Agriculture and Food Research Initiative: Rice in the Delta – The Potential to Mitigate Subsidence and Enhance Sustainability

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AFRI Grant (2010 – 2016).
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Demonstrate rice-based cropping systems as an agricultural solution in the Delta by:

a. Mitigating on-going degradation through changing redox, biogeochemistry and peat oxidation
   i. GHG emissions
   ii. soil loss
   iii. subsidence

b. Reducing risks to California water supply

a. Protecting water quality
Rice Impacts in the Delta

Drivers:
- Soil Organic Matter
- C:N ratio
- Redox (O2, NO3, Fe, SO4)
- Land Use
- Cultural Practices
- Irrigation
- Climate and Temperature

Water Resources
- Water Quality - DOC
- Water Quality - Hg
- Water Supply - Volume
- Water Supply - Conveyance
- Levee Stability
- Seepage
- Oxidation
- Subsidence / Accretion
- Accretion
- C - Sequestration
- GHGs

Rice Fields
- Seasonal Hydrology
- Agro-nomic Practices
- Cultivars

Terrestrial Crops
- Seasonal Hydrology
- Agro-nomic Practices
- Cultivars

Island Mgmt
- Flow to Drains

Net Island Exports

AFRI
U.S and California Paddy Rice Yields (CA Rice Commission, 2009)

80 sacks/ac
500,000 acres


500,000 acres +/- in California
Average Land Use in Primary Delta 2007-2012
Total Land Area is about 320,000 acres
(Butler and Zhou, 2012)

- Corn 36%
- Alfalfa & Pasture 26%
- Grain Crops 11%
- Vines 6%
- Tree Crops 2%
- Tomato & Vege 4%
- Wetlands 1%
- Rice 1%
- Fallow 2%
- Non-Irr Agric 6%
- Urban 5%
- Rice 1%
- Fallow 2%

Bottom Line

• Lots of rice in the Central Valley.
• About 1% of crops grown in Delta are rice.
• About 1% of rice grown in California is grown in the Delta.

• So why do we care about rice in the Delta?
Stories

• About the Delta, farming and water
• About politics that can feel like California vs. the Delta
• About levee costs and island values
• About shifting how we think of land stewardship and agriculture in the Delta
Stories

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  • About politics that can feel like California vs. the Delta
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Conveyance and Exports
Watershed of the Sacramento-San Joaquin Delta and Regions that Use Delta Water

CVP Target--
- Serves 2M Ac Irr. Ag
- Delivers 7M Ac-ft
  - 70% to Ag
  - 9% to Urban
  - 11% to wildlife

State Target --
- Serves 0.75M Ac Irr. Ag
- Delivers 3M Ac-ft
  - 30% to Ag
  - 70% to Urban
Island Transitions from Wetlands to Today’s Agriculture

Flooded Marshland

Reclaimed
To Early Agriculture

To Current Agriculture
Delta Island Model Before Farming

- Carbon Sequestration
- Accretion

Marsh Plants

- Peat

Wetland Slough Interactions

- Water Treatment
- Nutrient Sequestration and Removal
- Aquatic Habitat

High Groundwater Table

Groundwater Table
Early Agriculture

- Crops
- Peat
- Oxidized Peat
- Slough
- Groundwater Table
- Managed Groundwater Table

Comprised Wetland Slough Interactions

Carbon Losses
GHG Emissions
Subsidence Initiation

Pump
Siphon
AFRI
X
Current Agriculture

Sustainability Affected by Various Local, Regional and State Scale “Costs”

- Increased Pumping Costs
- Increased GHG Emissions
- Increased Non-Farmable Area
- Increased pressure head
- Increased Seepage
- Increased Levee Failure Risks

- Subsidence and Dropping Island Elevations
- Dropping GW Table
- Decreasing Peat Layer

AFRI
The Delta, Farming and Water

• 100 years of farming and water management has led to deep Delta with subsidence > 20 ft in some areas

• “Farmer” Expenses are rising with costs borne by both farmers and by society:
  – Levees and water resource risks
  – GHG emissions
  – Increased energy costs to drain islands
  – Water quality
  – Habitat value

Culture of Farming…. With Broad Implications
Stories

• About the Delta, farming and water
• About politics that can feel like California vs. the Delta
• About levee costs and island values
• About shifting how we think of land stewardship and agriculture in the Delta
Delta Economy

• To the Delta
  – Agricultural Economy (DPC, 2012)
    • $800M direct (DPC, 2012)
    • $2.6B Total w/i Delta ($5.4B Total for CA)
  – Recreation (DPB, 2012)
    • $330M
  – Fisheries (Goldman, 1998)
    • $336M expenditures

• Estimated Annual Economy from Agriculture, recreation and fishing: $3.5B
California Economy

• To California:
  – Drinking Water
    • Provides Drinking Water to 22M Californians
      – $3.6B billed by water agencies to households annually
  – Irrigation Water to 2.75M acres outside the Delta
    • Increases land values by about $24B
    • San Joaquin Valley – Ag production and processing $36B annually
  – Dependence upon within Delta Infrastructure
    • Highways, electrical grid, gas, etc....

>$60B
Stories

• About the Delta, farming and water
• About politics that can feel like California vs. the Delta
• About levee costs and island values
• About shifting how we think of land stewardship and agriculture in the Delta
DRMS: Smattering of risk information

**COMBINED RISKS**

The combined risk of an individual island being flooded due to earthquakes, high water and dry-weather events can be estimated. Considering the probability of levee failures from all hazards under business-as-usual practices, the expected annual probability of island flooding is illustrated in Figure 12. This figure shows that islands in Suisun Marsh and the western and central Delta are the most vulnerable.

### Table 1 – DURATION AND COST OF REPAIRS for earthquake-induced levee failures

<table>
<thead>
<tr>
<th>Number of flooded islands</th>
<th>Estimated range of cost of repair and dewatering [$million]</th>
<th>Estimated range of time to repair breaches and dewater [days]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>43 – 240</td>
<td>136 – 276</td>
</tr>
<tr>
<td>3</td>
<td>204 – 490</td>
<td>270 – 466</td>
</tr>
<tr>
<td>10</td>
<td>620 – 1,260</td>
<td>460 – 700</td>
</tr>
<tr>
<td>20</td>
<td>1,400 – 2,300</td>
<td>750 – 1,020</td>
</tr>
<tr>
<td>30</td>
<td>3,000 – 4,200</td>
<td>1,240 – 1,660</td>
</tr>
</tbody>
</table>

Source: DRMS Risk Report (URS/JBA 2008c), Table 13-9

<table>
<thead>
<tr>
<th>Mean annual probability of failure</th>
<th>Probability of failure over a 25-year period [2005 conditions]</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt; 7%</td>
<td>&gt; 84%</td>
</tr>
<tr>
<td>5 to 7%</td>
<td>72 to 84%</td>
</tr>
<tr>
<td>3 to 5%</td>
<td>53 to 72%</td>
</tr>
<tr>
<td>1 to 3%</td>
<td>22 to 53%</td>
</tr>
<tr>
<td>&lt; 1%</td>
<td>&lt; 22%</td>
</tr>
</tbody>
</table>

Figure 12  Mean annual probability of levee failure in the Delta Region from the combined risk of earthquakes, high water and dry-weather failures [2005 conditions]

Source: DRMS Risk Report (URS/JBA 2008c), Figure 13-15
Economic Costs include the direct economic losses associated with the repair of levees, tracts, islands, and infrastructure; the replacement of lost homes and the payment of living expenses for displaced persons; agricultural losses; and the lost water supply to State and federal water contractors and local water districts.

Economic Impacts include the indirect economic losses associated with the loss of potential revenues because of services not provided. These include the loss of revenue that customers of Pacific Gas and Electric Company, Metropolitan Water District of Southern California, railroads and other service providers suffer because they lose the services these companies provide, combined with lost wages and jobs that result because consumers lose these services.

Figure 10a  Probability of exceeding an amount in total economic costs due to high water-related levee failures over a 25-year period [2005-2030]

Figure 10b  Probability of exceeding an amount in total economic impacts due to high water-related levee failures over a 25-year period [2005-2030]

Source: Adapted from DRMS Risk Report [IERS/JBA 2008c], Figures 13-21a [costs] and 13-21b [impacts]
Stories

• About the Delta, farming and water
• About politics that can feel like California vs. the Delta
• About levee costs and island values
• About shifting how we think of land stewardship and agriculture in the Delta
Hypotheses

1. Rice can halt increasing risks due to subsidence
   – From seepage failures (direct)
   – From static slope stability failures (direct)
   – Potentially from seismic (implied)

2. Rice is feasible in the Delta

3. Cost / Benefits favor the adoption of rice

4. Other environmental impacts can be managed against BAU scenario
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Nitrogen Budget: Relating to Subsidence
Kirk et al (2013)

Field 10 Nitrogen Uptake in 0N plots = 167 kg N/ha

Calculations:

\[
121 + 40 \text{ kg N/ha (surface and subsurface)}
\]

\[
\% \text{ N use efficiency}
\]

**Assuming NUE from all sources to be equal

\[
\text{kg N/ha mineralized from peat during the growing season}
\]
Net Ecosystem Exchange (g-C/m²/d)  
Hatala et al 2012

Grazed peatland net ecosystem exchange

Rice paddy net ecosystem exchange
Subsidence in Corn and Rice – Deverel et al 2013

Corn Subsiding Approximately 1.2 cm/y

Rice Accreting Approximately 0.4 cm/y
### Estimating Subsidence Rates in the Delta

<table>
<thead>
<tr>
<th>Elevation Change</th>
<th>Reference</th>
<th>Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>mm/yr</td>
<td>Ft/50-years</td>
<td></td>
</tr>
</tbody>
</table>

**Corn**

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>-12</td>
<td>-2.0</td>
<td>Deverel et al 2013</td>
</tr>
<tr>
<td>-22</td>
<td>-3.6</td>
<td>Deverel and Leighton, 2010</td>
</tr>
</tbody>
</table>

**Average**: -2.8

**Peatlands**

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>-1.5 to -2.6</td>
<td>-0.3</td>
<td>Hatala et al 2012</td>
</tr>
<tr>
<td>-4.6</td>
<td>-0.8</td>
<td>Deverel and Rojstaczer, 1996</td>
</tr>
<tr>
<td>-5 to -20</td>
<td>0.0</td>
<td>Deverel and Leighton, 2010</td>
</tr>
</tbody>
</table>

**Average**: -0.4

**Rice**

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>-1 to -1.4</td>
<td>-0.2</td>
<td>Hatala et al 2012</td>
</tr>
<tr>
<td>4</td>
<td>0.7</td>
<td>Deverel et al 2013</td>
</tr>
<tr>
<td>-3</td>
<td>-0.5</td>
<td>Kirk et al 2013</td>
</tr>
</tbody>
</table>

**Average**: 0.0
Force Balance Enables Levees to Hold Back River

Further Subsidence Reduces Resistive Forces

Rice maintains elevations and forces

Soil Resistance Forces

Rice

Static Forces

Fill

3:1

2:1

River

Hydraulic Forces

Peat Mud

Sand

AFRI
Future Opportunities with Rice and Wetlands

Current Agriculture

With Rice (Now)

With Rice (One Future Scenario)
Implementing Rice on a Delta Island (Now)

- Raise GW elevation
- Stop (reverse) subsidence

Change GHG signature From rice

• Oxidized Peat
• Reducing Peat

Ground-water Table

Crop

Rice

Pump

Siphon

Slough
Implementing Rice (One future scenario)

- Stabilize GW elevation
- Stabilize or reverse subsidence
- Stabilize levee risks adjacent to rice
- Stabilize Seepage

Decrease Carbon Emissions
Hypotheses

1. Rice can halt increasing risks due to subsidence
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2. Rice is feasible in the Delta

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4. Other environmental impacts can be managed against BAU scenario
Estimates From Growers in the Delta (January 2013)

• Break-even
  – Grower 1: 70 sacs/ac at $18/sack = $1260/ac
  – Grower 2: 75 sacs/ac at $17/sack = $1275/ac

• Sample of Recorded Yields
  – Data from growers in 2004 and 2005 showed rice yields ranging from 65 – 85 sacks
  – Recent conversations with Delta farmer – 80 sacks/ac

California Average is about 80 sacks/ac +/-
Price of Rice ($/cwt.)

Weighted season-average farm price for rough rice, 1993/94 – 2009/10 (Butler et al 2012)

**Long grain:**
- 85 sacks needed at $15/sack

**Medium/short grain:**
- 70 sacks needed at $18/sack

AT $1275/ac then ....

**Legend:**
- Blue line: Long grain
- Red line: Medium/short grain
### Very Small Plot Yields, 2012

<table>
<thead>
<tr>
<th>Variety</th>
<th>Type</th>
<th>Grain Yield 14%</th>
</tr>
</thead>
<tbody>
<tr>
<td>M105</td>
<td>M</td>
<td>8250 (1)</td>
</tr>
<tr>
<td>S102</td>
<td>S</td>
<td>8060 (2)</td>
</tr>
<tr>
<td>09Y2141</td>
<td>SWX</td>
<td>7920 (3)</td>
</tr>
<tr>
<td>M104</td>
<td>M</td>
<td>7630 (4)</td>
</tr>
<tr>
<td>08Y3126</td>
<td>M</td>
<td>7480 (5)</td>
</tr>
<tr>
<td>M206</td>
<td>M</td>
<td>7440 (6)</td>
</tr>
<tr>
<td>06Y575</td>
<td>L</td>
<td>7430 (7)</td>
</tr>
<tr>
<td>11Y1044</td>
<td>L</td>
<td>7180 (8)</td>
</tr>
<tr>
<td>CM101</td>
<td>S</td>
<td>6930 (9)</td>
</tr>
<tr>
<td>09Y2179</td>
<td>S</td>
<td>6720 (10)</td>
</tr>
<tr>
<td>CH202</td>
<td>SPQ</td>
<td>6630 (11)</td>
</tr>
<tr>
<td>L206</td>
<td>L</td>
<td>6130 (12)</td>
</tr>
<tr>
<td>08Y3310</td>
<td>M</td>
<td>5190 (13)</td>
</tr>
<tr>
<td>M202</td>
<td>M</td>
<td>4650 (14)</td>
</tr>
<tr>
<td>09Y3887</td>
<td>M</td>
<td>3990 (15)</td>
</tr>
<tr>
<td>08Y3269</td>
<td>M</td>
<td>3640 (16)</td>
</tr>
<tr>
<td>CH201</td>
<td>SPQ</td>
<td>3520 (17)</td>
</tr>
</tbody>
</table>

### Summary of Large Plot Variety Trials, Yield (lb/ac)

<table>
<thead>
<tr>
<th>Variety</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
</tr>
</thead>
<tbody>
<tr>
<td>CM-101</td>
<td>9890 a</td>
<td>7580 a</td>
<td>8320 a</td>
<td>7160</td>
</tr>
<tr>
<td>S-102</td>
<td>X</td>
<td>6970 a</td>
<td>9310 a</td>
<td>8060</td>
</tr>
<tr>
<td>M-104</td>
<td>6440 c</td>
<td>6490 a</td>
<td>9200 a</td>
<td>8040</td>
</tr>
<tr>
<td>M-206</td>
<td>7450 b</td>
<td>4467 b</td>
<td>8380 a</td>
<td>6960</td>
</tr>
<tr>
<td>M-202</td>
<td>3870 d</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

(Linquist et al, 2012)
Example DAP Analysis

- Twitchell Island - rice subsidy (yield-based)
  - $0.50 - $10 per cwt

<table>
<thead>
<tr>
<th></th>
<th>Alfalfa</th>
<th>Corn</th>
<th>Other Deciduous</th>
<th>Pasture</th>
<th>Rice</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acres</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1,500</td>
<td>1,000</td>
<td>500</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Prices</td>
<td>$12.78</td>
<td>$13.28</td>
<td>$14.78</td>
<td>$17.28</td>
<td>$22.28</td>
</tr>
<tr>
<td>Subsidy</td>
<td>$0.50</td>
<td>$1.00</td>
<td>$2.50</td>
<td>$5.00</td>
<td>$10.00</td>
</tr>
</tbody>
</table>

MacEwan 2013
Hypotheses

1. Rice can halt increasing risks due to subsidence
   – From seepage failures (direct)
   – From static slope stability failures (direct)
   – Potentially from seismic (implied)

2. Rice is feasible in the Delta

3. Cost / Benefits favor the adoption of rice

4. Other environmental impacts can be managed against BAU scenario
Local, Regional and State Values
Subsidy Opportunities

<table>
<thead>
<tr>
<th></th>
<th>Local</th>
<th>Regional</th>
<th>State</th>
</tr>
</thead>
<tbody>
<tr>
<td>GHG Emissions</td>
<td></td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Water Resources Risks and Levees</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Water Quality</td>
<td></td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Agronomic Sustainability</td>
<td>x</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Carbon Sequestration</td>
<td>x</td>
<td>x</td>
<td></td>
</tr>
</tbody>
</table>

Potential Source for Subsidies
From Local, Regional and State Sources
Existing Through-Delta Water Conveyance:

Through-Delta Flows are part of “Dual Conveyance” plans and draws fresh water through deeply subsided Delta to state and federal project pumps.

One and two island ‘buffers’ are approximated areas that could safeguard flowpath from drawing saline waters towards pumps in event of one to multiple island levee failure.

(A. Merrill et al., 2012)
Possible Solutions for increased Water Conveyance security

Possible Solutions
Placing rice on islands to decrease levee failure risk along the through Delta conveyance corridor to:

1. Counter hydraulic head on levee interior (10+ ft below MSL)
2. Counter under-seepage in areas with thin peat (<4 ft thick)

---

### Buffer width for safeguarding corridor

<table>
<thead>
<tr>
<th>Buffer width for safeguarding corridor</th>
<th>ALL 10+ ft below MSL</th>
<th>10+ ft below MSL AND Peat &lt; 4'</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Island Buffer</td>
<td>59,411</td>
<td>21,979</td>
</tr>
<tr>
<td>2 Island Buffer</td>
<td>13,983</td>
<td>7,357</td>
</tr>
<tr>
<td>Total</td>
<td>73,394</td>
<td>29,337</td>
</tr>
</tbody>
</table>

(A. Merrill et al., 2012)
Rice – How Much to Manage Subsidence Risks to Levee Failure?

• Too early to know
  – Estimate of 10,000s of Acres
    • Say 15,000 – 40,000
  – Subsidy likely needed to promote rice
    • High value crops: Tomatos, grapes, etc...
    • Alfalfa ....
    • $10/ac?
  – Say $150 – 400K subsidy annually to prevent worsening of Levee

• Numbers will be product of AFRI
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3. Cost / Benefits favor the adoption of rice
4. Other environmental impacts can be managed against BAU scenario:
   1. GHG emissions
   2. Water Export as indicator of Water Quality
Drivers

- Soil Organic Matter
- C:N ratio
- Redox (O2, NO3, Fe, SO4)
- Land Use
- Cultural Practices
- Irrigation
- Climate and Temperature
Fertilizer and Yield, Espe 2013

Yield Vs N Fertilizer for Delta Soils as % Carbon

3% Carbon

23% Carbon

11% Carbon
Total CH$_4$ flux during the growing season

Ye et al 2014

Methane = F(Soil Organic Content)
Methane Not Affected by N Fertilizers
Total $\text{N}_2\text{O}$ flux during the growing season

- $\text{N}_2\text{O}-0.8$
- $\text{N}_2\text{O}-0.9$
Island Hydrologic Model

Scenario 1
W/Rice

- Reuse Main Drain, Reduce Siphon Demand
- Provide constant sink for Main Drain Water
- Increase Island ET losses
Total flows by year and season, complete seasons only

- Not Summer (October 1 - May 31)
- Summer (June 1 - September 31)

**Pre-Rice**

**Rice**
Average water use per acre rice, June 1 to Sept 30 2009 - 2011

Reduction in pumping off island is 25% greater than rice water use and ET rates, suggesting rice is decreasing seepage rates.
What Next For AFRI

• Field work is complete (+/-): Years 1 – 3 of project
• Years 4 – 5 for Data Analyses and Manuscripts
  – Effects: How much and can it be managed
    • GHG emissions
    • Water Quality
    • Water Resources Risk Reduction
    • Subsidence
  – Agronomics and BMPs for Rice in the Delta
  – Economics: Local, Regional and State Scale
  – Outreach
Next Talk

– CO2 & CH4 flux from natural & managed ecosystems

• Dennis Baldocchi (UC Berkeley)
• Tuesday - April 29 - 12:00 – 1:00 PM
  The Pagoda Building
  429 J Street
  Sacramento, CA 95814