Development of FBMPs: Global Experience

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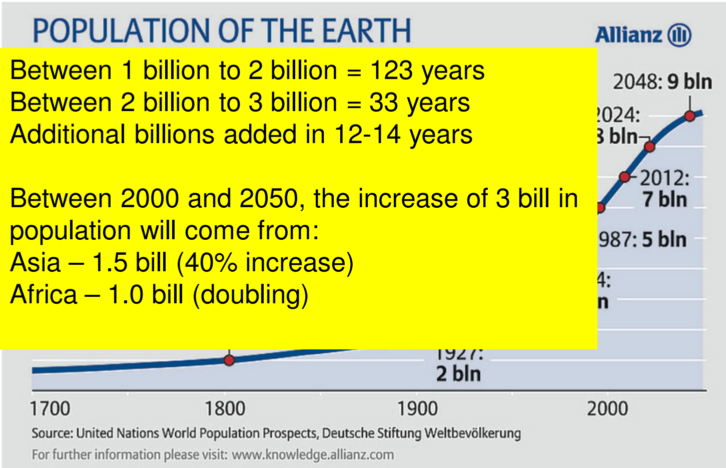
Context Setting

Global Population Trends and Predictions



Between 1 billion to 2 billion = 123 years
Between 2 billion to 3 billion = 33 years
Additional billions added in 12-14 years

Between 2000 and 2050, the increase of 3 bill in population will come from:
Asia – 1.5 bill (40% increase)
Africa – 1.0 bill (doubling)

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Secured Access to Food in an Ecologically Sustainable Manner is a Continuing Challenge

- "The seriousness or magnitude of the world food problem should not be underestimated. Recent success in expanding wheat, rice and maize production in Asian countries offers the possibility of buying 20-30 years of time." **Dr. Norman Borlaugh*, 1969***
- "The ***next few decades*** present a greater challenge to the world food systems than they may ever face again. The effort needed to increase production in pace with an unprecedented increase in demand, while retaining the essential ecological integrity of food systems, is colossal both in its magnitude and complexity. Given the obstacles to be overcome, most of them man-made, it can fail more easily than it can succeed."……**Advisory Panel on Food Security, Agriculture, Forestry, and Environment. *1987***

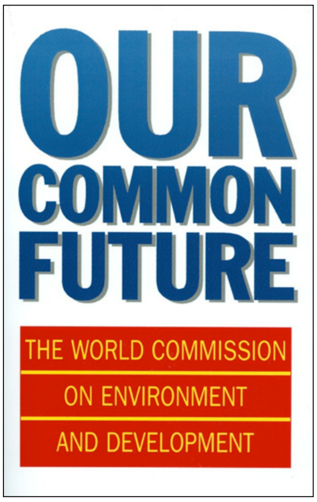
Brundtland's report

- *Our Common Future* (1987) addressed concerns "about the accelerating deterioration of the **human environment** and **natural resources** and the consequences

Definition

Accommodating the growing demand for production without compromising the natural resources upon which agriculture depends.

The concept of sustainability is multi-dimensional … applies to <u>social</u>, <u>economic</u>, and <u>environmental</u> dimensions simultaneously.



Source: Advisory Panel on Food Security, Agriculture, Forestry, and Environment World Commission on Environment and Development. 1987.

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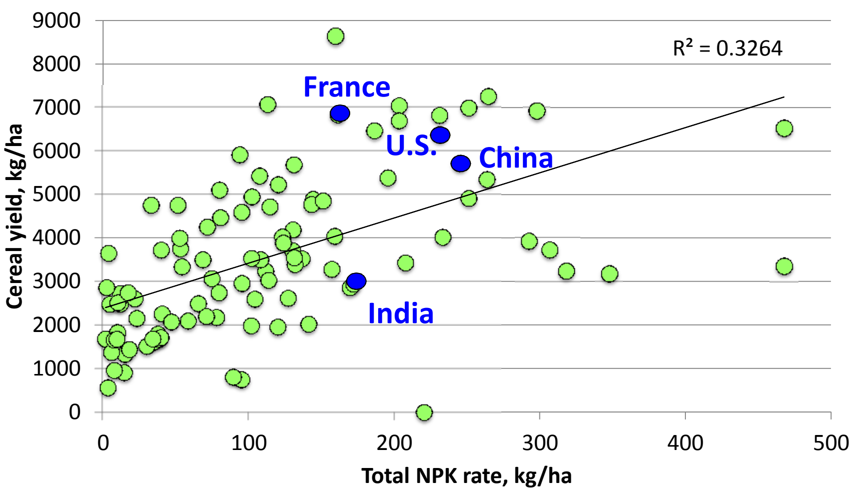
Relationship between Fertilizer use and cereal productivity – Global scenario



Source: FAOStat and IFA's "Assessment of Fertilizer Use by Crop at the Global Level 2010-2011" Report

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Cropland Management Measures to Help Mitigate GHGs

- Cropland management, which includes nutrient management, has a GHG mitigation potential approaching 1,600 MT CO_2-equivalent/yr

	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

Soil Quality Change (as % over Fallow)
under Different Management Practices & Cropping Systems

Treatment	Rice-Wheat	Rice-Lentil	Jute-Rice-Wheat
Control	-56.0	-8.0	-49.0
N-only	-	-11.7	-35.0
NPK-only	-10.8	-9.7	19.0
NPK+FYM	18.7	8.6	45.1

Mandal, B. (2005) Assessment and improvement of soil quality and resilience for rainfed production system. Completion Report, National Agricultural Technology Project. Bidhan Chandra Krishi Viswavidyalaya, Indian Council of Agricultural Research, New Delhi, pp. 30.

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Fertilizer Best Management Practices (FBMP)

What is FBMP

Fertilizer best management practices *(FBMPs) are agricultural production techniques and practices developed through scientific researches and verified in farmers fields to maximize economic, social and environmental benefits*

FBMP is aimed at managing the flow of nutrients in the course of producing affordable and healthy food in a sustainable manner that protect the environment and conserve natural resources at the same time profitable to producers.

With FBMPs, farmers implement, under specific site, crop and soil conditions, the concepts and elements of balanced fertilization, site-specific nutrient management (SSNM), integrated plant nutrient management (IPNM),among others.

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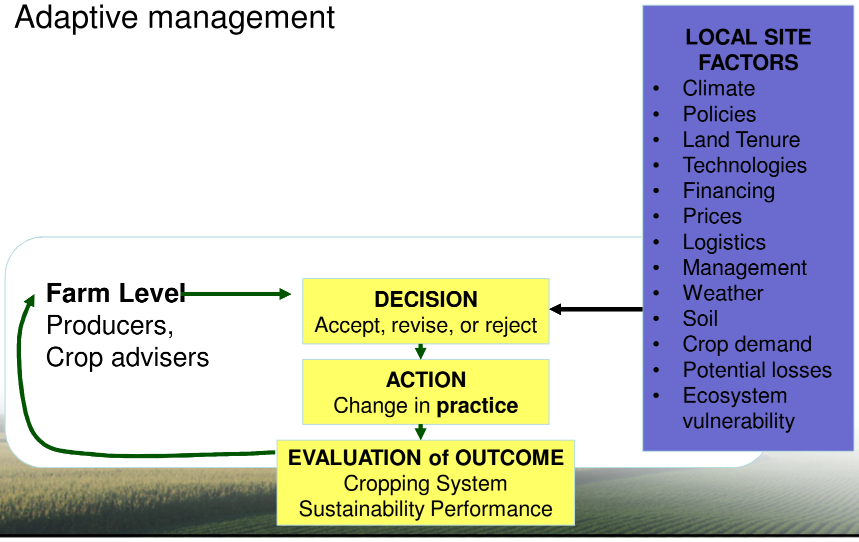
BMP adoption and evaluation – farm level

- Adaptive management



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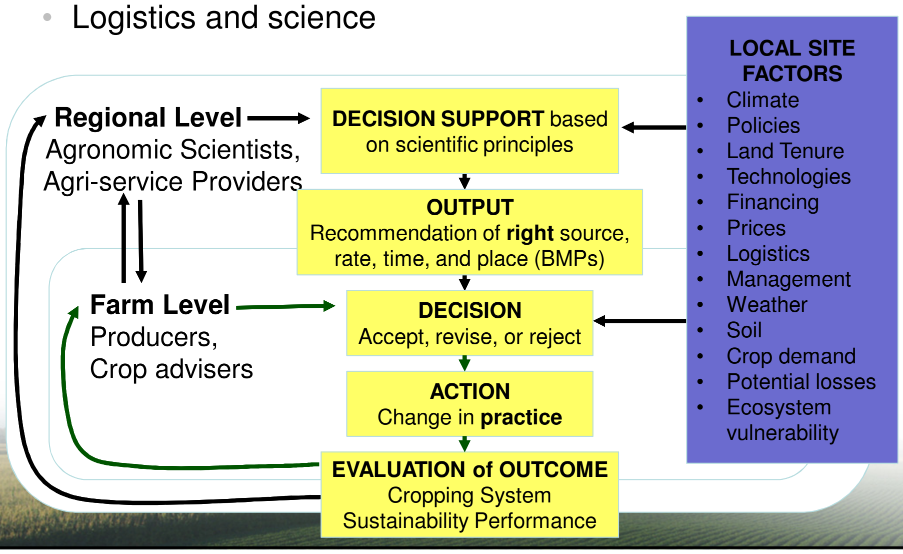
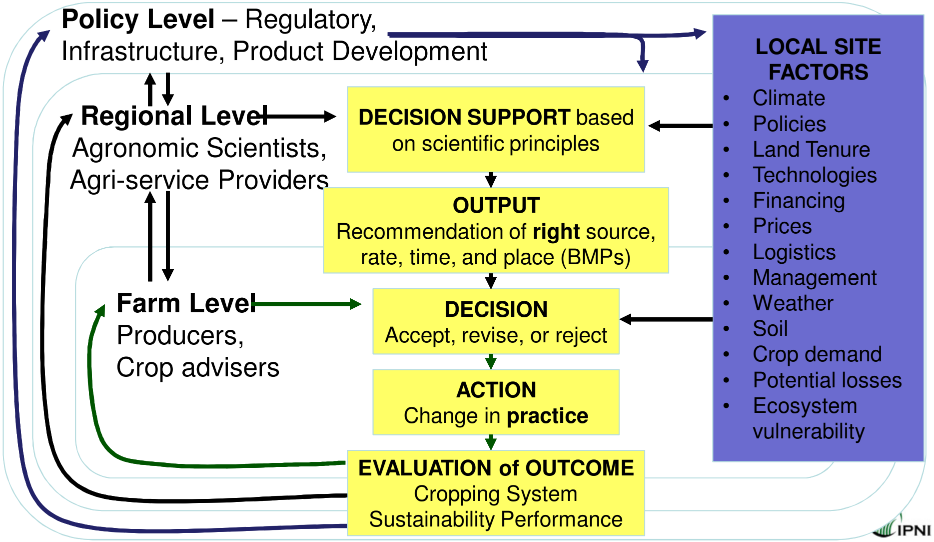
BMP adoption and evaluation – regional level

- Logistics and science



BMP adoption and evaluation – policy level

- Infrastructure and incentive



FBMP Focus

- USDA-ARS – Best management practices include soil and water conservation practices, other management techniques, and social actions that are developed for a particular region as effective and practical tools for **environmental protection**
- FDCO and FAO – A set of agronomic and other soil-crop management practices, which lead to the best possible use of applied inputs for crop production, resulting in **minimal adverse effect on the environment**. A pre-requisite for efficient and environment-friendly fertilizer use. Important for all soils, crops and fertilizers
- BMP Challenge – BMPs are designed to **save you money** by using your field history and soil test results to cut fertilizer costs and maintain yield
- North Carolina State University – Farming methods that assure **optimum plant growth** and **minimize adverse environmental effects**
- PPI – Practices which have been proven in research and tested through farmer implementation to give **optimum production potential, input efficiency and environmental protection**.

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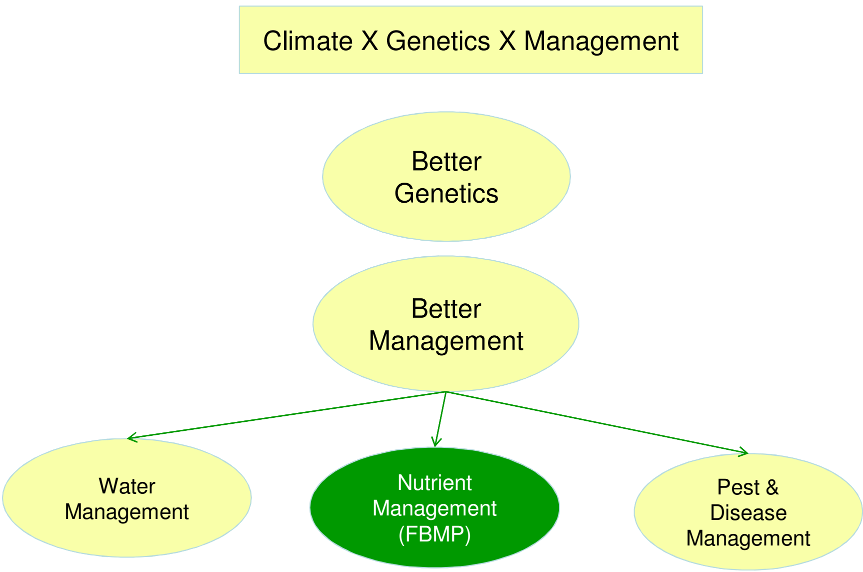
Why do we need FBMP

Improving Crop Productivity in a Sustainable Manner



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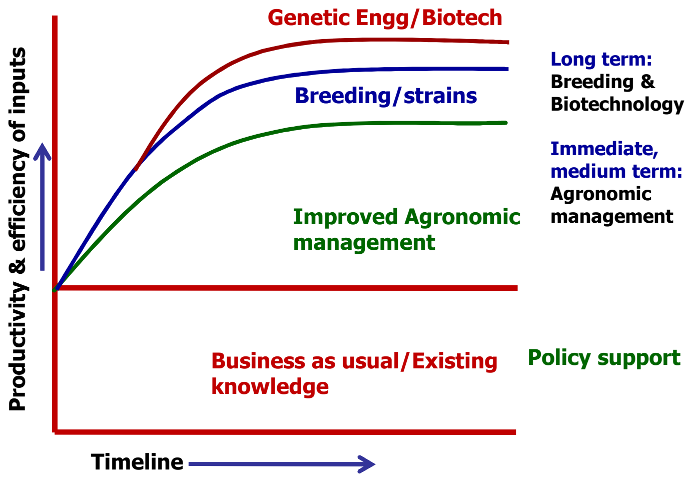
Productivity with Efficiency: Where Will Future Gains Come From?

Management Yield Gaps	
Rice	51%
Wheat	36%
Maize	66%
Potential Yield Gaps	
Rice	62%
Wheat	48%
Maize	74%



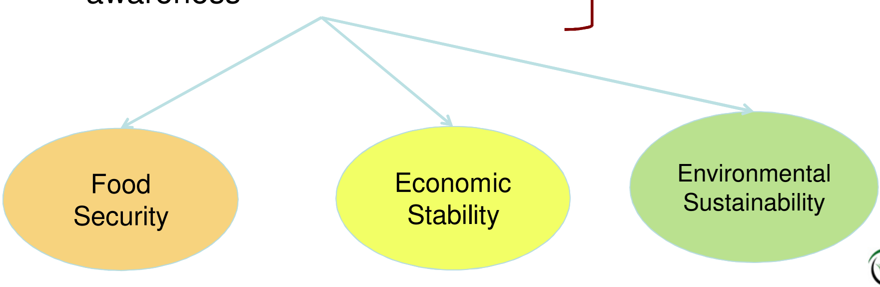
Slide courtesy Dr. M. L. Jat, 2014

FBMPs are Critical in the Current Scenario

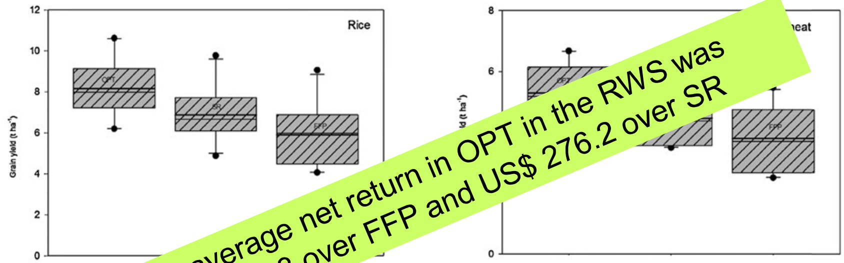
For sustainable access to food, crop production would have to increase on essentially the same land area, with less water, nutrients, fossil fuel, labor and as climate change

- Economic viability of farming
  - Increasing input cost
  - Unavailability of labor
- Increasing environmental awareness

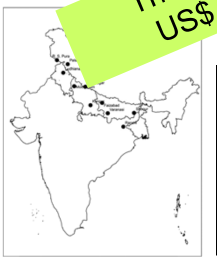
Effects are magnified in smallholder systems



Optimizing Nutrient Management in Rice-Wheat System (RWS): Yield and Efficiency Improvement



The average net return in OPT in the RWS was US$ 498.3 over FFP and US$ 276.2 over SR



Average on-farm PFP_N (kg grain/kg N); n=120;

	Optimum Fertilization	State Recommendation	Farmers' Practice
Rice	54.5 (± 2.5)	45.8 (± 2.1)	39.4 (± 1.9)
Wheat	35.3 (± 1.3)	29.8 (± 0.9)	25.3 (± 0.6)

Singh et al., 2014. Field Crops Res. 164: 30–44

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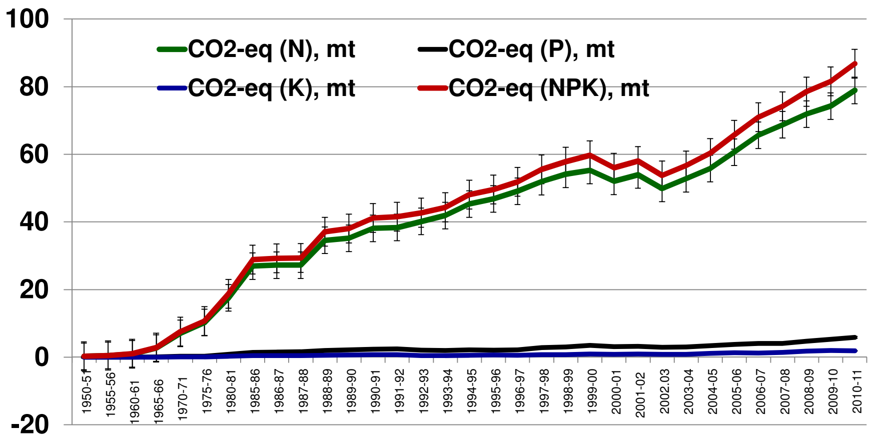
Environmental footprints of fertilizer NPK production in India - Trends



Source: Jat et al (2014), based on IPCC protocols

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Inappropriate fertilizer use a growing challenge in India

- Environmental Impacts:
  - It is estimated that 80% of N_2O emissions come from agriculture and burning in India
  - With crop N recovery estimated at 33-50%, unused N in soils can impact the environment
  - P losses in soil runoff, especially where fertilizer is surface applied
- Agricultural Impacts:
  - Nutrient mining of soils….severe depletion in many instances affecting crop productivity
  - Nutrient losses lead to lower NUE, lost profit
  - Nutrient losses lead to lower quality product, lost profit

In India, adverse impacts are more commonly associated with unbalanced use, rather than overuse

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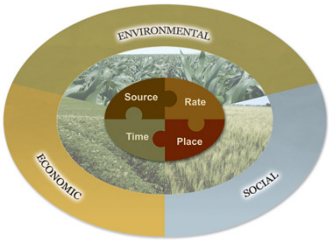
4R Nutrient Stewardship

Source, Rate, Time, and Place describe any nutrient application

4R Nutrient Stewardship — applying the **right** nutrient source, at the **right** rate, **right** time, and **right** place — is an essential tool in the development of sustainable agricultural systems.



- Implementation of 4R Nutrient Stewardship can positively influence the sustainability of agricultural systems beyond the immediate benefits of improved crop nutrition and production.

4R: Science-based Practical Choices to Implement FBMPs

Examples of key scientific principles

IPNI, 2012. 4R Plant Nutrition

	The Four Rights (4Rs)			
	Source	Rate	Time	Place
Key Scientific Principles	• Ensure balanced supply of nutrients • Suit soil properties	• Assess nutrient supply from all sources • Assess plant demand	• Assess dynamics of crop uptake and soil supply • Determine timing of loss risk	• Recognize crop rooting patterns • Manage spatial variability

Examples of practical choices

Source	Rate	Time	Place
Commercial fertilizer	Test soils for nutrients	Pre-plant	Broadcast
Livestock manure	Calculate economics	At planting	Band/drill/inject
Compost	Balance crop removal	At flowering	Variable-rate application
Crop Residue		At fruiting	

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What is the Connect between FBMP & 4R

Concept — Fertilizer Best Management Practices

↓

Application — 4R Nutrient Stewardship Principles

↓

Outcome — <u>Social</u>, <u>Economic</u>, and <u>Environmental benefits to the Society</u>

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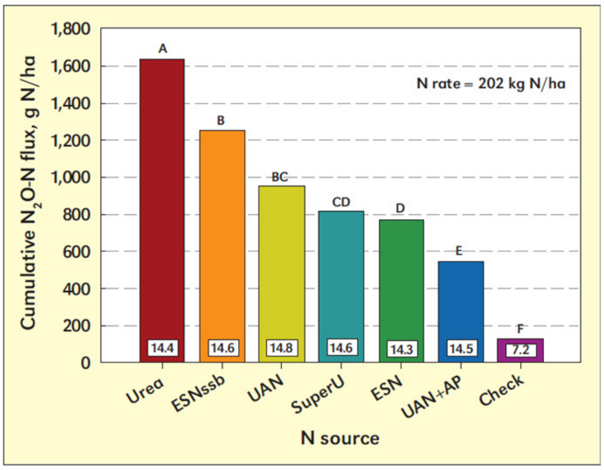
4R Interventions

Expected Outcome from Application of 4R

- Maintain or improve crop productivity
  - Appropriate nutrient management for
    - nutrient acquisition efficient cultivars
    - Drought, flood and heat resistant cultivars
  - Crop Management
    - Manage abiotic and biotic stresses
    - Provide adequate and balanced plant nutrition
    - Soil fertility depletion
- Reduce environmental footprints of plant nutrients
  - GHG emission
  - Eutrophication
- Convergence of scale-neutral technologies to achieve the above goals
  - Farm size
  - Farmer resources

Source-Effect of N fertilizer Source on N_2O Emission from Semi-arid, irrigated Maize

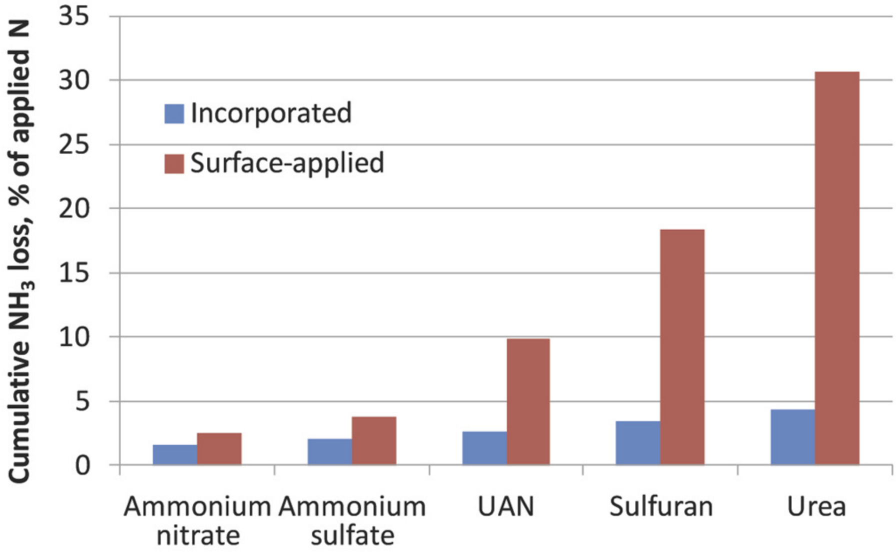


Nitrogen sources compared to the commonly used granular urea (46% N) and liquid UAN (32% N) included a controlled-release polymer-coated urea (ESN®), stabilized urea and UAN products containing nitrification and urease inhibitors (SuperU and UAN+AgrotainPlus®), and UAN containing a slow release N source (Nfusion®). A subsurface band ESN treatment (ESNssb) was also included.

Halvorson and Del Grosso, Better Crops/Vol. 96 (2012, No. 4), pp. 7-9

4R - Source X Place

Reduction in N loss through proper placement in Maize



Lara-Cabezas et al. 1997

4R – Time: Effect of N Application time on Yield and Agronomic Efficiency of Irrigated Maize

Treatment	Maize Grain Yield Mg ha^{-1} and AE (kg kg^{-1})			
	Maros (Indonesia)		O Mon (Vietnam)	
	2008	2009	2008	2009
2-Split Fixed Rate	11.2 (58.7)	10.6 (46.8)	5.4 (30.1)	6.6 (36.9)
3-Split Fixed Rate	11.4 (62.8)	10.5 (45.8)	5.6 (31.4)	6.7 (37.6)
3-Split LCC1	12.3 (64.8)	11.1 (47.0)	6.0 (30.3)	7.0 (34.7)
3-Split LCC2	12.6 (65.7)	12.1 (46.4)	6.1 (30.4)	7.3 (32.4)

1.0 t/ha from increased split and use of LCC

Pasuquin et al., 2012, Field Crops Research 134: 153–157

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4R-Rate X Time: GreenSeeker based N application in rice

Cultivar	N Management Strategy	Total N applied (kg/ha)	Rice grain yield (kg/ha)	Total N Uptake (kg/ha)	AE_N (kg/kg)	RE_N (%)
PAU 201	No N	0	3.99	57.8	-	-
	Three equal splits	120	6.96	131.7	24.7	61.6
	GreenSeeker-based	102	7.16	130.8	31.0	71.5
PUSA 44	No N	0	3.94	63.1	-	-
	Three equal splits	120	6.38	121.6	20.3	48.7
	GreenSeeker-based	97	6.37	117.0	25.1	55.6
HKR 127	No N	0	3.75	57.9	-	-
	Three equal splits	120	6.04	120.4	19.1	52.1
	GreenSeeker-based	102	6.19	117.7	23.8	58.6

Bijay-Singh et al., 2015

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4R – Source X Rate X Time: Nutrient Expert® (NE) for Maize in India, Indonesia, and Philippines (2010-14)

Current situation: Farmers' yield < attainable yield

Parameter	Unit	Effect of NE (NE – FFP)		
		India	Indonesia	Philippines
		(n = 412)	(n = 26)	(n = 190)
Grain yield	t/ha	**+1.27** ***	**+0.92** ***	**+1.10** ***
Fertilizer N	kg/ha	–6 ns	–12 ns	+3 ns
Fertilizer P_2O_5	kg/ha	–16 ***	–5 ns	+18 ***
Fertilizer K_2O	kg/ha	+22 ***	+15 ***	+18 ***
Fertilizer cost	USD/ha	–1 ns	+16 ns	+37 ***
Gross profit	USD/ha	**+256** ***	**+234** ***	**+267** ***

*** significant at P<0.001; ns = not significant

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4R – Source X Rate X Time: Nutrient Expert® in China (2010-13)

Current situation: farmers' yield ≈ attainable yield

Parameter	Unit	Wheat (n = 290)			Maize (n = 541)		
		FP	NE	Soil test	FP	NE	Soil test
Grain yield	t/ha	7.9	8.0	8.3	9.9	10.2	10.3
N	kg/ha	271	162	237	230	158	202
P_2O_5	kg/ha	118	82	105	62	56	57
K_2O	kg/ha	50	74	73	47	68	75
Fert. cost	USD/ha	357	267	344	272	234	274
Gross profit	USD/ha	2282	2417	2459	2902	3031	3006
REN	%	17.5	30.2	22.5	18.5	29.1	23
AEN	kg/kg	5.2	8.6	6.3	7.8	11.8	10

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

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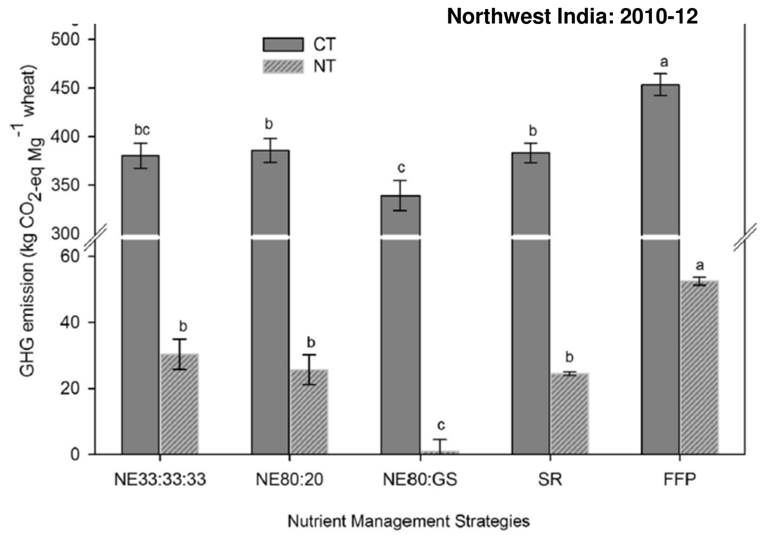
4R – Source X Rate X Time: Nutrient Expert®
reduced GHG emission in wheat with increased yield and profit



Source: Sapkota et al. 2014, Field Crops Res. 155: 233-244

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Researchable Issues

What are the Grey Areas

- Source
  - Conventional vs. Enhanced Efficiency Fertilizer
  - Commodity vs. Specialty Fertilizer
- Rate
  - Sole vs. Intercropping or Relay Cropping
  - When foliar application is part of the strategy
  - In high P fixing soils
- Time
  - Intercropping
- Place
  - Surface Application vs. Sub-surface Drilling vs. Fertigation at Root Zone

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What are the Grey Areas

- 4Rs for Cropping systems
  - Individual Crop vs. Cropping System
  - When crops are grown in sequence under anaerobic and aerobic growing environment
- 4Rs under CA systems
  - Conventional vs. Zero-till crop establishment
  - Under differential residue retention
- 4Rs for Climate Change Adaptation/Mitigation
  - Drought
  - Excess precipitation
  - Heat stress

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Conclusions

- World-wide increasing population needs sustainable access to food
- Fertilizer plays a critical role in ensuring food security
- **Fertilizer best management practices** (FBMPs) are agricultural production techniques and practices to give optimum production potential, input efficiency and environmental protection
- The 4R Nutrient Stewardship provides science-based practical choices for on-farm implementation of FBMPs
- Fine tuning of 4R strategies in specific crop growing environments and management practices are required through further research