Environmental effects of rice paddies in monsoonal climate

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SWAT2015, Sardinia, Italy, June 24-26, 2015
APEX-paddy Model

**Problem:** Rice paddies are considered agricultural NPS for water pollution

**Objective:** Assess the effects of ag bmps to reduce NPS pollutants load from paddies in Korea

**Tasks:** We develop paddy algorithms in APEX, build databases for soils, weather, and paddy management for the whole country.

**Benefits:** Quantitative assessment of paddy discharge and GHG, BMP policy development, etc.
Agricultural Lands in Korea

Total area: 99,600 km²
Forest: 69,720 km² (70%)
Agriculture: 18,240 km² (18%)
Paddy: 11,530 km²

Map of Korea with legend:
- Paddy
- Upland
- Orchard
- Other

Paddy: 63%
Upland: 25%
Orchard: 10%
Other: 2%
Topographical impact on agricultural NPS pollution

![Bar chart showing the distribution of slope degree (%)](chart.png)

- **Slope degree (%)**: 0-2, 2-7, 7-15, 15-30, > 30
- **Distribution (%)**: Paddy, Upland & Orchard
Paddy Algorithm

- Management
  - Discharge
  - Puddling
  - Irrigation
  - Fertilizer
- Crop growth
  - Transplanting
  - Parameters
- Processes
  - Sediment
  - Evaporation

```
Paddy Algorithm

Begin Subarea Processes

Loop

Flooded?

Dry

Runoff (SCS-CN)
Erosion (MUSLE)
Nutrient Dynamics
Evapotranspiration
Crop Growth

No

End Subarea Processes

Loop

Yes

Discharge (WB)
Sediment (Puddling)
Nutrient Fate
Evapotranspiration
Crop Growth

Daily loop

End Subarea Processes
```
Rice Growth Simulation

- Transplanting
  - Initial LAI value (=0.1) to input on a PLANTING operation
  - Heat units required for maturity is reduced from 2,200 degrees to 1,500 degrees
- Plant population: 124 plants/m²
Case Study: Icheon Field

- **Sampling point of irrigation water at the inlets**
- **Sampling point of drainage water at the outlets**
  - Water depth and water velocity logger
  - Sampling point of percolation water

- **Area:** 15 ha
- **Soil type:** coarse Loamy soil
- **Monitoring period:** 2002-2004
- **Spin-up period:** 1999-2001
- **Rainfall, irrigation, discharge, mineral N in runoff**
Crop Growth

Simulated Rice Yield

<table>
<thead>
<tr>
<th>Obs (t/ha)</th>
<th>Pred (t/ha)*</th>
<th>Standard deviation</th>
<th>Percent error</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.63</td>
<td>6.46</td>
<td>1.03</td>
<td>2.6%</td>
</tr>
</tbody>
</table>

* Three year average during 2002-2004
Discharge

![Graph showing discharge over time with observed, predicted, and rainfall plus inflow data points. The graph highlights periods of no ponding/IRR and intermittent IRR.]

- **Observed**
- **Predicted**
- **Rainfall + Inflow**

The graph includes two scatter plots with regression lines:

- **(2002)**
  - $y = 1.11x$
  - $R^2 = 0.88$

- **(2003)**
  - $y = 0.96x$
  - $R^2 = 0.81$
Water Balance

- **Total input**:
  - **Irrigation**: 60% (1200)
  - **Rainfall**: 40% (800)

**Water Balance**

- **Infiltration**: 44%
- **ET**: 28%
- **Discharge**: 28%
Nitrogen Yield

![Graph showing nitrogen yield over time with fertilizer applications highlighted for 2002 and 2003.](image)

- **(2002)**
  - Observed vs. Predicted plot with $y = 1.19x$ and $R^2 = 0.65$

- **(2003)**
  - Observed vs. Predicted plot with $y = 1.61x$ and $R^2 = 0.39$
Scenarios

Reduction in Nitrogen Load with Fertilizer Management

10% Reduced | 20% Reduced

<table>
<thead>
<tr>
<th>Component</th>
<th>10% Reduced</th>
<th>20% Reduced</th>
</tr>
</thead>
<tbody>
<tr>
<td>FN MN</td>
<td>10.2%</td>
<td>20.1%</td>
</tr>
<tr>
<td>QN</td>
<td>6.9%</td>
<td>13.8%</td>
</tr>
<tr>
<td>YN</td>
<td>0.1%</td>
<td>0.1%</td>
</tr>
<tr>
<td>VOL</td>
<td>0.6%</td>
<td>4%</td>
</tr>
<tr>
<td>RSFN</td>
<td>8.4%</td>
<td>16.4%</td>
</tr>
<tr>
<td>TN</td>
<td>8.3%</td>
<td>16.1%</td>
</tr>
<tr>
<td>Rice YLD</td>
<td>1.1%</td>
<td>2.3%</td>
</tr>
</tbody>
</table>

N Balance (Pie Chart): RSFN (X%), QN (Y%), VOL (Z%)
National Scale Paddy Modeling

- LU map for paddies – 10 m pixels
- Soils – 377 soils at 1:5000 scale compiled
- Daily Weather – 91 Stations (~30yr)
- Paddy Mgt. – 26 climatic regions

(Yi, 2011)
Conclusion

- Accurate simulation of paddy discharge and nutrient yield is achieved by linking agricultural operations to biophysical processes.
- APEX predicts rice yields well with the implementation of transplanting and crop parameters calibration.
- Nutrient/carbon dynamics needs improvement to better represent microbial effects in standing water and in the anoxic zone of the subsoil layers.
- Fertilizer management can improve discharge water quality while maintaining rice production.
- Ongoing: database development, national scale modeling framework development.
Questions?