Fertilizer N management strategies for reducing greenhouse gas emissions while optimizing grain yields from US rice and maize systems



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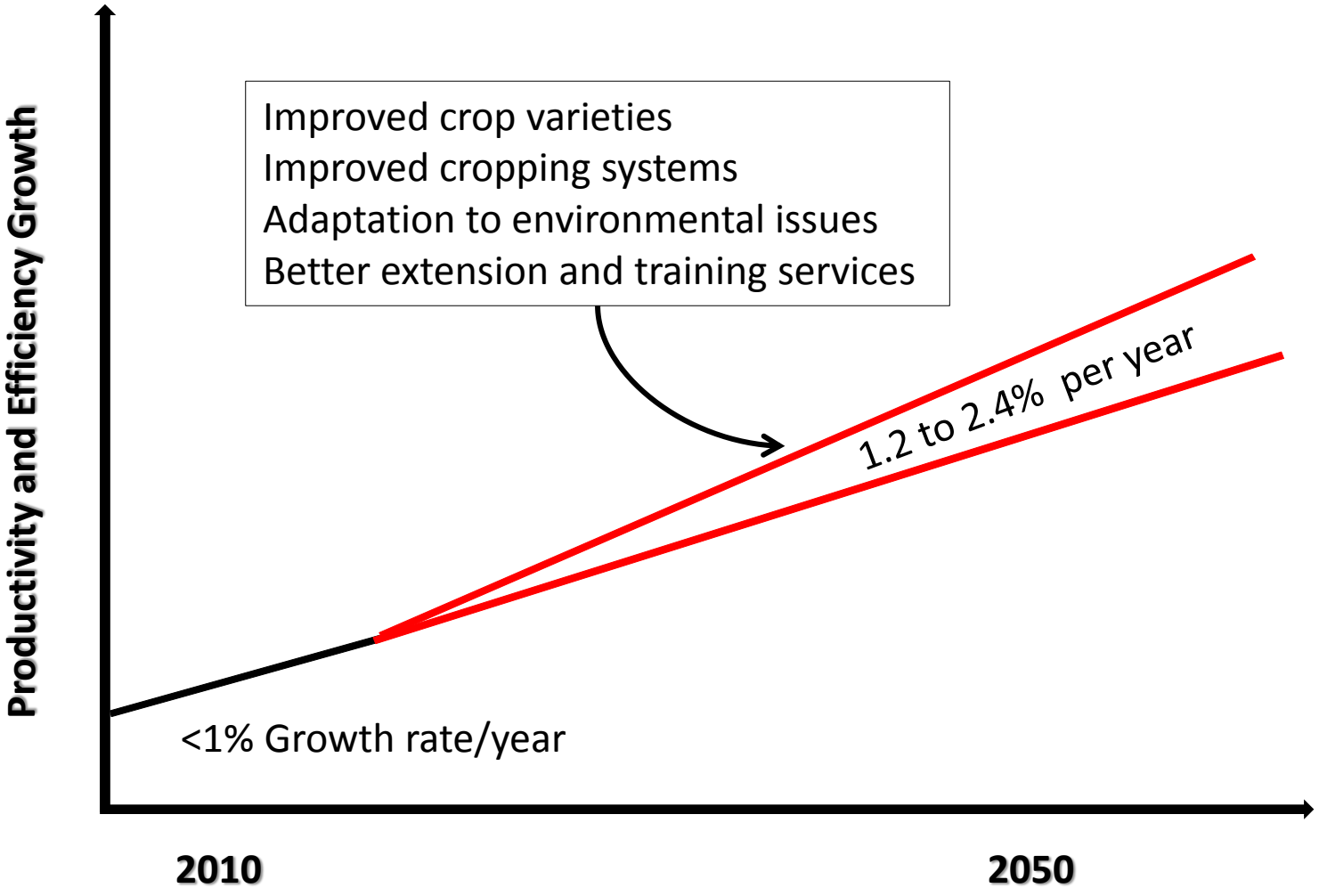
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Important cereal crops

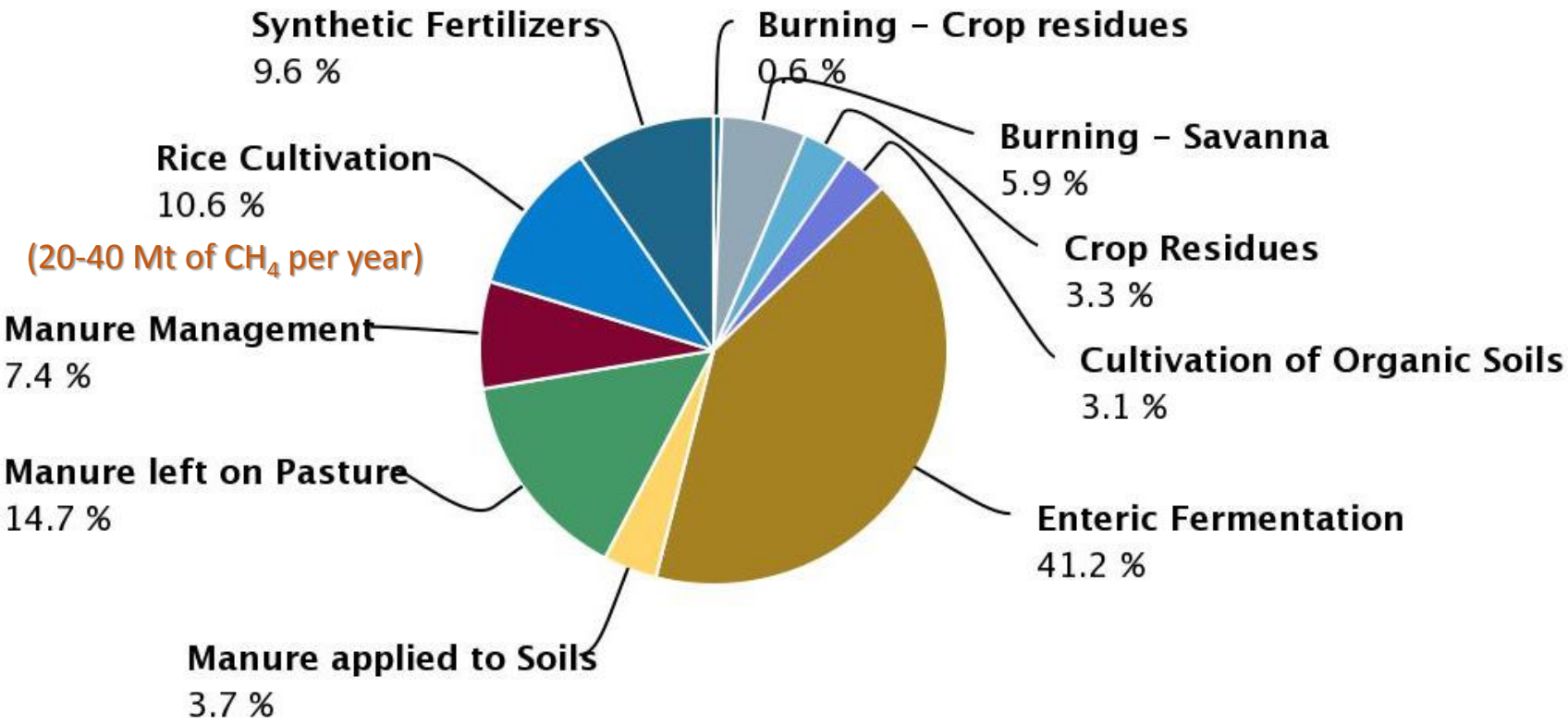


- Rice (*Oryza sativa*), maize (*Zea mays*), and wheat (*Triticum aestivum*) are the most important crops for food security
- Provide ~60% of all human calories (as human food or livestock feed)
- Grown on 546 M ha or 36% of global croplands
- The Green revolution, intensification of rice and maize systems are responsible for averting short food supply during the past decades.

Feeding the world while protecting the environment

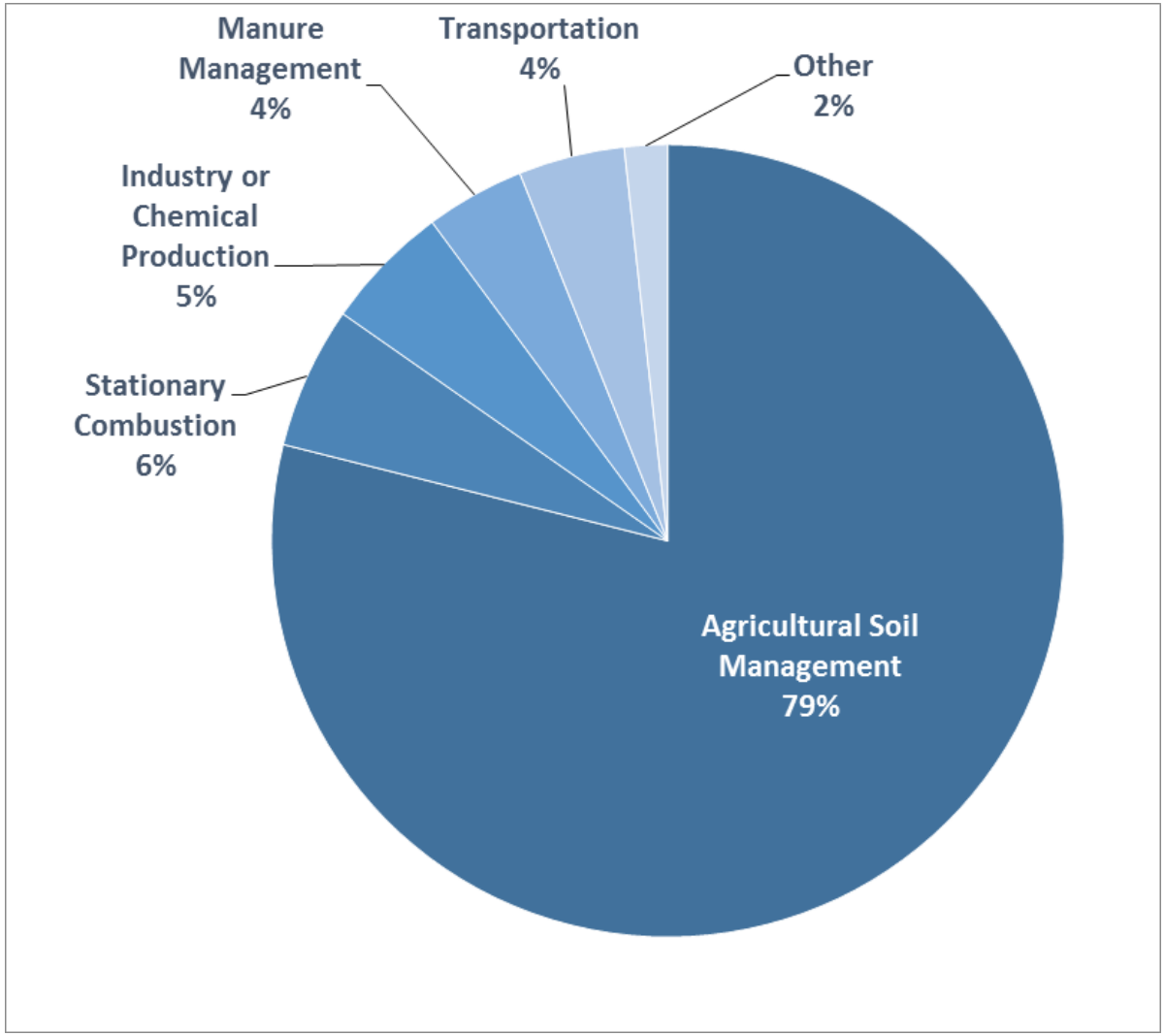


Emissions of CH_4 and N_2O produced from agricultural activities (1961-2011)

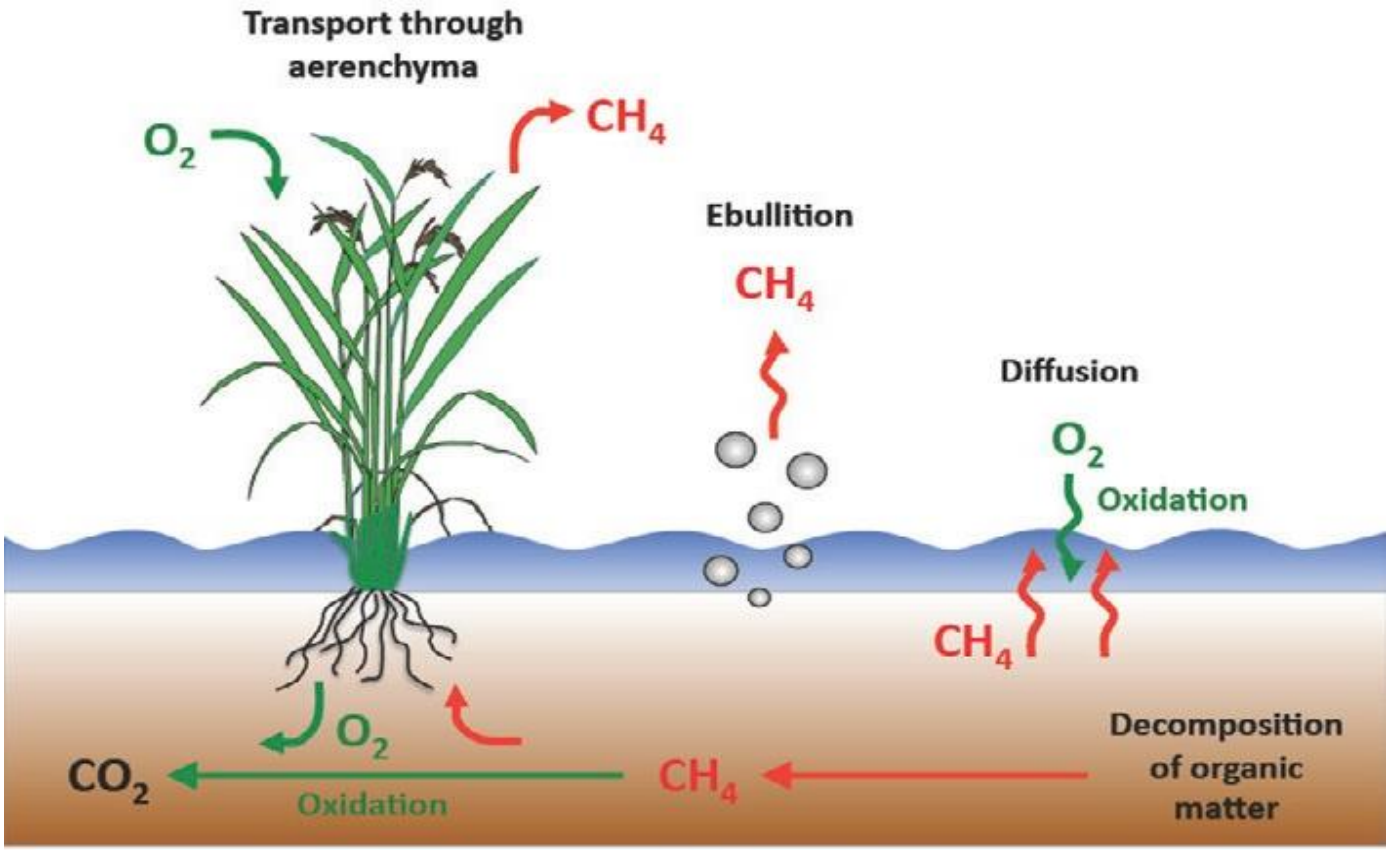


Source: FAOSTAT

US Nitrous oxide emissions by source (1990-2014)



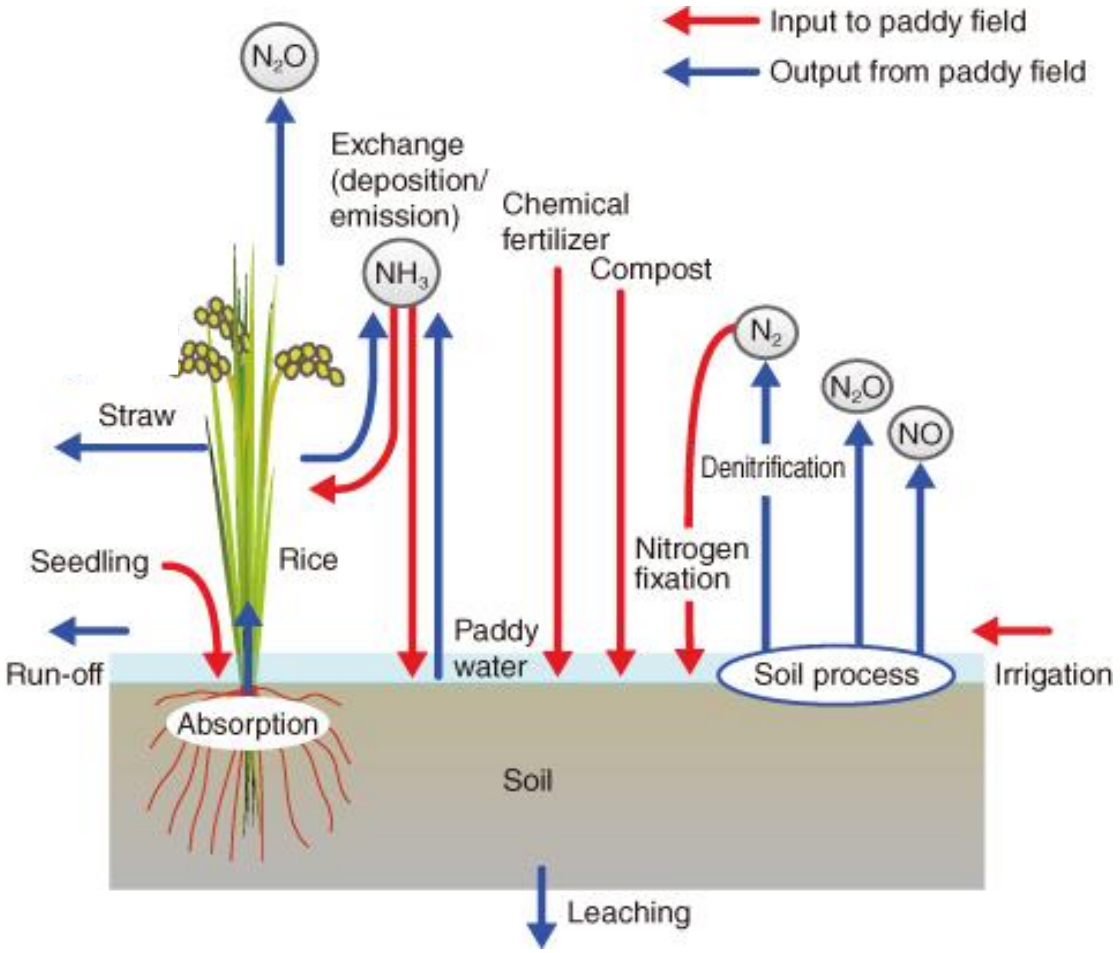
Emissions of CH_4 from flooded rice fields



Source: ECBrevik. 2012. Soil Horizon. doi:10.2136/sh12-04-0012

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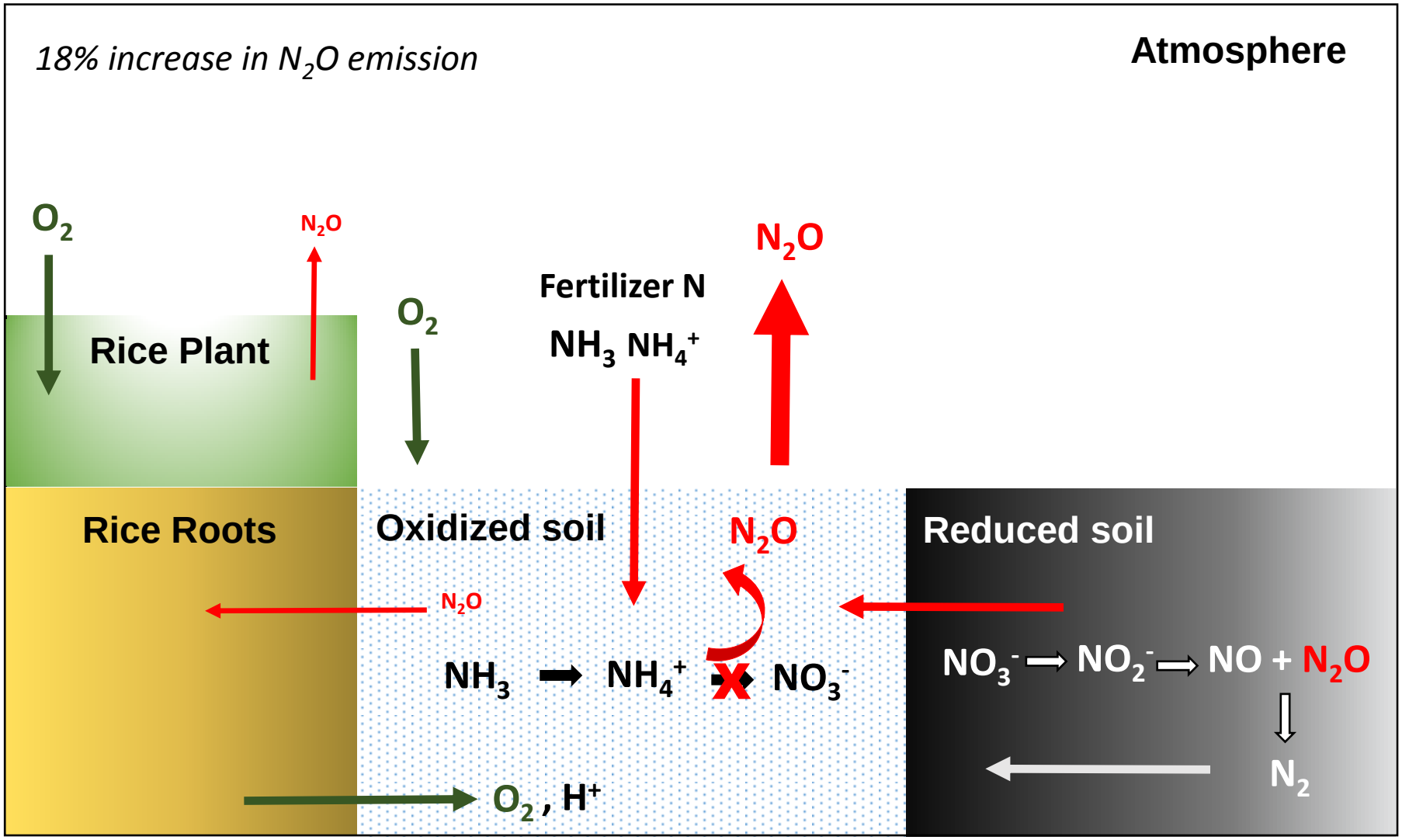
Emissions of N_2O from flooded rice fields



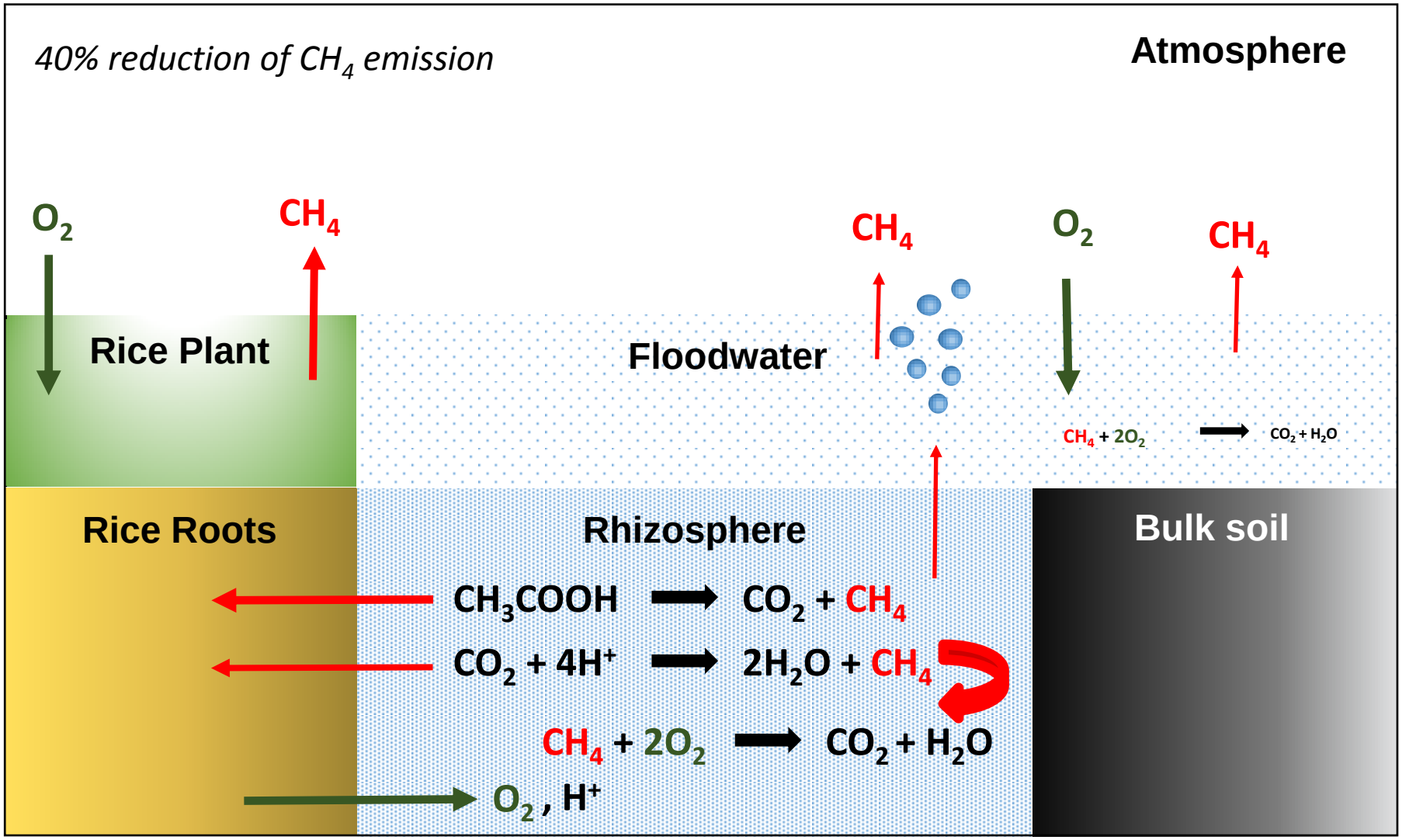
Source: Katata, G. et al., 2013. Agric. For. Meteorol. 180:1-21.

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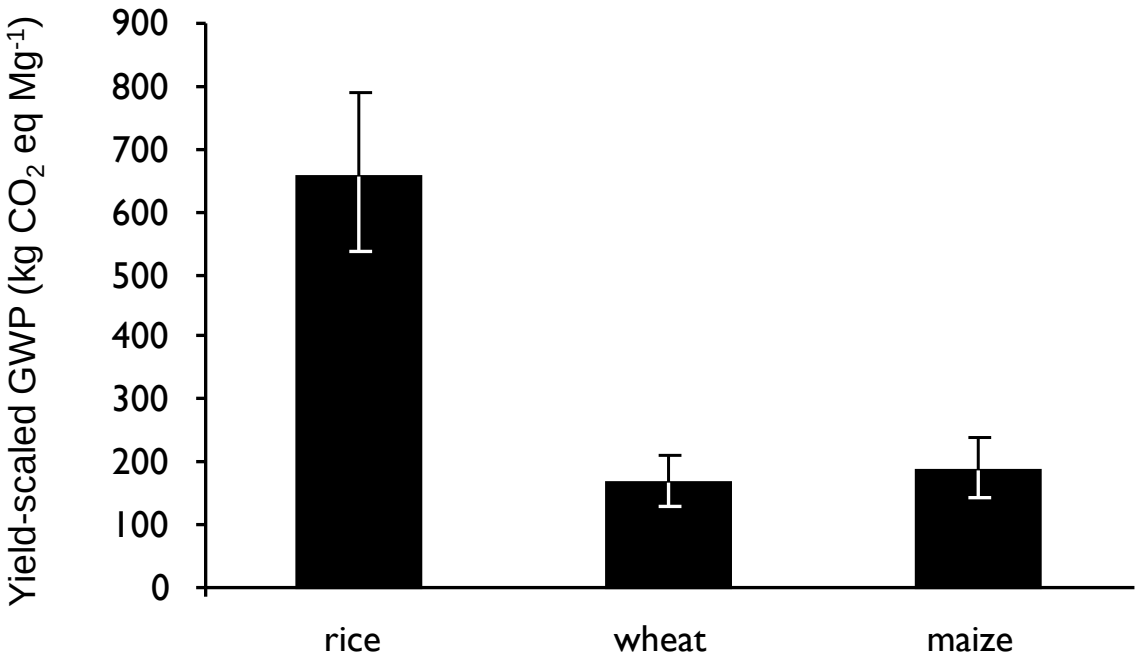
Influence of N fertilizer on N_2O emissions in flooded rice fields



Influence of N fertilizer on CH_4 emissions in flooded rice fields



Global warming potentials in cereal crops



Linquist et al. 2012. An agronomic assessment of greenhouse gas emissions from major cereal crops. Global Change Biology. 18:194-209.

Objectives

1. To quantify methane, nitrous oxide and carbon dioxide emissions from irrigated cereal cropping systems,
2. To quantify grain yield under different N fertilizer management practices, and
3. To asses various N fertilizer rates in greenhouse gas emissions from irrigated rice and maize systems.

Experimental sites



RICE system: Cropping practice and N rate trials






Agronomic practices

- **Surface urea N application**
- **Irrigated**
  - **Flushed twice and permanently flooded**

Rice variety

- **CA: Koshihikari (70 kg seed ha^{-1})**
- **AR: CLXL 745 (28 kg seed ha^{-1})**

Robbins, CA		Stuggart, AR	
Field Treatment	Urea N rates, kg N ha^{-1}	**Field Treatment**	Urea N rates, kg N ha^{-1}
N0	0	**N0**	0
N50	50	**N112**	112
N100	**100**	**N168**	**168**
N150	150	**N224**	224
N200	200		

RICE systems: Measurements of CH_4 and N_2O emissions





- **30.5 cm diameter vented flux chamber with 17 CFM/5800 RPM fan**
- **daily to weekly gas sampling (90+ sampling dates)**





- **varying chamber height (13 - 122 cm; 8-90 L) based on height of growing rice**





- **12 mL gas vial double sealed with silicon**
- **Multi-point valves GC-2014 gas chromatograph with a ^{63}NI ECD and FID detectors**

MAIZE system: Cropping practice and N rate trials



Agronomic practices

- **Surface urea N application**
- **Fall application of Urea ammonium nitrate solution**
- **Irrigated**

Maize variety

- **NE:** Pioneer 31N28 (2003–2004), Pioneer 31G68

Treatment	Crop Rotation	Plant population	Yield Goal	Fertilizer N rate, kg N ha^{-1}		
		Maize plant m^{-2}	Mg ha^{-1}	2003	2004	2005
Recommended	Maize-Maize	7-9	12.5	180	200	240
	Maize-Soybean	7-9	12.5	130	140	0
Intensive	Maize-Maize	9-11	18	250	280	310
	Maize-Soybean	9-11	18	250	230	130

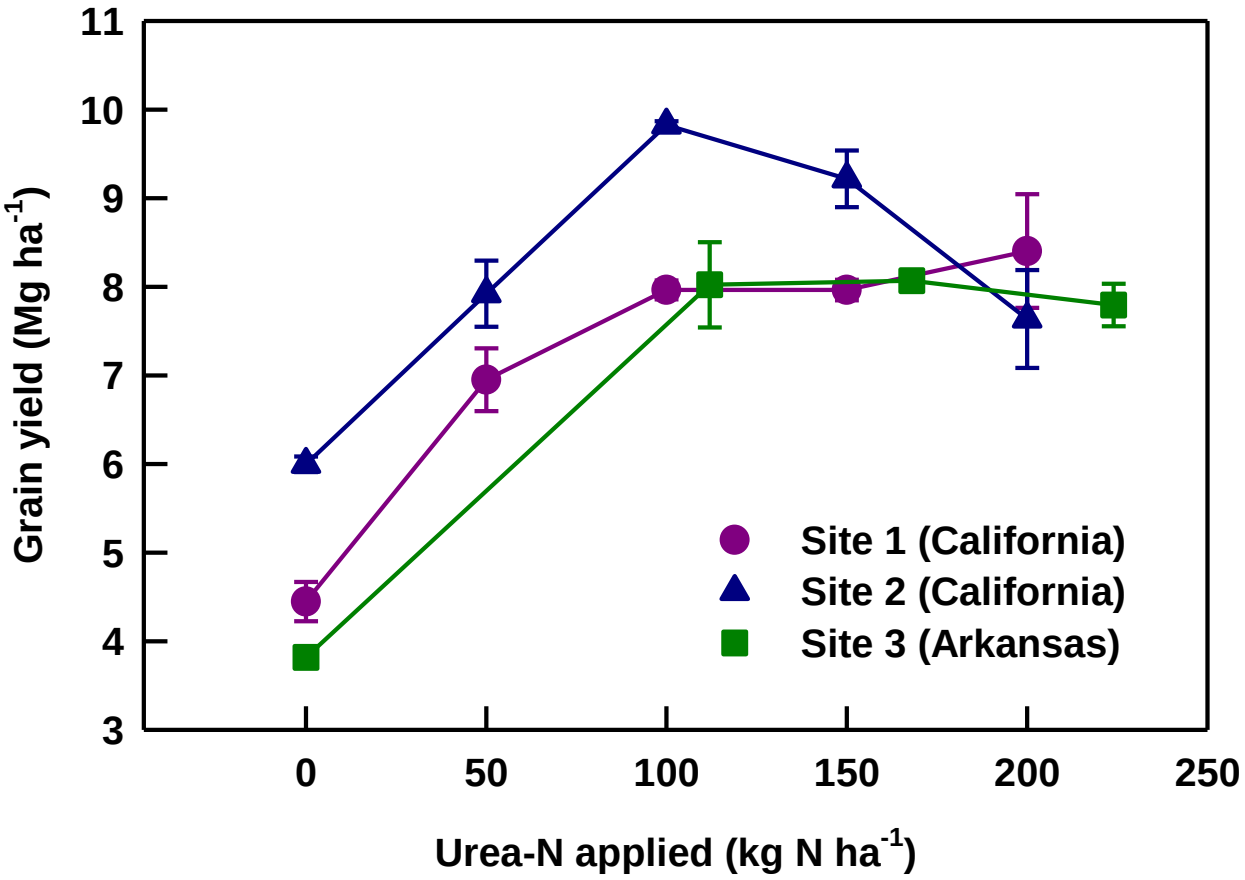
MAIZE systems: Measurements of CO_2, CH_4 and N_2O emissions



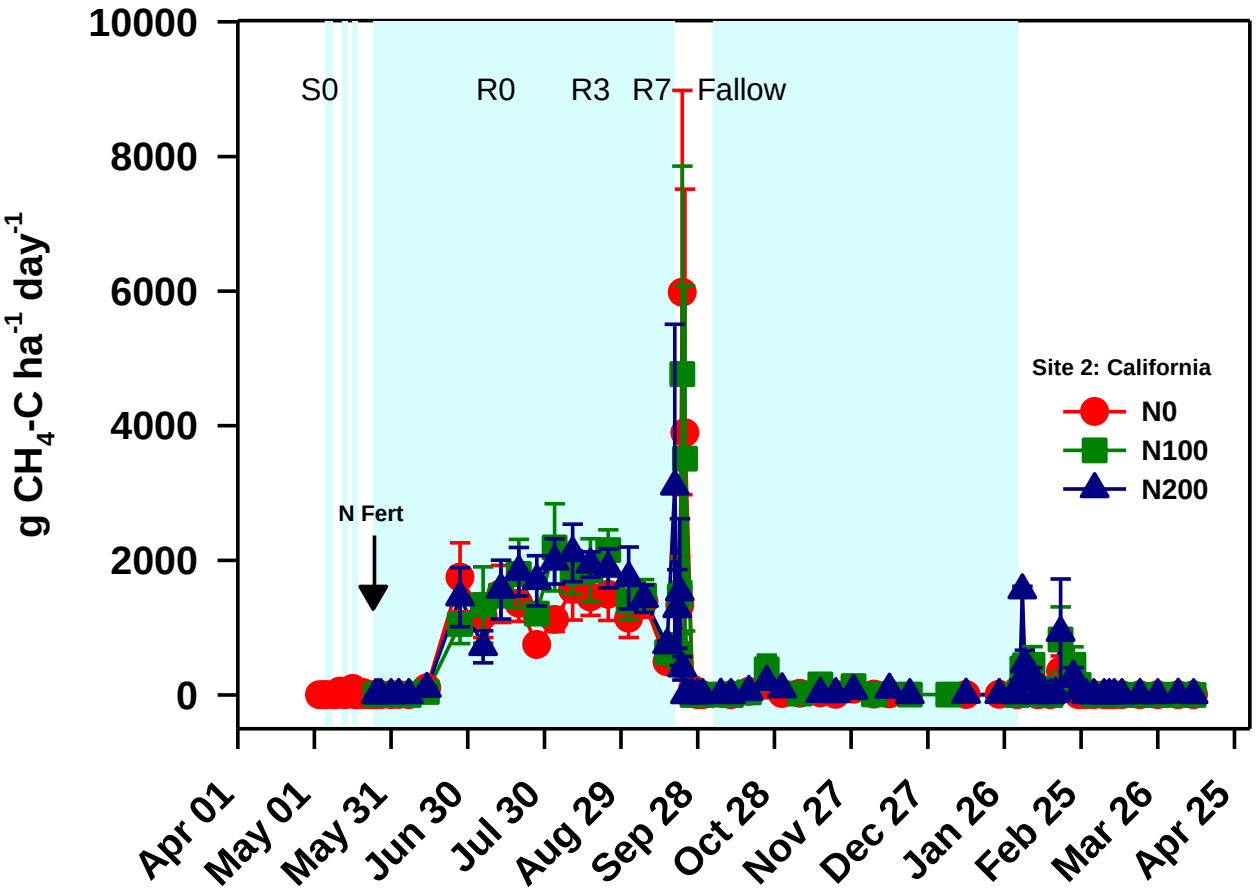
- N_2O, CH_4 and CO_2 emissions measurements
- 75 x 10 x 20 cm vented chamber (15 L)
- 14 min measurement time at 2 min interval (1.8 L min^{-1})

- Soil measurements at 0-5, 5-15, 15-30 cm depths
  - -soil temperature and water content
  - -Electrical conductivity,
  - -pH
  - -inorganic NO_3-N and NH_4-N
  - -bulk density
  - -residual soil NO_3-N content

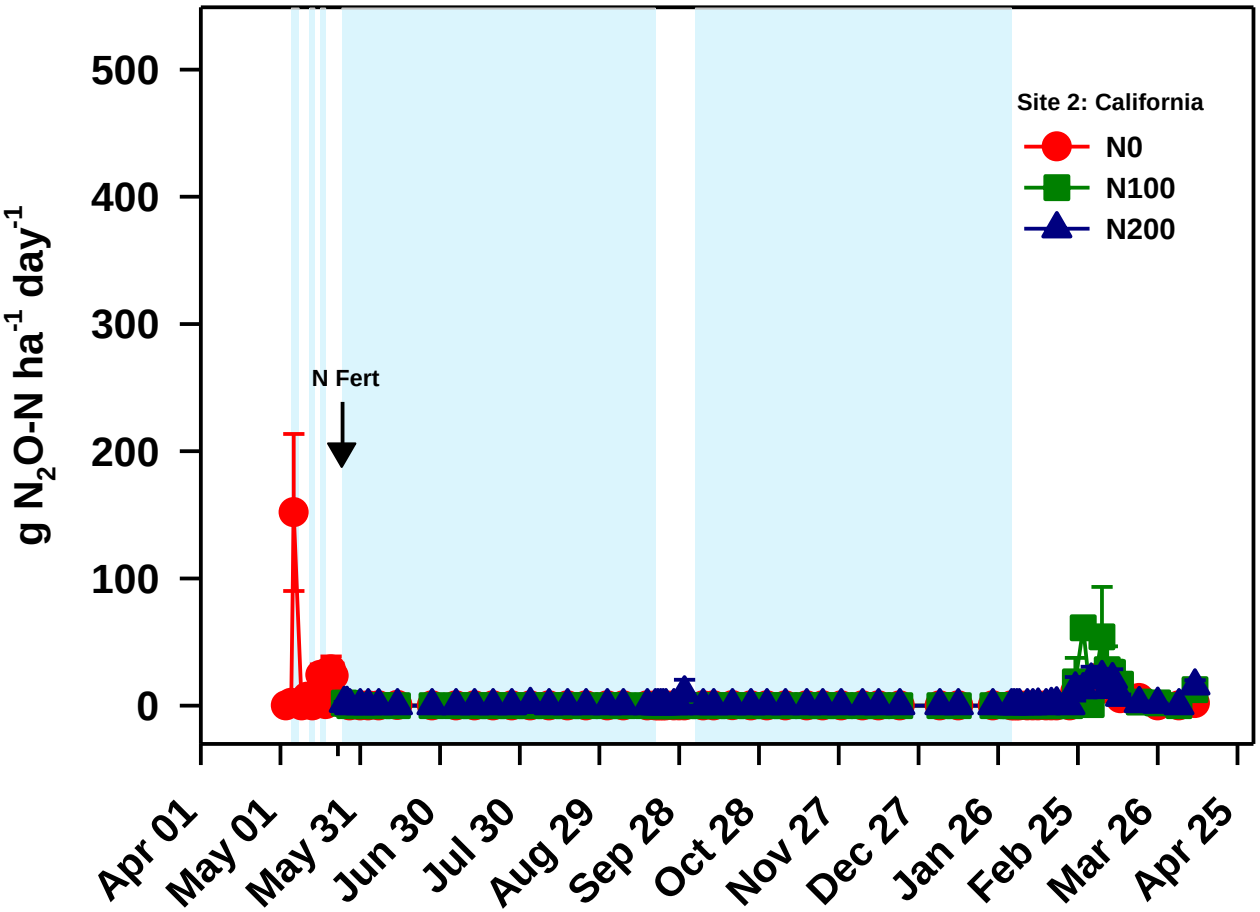
RICE system: RESULTS
Grain yields



RICE system: RESULTS
Methane emission profiles in various N rates



RICE system: RESULTS
Nitrous oxide emission profiles in various N rates



RICE system: RESULTS
Cumulative GHG emissions

Site/N rate	Cumulative CH_4 emissions		Cumulative N_2O emissions		Fertilizer-induced N_2O emissions
kg N ha^{-1}	kg CH_4-C ha^{-1} yr^{-1}	kg CO_2 eq ha^{-1} yr^{-1}	kg N_2O-N ha^{-1} yr^{-1}	kg CO_2 eq ha^{-1} yr^{-1}	%
Site 1					
0	13	429	0.49*b*	229*b*	
50	12	408	0.87*b*	409*b*	0.8
100	**9.3**	**310**	**0.86b**	**402*b***	0.4
150	17	566	2.0*a*	926*a*	1.0
200	19	644	1.9*a*	896*a*	0.7
Site 2					
0	140	4661	0.85	400	
50	164	5488	1.1	624	0.5
100	**176**	**5887**	**1.9**	**881**	1.0
150	193	6452	1.4	673	0.4
200	166	5539	1.6	762	0.4
Site 3					
0	20*b*	678*b*	0.83	390	
112	42*a*	1390*a*	1.3	628	0.5
168	**47*a***	**1556*a***	**1.1**	**514**	0.2
224	41*a*	1363*a*	1.8	875	0.5

RICE system: RESULTS
Cumulative Global Warming potentials

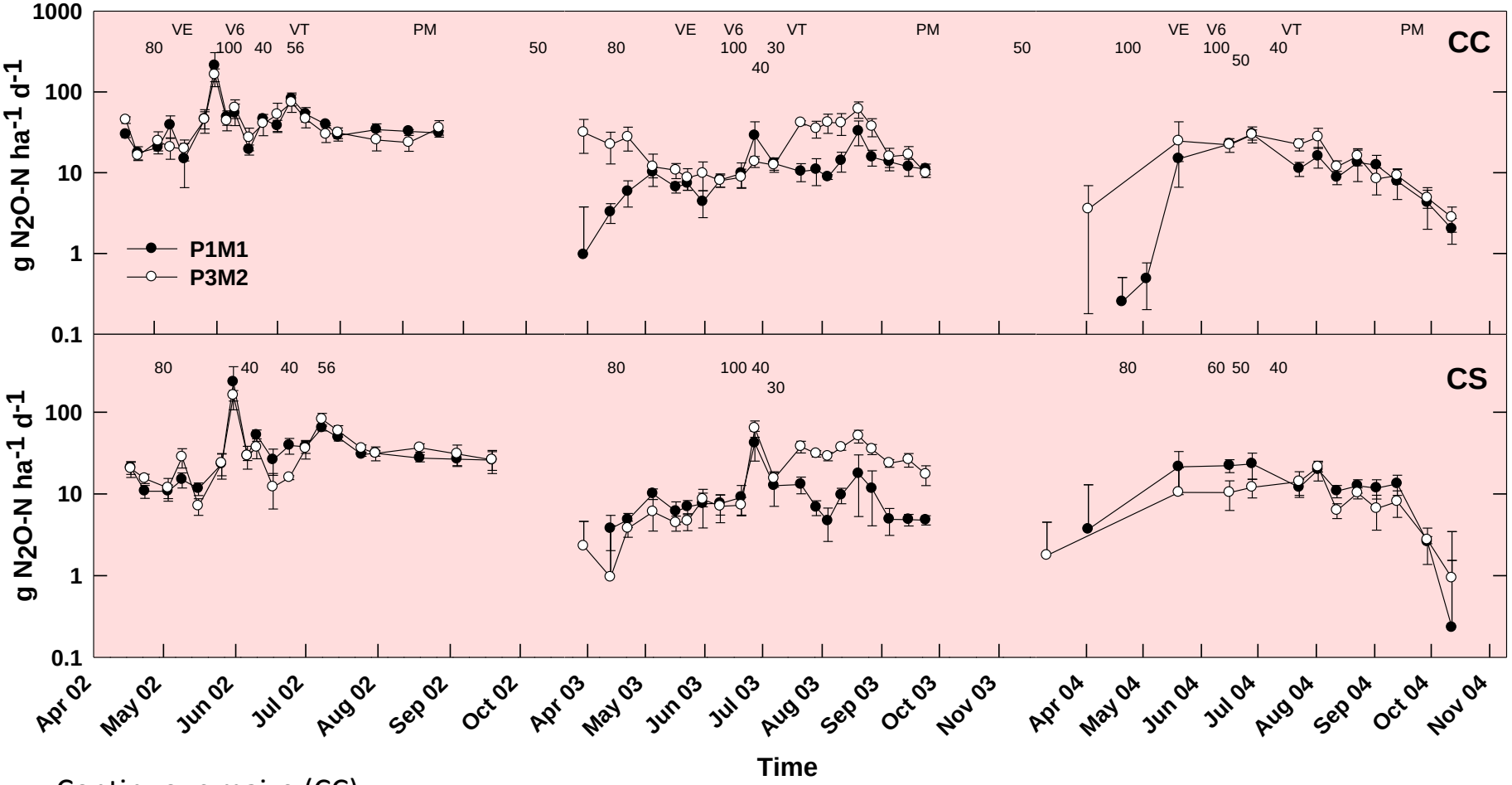
Site/ N rate	Global warming potential	
kg N ha^{-1}	kg CO_2 eq ha^{-1} yr^{-1}	kg CO_2 eq Mg^{-1} yr^{-1}
CA: Site 1		
0	658*b*	156
50	816*b*	120
100	712*b*	91
150	1491*a*	188
200	1541*a*	190
CA: Site 2		
0	5061	844
50	6012	772
100	6768	687
150	7126	776
200	6300	874
AR: Site 3		
0	1068*b*	278
112	**2018*a***	**265**
168	2069*a*	257
224	2238*a*	286

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MAIZE system: RESULTS
Grain Yield

	Year	Maize-Maize rotation			Maize-soybean rotation			
		Crop	Recommended	Intensive	Relative % increase	Crop	Recommended	Intensive	Relative % increase
			Mg ha^{-1}		%		Mg ha^{-1}		%
Yield	2003	Maize	16.01	15.83		Maize	16.80	17.83	
	2004	Maize	15.52	16.74		Maize	16.35	18.01	
	2005	Maize	15.85	11.99		Soybean	5.07	5.31	
	Mean	Maize	15.79	14.85	-6	Maize	16.58	17.92	8
Fertilizer N		---------- *kg N ha^{-1}* ----------				---------- *kg N ha^{-1}* ----------			
	2003	Maize	180	250	39	Maize	130	250	92
	2004	Maize	200	280	40	Maize	140	230	64
	2005	Maize	240	310	29	Soybean	0	130	

MAIZE system: RESULTS
N_2O emission profiles

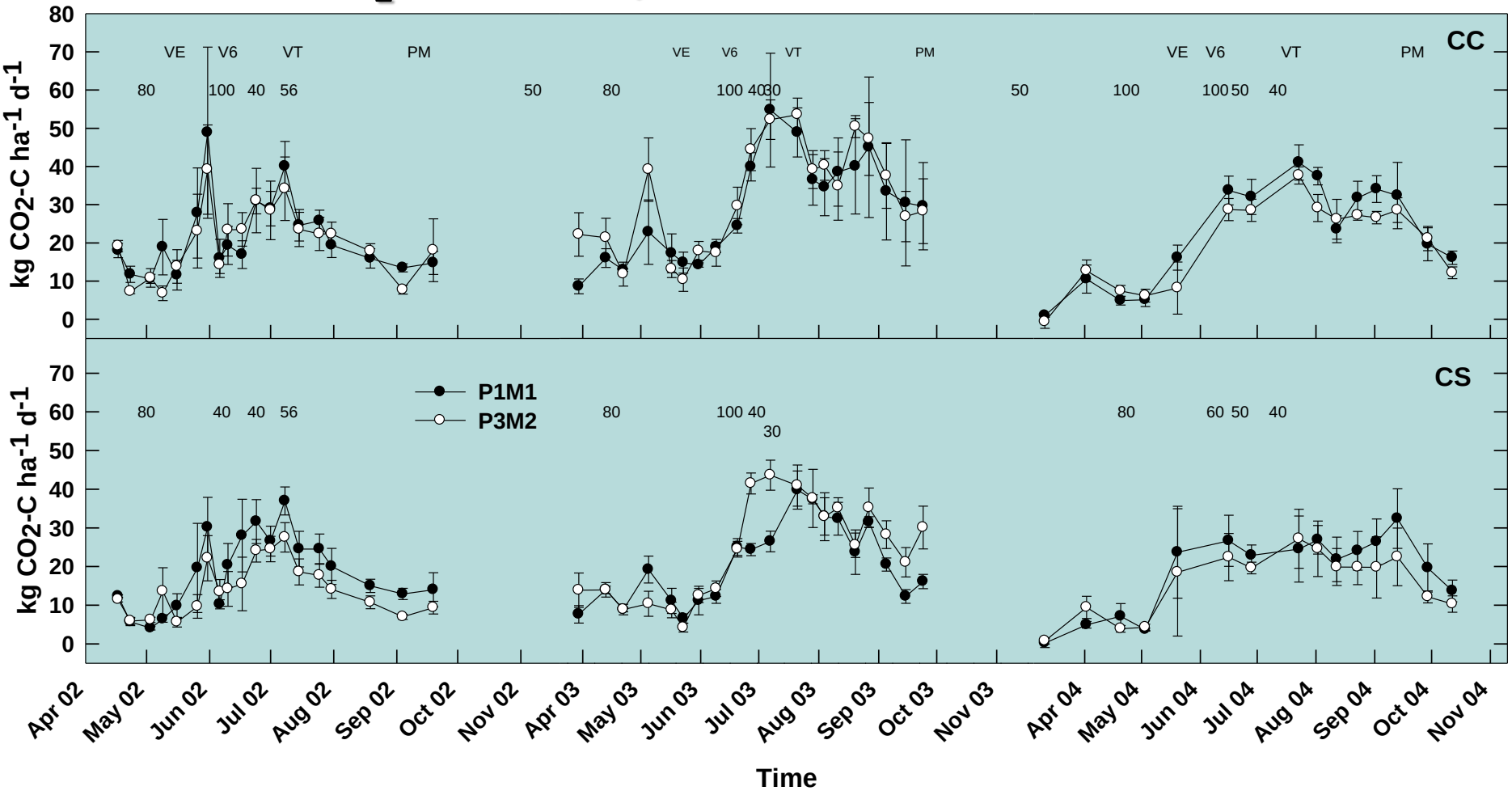


-Continuous maize (CC)
-Maize following soybean (CS)

-Recommended (P1M1)
-Intensive input levels (P3M2).

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MAIZE system: RESULTS
Cumulative CO_2 emission profiles



-Continuous maize (CC)
-Maize following soybean (CS)

-Recommended (P1M1)
-Intensive input levels (P3M2).

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MAIZE system: RESULTS
Cumulative GHG emissions

Treatment	Crop Rotation	Mean Fertilizer N rate	Cumulative N_2O emissions	Cumulative CO_2 emissions	% Fertilizer N
		kg N ha^{-1}	kg N_2O-N ha^{-1} yr^{-1}	kg CO_2-C ha^{-1} yr^{-1}	%
Recommended	Maize-Maize	187	6.9*a*	6875*a*	3.6
	Maize-Soybean	130	5.9*a*	5337*b*	4.4
Intensive	Maize-Maize	273	9.7*a*	6699*ab*	3.6
	Maize-Soybean	232	7.9*a*	5298*b*	3.5

MAIZE system: RESULTS
Annual Net Global Warming Potentials

GWP Components	Maize-maize rotation ($g\ CO_2$-Ceq $m^{-2}\ yr^{-1}$)		Maize-Soybean rotation ($g\ CO_2$-Ceq $m^{-2}\ yr^{-1}$)	
	Recommended	Intensive	Recommended	Intensive
Agricultural Production				
N Fertilizer	22	33	8	18
P, K fertilizer	0	6	0	6
Lime	6	9	6	9
Seed, pesticides	5	6	5	6
Machinery, transport	2	3	2	3
Diesel	9	9	8	8
Irrigation	14	14	11	11
Grain drying	11	12	9	10
Total	69	92	49	71
Change in Soil C	-44	-62	30	-2
Soil N_2O	32	57	25	34
Soil CH_4	-3	-3	-2	-1
GWP ($g\ CO_2$-Ceq $m^{-2}\ yr^{-1}$)	**54**	**84**	**102**	**102**
GWPY (kg grain $m^{-2}\ yr^{-1}$)	**29**	**18**	**16**	**17**

Summary:

1. Optimal rates for rice was 112-120 kg N/ha. In maize system, it is possible to reach 80% of yield potential with N rates and irrigation that are based on maize demand.
2. CH_4 emission is the major source of GHG from rice systems while CO_2 emission contributed largely to GWP in maize systems
3. Excessive application of fertilizer N increased N_2O emissions in both cereal crop systems.
4. Higher fertilizer N rates had no significant effect on CH_4 emissions.
5. Optimal N fertilization had little or no effect on total global warming potential.
6. Results suggest that higher grain yield and reduced GHG emissions can be achieved in rice and maize systems at minimum fertilizer inputs for maximum grain yield.

Online resources:

Environ. Qual. 2013, 42:1623-1634

Journal of Environmental Quality

TECHNICAL REPORTS

ATMOSPHERIC POLLUTANTS AND TRACE GASES

Optimal Fertilizer Nitrogen Rates and Yield-Scaled Global Warming Potential in Drill Seeded Rice

Maria Arlene Adviento-Borbe,* Cameron M. Pittelkow, Merle Anders, Chris van Kessel, James E. Hill, Anna M. McClung, Johan Six, and Bruce A. Linquist

Global Change Biology (2007) **13**, 1972–1988, doi: 10.1111/j.1365-2486.2007.01421.x

Soil greenhouse gas fluxes and global warming potential in four high-yielding maize systems

M. A. A. ADVIENTO-BORBE, M. L. HADDIX, D. L. BINDER, D. T. WALTERS and A. DOBERMANN[1]

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Thank you!