The Economist

World politics Business & finance Economics Science & technology Culture Blogs Debate Multimedia Print edition

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Science

The new NUE thing

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Nitrogen-use efficiency, the next green revolution

Nov 13th 2009 | From The World in 2010 print edition

Like 1 Tweet 1

Imagine you could wave a magic wand and boost the yield of the world's crops, cut their cost, use fewer-fossil fuels to grow them and reduce the pollution that results from farming. Imagine, too, that you could both eliminate some hunger and return some land to rain forest. This is the scale of the prize that many in the

GET INVOLVED NOW

"Imagine you could wave a magic wand and boost the yield of the world's crops, cut their cost, use fewer-fossil fuels to grow them and reduce the pollution that results from farming.

Imagine, too, that you could both eliminate some hunger and return some land to rain forest."

http://www.economist.com/node/14742733; 2009

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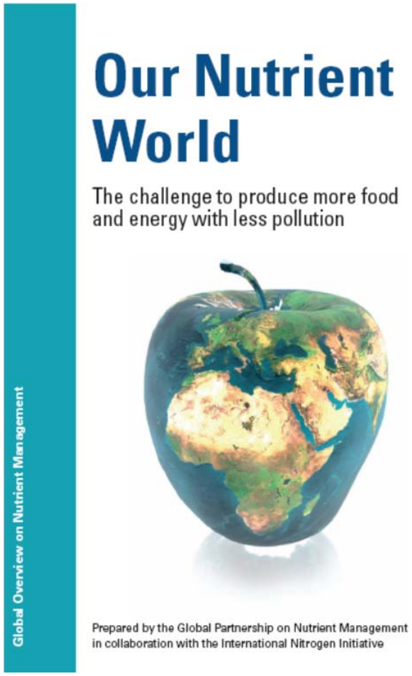
Our Nutrient World

(Sutton *et al*., 2013)



Prepared by the Global Partnership on Nutrient Management in collaboration with the International Nitrogen Initiative

http://www.ccst.inpe.br/wp-content/uploads/2013/02/Relat%C3%B3rio_completo_PDF.pdf

"But about two-thirds of the nearly $100 billion of nitrogen fertiliser spread on fields each year is wasted….

…Some of that waste is avoidable with sensible agronomic measures: timing the application of fertiliser carefully, for example…

…The benefits from increasing nutrient use efficiency by 20% by 2020 may lead to savings of 20 million mt nitrogen, with the value of USD 170 billion if in the benefits from this saving, human health, climate and biodiversity worth are calculated (Sutton *et al*., 2013).

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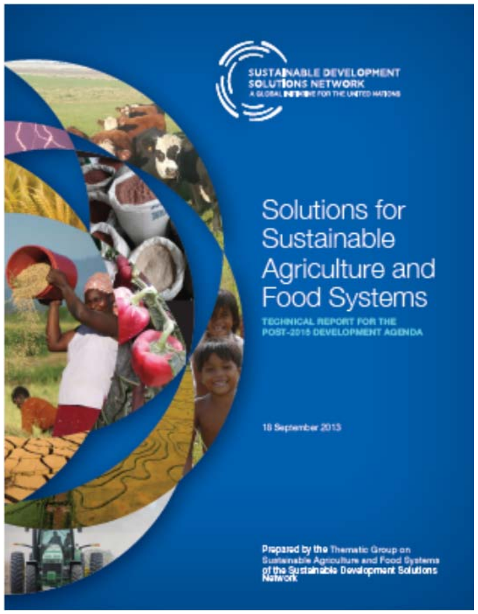
Solutions for Sustainable Agriculture and Food Systems

TECHNICAL REPORT FOR THE POST-2015 DEVELOPMENT AGENDA



Prepared by the Thematic Group on Sustainable Agriculture and Food Systems of the Sustainable Development Solutions Network
www.unsdsn.org

- "Improving the full-chain Nutrient Use Efficiency (NUE) of nitrogen and phosphorus, defined as <u>the ratio of nutrients in final products to new nutrient inputs</u>, is a central element in meeting the challenge to produce more food and energy with less pollution and better use of available nutrient resources. "

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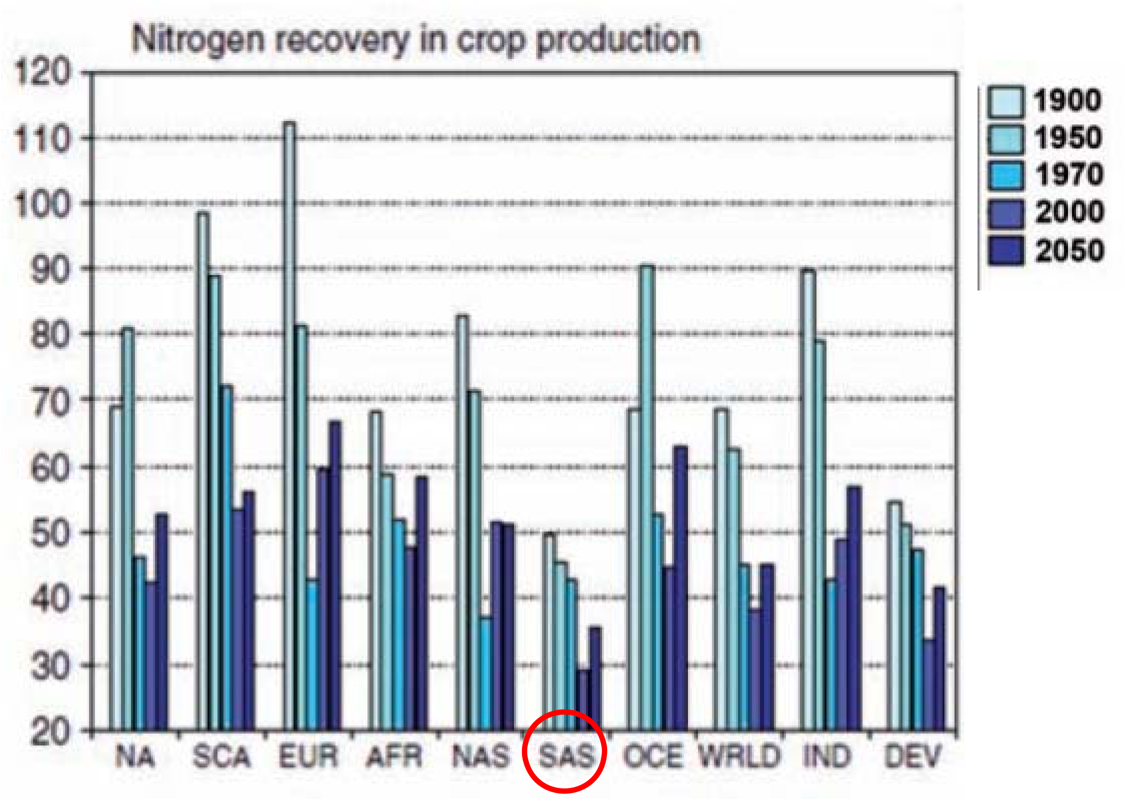
Regional estimates of nutrient use efficiency* for N in crops

$* NUE_N(crop) = N_{harvest} / (N_{fertilizer} + N_{manure} + N_{fixation} + N_{deposition}) * 100$

* recovery efficiency



NA, North America (Canada, United States);
SCA, South and Central America;
EUR, Europe;
AFR, Africa;
NAS, North Asia (Russian Federation, Belarus, Ukraine, Republic of Moldova);
SAS, South Asia (rest of Asia);
OCE, Oceania (Australia and New Zealand);
WRLD, World;
IND, Industrialized countries;
DEV, developing countries

Source: Sutton *et al.*, 2013

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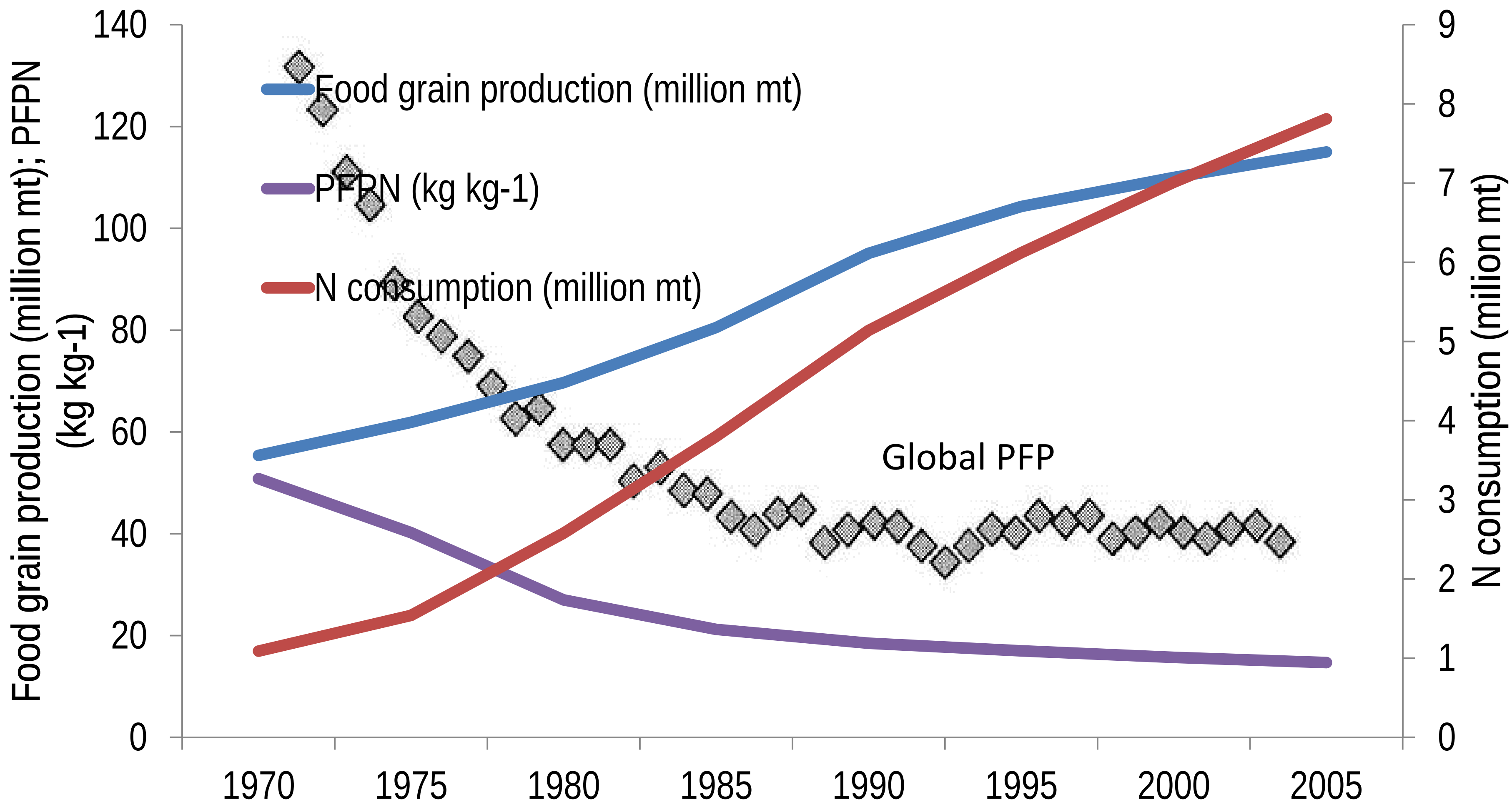
India: 35 years of food grain production in irrigated areas, N consumption and PFPN evolution (1970-2005)



Source: Calculated from Biswas and Sharma, 2008. IJF 4(7).; Global PFP from Schepers and Raun (eds.) 2008; Nitrogen in Agricultural systems; Ag. Mon. 49, pp 677;

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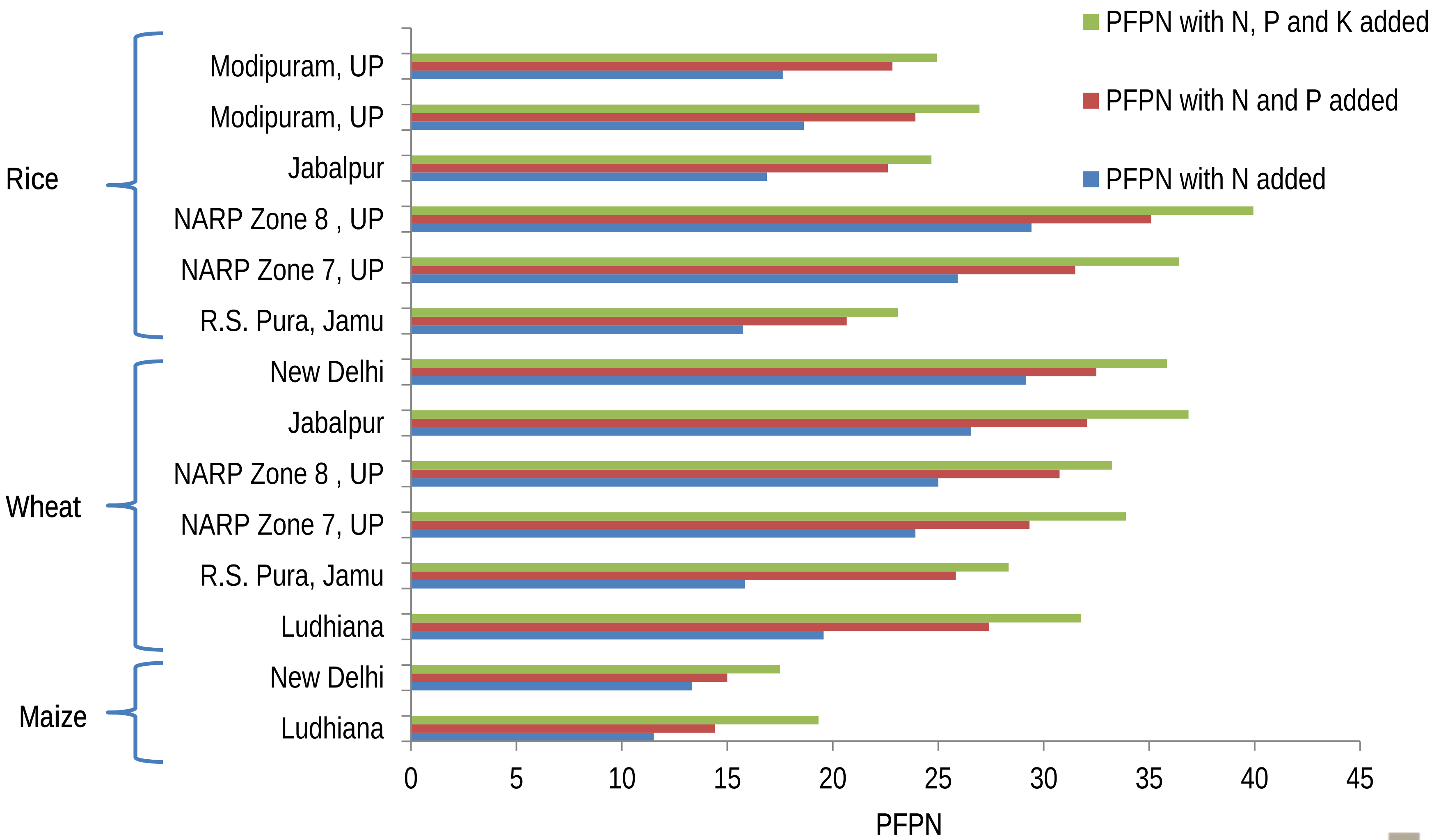
Partial factor productivity of N fertilizer (PFP_N) when N, NP and NPK added



Calculated from Biswas and Sharma (2008).

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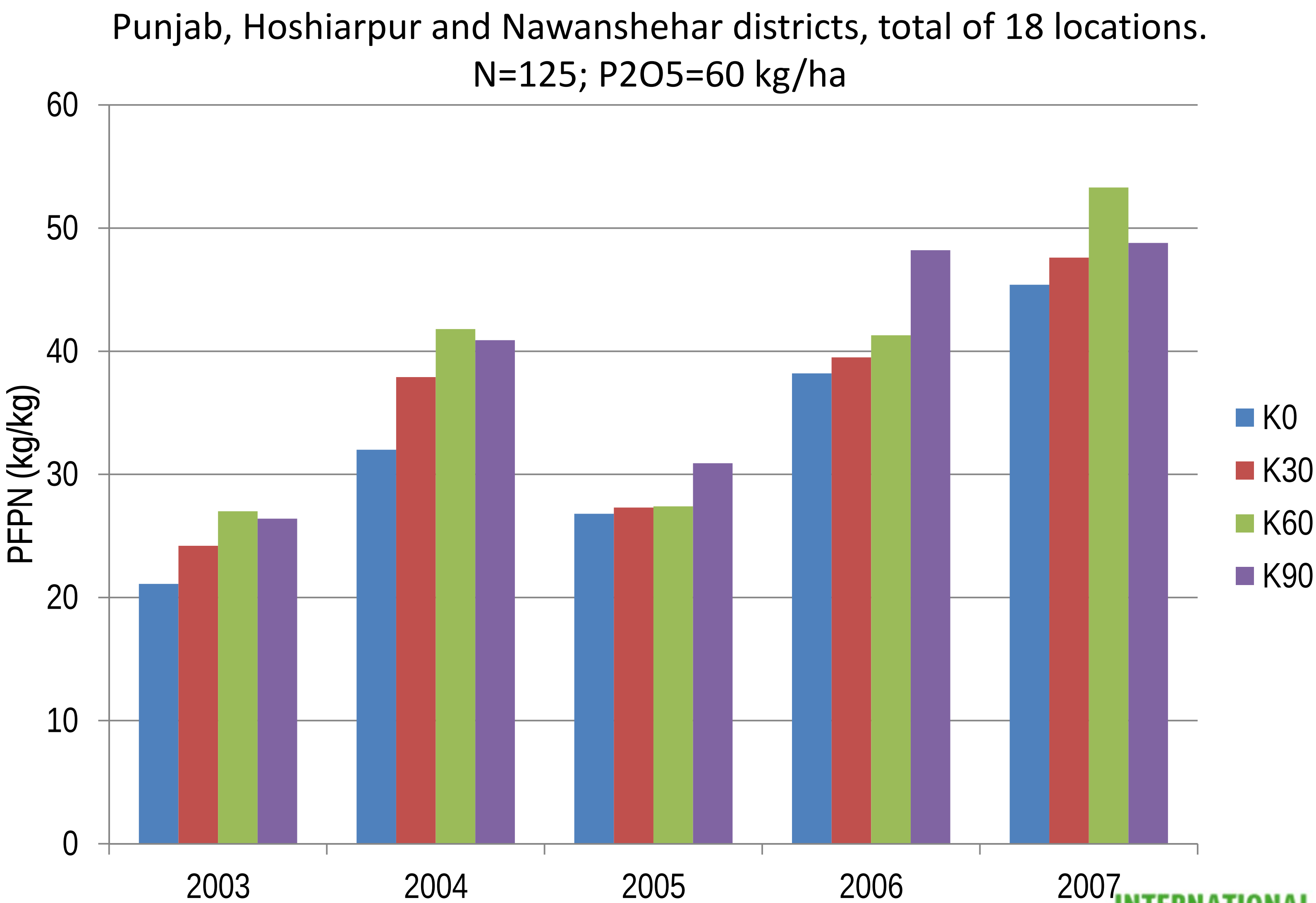
Partial factor productivity of N fertilizer (PFP_N) in maize with increasing K levels



Brar *et al.*, 2012. e-ifc; http://www.ipipotash.org/en/eifc/2012/30/2

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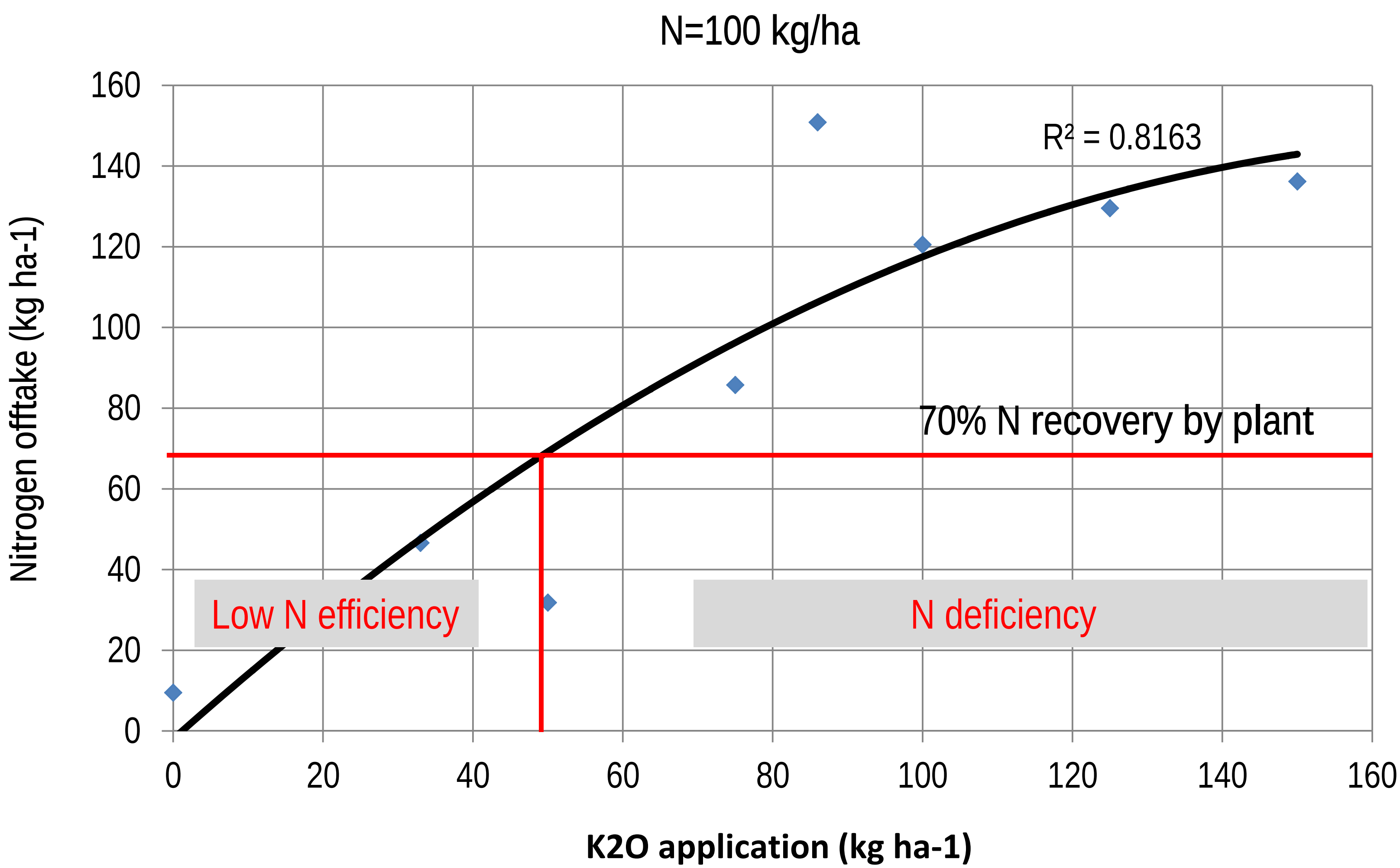
K increases N use efficiency in onion bulbs: N offtake increases with higher K application



Source: IPI project; Deshpande *et al.*, 2013

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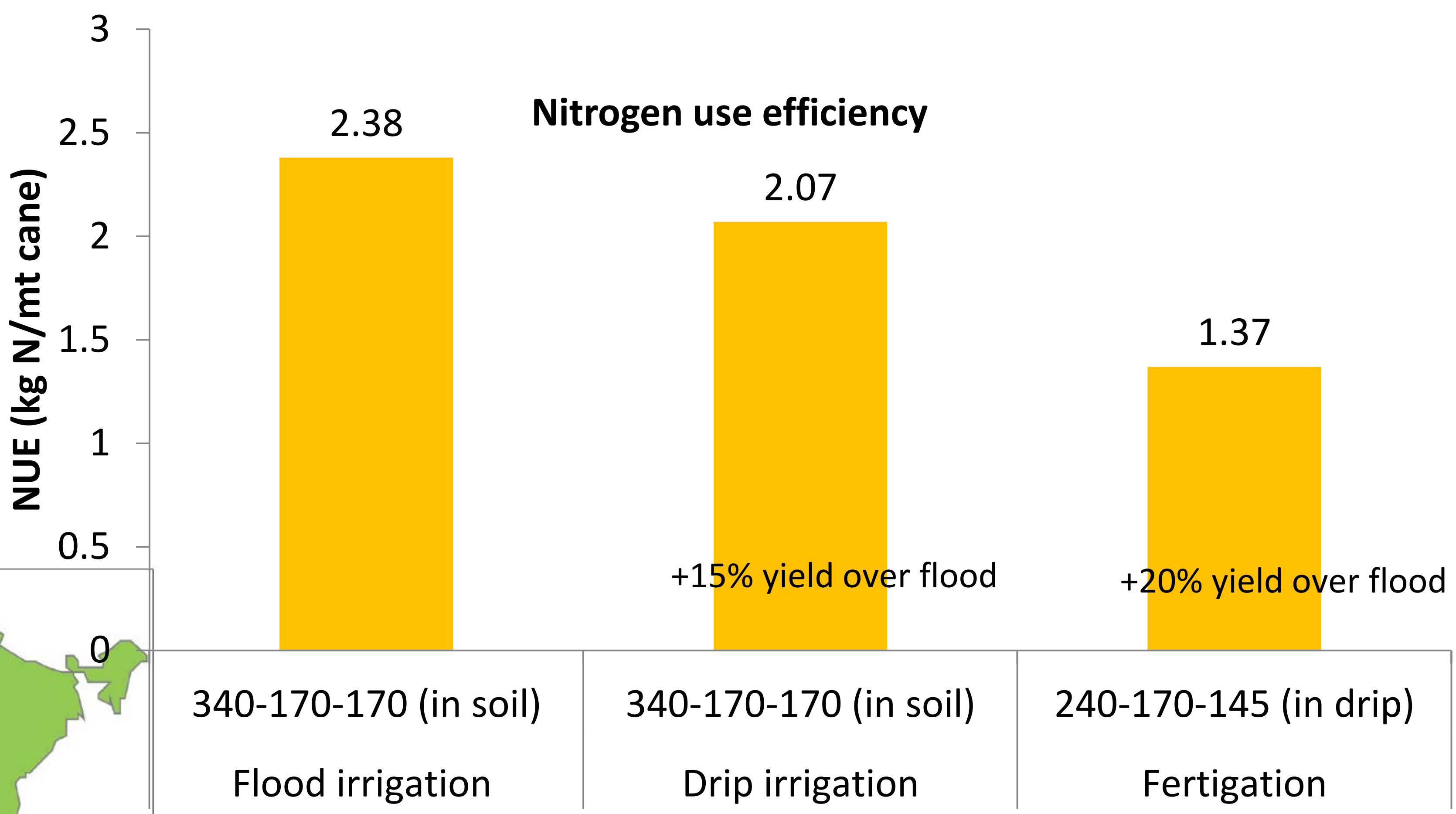
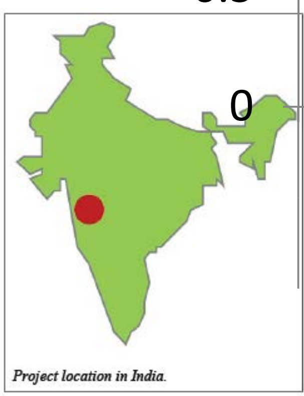
Effect of water management and N+K application through drip irrigation on NUE in Sugarcane





Deshmukh et al., ifc 24, September 2010, IPI; presented at IFA meeting in Beijing, 9/2013

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Improving nutrient use efficiency by better K application

Data calculated from
Wheat: Niu *et al*., 2013; Field Crops Research 140
Maize: Niu *et al*., 2011; Agron. J. 103

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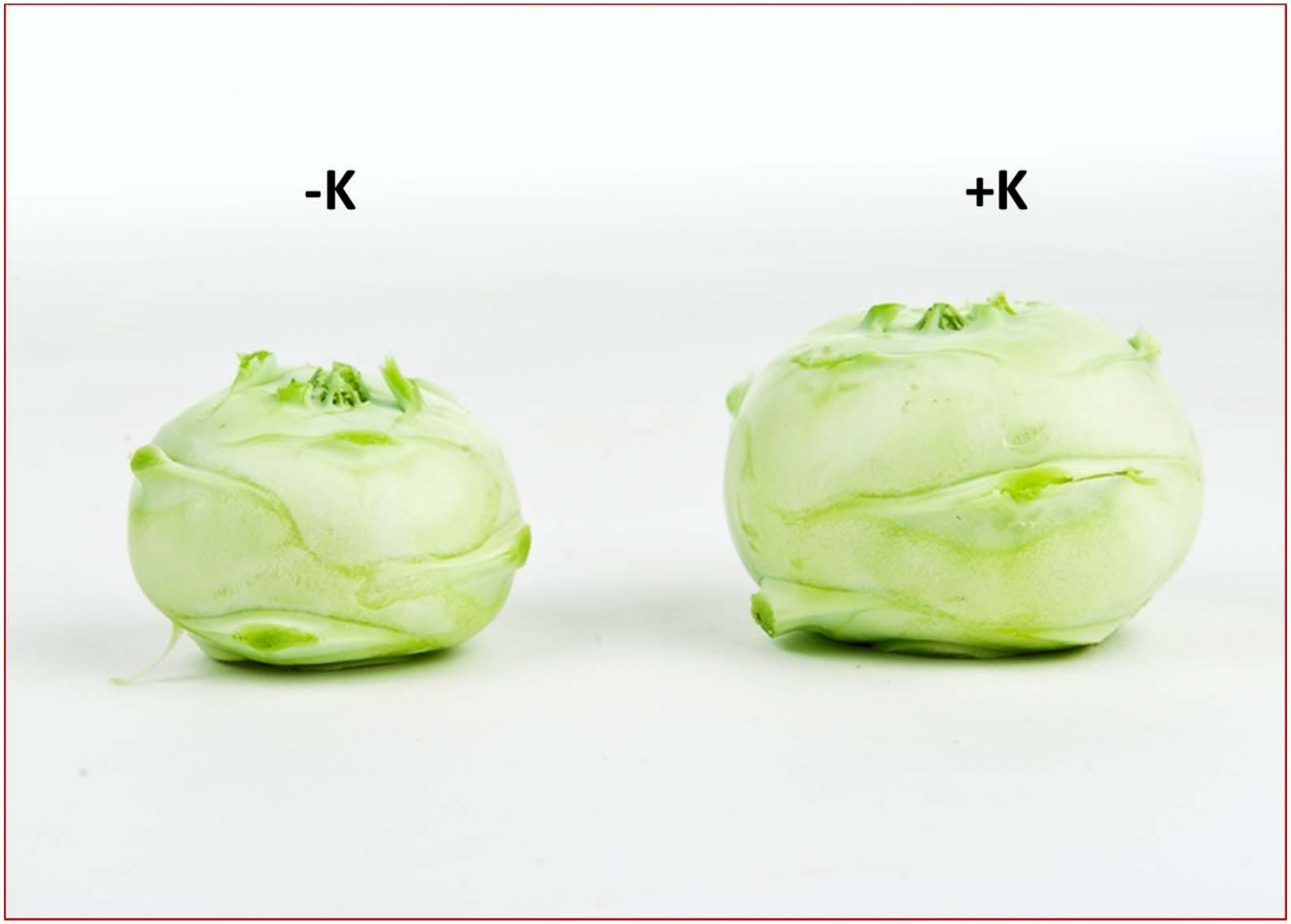
Introduction; BF for improving NUE; BF for improving agricultural productivity ; BF for maintaining soil health and fertility; BF and fertilizer subsidies; Conclusions



Omitting K; Kohlrabi. Courtesy U. Yermiyahu, Gilat, Israel.

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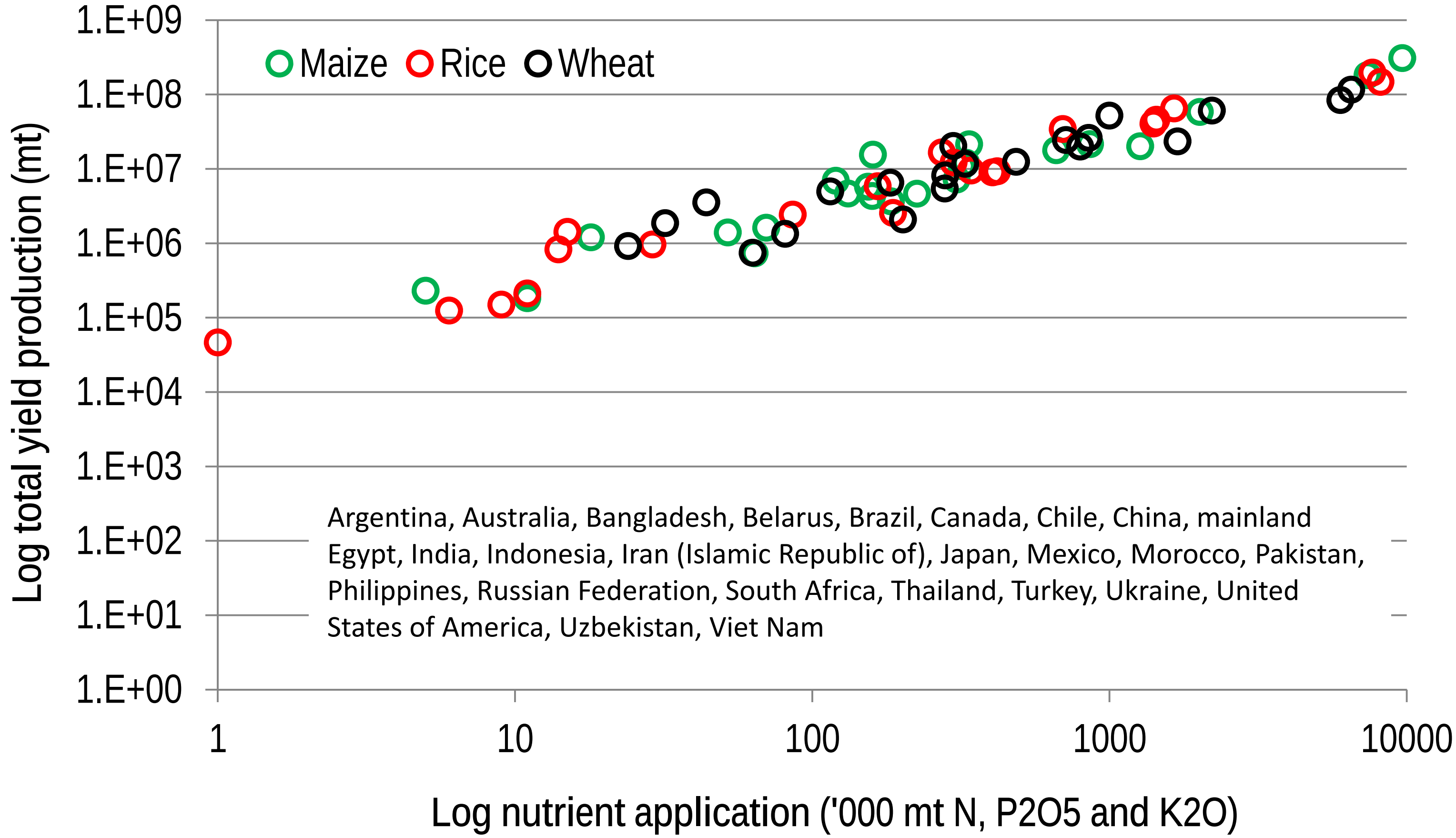
Relation between nutrients applied ($N+P_2O_5+K_2O$), and maize, wheat and rice yields in 26 countries.



Source: nutrient application from Heffer, 2013; cereal yield production from FAOSTAT accessed 10/10/2013

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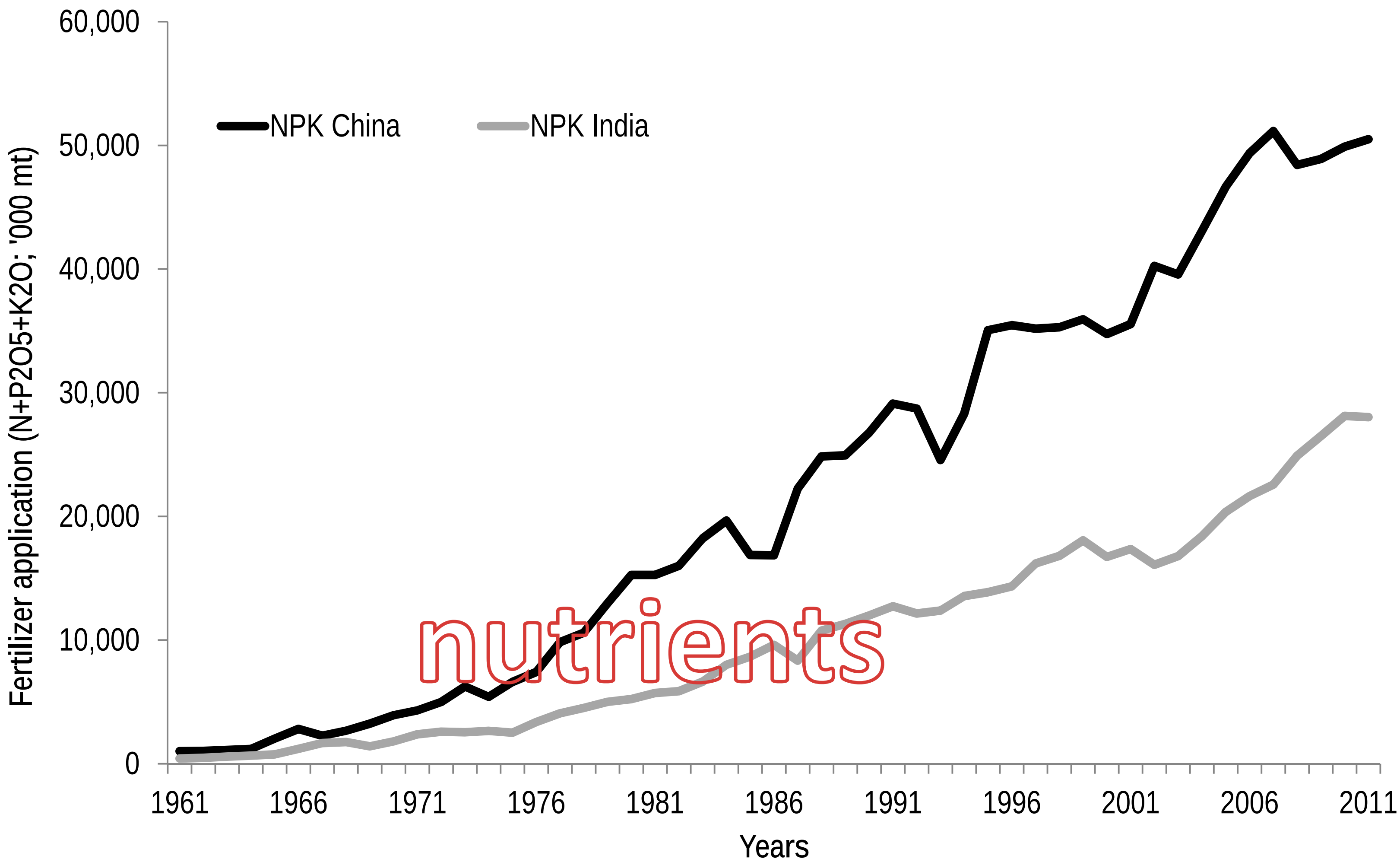
Fertilizer consumption (mt; 1961-2011) and food supply (kcal/capita/day; 1961-2009) in China and India (from crops only)



Source: FAOSTAT

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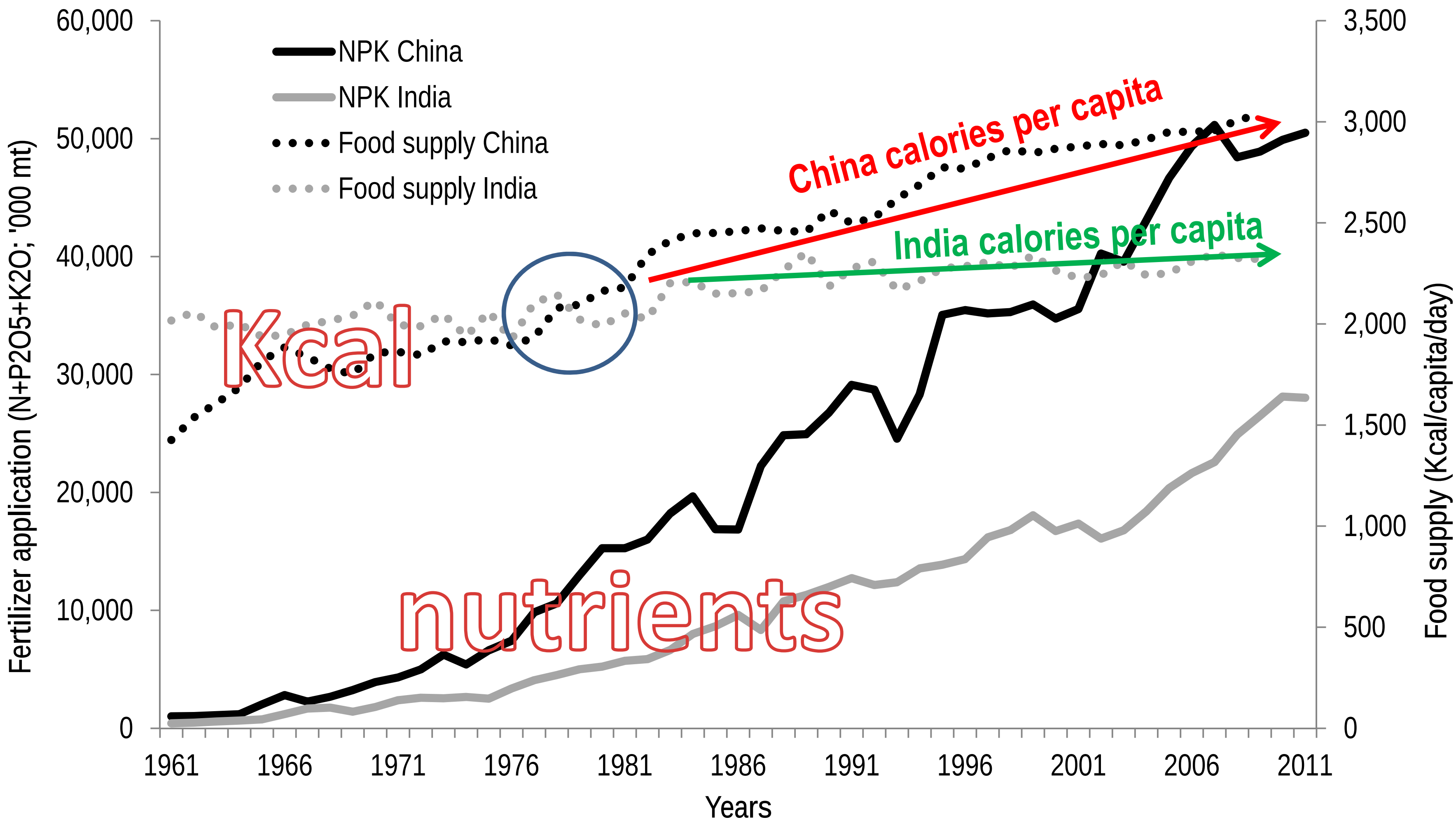

Source: FAOSTAT

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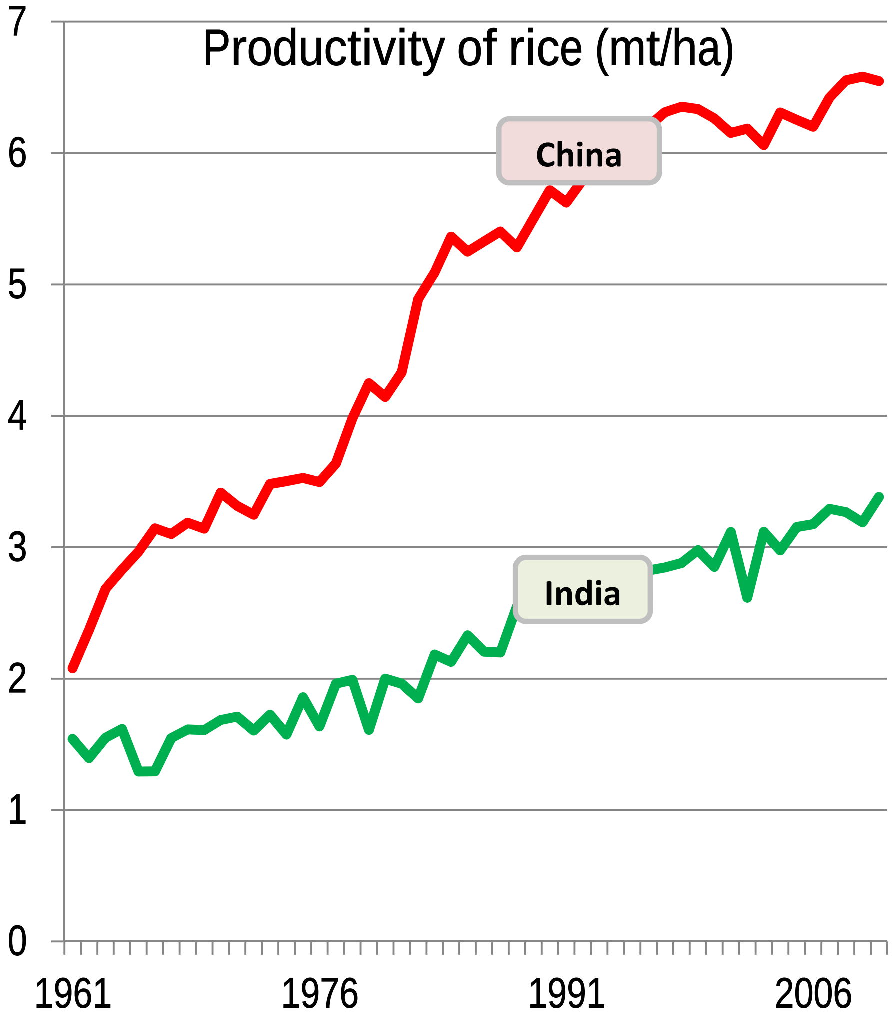
Productivity of rice in India and China: how to increase productivity while keeping high PFP_N?



Source: FAOSTAT

		India	China
		Application rate (kg/ha)	
Rice	N	103.0	187.1
	P_2O_5	33.6	59.8
	K_2O	21.2	57.9
	PFP_N	32.9	33.3

Application rates of nutrients in China are
+82% for N
+78% for P
+173% for K

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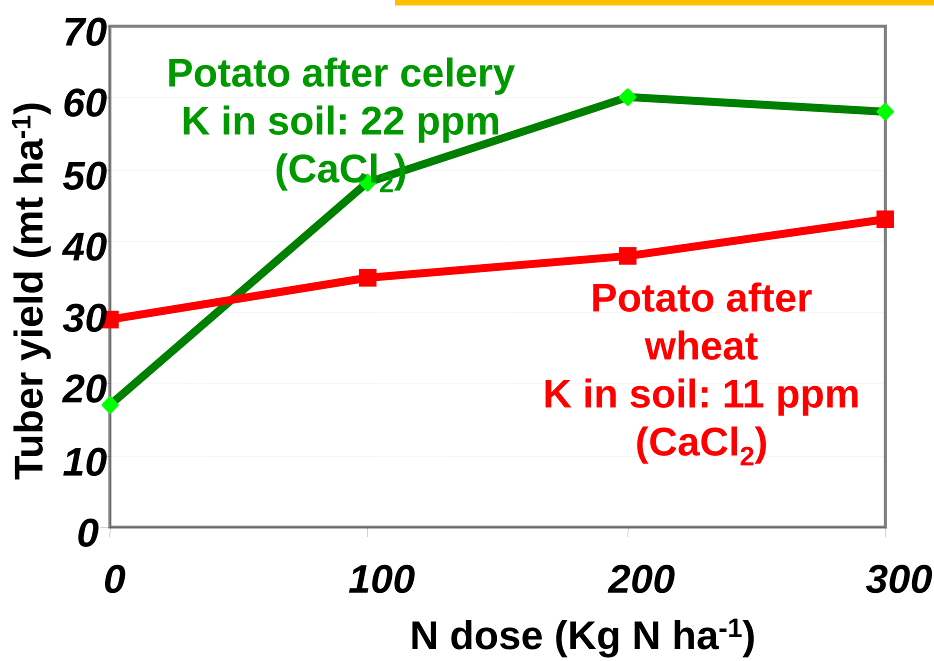
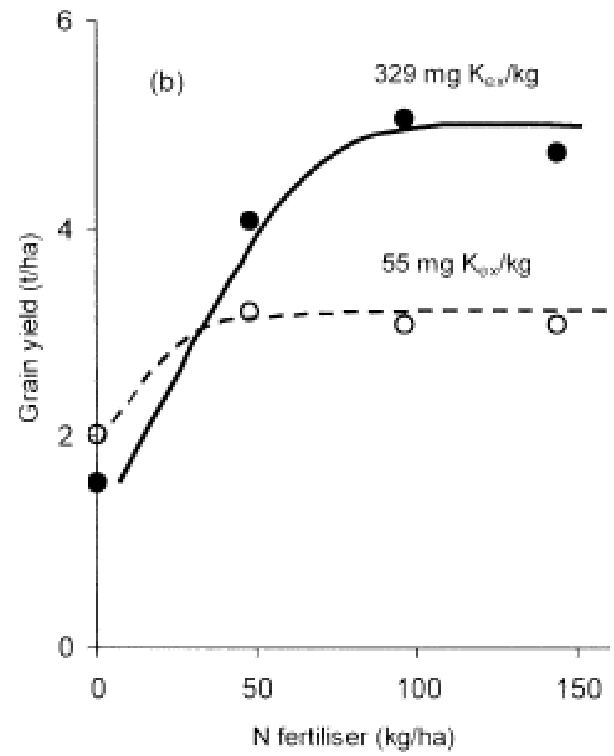
Response to N under different K soil levels

"It does no good to worry about nitrogen use efficiency and managing your nitrogen properly if your soil test potassium or phosphorus is low"
(Greg Schwab, University of Kentucky)





Potassium Nutrition Management for Enhancing Tuber Yield of Potato Grown Under Short Day Irrigated Condition in Eastern Indo - Gangetic Plains of India
S.K. Singh , S. K. Bansal and T. Baladzhoti; Presented by Hillel Magen, Director, International Potash Institute (IPI)
12th ISSPA International Symposium, June 6-10, 2011, MAICh, Crete; REDRAWN FROM DATA OF FEIGIN AND SAGIV, 1977

Milford and Johnston, Rothamsted results presented at Proc. 615, IFS, UK.IFS

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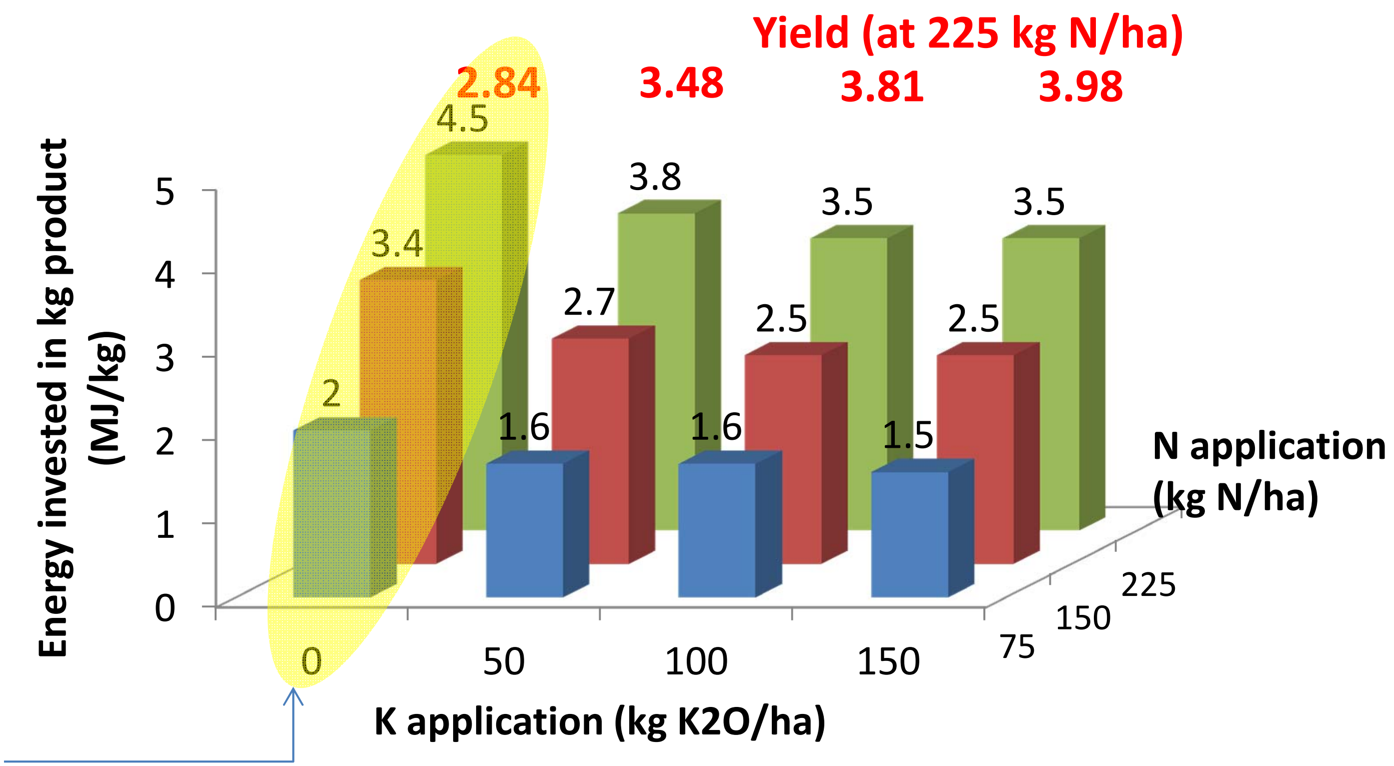
BF for lower carbon foot print: energy invested to produce N and K fertilizers per kg of potato (Mj/kg) with increasing N and K levels

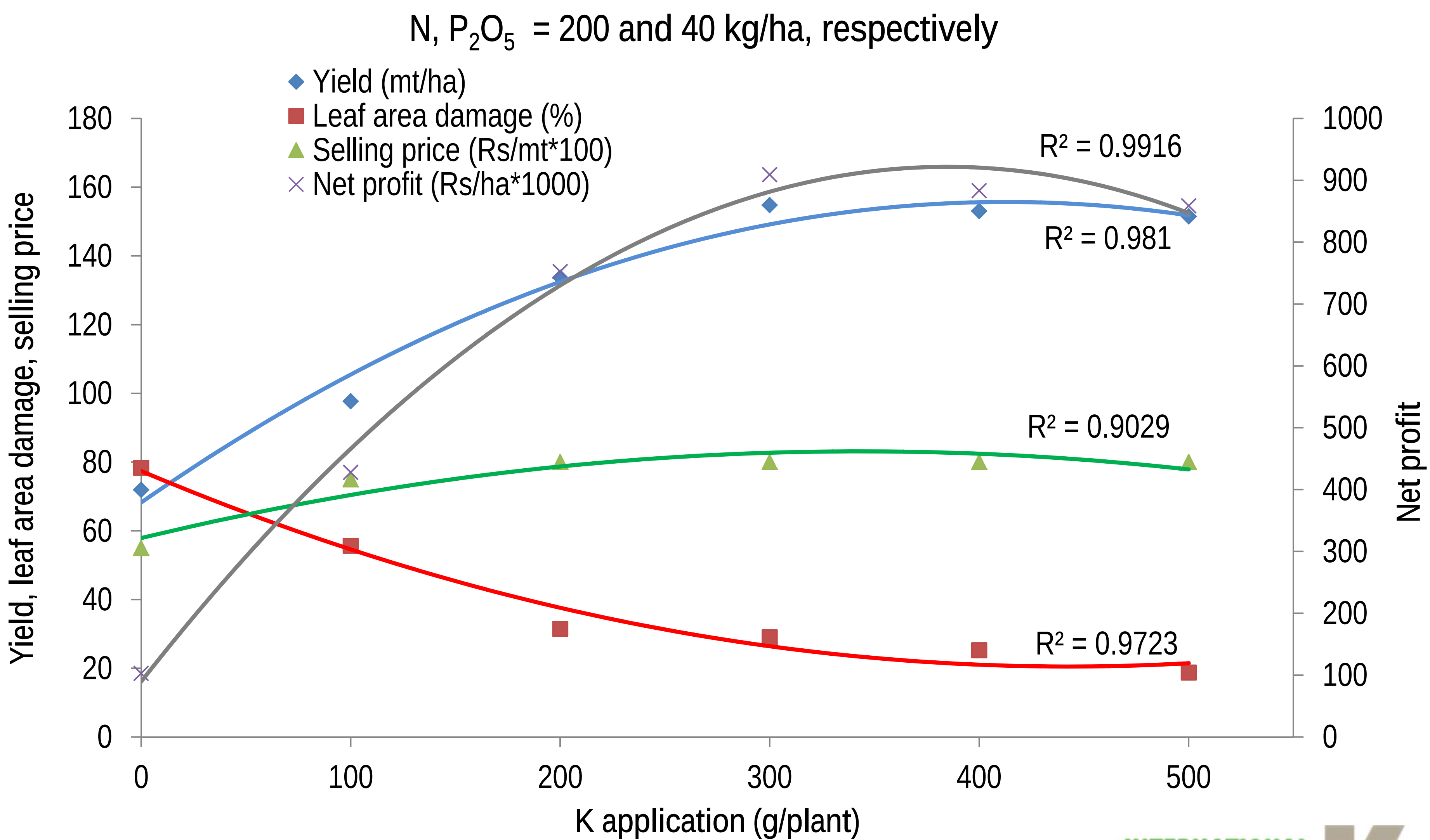
1 kg of N, P_2O_5 and K_2O requires 56.9, 9.3 and 6.97 MJ per 1 kg of nutrient (Cruse et al., Agron. J., 2010)



At K=0, energy cost is higher

calculated from Singh and Lal, 2012; and Cruse et al., 2010

Effect of K on banana yield, frost damage, selling price and net profit (MPKV, Rahuri; 2011-12)



Source: Bhale Rao and Deshpande, 2012

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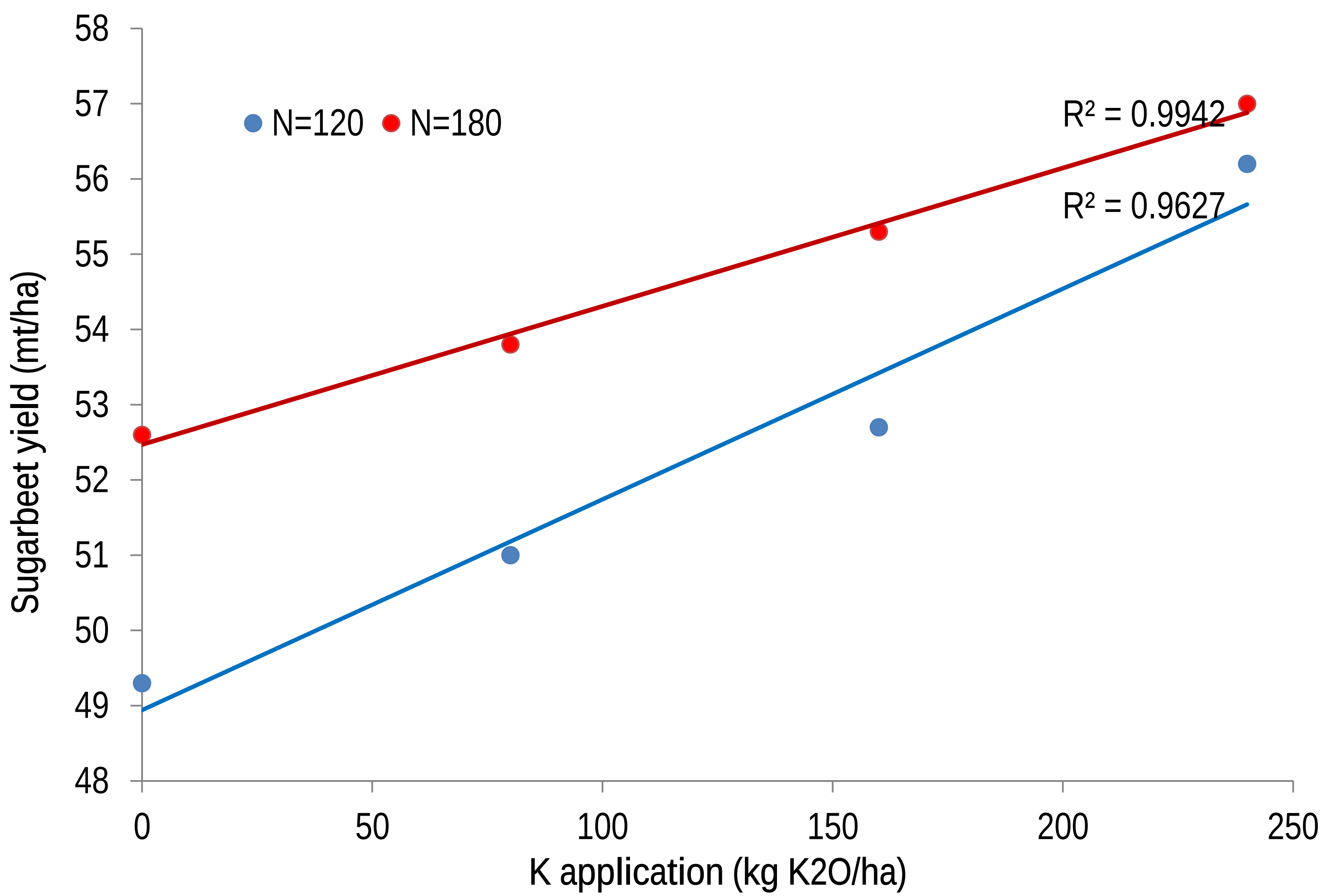
Effect of K on yield of sugar beet in Ukraine



Source: IPI report; Ukraine project; G. Peskovski, 2012.

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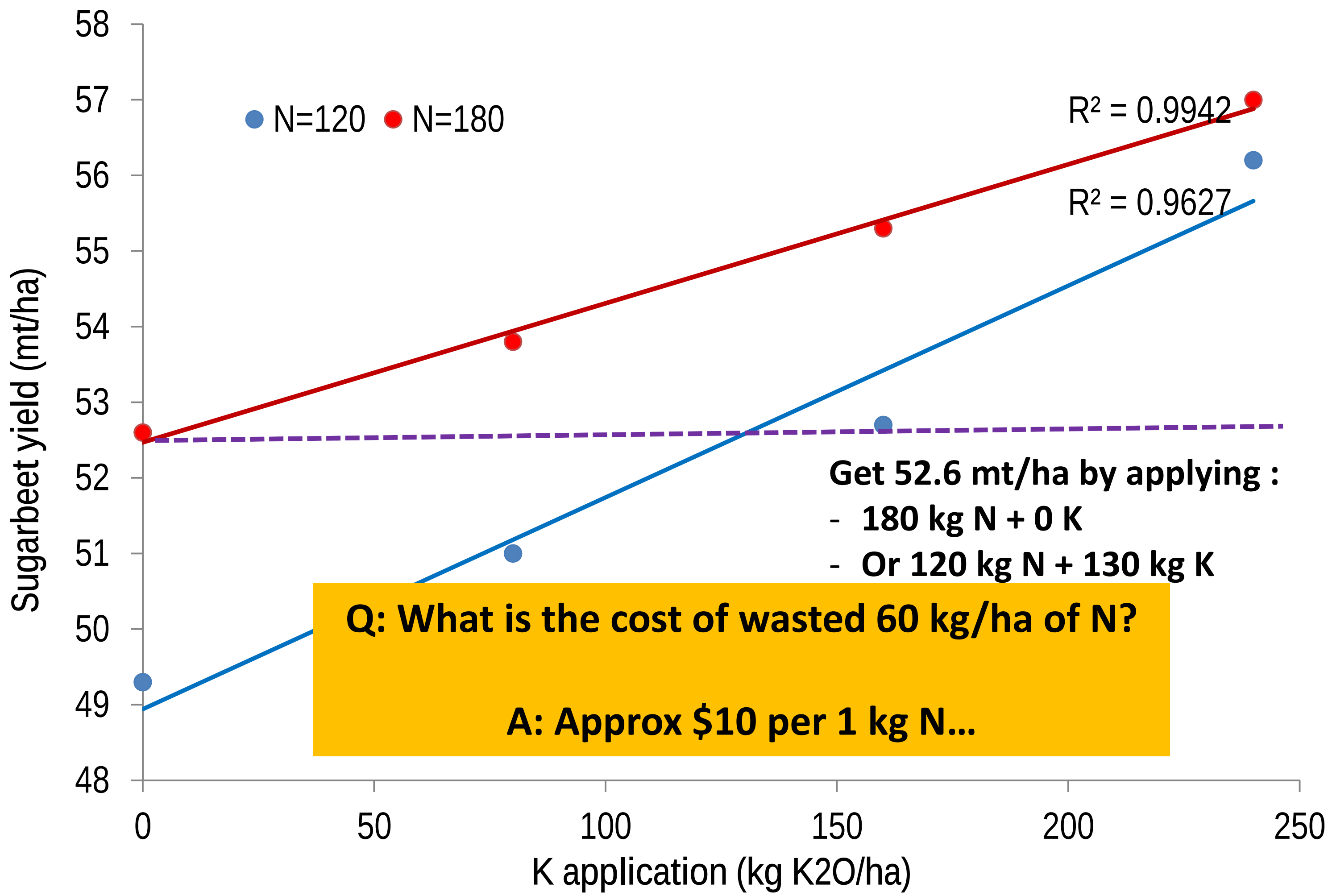

Q: What is the cost of wasted 60 kg/ha of N?

A: Approx $10 per 1 kg N…

Source: IPI report; Ukraine project; G. Peskovski, 2012.

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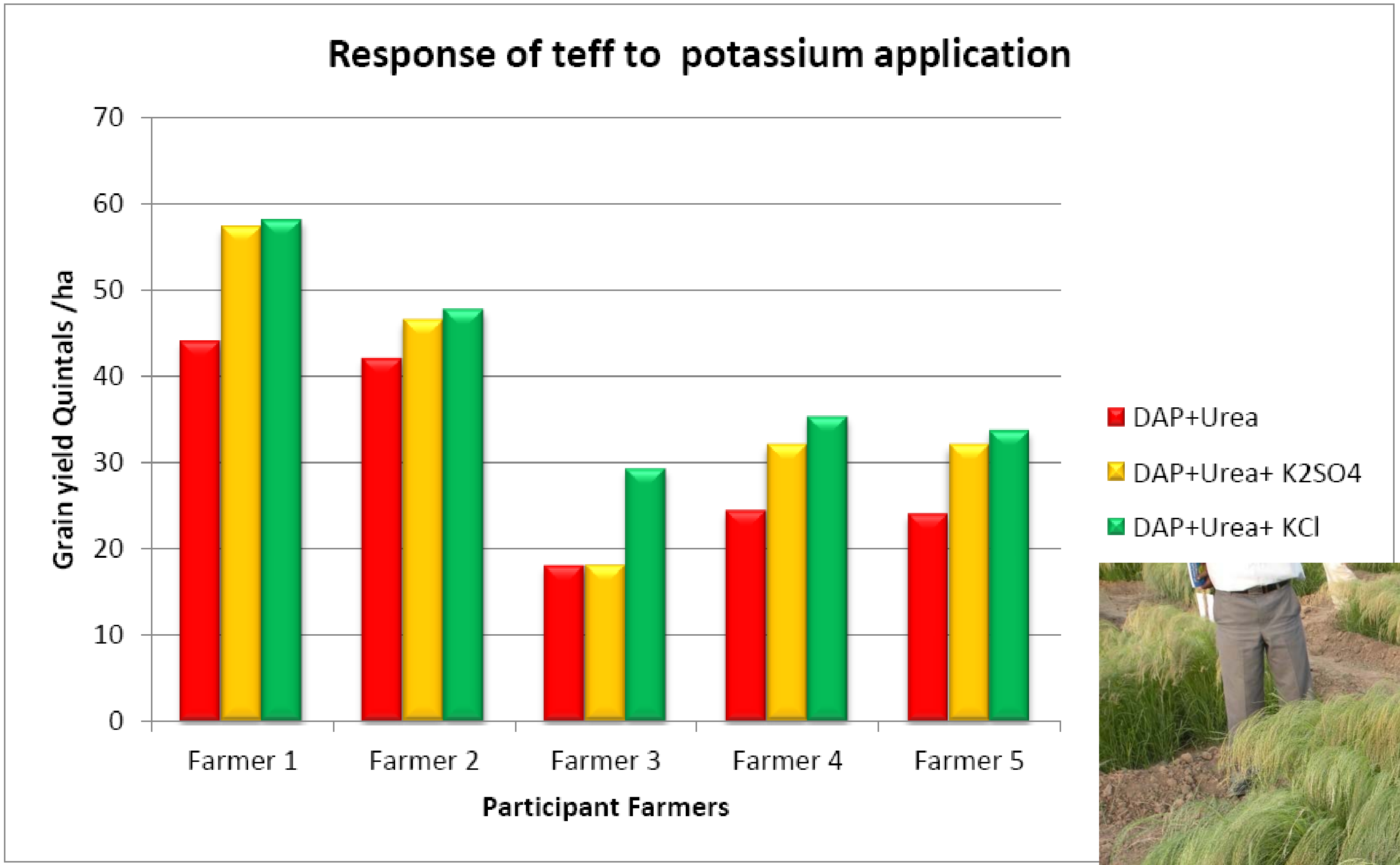
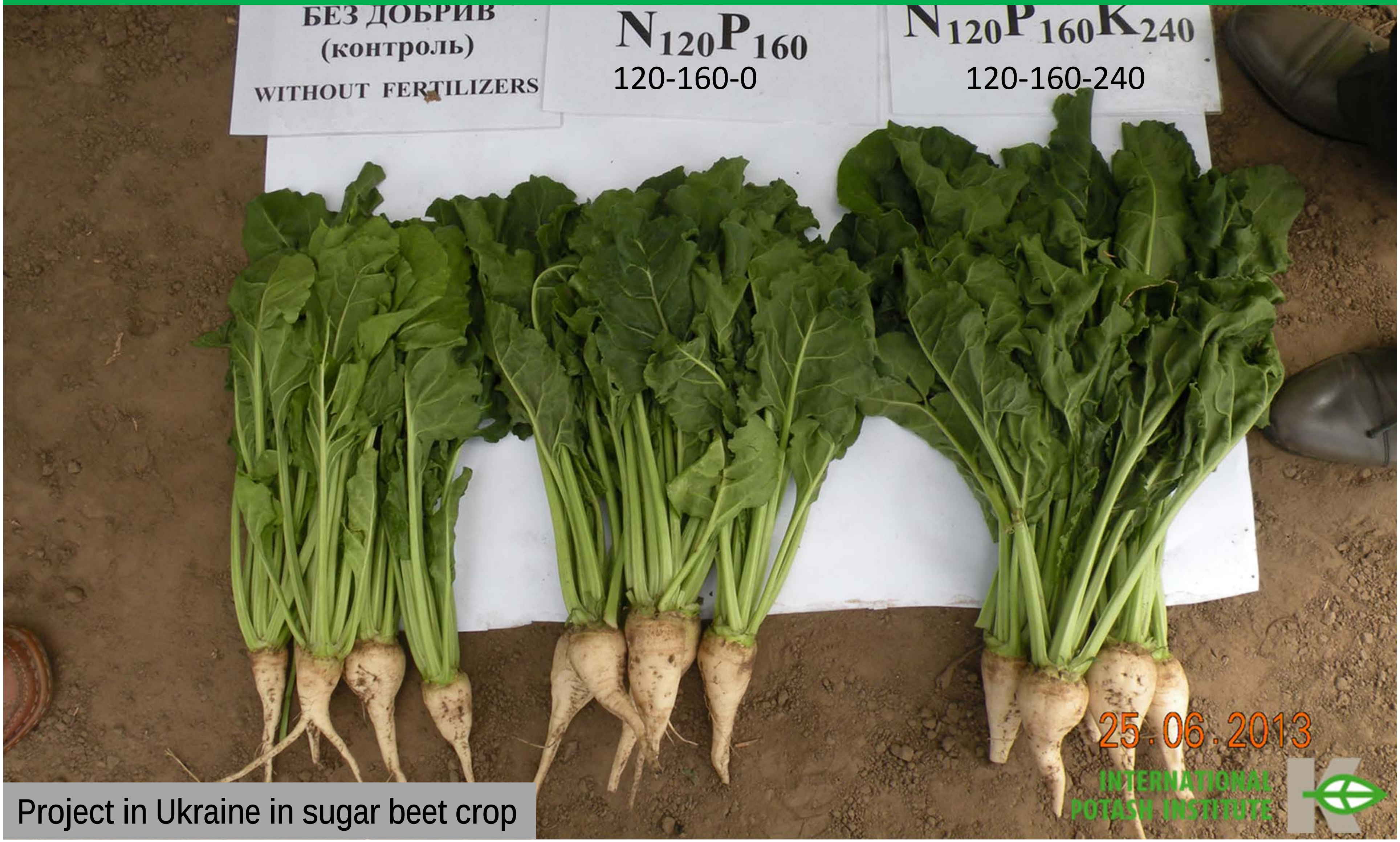
Response of Teff (*Eragrostis tef* Zucc.) to K in Ethiopia



Source: IPI internal report

Introduction; BF for improving NUE; BF for improving agricultural productivity ; BF for maintaining soil health and fertility; BF and fertilizer subsidies; Conclusions



Project in Ukraine in sugar beet crop

Sustainability Yield Index (SYI¶) after 38 years

Centre	Crop	Yield				SYI			
		Control	N	NP	NPK	Control	N	NP	NPK
		------------------*kg ha-1*------------------							
Akola	Sorghum	290	1,975	2,701	3,353	0.01	0.14	0.20	0.27
Jabalpur	Soybean	814	1,021	1,652	1,818	0.13	0.14	0.27	0.32
Junagadh	Groundnut	750	803	838	951	0.25	0.27	0.27	0.32

SYI = $(w' - s_{n-1}) y_m^{-1}$ where w' denotes mean yield, s_{n-1} denotes standard deviation and y_m^{-1} is the maximum yield obtained under a set of management practices across the years.

Source: adapted from Singh and Wanjari, 2012

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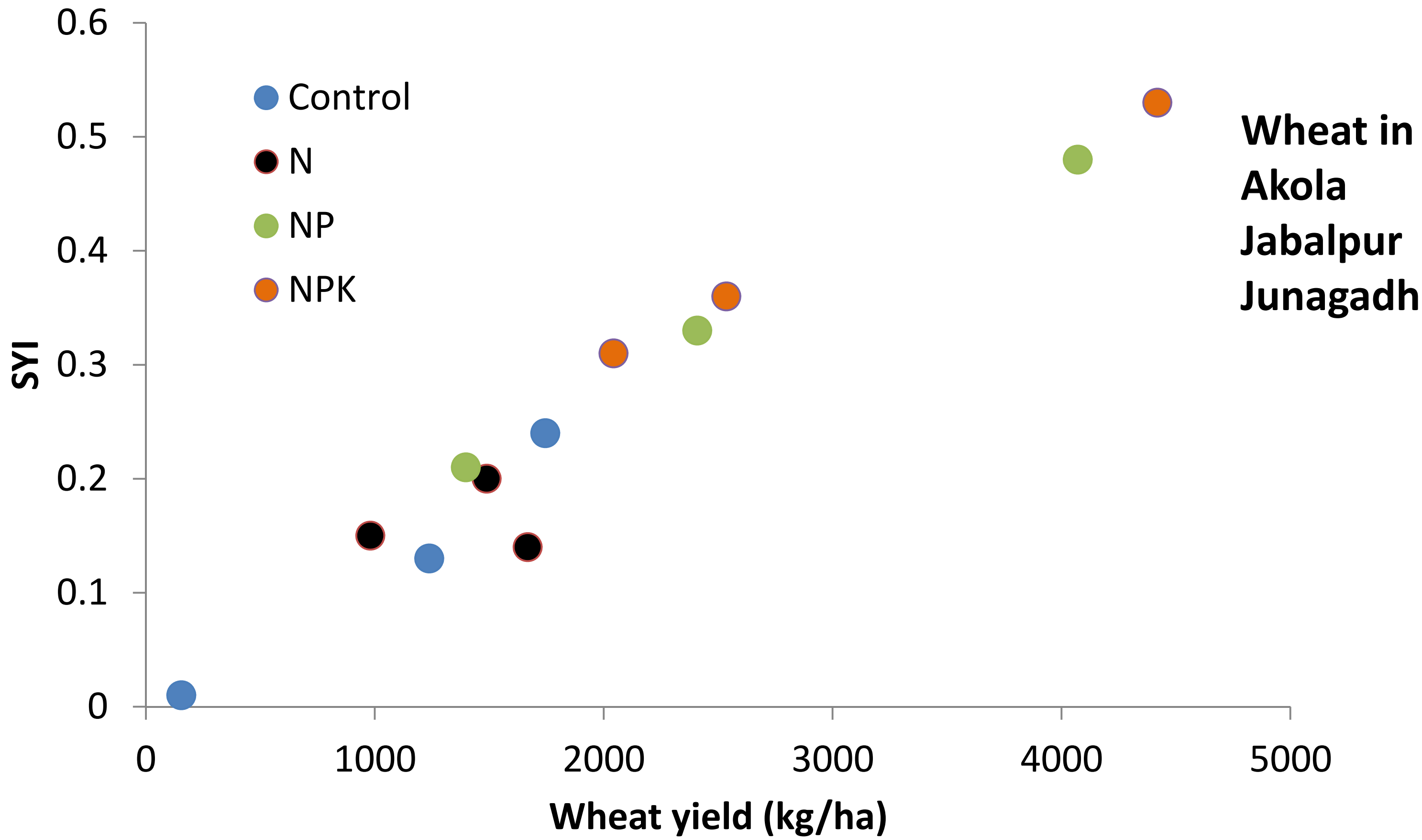

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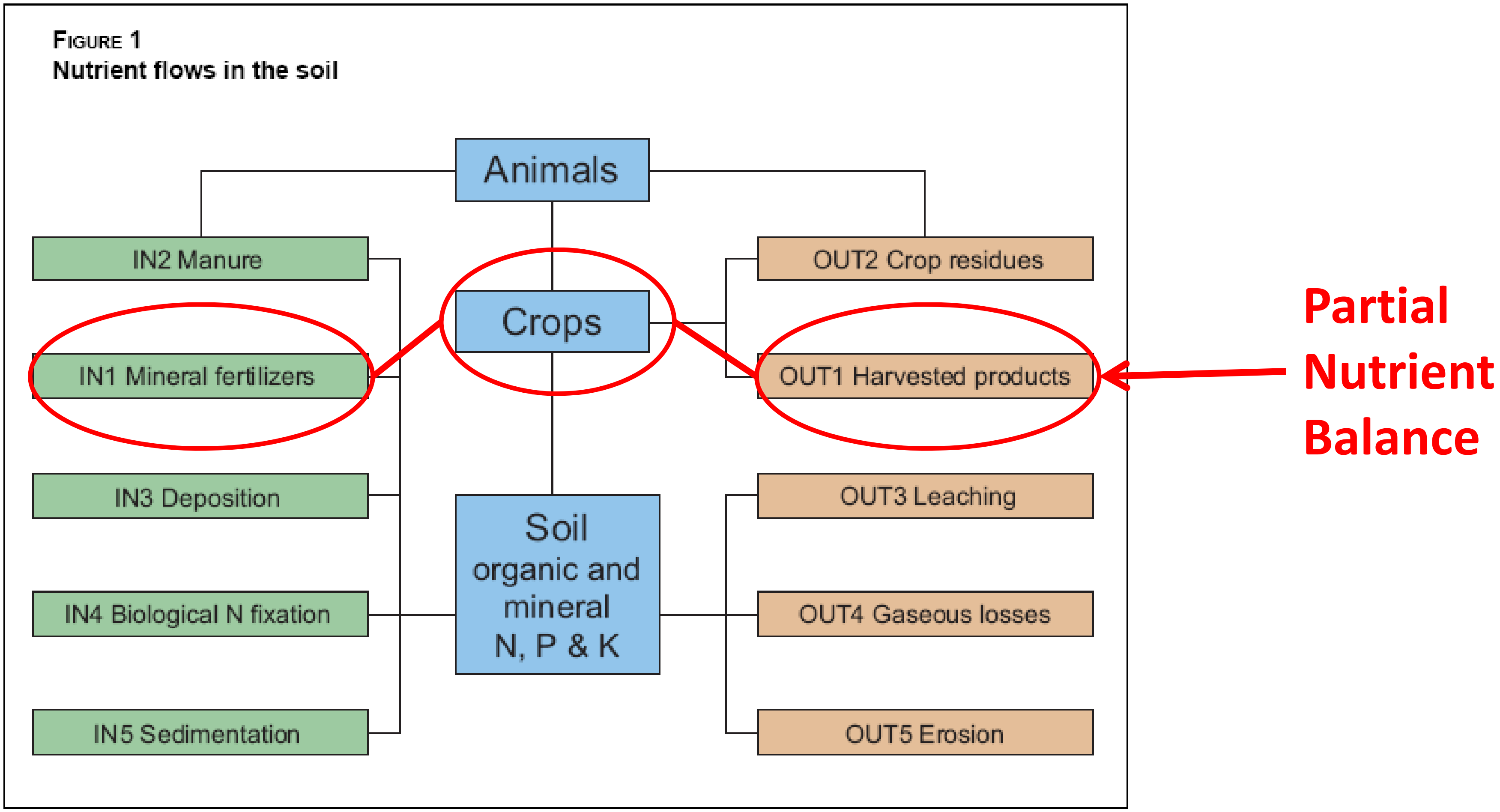
Model of nutrient flows in the soil



Source: Roy et al., 2003. FAO FAO FERTILIZER AND PLANT NUTRITION BULLETIN 14.

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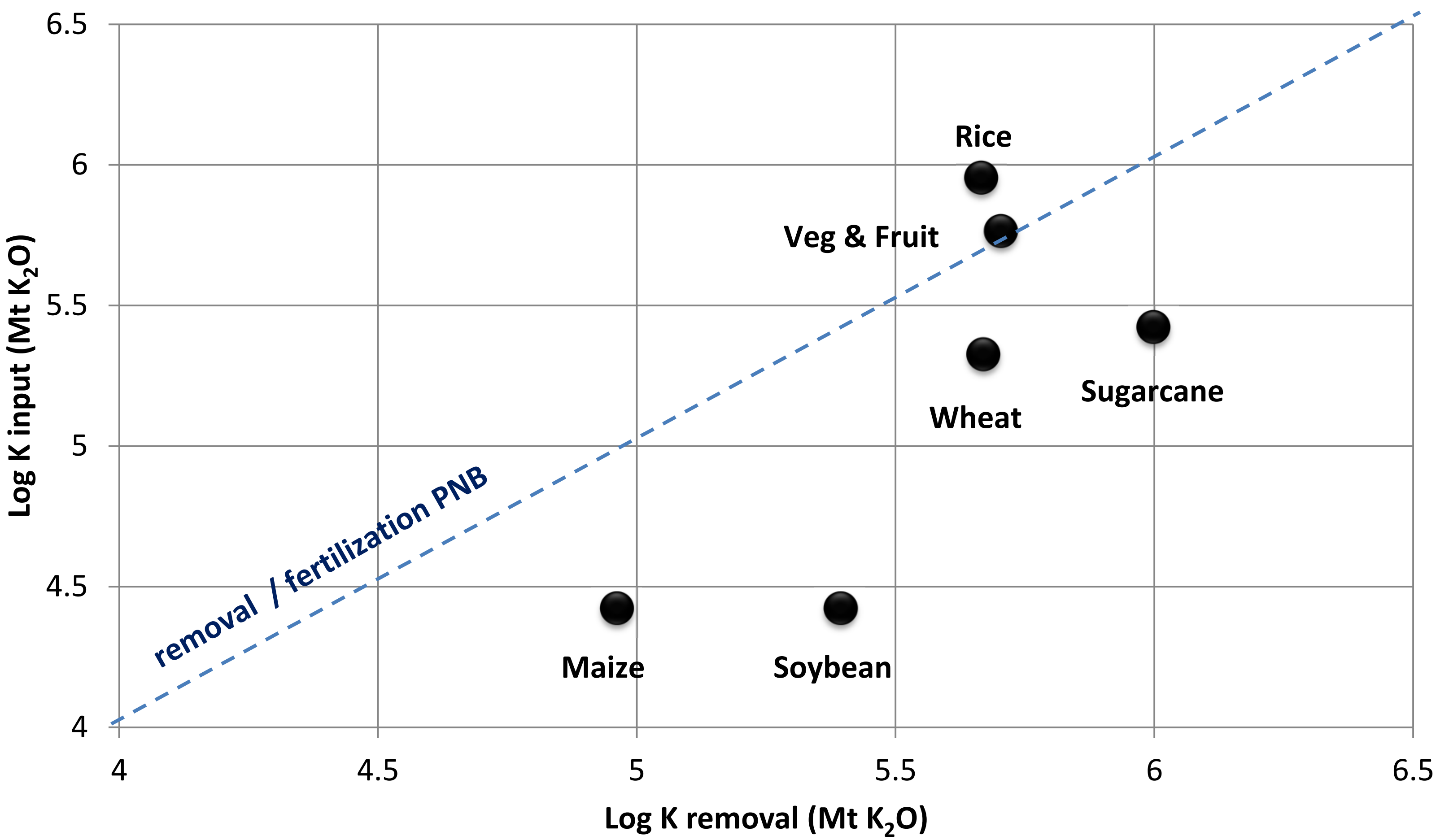
PNB$_K$ in major crops in India

Assuming all crop residues remain in the field



Source: K input from Heffer, 2013; K removal from data at IPI

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K balance estimation in Indian agriculture

Source	Amount added to the fields	Comments
	million mt K_2O	
Potash fertilizers	3.62	
Urban compost	0.07	K content is 1% of 7 million mt compost
Rural compost	1.4	K content is 0.5% of 280 million mt compost
Manure	1.45	K content is 5% of 290 million mt dung
Crop residues	0.979	K content is 1.5% of 65 million mt residues
Irrigation water	1.75	K content is 3.5 ppm; 50% of irrigated land; 50 cm irrigation
Total inputs	9.27	
Total removal	14.50	Includes removal by harvested crop and residues, leaching and erosion
Balance	-5.23	Equivalent to -27 kg K_2O ha^{-1} yr^{-1}

Source: Bansal, 2010

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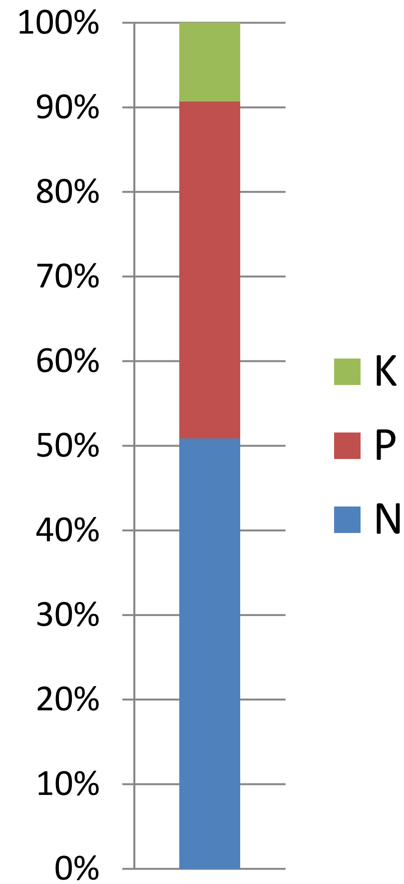
Introduction; BF for improving NUE; BF for improving agricultural productivity ; BF for maintaining soil health and fertility; BF and fertilizer subsidies; Conclusions

Project in India in banana crop

Subsidy on N and K fertilizers during 2011-12 in India and possible saving due to enhanced N use efficiency with K application

Item	Amount	Subsidy allocated
	million t	*Billion INR*
N imported (urea)	5.57	175
N indigenously produced	12.28	202
Total quantity N consumed	17.30	377 (US$7.85 billion¶)
P imported	4.26	
P indigenously produced	4.36	
Total quantity P	8.62	295 billion (US$ 6.15)
K fertilizers	2.57	69 (US$1.44 billion)
Total NPK consumed	27.79	741 (US$ 15.4 billion)



¶US$ 1 = INR 48, exchange rate at the time

Source: FAI Statistics 2011-12

Subsidy on N and K fertilizers during 2011-12 in India and possible saving due to enhanced N use efficiency with K application

K can improve NUE by 7.5%

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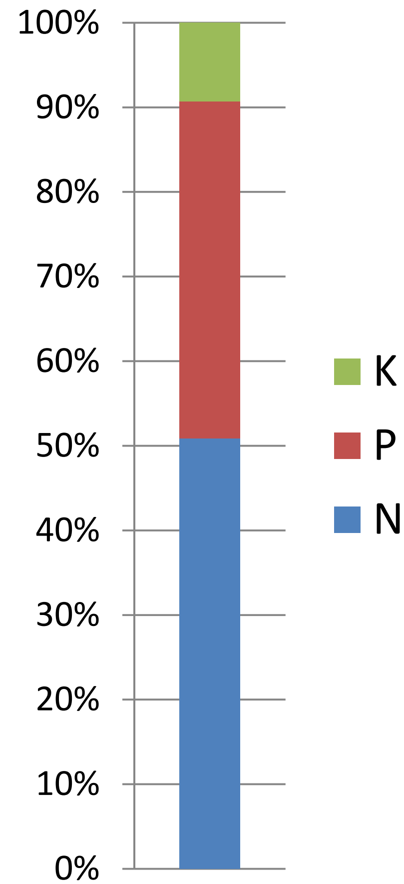
Potential subsidy saving through BF (value of saving 7.5% N)	1.29	28 (US$ 590 million)



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Source: FAI Statistics 2011-12

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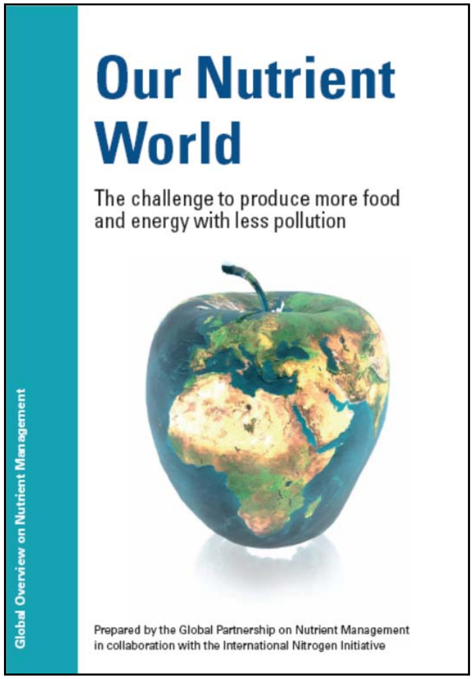
The real value of saving N



Prepared by the Global Partnership on Nutrient Management in collaboration with the International Nitrogen Initiative

http://www.ccst.inpe.br/wp-content/uploads/2013/02/Relat%C3%B3rio_completo_PDF.pdf

"Nutrient Use Efficiency represents a key indicator to assess progress towards better nutrient management.

An aspirational goal for a 20% relative improvement in full-chain NUE by 2020 would lead to an annual saving of around **20 million tonnes of nitrogen** ('20:20 by 2020'), and equate to an initial estimate of improvement in human health, climate and biodiversity worth around **$170 billion per year."**

(mostly related to human health and ecosystem damage)

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Subsidy on N and K fertilizers during 2011-12 in India and possible saving due to enhanced N use efficiency with K application

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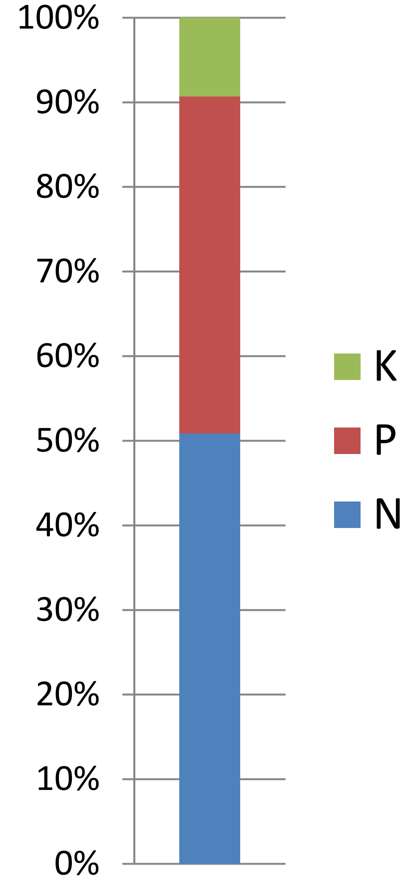
Potential saving when full cost is calculated (7.5% N; Sutton et al., 2013)	1.29	US$ 10.96 billion



¶US$ 1 = INR 48, exchange rate at the time

Source: FAI Statistics 2011-12

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Introduction; BF for improving NUE; BF for improving agricultural productivity ; BF for maintaining soil health and fertility; BF and fertilizer subsidies; Conclusions

Project in Sri Lanka in mango trees

Typical yield increases and increased NUE achieved at IPI on-farm experiments in various crops in Asia and Europe.

Crop	Country	Analyzed parameter	N rates[1]	K rates	Yield increase[2]	Increase in NUE[3]
			………..…….kg/ha	…………………		……%……
Maize	India	grain	125	30-90	200-1,300	18 (6-29)
	China[4]	grain	150-300	75-180	200-1,800	18 (5-29)
	Ukraine	grain	30	30	720	15.5
Rice	Bangladesh	grain	100	33-66	690-900	26.3 (23-30)
Rape seed	China[5]	seeds	180	112.5-187.5	142-704	44 (35-53)
Sugar cane	India[6]	cane	240-340	85-200	2,200[7]	70
Sunflower	Hungary[8]	seeds	80	100-200	200-1,100	(10-30)
	India	seeds	60	30-90	400	18
Wheat	China[9]	grain	180-300	75-150	200-1,370	19 (2-26)
Winter rye	Belarus[10]	grain	90	60-120	230-610	(10-23)

Published also at IFA, Fertilizers & agriculture 9/2007 issue; http://www.fertilizer.org/ifa/publicat/f&a/2007_09pt.asp).

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Balanced fertilization: a modern concept…since 1855

BF becomes an issue when there is –

- Lack of availability of some nutrients
- Lack of farmers' awareness
- Uncompetitive cost of nutrients (which leads to low VCR)
- Scheme that presents external (to plant nutrition) benefits/values (e.g. a subsidy scheme)

BF brings added value to the farmer, country and environment –

- It improves yield, quality and returns to the farmer, and by that presents gains in Food Security
- It improves the sustainability of the agricultural system
- It provides an immediate (management) tool to reduce costly spill over and risks of unused nutrients in the environment

Thank you for your attention