Overview of ARB’s Research on Nitrous Oxide (N₂O) Emissions from Agriculture

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ARB Research Seminar
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California’s 2013 Emission Inventory

- \( \text{N}_2\text{O} \) is a potent GHG
  - long-lived - 114 years
  - GWP of 298 (AR4, 100-year)
- Agriculture is the dominant source of \( \text{N}_2\text{O} \)
Background on Soil $\text{N}_2\text{O}$ Emissions

• Highly variable
• Production and consumption are microbially driven
• Regulating factors
  ▫ Ag practices
    • N application rate
    • Crop type
    • Fertilizer type
  ▫ Soil conditions
    • Soil moisture
    • Soil organic carbon content
    • Soil pH
    • texture
Variability of N$_2$O Emission Rates

IPCC default emission factor of 1%
Variability of N$_2$O Emission Rates

![Graph showing variability of N$_2$O emission rates over time with annotations for different seasons and events.](image-url)
Spatial Variability of $\text{N}_2\text{O}$ Emission Rates

Mathieu et al., 2006
Motivation

- AB 32 Early Action Measure 31
- Limited field observations in California
- Discrepancy between top-down and bottom-up inventories

Objectives

- **Baseline Emissions**
  - Improve emission estimates of $\text{N}_2\text{O}$ for CA agricultural

- **Mitigation Options**
  - Identify mitigation opportunities from soil management

- **Track Progress**
  - Verify assumed reductions are achieved
Research Strategy

- Multi-agency collaboration: ARB, CDFA, CEC, CalRecycle, Packard Foundation, USDA
- Total budget $2.9 million
- Stakeholder oversight
  - San Joaquin Valley Agricultural Technical Committee
  - $N_2O$ work group
- Stakeholders: Researchers, growers, fertilizer industry, air districts, federal (US EPA, USDA), state
ARBIT Project Progress

- Ag baseline and mitigation field studies - completed
- Modeling tool development - near completion
- Emission verification and inventory development - ongoing

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<tr>
<td></td>
<td>Monitoring baseline N2O emissions from CA ag soils</td>
<td>N2O emissions from CA dairy systems</td>
<td>Modeling baseline N2O emissions from CA ag soils (DNDC)</td>
<td>Atmospheric Measurements of GHGs and Inverse Modeling of Emissions</td>
<td>Dairy Silage Emissions and Mitigation Strategies</td>
<td>Evaluating N2O Mitigation Options in California Cropping Systems</td>
<td>Ag Soil GHG Mitigation Tool Development (DNDC)</td>
<td>Temporal and spatial emission maps for counties, air basins, and state (DNDC, in-house research)</td>
<td>Data analysis of regional GHG emissions and inverse modeling (in-house research)</td>
<td>N2O emissions from motor vehicles (in-house)</td>
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Methods

Aerial Measurements

Walnut Grove Tower

Chamber Measurements

Mobile Monitoring Platform
## California Crops Studied

<table>
<thead>
<tr>
<th>Crop</th>
<th>Acreage, 1000 acres</th>
<th>Value in billion $</th>
<th>N Application Rate kg N/ha</th>
<th>Emission Factor %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hay (61% alfalfa)</td>
<td>1370</td>
<td>1.6</td>
<td>43-55</td>
<td>4-12</td>
</tr>
<tr>
<td>Almonds</td>
<td>840</td>
<td>5.8</td>
<td>230</td>
<td>0.4</td>
</tr>
<tr>
<td>Grapes</td>
<td>820</td>
<td>5.6</td>
<td>5-17</td>
<td>0.3-8</td>
</tr>
<tr>
<td>Corn</td>
<td>595</td>
<td>0.7</td>
<td>600-1200 (silage)</td>
<td>0.9-2</td>
</tr>
<tr>
<td>Rice</td>
<td>562</td>
<td>0.8</td>
<td>140-224</td>
<td>0.1-0.6</td>
</tr>
<tr>
<td>Wheat</td>
<td>394</td>
<td>0.3</td>
<td>91-254</td>
<td>0.2-0.6</td>
</tr>
<tr>
<td>Tomatoes</td>
<td>288</td>
<td>1.2</td>
<td>75-300</td>
<td>0.9-2</td>
</tr>
<tr>
<td>Cotton</td>
<td>278</td>
<td>0.6</td>
<td>50-150</td>
<td>0.3-0.7</td>
</tr>
<tr>
<td>Lettuce</td>
<td>215</td>
<td>1.7</td>
<td>84-336</td>
<td>0.4-0.8</td>
</tr>
</tbody>
</table>

Source: USDA 2014
Process-Based Geochemical Model

**INPUT**
- Climate
  - Temperature
  - Precipitation
  - N deposition
- Soil properties
  - Texture
  - Organic matter
  - Bulk density
  - pH
- Management
  - Crop rotation
  - Tillage
  - Fertilization
  - Manure use
  - Irrigation
  - Grazing

**PROCESSES**
- DNDC
  1. Soil water movement
  2. Plant-soil C dynamics
  3. N transformation
- Availability of water, NH4, NO3, and DOC
- Competition

**OUTPUT**
- Used by soil microbes
  - Emissions of N2O, NO, N2, CH4 and CO2
- Used by plants
- N, P leaching
- Crop growth
• 40 sites
• 9 California crops - alfalfa, almonds, beans, corn silage, grapes, rice, sunflowers, tomatoes and wheat
## Mitigation Measures Simulated by DNDC

<table>
<thead>
<tr>
<th>Farming Practice</th>
<th>Mitigation Option</th>
<th>Mitigation Potential (% Reduction)</th>
<th>Included in ARB studies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fertilization</td>
<td>Adjusted rate</td>
<td>Various</td>
<td>×</td>
</tr>
<tr>
<td></td>
<td>Split application</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Nitrification &amp; urease inhibitor</td>
<td>&gt;40</td>
<td>×</td>
</tr>
<tr>
<td></td>
<td>Organic fertilizer</td>
<td>various</td>
<td>×</td>
</tr>
<tr>
<td></td>
<td>Fertilizer formulation</td>
<td>30-75</td>
<td>×</td>
</tr>
<tr>
<td></td>
<td>Fertilizer placement</td>
<td>70</td>
<td>×</td>
</tr>
<tr>
<td>Irrigation</td>
<td>Surface drip</td>
<td>40</td>
<td>×</td>
</tr>
<tr>
<td></td>
<td>Subsurface drip</td>
<td>80</td>
<td>×</td>
</tr>
<tr>
<td>Tillage</td>
<td>Reduced till</td>
<td></td>
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<tr>
<td></td>
<td>No-till</td>
<td></td>
<td></td>
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<tr>
<td>Cover crops</td>
<td>Legume</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Nonlegume</td>
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DNDC Applications

- Statewide \( \text{N}_2\text{O} \) emissions estimate for agricultural soil management
- Identifying management practices that may mitigate \( \text{N}_2\text{O} \) emissions
Continued Multi-Sector N$_2$O Research

- DNDC’s to quantify ag mitigation potential (U. New Hampshire, due Fall 2017)
- On-road motor vehicle emission research (in-house)
- Expand ambient monitoring (in-house, JPL, starts Fall 2016)
  - Tower monitoring
  - Aerial grab samples
  - Mobile monitoring platform
- Improve emission estimates from manure management (external contract, beginning Fall 2016)
Today’s Presentation

Evaluating Mitigation Options of Nitrous Oxide Emissions in California Cropping Systems

Dr. Martin Burger
University of California, Davis