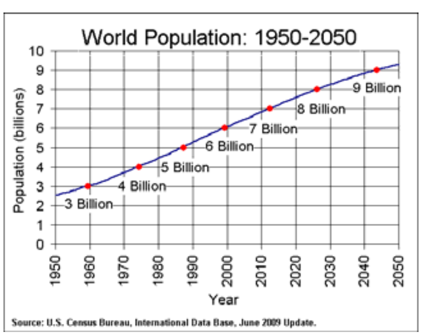
Role of Nutrient Management in the Reduction of Greenhouse Gases

C.S. Snyder and A.M. Johnston

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.

A Growing World Population Requires an Increased Global Food Supply



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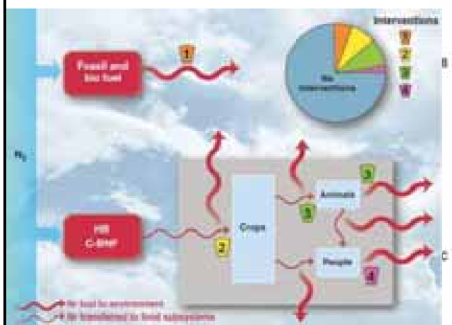
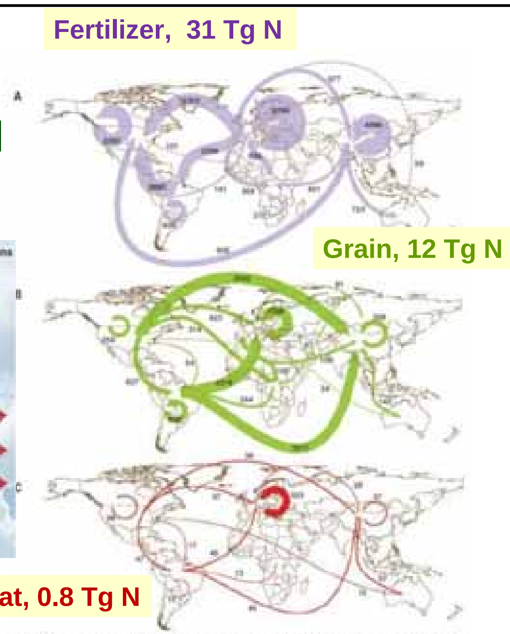
IFPRI 2009 Global Hunger Index – By Severity

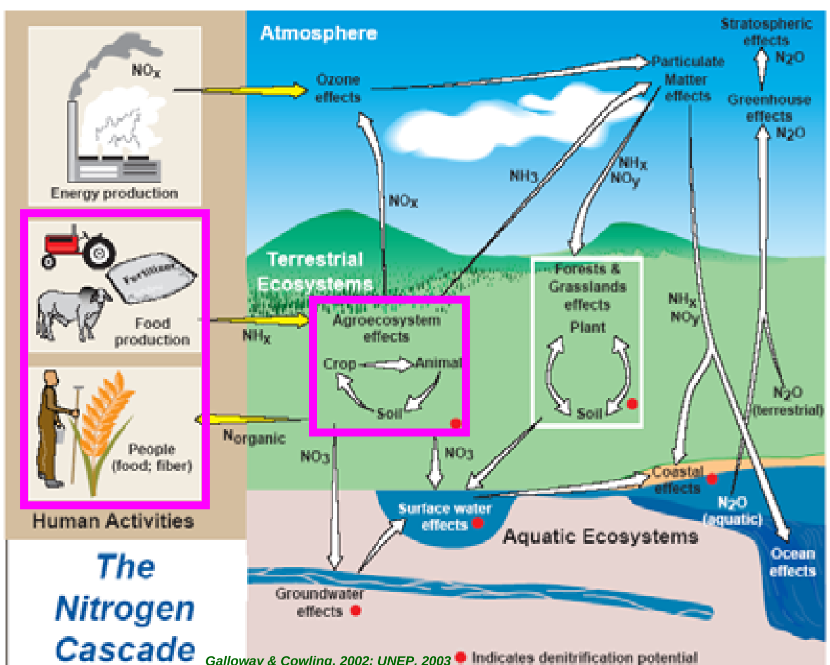
Global N Situation

Increased N Inputs and Global N Flows Pose Environmental Challenges



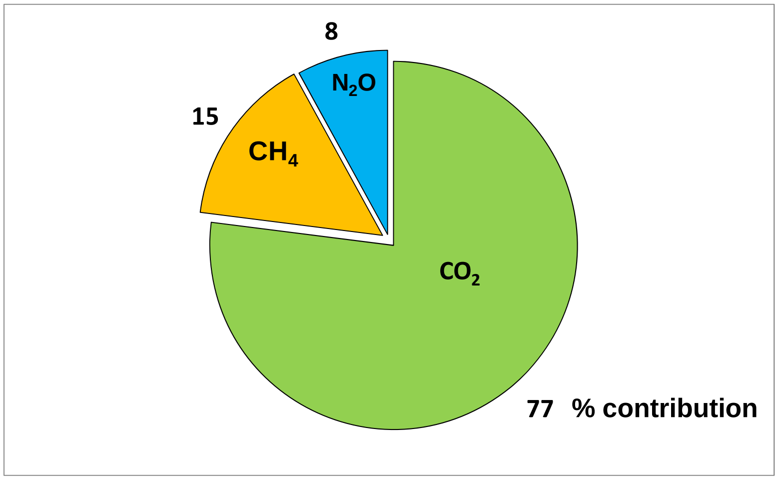


Galloway et al. 2008.
Science 320, 889

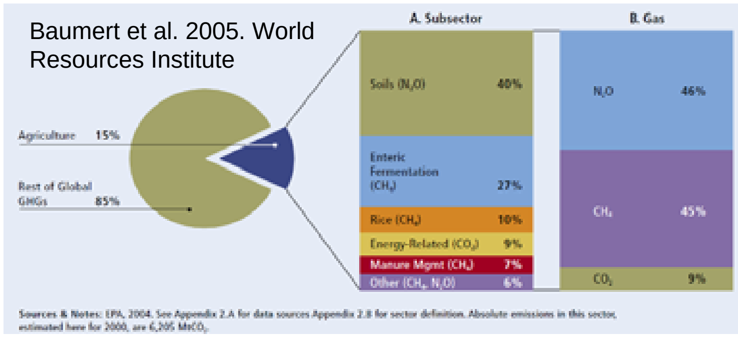


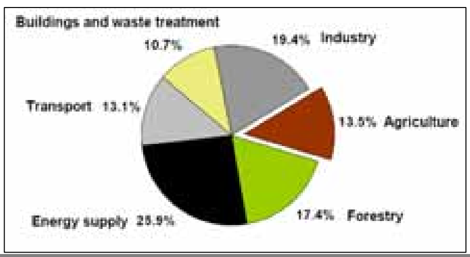
Global Greenhouse Gas Emissions

Global CO_2- equiv. GHG Contributions All Sectors (EPA, 2006)



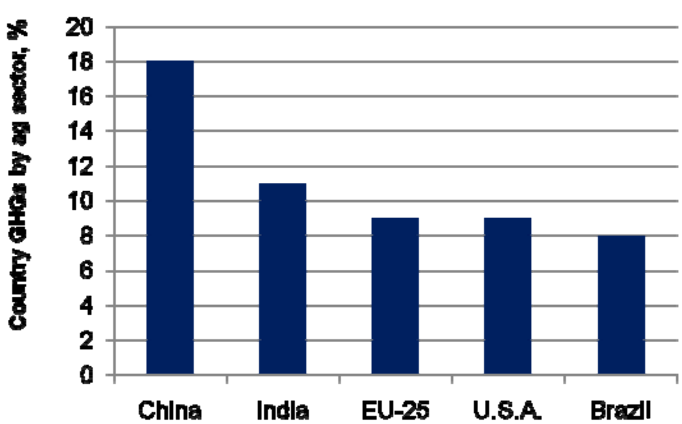
Agriculture: 13 to 15% of Global GHGs





IPCC, 2007 (2004 data). cited by Brentrup and Palliere. 2008. International Fertilizer Society Proceedings 639

Countries with Largest Agricultural Sector GHG Emissions in 2000



Baumert et al., 2005

GHGs and Global Warming Potential (GWP)

- Since CH_4 and N_2O have GWPs so much higher than CO_2 (23 and 296 times more, respectively), agricultural management that reduces the emissions of these two GHGs is likely to have a large mitigation potential.
- Improved cropping system and nutrient management practices are needed to increase crop yield and quality to meet growing global food, fiber, and biofuel demands
- Agriculture and agricultural soil management account for the majority of N_2O emissions
- Nutrient and cropping system management should also consider opportunities for reduced N_2O emissions; especially per unit of food, fiber, or biofuel produced

Estimates of N_2O Emissions from Cropland in 1995 (adapted from IFA/FAO, 2001)

Region	Area (million ha)	Fertilizer N Applied	Animal Manure N Applied	N_2O-N emitted		
				total	Fertilizer-induced [1]	
		million tonnes				% of total
Canada	46	1.58	0.21	0.067	0.016	24
U.S.	190	11.15	1.58	0.316	0.112	35
World	**1,436**	**73.48**	**20.66**	**3.150**	**0.735**	**23**

[1] Estimated using IPCC emission factor of 1%

In 2007, fertilizer N use and application accounted for the following portion of direct ag soil management related N_2O emissions: Canada 47%, U.S. 28%, EU-15 27%.

Crutzen et al. (2008) suggest terrestrial and aquatic N_2O-N emissions may range from 2 to 5% of "new N" (Atmos. Chem. Phys., 8, 389–395)

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Global Non-CO_2 Emissions by Sector

1990-2020 (EPA 2006)

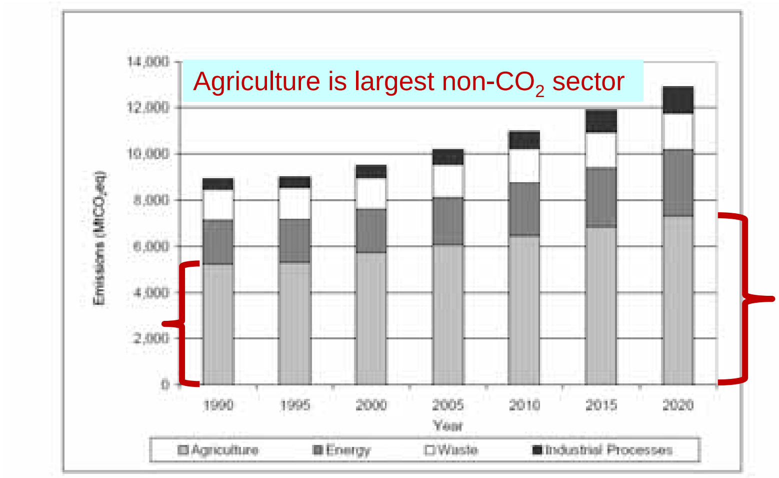
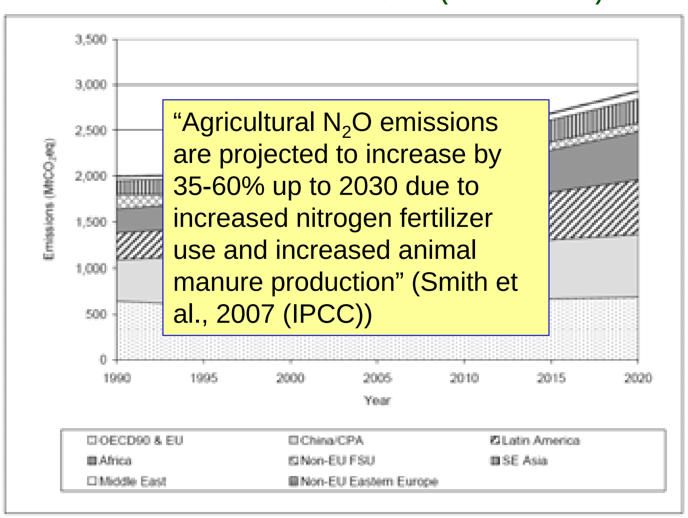


Exhibit 2-4. Global Non-CO_2 Emissions by Sector and Year ($MtCO_2eq$)

Global N_2O Emissions from Agricultural Soils

1990-2020 (EPA 2006)



"Agricultural N_2O emissions are projected to increase by 35-60% up to 2030 due to increased nitrogen fertilizer use and increased animal manure production" (Smith et al., 2007 (IPCC))

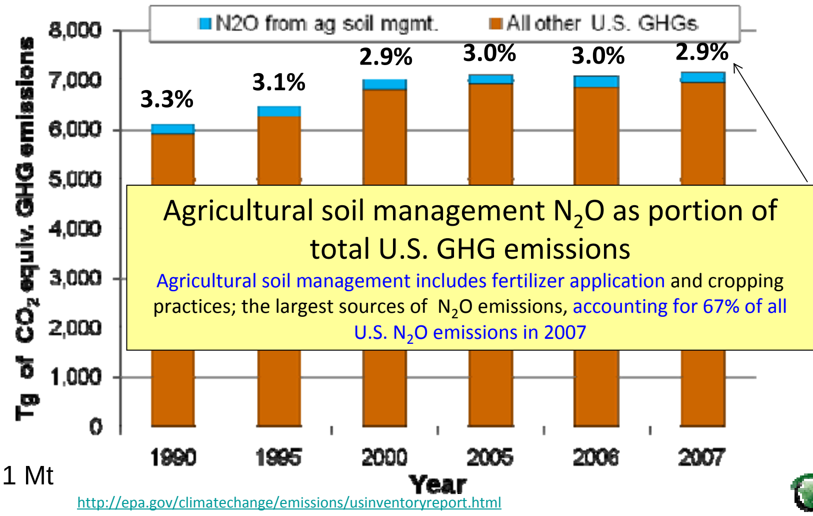
The IPCC estimates 10% of applied fertilizer N volatilizes to NH_3 and NOx, and 1% of total volatilized N is emitted as N_2O (IPCC, 1997).

EPA uses the IPCC estimate that 30% of total N applied is lost to leaching and surface runoff, and 2.5 % of this lost N is emitted as N_2O(IPCC, 1997).

OECD- Organization for Economic Cooperation and Development (which includes the U.S. and Canada), EU- European Union, FSU- Former Soviet Union

U.S. GHG Emissions & N_2O from Ag Soil Management

(U.S. EPA final April 15, 2009 - GHG inventory, 1990-2007)



Agricultural soil management N_2O as portion of total U.S. GHG emissions

Agricultural soil management includes fertilizer application and cropping practices; the largest sources of N_2O emissions, accounting for 67% of all U.S. N_2O emissions in 2007

1 Tg = 1 Mt

http://epa.gov/climatechange/emissions/usinventoryreport.html

Fertilizer N Consumption

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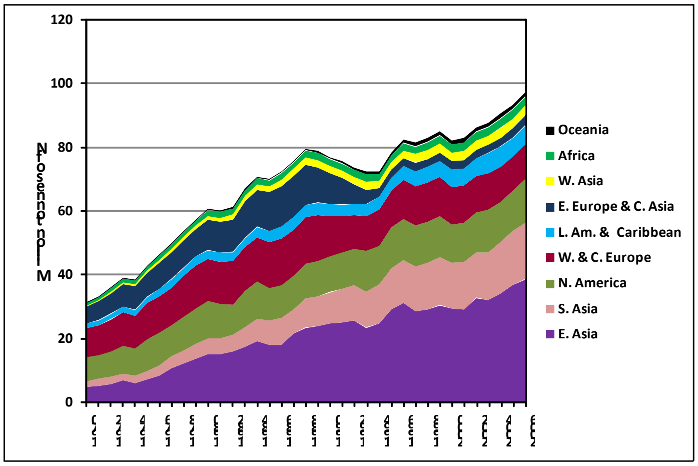
Global Fertilizer N Consumption
(IFA Statistics, 2007)



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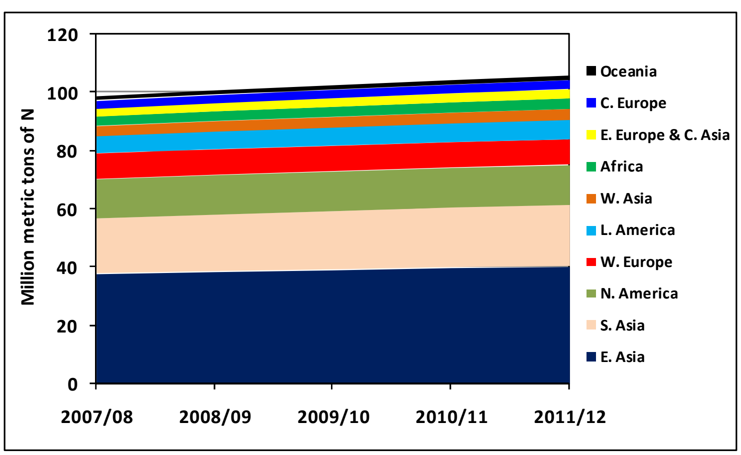
Projected World Fertilizer N Consumption
(FAO, 2009)



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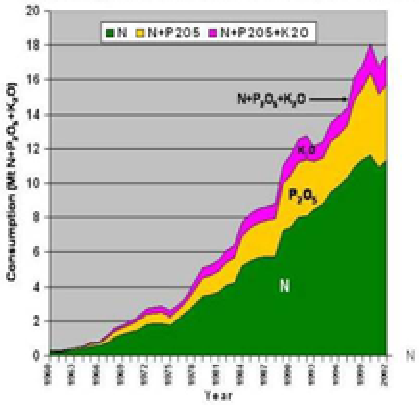
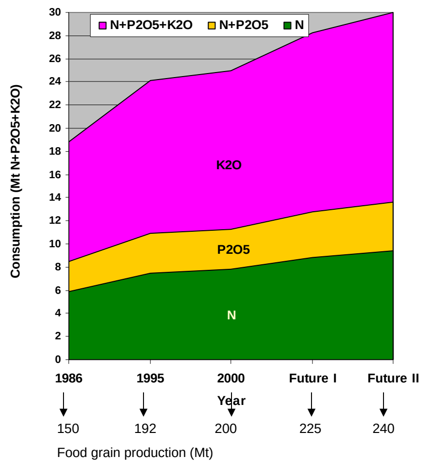
Overall growth of fertilizer consumption in India



Overall growth of nutrient removal in India



What can Agriculture do to minimize GHG emissions?

Can Soil and Fertilizer Management Help Reduce GHG Emissions ?

- Wider implementation of fertilizer BMPs: right source, at the right rate, with right timing, and right placement ?
  - Requires
    - more research to evaluate optimum "Rs"
    - more education and technology transfer
    - greater nutrient management skills by crop advisers and farmers
- Conservation tillage practices ?
- Optimum irrigation practices, and soil drainage management?
- Improved genetics and seed technology?

GHG Mitigation Potential by Agriculture

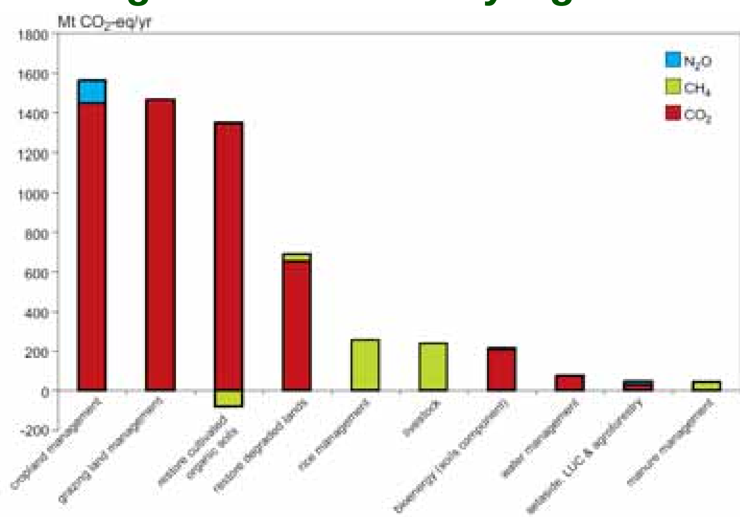


Figure 8.4: *Global technical mitigation potential by 2030 of each agricultural management practice showing the impacts of each practice on each GHG.*

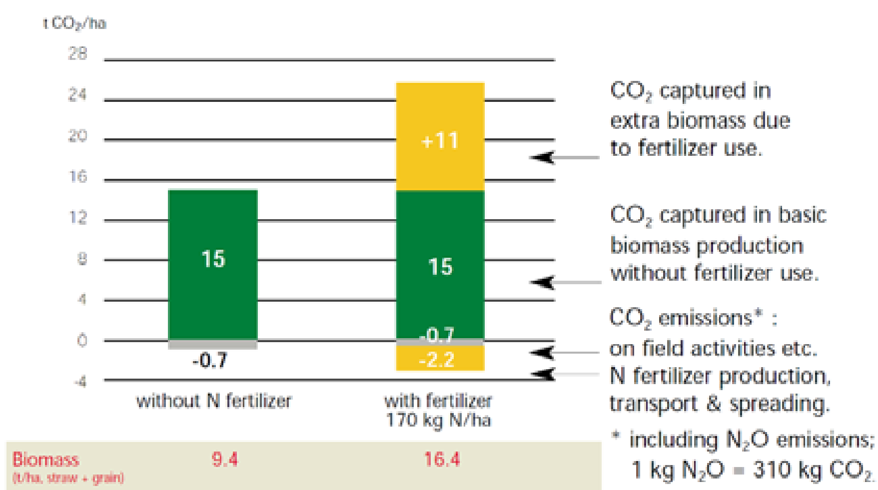
Smith et al. 2007. Agriculture. In Climate Change 2007: Mitigation. IPCC

Cropland Management Measures to Help Mitigate GHGs

	Mitigative effects[a]			Net mitigation[b] (confidence)	
Examples	CO_2	CH_4	N_2O	Agreement	Evidence
Agronomy	+		+/-	***	**
Nutrient management	+		+	***	**
Tillage/residue management	+		+/-	**	**
Water management (irrigation, drainage)	+/-		+	*	*
Rice management	+/-	+	+/-	**	**
Agro-forestry	+		+/-	***	*
Set-aside, land-use change	+	+	+	***	***

Smith et al. 2007. Agriculture. In Climate Change 2007: Mitigation. IPCC

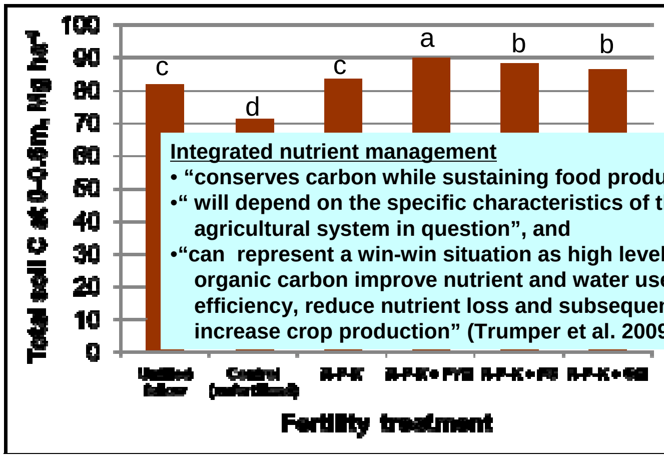
CO_2 fixed on 1 ha wheat



Source : Data taken from Küsters and Lammel, 1999.

Cited by EFMA, 2008. Harvesting Energy with Fertilizers

Fertilization and Organic Matter Effects on Total Soil Carbon after 19 Years in Rice-Wheat Rotation India



Integrated nutrient management

- "conserves carbon while sustaining food production",
- " will depend on the specific characteristics of the agricultural system in question", and
- "can represent a win-win situation as high levels of soil organic carbon improve nutrient and water use efficiency, reduce nutrient loss and subsequently increase crop production" (Trumper et al. 2009)

•FYM= farm yard manure (7.5 Mg ha^{-1}), PS=paddy straw (10 Mg ha^{-1}), GM=green manure (8 Mg ha^{-1}), all on wet-weight basis

•120–60–60 kg ha^{-1} (N–P_2O5–K_2O) for rice and 100–60–40 kg ha^{-1}(N–P_2O5–K_2O) for wheat

Majumder et al. 2008. Soil Sci. Soc. Am. J. 72:775-785

P and K Fertility Condition of Sampled Soils in the U.S., China, and India and Median Soil Test Levels in North America (adapted from Fixen et al. 2005)

	Plant available soil P			Plant available soil K		
Level	U.S.	China	India	U.S.	China	India
	% of soil samples			% of soil samples		
Low	24	46	46	14	58	13
Medium	23	25	49	29	18	53
High	53	29	5	57	23	34

North America [a]	Median soil test P (mg kg^{-1})		Median soil test K (mg kg^{-1})
2001	**27**		**154**
2005	**31**		**154**
% of soil samples with < 25 mg kg^{-1} soil test P in 2005	**42**	% of soil samples with < 160 mg kg^{-1} soil test K in 2005	5

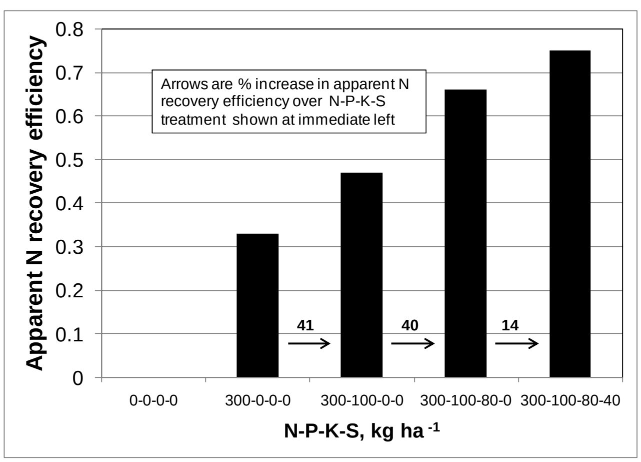
Inadequate, or below optimum, P and K fertility limits crop production in much of the world and may also limit crop N uptake efficiency

Crop response to applied potash in Haryana

Crop	Soil Type/Soil K Fertility Status	Yield without K application (kg/ha)	Increase (kg/ha) in yield by Potash application at indicated rate (kg K2O/ ha)	Net Return Rs./Re invested on potash
Pearlmillet	Low K	1730	570 (K120)	3.09
	Medium K	1819	710 (K120)	3.86
	High K	1920	570 (K120)	3.09
Rice	Silty loam	7000	620 (K80)	5.53
	Loamy sand	4460	310 (K80)	2.76
Wheat	Silty loam	4100	640 (K80)	6.68
	Loamy sand	3250	330 (K80)	3.44
Mustard	loam	1690	360 (K80)	8.06
Cotton	Loamy sand	1320	110 (K30)	8.26
Sugarcane (t/ha)	Planted	49.0	4.60 (K50)	8.59
	Planted	53.0	4.30 (K50)	8.03
	Ratoon	52.9	4.50 (K75)	5.61

Compiled from various sources

Balanced Fertilization Effects on Apparent N Recovery by Maize (assuming 25 kg of N uptake per tonne of grain (Gordon, 2005. Kansas, U.S.))



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How to rank cropping systems for GHG emissions – crop intensification

Table 1. Comparison of selected agricultural cropping systems for net GWP.

Cropping system			GWP in CO_2 equivalents, kg/ha/yr					N_2O GWP/ Food Yield	Net GWP/ Food Yield
Location	Rotation[4]	Tillage	Soil C[5]	N fert. production[6]	fuel	N_2O	Net GWP		
MI[2]	C-S-W	CT	0	270	160	520	1,140	43	95
MI[2]	C-S-W	NT	-1,100	270	120	560	140	43	11
MI[2]	C-S-W low input with legume	CT	-400	90	200	600	630	50	53
MI[2]	C-S-W organic with legume	CT	-290	0	190	560	410	62	46
NE[3]	CC BMP	CT	-1,613	807	1,503	1173	1,980	24	41
NE[3]	CC intensive	CT	-2,273	1,210	1,833	2090	3,080	41	60
NE[3]	C-S BMP	CT	1,100	293	1,283	917	3,740	26	107
NE[3]	C-S intensive	CT	-73	660	1,613	1247	3,740	34	101
MI[2]	Cropland conversion to poplar forest	NT	-1,170	50	20	100	-1,050		

Mean crop yields, t/ha; Food yield[1]

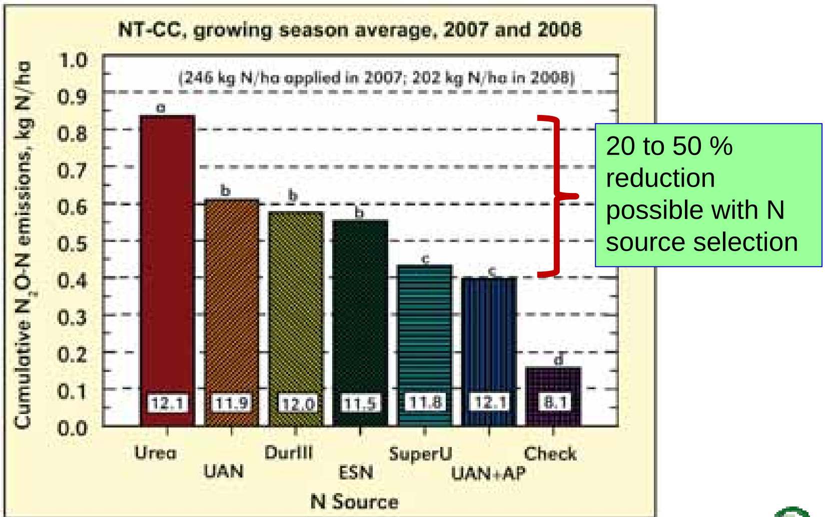
[1] Food energy calculated from crop yields and USDA national nutrient database /.nal.usda.gov/NDL/index.html
[2] Rainfed cropping system (Robertson et al., 2000)
[3] Irrigated cropping system (Adviento-Borbe et al., 2007)
[4] C-S-W = corn – soybean – wheat; CC = continuous corn
[5] Estimates of net soil C storage are based on changes in soil C measured to a depth of 7.5 cm in the MI study and 30 cm in the NE study. Shallower sampling depths tend to upwardly bias the C sequestration estimates in no-till systems.
[6] GWP for manufacture and transport of fertilizer N was assumed to be 4.51 and 4.05 kg CO_2/kg N in the MI and NE studies, respectively.

What about new fertilizer technology?

Summary of N_2O Emissions Induced by Common Fertilizer N Sources (based on Bouwman et al. (2002a, 2002b) and Stehfest and Bouwman (2006))

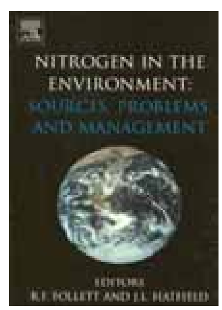
	Mean fertilizer induced emission [1]		Balanced median emission [2]	
N source	**n**	**N_2O as % of applied N**	**n**	**kg N_2O-N ha^{-1}**
calcium ammonium nitrate	61	0.7	73	1.56a[3]
ammonium nitrate	59	0.8	131	1.12a
anhydrous ammonia	38	0.9	38	1.04a
nitrate-based fertilizers [4]	53	0.9	53	0.80b
urea ammonium nitrate (solutions)	37	1.0	40	0.78b
urea	98	1.1	131	0.96b
ammonium-based fertilizers [5]	59	1.2	74	0.82b
IPCC default		***1***		

Nitrogen Rate and Source Effects on N_2O Emissions in No-till Continuous Corn



Halvorson et al. 2009. Better Crops 93(1):16-18

Kitchen and Goulding (2001) *in* Nitrogen in the Environment: Sources, Problems and Management



- " nitrogen use efficiency …rarely exceeds 70% ……. often ranges from 30-60%"
- "conversion of N inputs to products for arable crops can be 60-70% or even more"

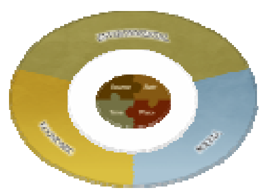
IPNI programs to address GHG emissions

4R Nutrient Stewardship Promotion

Know your fertilizer rights

By Tom Bruulsema, International Plant Nutrition Institute, Guelph, ON, Canada; ***Jerry Lemunyon***, USDA-NRCS, Fort Worth, TX; and ***Bill Herz***, The Fertilizer Institute, Washington, DC

Crops & Soils 42(2): Mar-Apr 2009



The four fertilizer rights: Selecting the right source

By Robert Mikkelsen, International Plant Nutrition Institute, Merced, CA; ***Greg Schwab***, University of Kentucky, Lexington; and ***Gyles Randall***, University of Minnesota, Waseca

Crops & Soils 42(3): May-Jun 2009

Selecting the right fertilizer rate: A component of 4R nutrient stewardship

By S.B. Phillips, International Plant Nutrition Institute, Owens Cross Roads, AL; ***J.J. Camberato***, Purdue University, West Lafayette, IN; and ***D. Leikam***, Fluid Fertilizer Foundation, Manhattan, KS

Crops & Soils 42(4): Jul-Aug 2009

The four fertilizer rights: timing

By W.M. Stewart, International Plant Nutrition Institute, Norcross, GA; ***J.E. Sawyer***, Iowa State University, Ames, IA; and ***M.M. Alley***, Virginia Tech, Blacksburg, VA

Crops & Soils 42(5): Sep-Oct 2009

The four fertilizer rights: placement

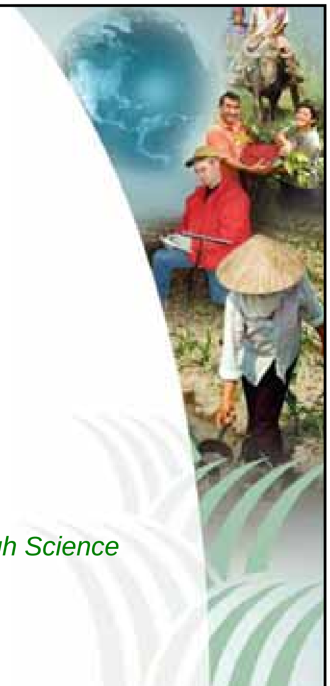
Scott Murrell (IPNI), Tony Vyn (Purdue), Guy Lafond (AAFC), Dave Finlayson (CFI),

Crops & Soils 42(6): Nov-Dec 2009 (in process)

Intensified Fertilizer BMP Education & Outreach

Agricultural policy has to consider food security in India – no other option

Thank You



Better Crops, Better Environment … through Science

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