Rice irrigation strategies: Alternate wetting and drying and methane reductions

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United States Rice Production

Although the US produces <2% of the world’s rice, it is among the top 5 rice exporting nations

USDA NASS Quick Stats, 2015
Arkansas’s Delta Aquifers

Demand:
• Some rice-growing counties in the AR delta need to reduce groundwater pumping by 74% to reach sustainable levels – USGS, 2013

Alternate Wetting and Drying (AWD) irrigation
• Reduces water usage by 20-70%
• Reduces methane emissions by almost 50%
• Minimal yield loss (Nalley et al., 2014)

Has Financial Encouragement for Implementation:
1. Water: Since May 2016 in AR by USDA’s NRCS Environmental Quality Incentives Program (EQIP)
2. GHG: Qualifies with American Carbon Registry for selling CH₄ savings on open CO₂ offsets market
Anthropogenic contributions are 60% of global CH$_4$ emissions to atmosphere.

CH$_4$ has 28 to 34 times the radiative forcing capacity of CO$_2$ over a 100 year time horizon (with and without climate-carbon feedbacks).

- **29%**
  - 96 Tg yr$^{-1}$ [85-105]
  - Fossil fuels

- **27%**
  - 89 Tg yr$^{-1}$ [87-94]
  - Ruminants

- **23%**
  - 75 Tg yr$^{-1}$ [67-90]
  - Landfills

- **11%**
  - 36 Tg yr$^{-1}$ [33-40]
  - Rice agriculture

Myhre et al., 2013 IPCC report.
Research Questions

1) What degree of methane reduction can AWD generate at the production field scale?

2) How does AWD irrigation affect rice yield?
Site Information

Isbell Family Farm
50+ years of rice production

**Soil type:** Perry silty clay
(poorly drained), with clayey alluvium parent material

**Planted:**
RiceTec CLXL 745 hybrid
In rice-rice rotation

**Slope:** 0%
(12.3% of total rice in Arkansas is grown on zero-grade)

Picture from: http://www.isbellfarms.com/
Research Approach

Open-path eddy covariance measurements:
- CO$_2$, H$_2$O, CH$_4$, LE, H (Li-7500A, Li-7700)
- CSAT3-3D sonic anemometer
- 20 Hz
Southern winds in summer

Bio-met data:
Single time point
- Soil BD, particle size, mineral concentration
Plant growth – Sporadic
- Crop growth stage
- GPS-Yield monitor
Slow response (30 min)
- Relative humidity
- Air, soil temperature
- Water table depth

2015 design with 2 x 60 acre fields
cf. plot studies of 144 m$^2$
Production-scale Research Approach: Continuous measurements

- Air temp, RH, pressure, Wind speed
- Camera
- Dataloggers
- Rainfall
- Solar power supply system

Fast eddy covariance to measure turbulent transport of:
- \( \text{CH}_4 \)
- \( \text{CO}_2 \) and \( \text{H}_2\text{O} \)

Soil:
- Heat flux
- Temperature
- Moisture, pH

Solar and long-wave radiation
Photosynthetically active radiation
Eddy covariance measures turbulent transport

The vertical transport of energy and matter in the atmospheric boundary layer is almost entirely governed by turbulent motion.

\[ F = \rho_{\text{air}} w' s' \]

w’ = vertical wind fluctuations, s’ = scalar concentration fluctuations

Figure modified after LI-COR, Inc.
$\text{CO}_2$ and $\text{H}_2\text{O}$ concentrations from a May afternoon

Just 4 minutes!
Transport of gases

A parcel of air with above average methane moving away from the surface.

A parcel of air with low methane concentration moving towards the surface.
Q1: Seasonal Methane Emissions

Gap-filling with ANN model similar to Knox et al., 2015 GCB; Code from Sturtevant
Model fit with $r^2$ of 0.77-0.79 and RMSE of 0.068 (CF) and 0.025 (AWD) $\mu$mol m$^{-2}$ s$^{-1}$

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## Q1: Total Methane Emissions

<table>
<thead>
<tr>
<th></th>
<th>Conventional flooding</th>
<th>AWD</th>
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<tbody>
<tr>
<td>This study (2015)</td>
<td>182</td>
<td>38</td>
<td>kg CH$_4$-C ha$^{-1}$</td>
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<td><strong>79% total difference; AWD cuts CH$_4$ by 52-64%</strong></td>
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<td><strong>Other Arkansas studies (closed chamber measurements at field station):</strong></td>
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<td>Linquist et al., 2015</td>
<td>144</td>
<td>11.8-71.4</td>
<td>kg CH$_4$-C ha$^{-1}$</td>
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<tr>
<td>Rogers et al., 2014</td>
<td>195 (mean)</td>
<td></td>
<td>kg CH$_4$-C ha$^{-1}$</td>
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<td><strong>EPA emission factor: 177 kg CH$_4$-C ha$^{-1}$</strong></td>
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Q2: Yield Results – Minimal Differences

Although there was spatial variation in yield, there was little overall difference between the two fields.

The AWD field actually had a marginally higher yield than the conventionally flooded field.
The new “Delta Flux” (ΔF) Network Regional contribution to AmeriFlux

Up to 20 more towers across 10-12 sites!

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Runkle et al., 2017, Agricultural & Environmental Letters