SOURCES AND MITIGATION POTENTIAL FOR NITROUS OXIDE FROM AGRICULTURE ACTIVITIES

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Managing Agricultural Nutrients

Challenges of Nutrient Efficiency for the Future

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DoubleTree Hotel • Modesto, California

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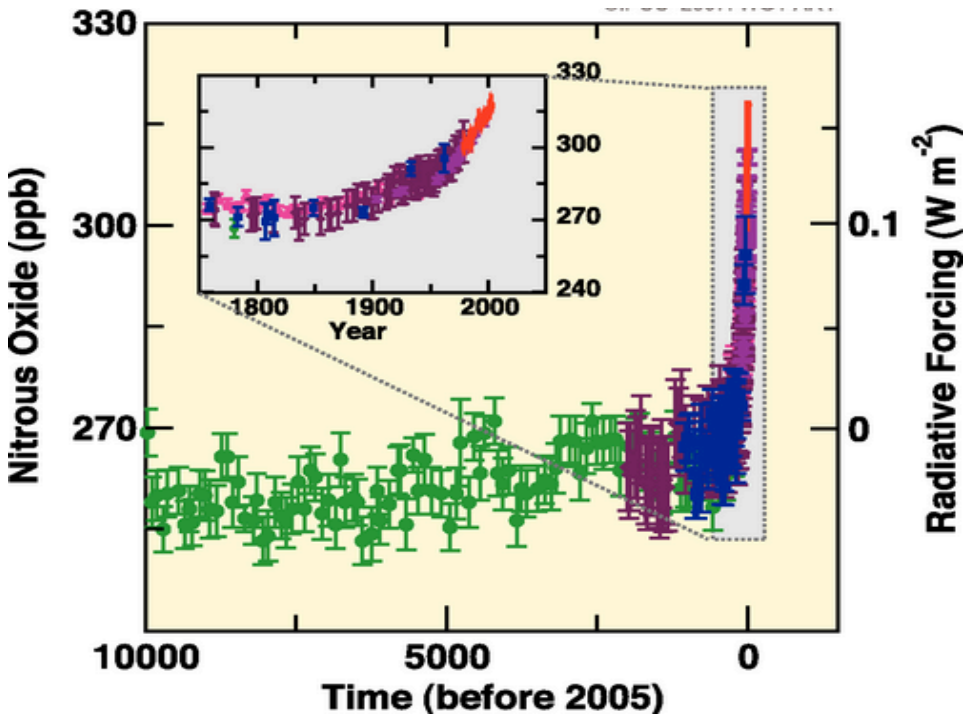
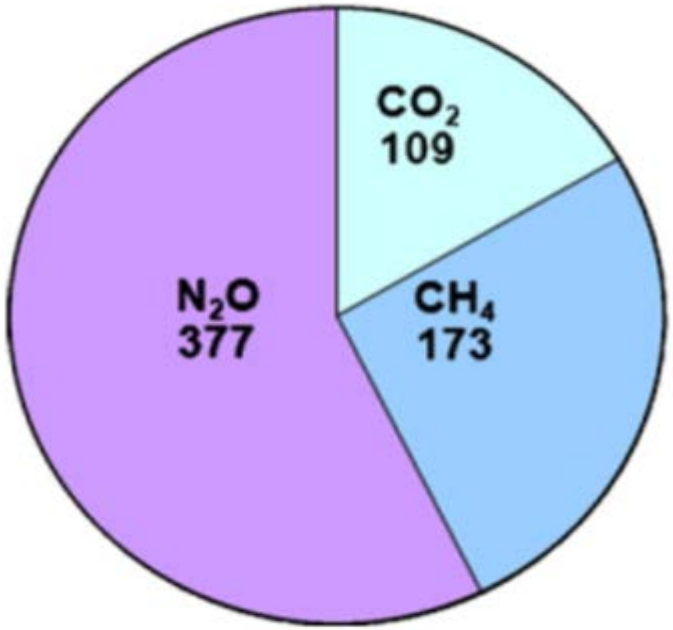
Objectives

1) Background on N_2O emission
2) Examples of field monitoring and developing emission factors
3) Quantitative assessment of the biophysical potential of various agricultural mitigation strategies to reduce N_2O emissions relevant to California cropping systems.

N_2O concentration in atmosphere



N_2O emission from U.S. Agriculture,2005



Unit: million tonnes CO_2 eq.

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Introduction

- California's Global Warming Solutions Act (Assembly Bill 32)- reduce CA GHG emissions to 1990 levels by 2020 and a further 80% by 2050
- In 2009, California emitted a total of 457 Tg CO_2e across all economic sectors, with agriculture contributing 32.1 Tg CO_2e, or 7.0% of the state's total (CARB, 2011)

California Agricultural Emissions by GHG (CARB, 2011)

Agricultural Source	2009 Emissions (Tg CO_2e)	Percentage of Total (%)
CH_4	18.7	58
CO_2	2.8	9
N_2O	10.6	33
Total	**32.1**	**100**

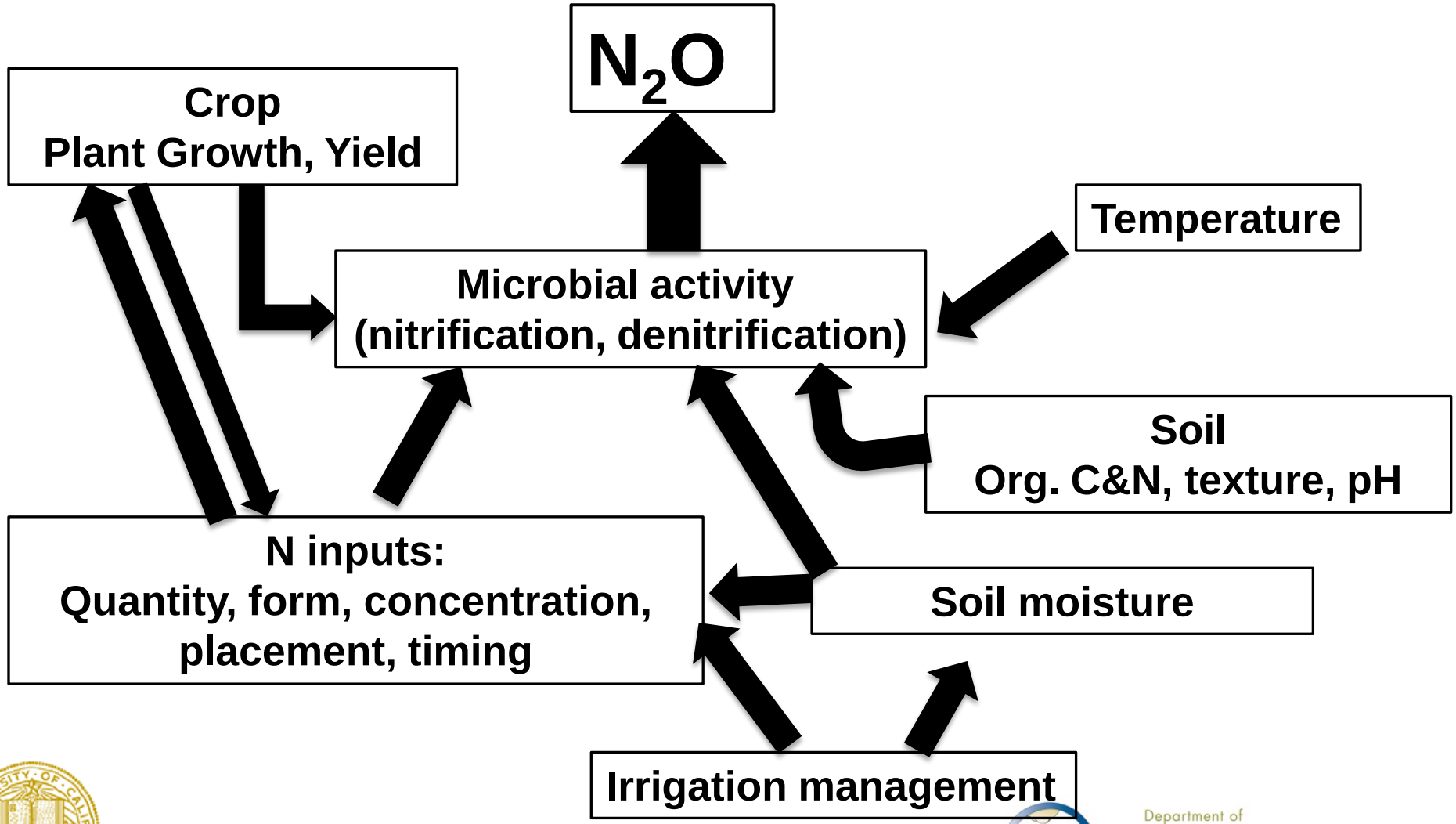
- N_2O emissions made up 33% of emissions from the agricultural sector, but only made up 4% of total emissions across all economic sectors.
- CO_2 accounts for 9% of agricultural emissions, while accounting for 86% of emissions across all sectors of California.

California Agricultural Emissions by Source (CARB, 2011)

Agricultural Source	2009 Emissions (Tg CO_2e)	Percentage of Total
Manure management	10.34	32.2
Enteric fermentation	9.28	28.9
Soil management	9.02	28.1
Energy use	2.63	8.2
Rice cultivation	0.58	1.8
Histosol cultivation	0.16	0.5
Residue burning	0.06	0.2

Cropland emissions make up <40% of total agricultural emissions, and <3% of total California state emissions

Controls on N_2O Emissions from Agricultural Soil



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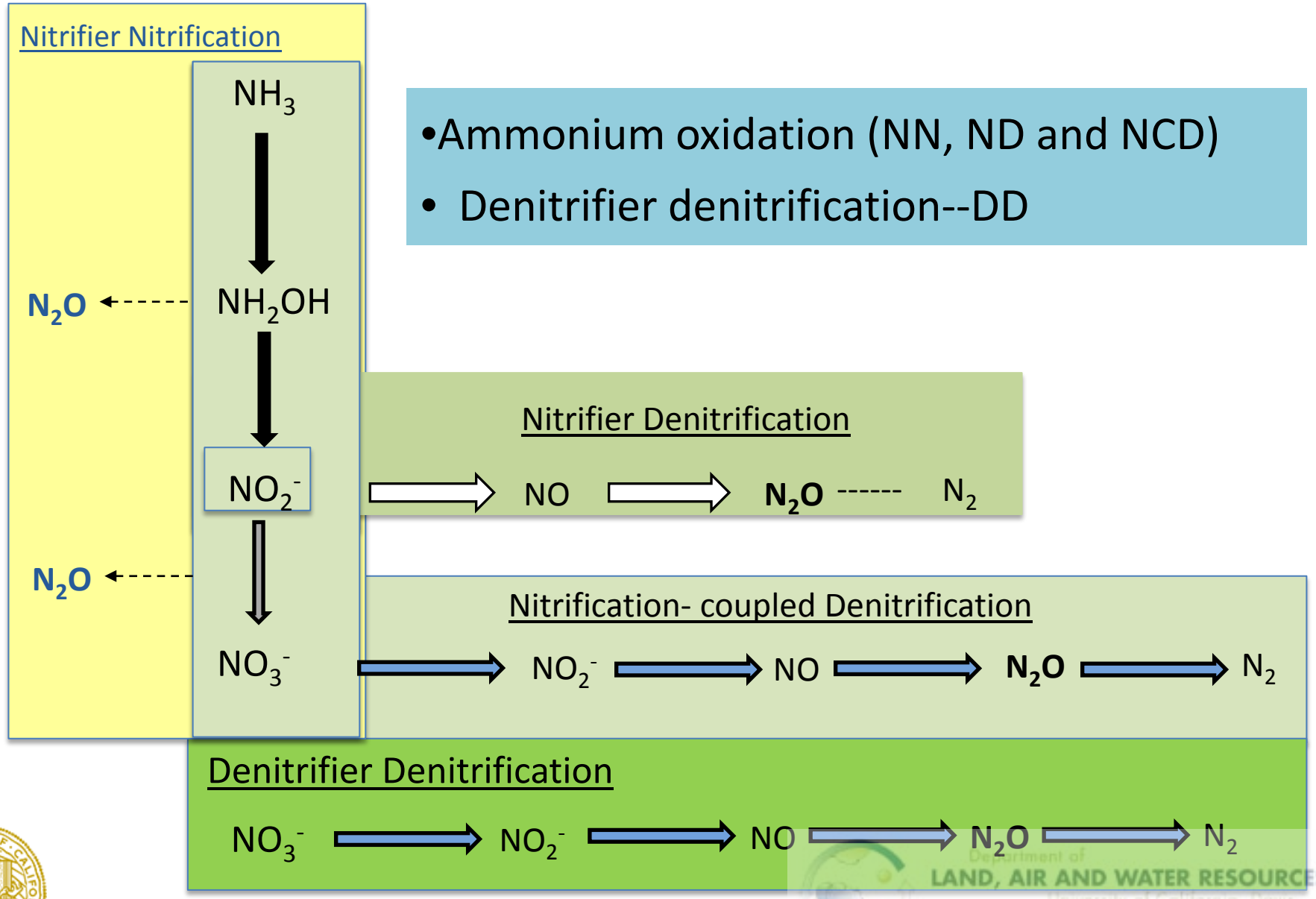
N_2O production pathways



- Ammonium oxidation (NN, ND and NCD)
- Denitrifier denitrification--DD

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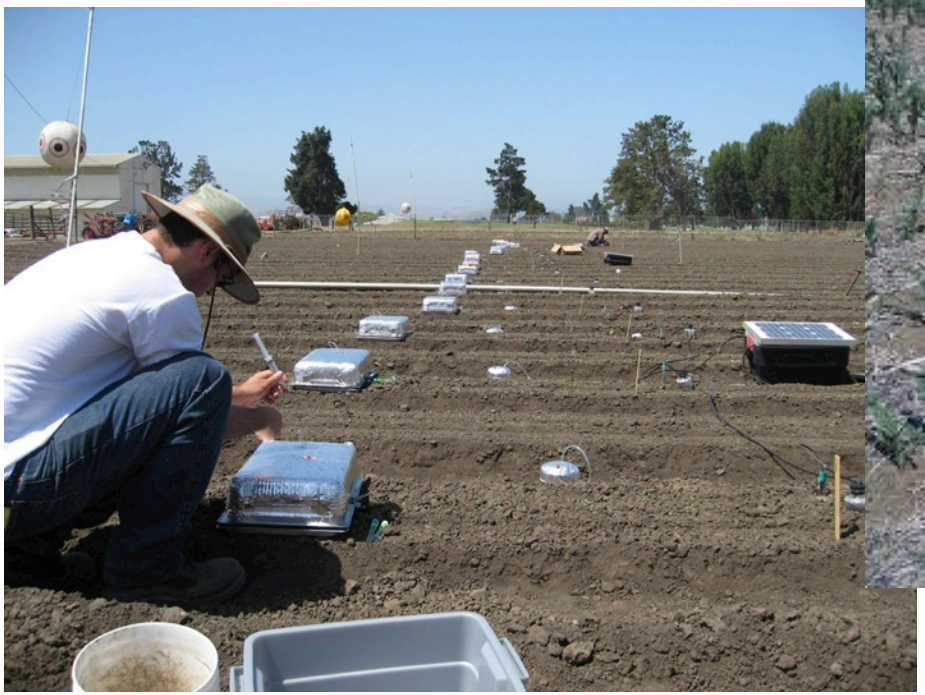
N_2O Flux in Response to N Fertilizer Rates

- 5 N fertilizer rates (n=4)



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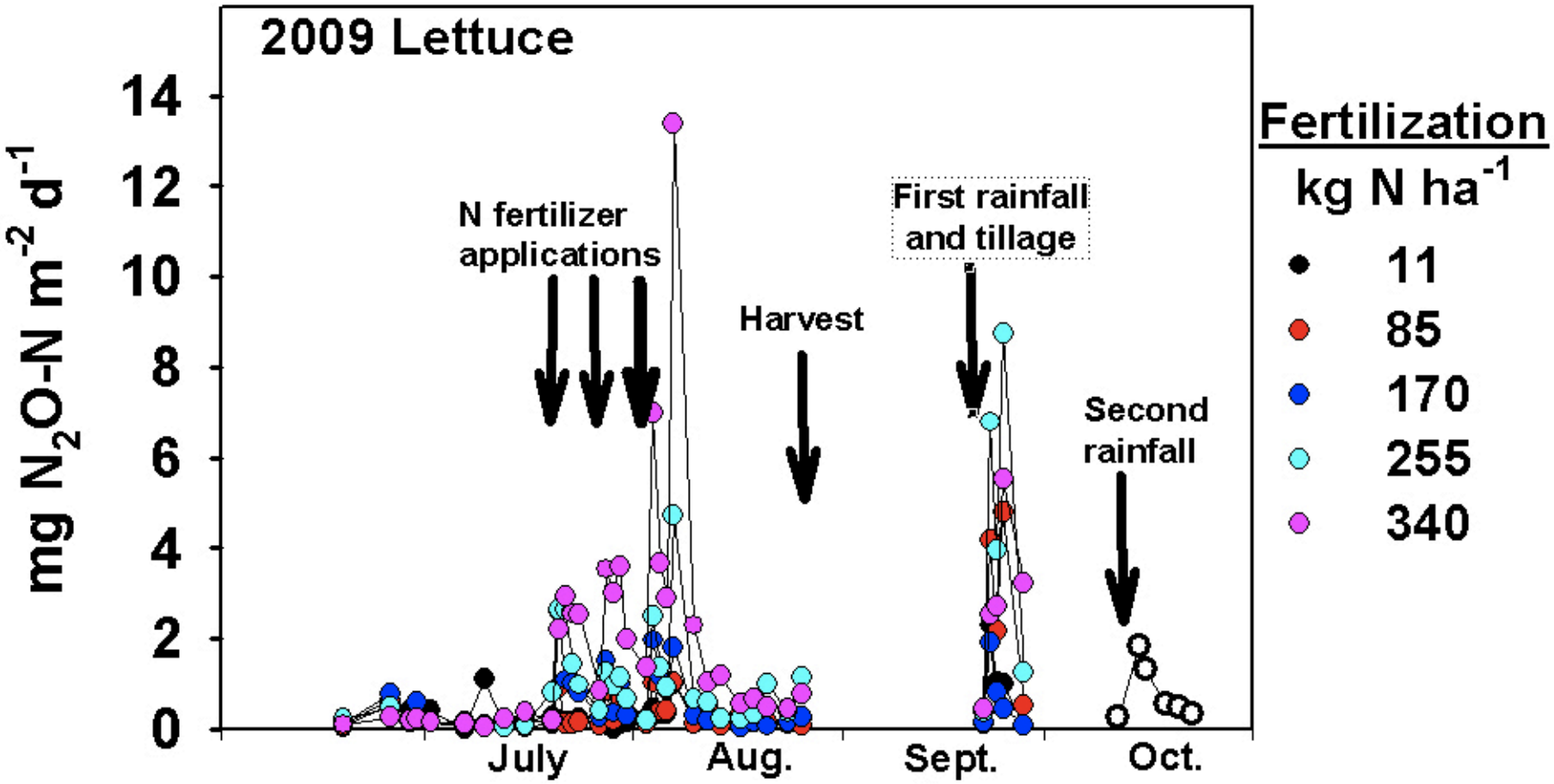
N_2O emissions are event based



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Emission Factors

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Emission Factors: tomato and lettuce

Lettuce				
kg N ha^{-1}	85	170	225	340
2009/10	.83	.41	.44	.40
2010/11	.76	.46	.41	.31
Tomato				
kg N ha^{-1}	75	162	225	300
2009/10	1.75	.91	1.35	1.51
2010/11	2.45	1.34	2.58	1.79

Note: Both low and high fertilizer N can cause increased N_2O emissions

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Mitigation Potential: Agricultural Croplands Methods and Approach

- Identified the “standard” or “conventional” management practice across studies
- Determined the baseline emissions value for this practice
- Calculate emissions with alternative management(s)
- Standard – alternative = Biophysical Mitigation Potential

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Management Activities Addressed

- Farmland Preservation
- Expansion of Perennial Crops
- Conservation Tillage
- Cover Crops and Organic Amendments
- Nitrogen Fertilizer Rate and Source
- Nitrogen Fertilizer Placement and Timing
- Nitrogen Fertilizer Efficiency Enhancers
- Irrigation Practices

Farmland Preservation

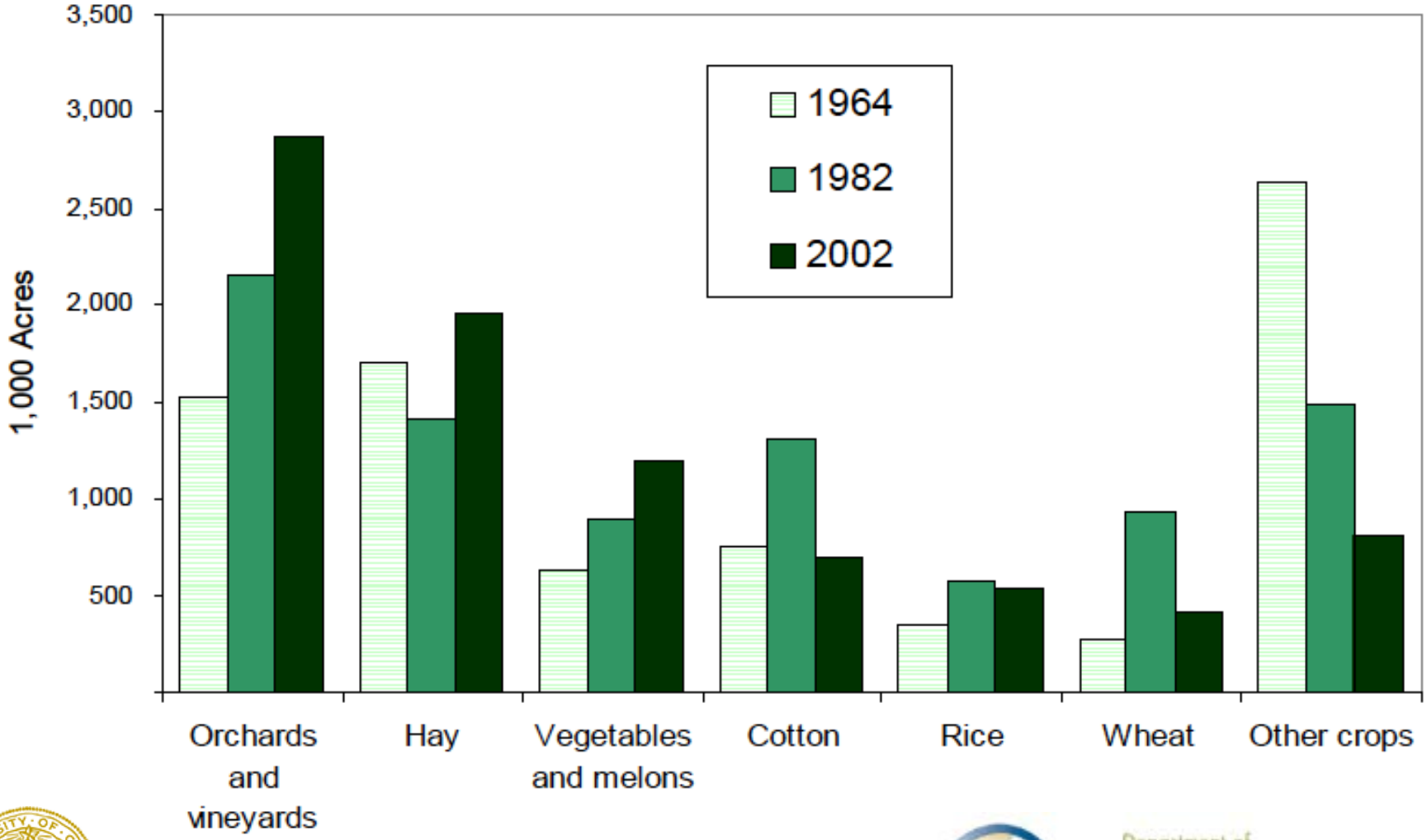
	Land Area (ha)		Average Emissions Rate ($t\ CO2e\ ha^{-1}\ yr^{-1}$)	
Land-use Category	**1990**	**2008**	**1990**	**2008**
Urban Land-uses	9,078	12,072	152.0	Data not available
Irrigated Cropland	139,407	131,439	2.19	1.99

- Haden et al. (2013) conducted an inventory of agricultural emissions from Yolo County
- Average emissions per unit area were about 70 times higher for urban land uses relative to irrigated cropland

Expansion of Perennial Crops

- The majority of California croplands (57%, 4.8 million acres) is occupied by perennial crops
  - Orchards and vineyards – 34%
  - Alfalfa and hay – 23 %
- Few reports of emissions on these crops in CA
  - Grapes – 1 study (Garland et al., 2011)
  - Almonds – 3 studies (Smart et al., 2006; Schellenberg et al. 2012; Alsina et al., 2013)
  - Alfalfa – 1 study (Burger and Horwath, 2012)

Trends show increasing perennial crops in California



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Conventional to Conservation Till or No-till

- Reduce the amount of physical disturbance
- GHG Mitigation
  1. Direct fuel savings
     - 0.03 - 0.10 t CO_2e ha^{-1} yr^{-1} with conservation tillage
     - 0.07 - 0.18 t CO_2e ha^{-1} yr^{-1} with no tillage
  2. Can reduce CO_2 emissions via building soil C
     - Difficult to quantify
       - Veenstra…Horwath (2007) show no effect of no till on soil C
       - Recent unpublished data from same plots do show C sequestration in no till
  3. Can increase N_2O emissions in first years
     - May only be realized in long-term no tillage systems

Conventional to Conservation Till or No-till

- Adoption very limited in California
  - <2% of acreage in 9 Central Valley Counties
- N_2O emissions reduced 0.04 t CO_2e ha^{-1} yr^{-1} across 5 studies (range -0.69 – 0.65 t CO_2e ha^{-1} yr^{-1})

Source	Data Type	Crop
Lee et al., 2009	Field	Corn, Sunflower, Chickpea
Garland et al., 2011	Field	Grapes
Kallenbach et al., 2006	Field	Tomato
Kennedy, 2012	Field	Tomato
De Gryze et al., 2009	Modeled	Alfalfa, Corn, Rice, Tomato, Wheat, Sunflower, Safflower, Cotton, Mellon

Cover Crops

- Plants that are typically not harvested
- Can be planted anytime of year
  - Winter legume to fix nitrogen and build soil organic matter
  - Rye in the fall to scavenge excess soil nutrients and suppress weeds

Mitigation Potential

- Decrease greenhouse gas emissions by sequestering soil C
- Increasing the efficiencies of N fertilization (i.e., scavenging for residual soil nutrients not taken up by cash crop)
- Leguminous cover crops may:
  - Increase direct field emissions since by increasing available soil nitrogen via BNF
  - Decrease indirect emissions by reducing the need for external N fertilizer inputs

  Increase emissions if irrigation is necessary to replenish soil moisture

Cover Crops

- Limited number of studies in California
- N_2O emissions reduced 0.04 t CO_2e ha^{-1} yr^{-1} across 4 studies (range -1.69 – 0.89 t CO_2e ha^{-1} yr^{-1})

Source	Data Type	Crop
Kallenbach et al., 2010	Field	Tomato
Kennedy, 2012	Field	Tomato
Smuckler et al., 2012	Field	Tomato
De Gryze et al., 2009	Modeled	Tomato, Alfalfa, Corn, Rice, Wheat, Safflower, Sunflower, Cotton, Melon

Organic Amendments

Mitigation Potential

- Decrease greenhouse gas emissions by sequestering soil C
- Increasing N fertilization efficiencies
- Modeling results show that combining farming practices (conservation tillage or cover cropping with manure application) reduce emissions

Source	Data Type	Crop
Burger et al., 2005	Field	Tomato
De Gryze et al., 2009	Modeled	Tomato, Alfalfa, Corn, Rice, Wheat, Safflower, Sunflower, Cotton, Melon

Crop Rotation

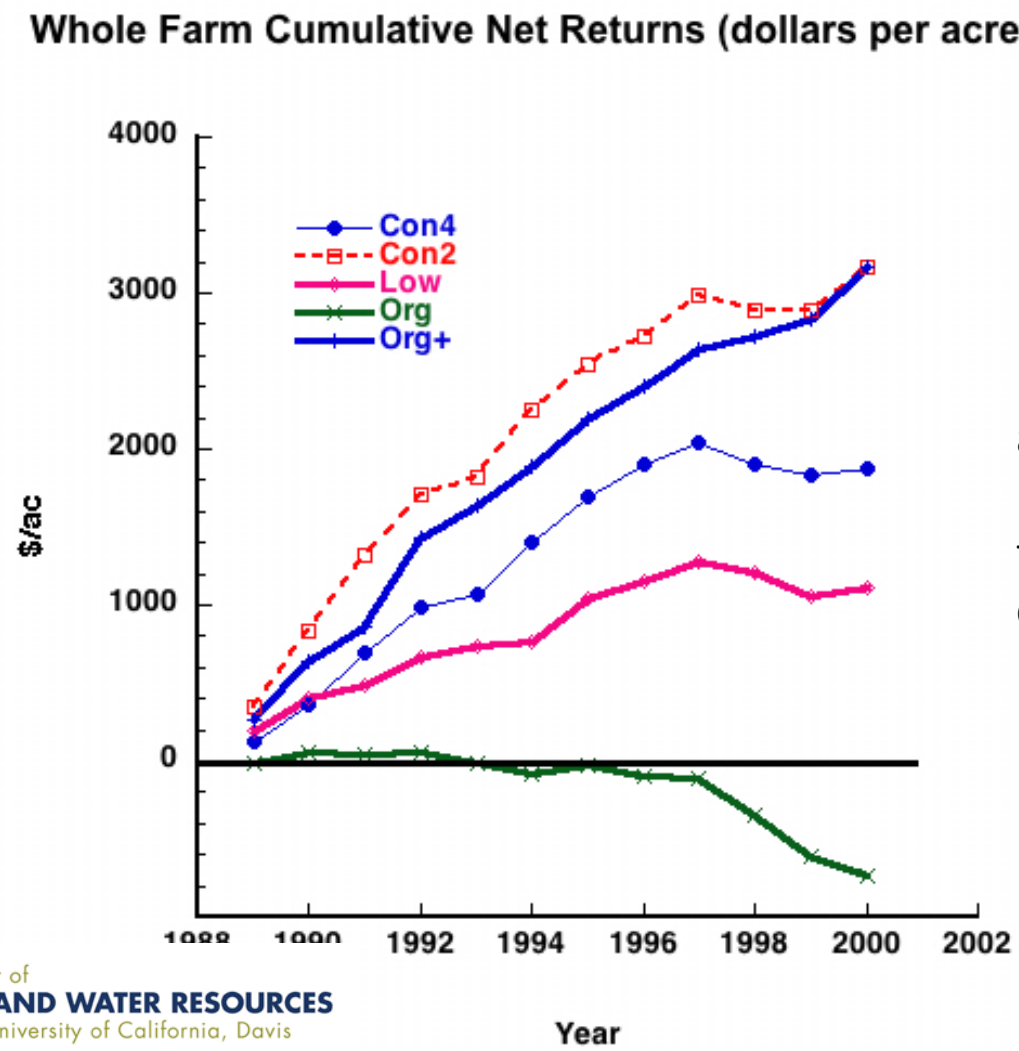
(Little research done; UCD)

Cumulative (kg ha^{-1}) N input, N output, soil N storage and loss (%) for organic, low-input, and conventional cropping systems at UCD long-term experiments, over 10 years

System	N input	N output	Soil N storage	Loss of Applied N %
			SAFS	
Organic	**1924**	**933**	**901**	**4.6**
Low-input	**1550**	**1186**	**327**	**2.4**
Conv-4	**1827**	**1339**	**79**	**22.3**
			LTRAS	
Organic	**3368**	**905**	**685**	**63.0**
Low-input	**1500**	**921**	**-329**	**60.5**
Conv-2	**2064**	**1288**	**-383**	**56.2**

Crop rotation diversity has a significant impact on N retention

Why growers shy away from multicrop rotations and cover crops



Multicrop rotations are generally less profitable if only on-farm economics are considered.

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Nitrogen Fertilizer Rate

- Nitrogen fertilization is an essential input in California croplands
- Numerous studies show increasing nitrogen fertilizer rates increases N_2O emissions
- Limited nitrogen rate studies on N_2O emissions in California
- Most comprehensive evaluation of the effects of N rate on emissions was recently completed and in process (Burger and Horwath, 2012, CARB report)

Nitrogen Fertilizer Rates in a California Vineyard

- Study in Napa County vineyard showed clear relationship between nitrogen fertilizer rate and N_2O emissions (Smart et al., 2006)

N input (kg N ha^{-1})	N_2O Emissions (kg CO_2eq ha^{-1} y^{-1})	Emission Factor (% of applied N emitted as N_2O)
0	14.88	
5.61	23.56	1.51
44.9	40.3	0.32

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Nitrogen Source in California Almonds

- Across 9 studies, fertilizer source reduced N_2O emissions 0.34 t CO_2e ha^{-1} yr^{-1} (-0.16 – 1.85 t CO_2e ha^{-1} yr^{-1})
- In almonds, replacing UAN with CAN reduced N_2O emissions 0.08 t CO_2e ha^{-1} yr^{-1}

Source	Data Type	Crop
Schellenberg et al., 2010	Field	Tomato
8 other studies	Field	Corn, Wheat outside of California

Nitrogen Fertilizer Placement and Timing

- Placement
  - Surface applied, injected into subsurface or delivered through irrigation
  - Lower emissions reported with shallow placement over deep placement in soil
  - No CA studies to date
- Timing
  - No CA studies, but the general relationship is understood
  - Lower emissions associated with fertilization when plant demand is high
- Concentration
  - lower emissions reported for less concentrated fertilizer formulations

Nitrogen Fertilizer Efficiency Enhancers and stabilizers

- Shows large promise of reducing N_2O emissions; cost and availability are major constraints
- Few studies conducted in CA to date
- Polymer coated fertilizers
  - Encapsulated or modified fertilizers for slow release
  - Over 20 studies showed 35% reduction in N_2O emissions
- Nitrification Inhibitors
  - A review of 80 studies showed an average reduction of 38% N_2O
- Urease Inhibitors
  - Not as effective as polymer coated or nitrification inhibitors

Irrigation Practices

- N_2O emissions reduced 0.78 t CO_2e ha^{-1} yr^{-1} across 3 studies (range 0.31 – 1.26 t CO_2e ha^{-1} yr^{-1})
- Sub-surface drip irrigation offer opportunities to reduce N_2O emissions with co-benefits of improved yield and water use

Source	Crop	Irrigation type
Kallenbach et al., 2010	Tomato	Furrow to subsurface drip
Kennedy, 2012	Tomato	Furrow to subsurface drip
Smuckler et al., 2012	Almond	Surface drip to microsprinkler

Summary of Managements

		Mitigation Potential ($t\ CO_2e\ ha^{-1}\ yr^{-1}$)			
Management Activity	**Predominant Gases Involved**	**Min**	**Mean**	**Max**	**Relative Potential**
Farmland Preservation	CO_2, N_2O, CH_4				Very High
Expansion of Perennial Crops	CO_2 N_2O				High
Conventional to Conservation Till	N_2O	-0.69	0.04	0.65	None – Low
Cover Crops and Organic Amendments	N_2O	-1.69	0.04	0.89	Low – Medium
N Fertilizer Rate	N_2O				Medium
N Fertilizer Source	N_2O	-0.16	0.34	1.85	Low – Medium
N Fertilizer Timing and Placement	N_2O				Low – Medium
N Fertilizer Efficiency Enhancers[1]	N_2O				Low - Medium
Irrigation Practices	N_2O	0.31	0.78	1.26	Medium

Key Findings

- Farmland preservation reduces GHG emissions compared to urbanization.
- Perennial crops emit less GHG than row crops.
- Conservation tillage practices provide agronomic and environmental benefits, but is uncertain to its potential to reduce GHG.
- Cover crops and organic amendments reduce N inputs and increase nutrient cycling efficiencies, but may also increase direct N_2O emissions.
- Increasing N fertilizer rates increases N_2O emissions, but, N fertilization is required for max yield. **Must increase fertilizer N use efficiency.**
- N fertilizer source: low to moderate potential to reduce N_2O emissions.
- N placement, concentration and timing can reduce N_2O emissions.
- Nitrification inhibitors & slow release fertilizers can reduce N_2O emissions
- Irrigation technologies: sub-surface drip irrigation improve yield and reduce N_2O emissions.

Thank you!

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