Integrating Landsat, PALSAR-2 and Sentinel-1 Data with DNDC for Regional Rice GHG Inventories

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Rice Management & INDC Targets

- Rice produces significant methane (Global annual emissions 30-100 Tg (10-20% anthropogenic)).

- Increased focus Short-lived climate pollutants (methane, black carbon and F-gases)

- 20-yr GWP = 86 (100-yr =34) [AR5]

- COP 21: 48 countries mention rice methane mitigation as part of INDC targets

- Alternating Wetting and Drying (AWD)
  - Reduces Methane
  - Reduces water requirements: adaptation strategy as well
RiceDSS Vision

- Build a rice monitoring system to track and monitor rice production (extent and yields), drought risk and GHGs.

- Multi-EO Platforms: Integrate moderate resolution optical and radar data for mapping rice extent, crop intensity, inundation dynamics and crop development stages.

- EO data assimilations to drive rice growth and soil biogeochemical model (DNDC) for quantification of GHG emissions and rice yields.

- Deliver **open source system** for national and jurisdictional rice GHG assessment to support INDCs, carbon markets (offsets and “insetting”)

Presentation Outline

- Mapping rice at regional to national scales with multi-sensor EO data
- DNDC Modeling rice yields and GHG emissions
- Example results for Red River Delta
- Next Steps...
Mapping rice at regional to national scales with multi-sensor EO data
Mapping Rice with Timeseries Optical and SAR
Rice Mapping and Modeling System

- **Landsat 8 OLI**
  - Ingestion, preprocess, projection, resampling: Uniform grid
  - Clouds (ACCA, FMASK, AutoCloud)
  - Weekly NDVI, LSWI, SATVI, MSAVI

- **MODIS**

- **Sentinel-2**

- **Skybox, RE**

- **ALOS-2**
  - Ingestion, preprocess, terrain geocoding, resampling: Uniform grid
  - DEM, Layover, shadow, flags, quality masks
  - Time series
  - Time series C & L backscatter dB

- **Sentinel-1**

- **TerraSAR-X**

**Training Data**
- Geofield photos
- Field surveys
- Govt statistics
- HR images from NGA
- Google Earth

**Construction of temporal vectors**

**Classification And Regression Tree Algorithms**

**Weekly Maps**
- extent, inundation, active v fallow, condition metrics

**Time Series Map**
- hydroperiod, growth stage, deviation from normal, risk, crop calendar, rotations

**Web-GIS, mobile**

**DNDC - Oryza**

**Validation, Accuracy, Uncertainty Statistics**

- Existing Masks, SMAP, GPM, WRF, MERRA

**Applications**
- food security, disaster support, water management, yield forecasts, GHG emissions, tech transfer, decision making
A.) Map of LULC in West Java generated from multitemporal FBS/D PALSAR (n=48)
B.) Rice extent across Java (scaled to percent of 10km cell for visualization) derived from Mosaics and ScanSAR
C.) Rice extent across Indochina (% 10km cell for visualization) derived from Mosaics and ScanSAR
PALSAR ScanSAR Results:

- Mixed results vs census.
- PALSAR temporal resolution (46 day repeat) insufficient for mapping rice details
- Built mapping framework... ... on to Sentinel-1 !!!
Preliminary Results with Sentinel-1

A.) Wall-to-wall Sentinel-1 (~650 IW mode scenes) with example B.) sowing and C. peak for Irrawaddy Delta, Myanmar 2015.

Encouraging results, needs more QA/QC and validation
Modeling rice yields and GHG emissions
The DNDC Model

- **DNDC** stands for DeNitrification-DeComposition

- DNDC is a soil biogeochemical model that has been used for quantifying GHG emissions from agricultural systems.
- DNDC is a process (as known as mechanistic) model that simulates the biogeochemical processes to drive C and N cycling in agricultural soils. DNDC can simultaneously simulate anaerobic (flooded) and aerobic (non-flooded) conditions in soils.
- DNDC can model both Methane and Nitrous Oxide emissions: critical for rice agro-ecosystems.
- DNDC has been extensively validated for rice globally.
Rice: CH$_4$ production and emission
(REDOX < -100 to -200 mv)

DNDC Models 3 Pathways
✓ Plant mediated transport
✓ Ebullition, diffusion
✓ Soil out gassing

\[
\text{CO}_2 + 4\text{H}_2 \rightarrow \text{CH}_4 + 2\text{H}_2\text{O}
\]

\[
\text{CH}_3\text{COOH} + \text{H}_2 \rightarrow \text{CH}_4 + \text{CO}_2
\]

Methanogenesis

Labile C → CO$_2$ + 4H$_2$ → CH$_4$ + 2H$_2$O

source

\[
\text{CH}_4 + 2\text{O}_2 \rightarrow \text{CO}_2 + 2\text{H}_2\text{O}
\]

Methane oxidation

Slide from Will Horwath
DNDC Model Validation

DNDC Rice Methane Validation
(Field data from Dr. Trinh MARD IAE)

- Bar chart showing methane emissions (kg C/ha/season) for Continuous Flooding and AWD conditions.
- Graph comparing measured methane emissions (kg C/ha) against DNDC modeled methane emissions.

Source: Applied Geosolutions
Example results for regional GHG Red River Delta
Red River Delta Multiscale Imagery
Collecting field training data for cal val, Ground Truth, surveys.
Left) RRD land use land cover map (rice=yellow) generated from fused Sentinel-1, PALSAR-2, and Landsat-8; Right) Scatterplot of rice extent and national census statistics show strong agreement.
Used Sentinel-1 to map rice extent, crop calendar, hydroperiod (duration of flooding) for Red River Delta
Sentinel-1 Crop Calendar Products

Distribution of Start of Season Dates per Commune
Sentinel-1 Crop Intensity and Hydroperiod
DNDC Model Inputs

- Crops
- Soils
- Weather
- Irrigation
- Flooding
- Tillage
- Fertilizer
- Manure
Red River Delta 2015 Rice CH$_4$ Emissions

<table>
<thead>
<tr>
<th>Province</th>
<th>Rice CH$_4$ emissions (MgCO$_2$/y)</th>
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<tbody>
<tr>
<td>DNDC</td>
<td>345 11,515</td>
</tr>
<tr>
<td>IPCC Tier 1</td>
<td>mean 324 10,788</td>
</tr>
<tr>
<td>low</td>
<td>243 8,087</td>
</tr>
<tr>
<td>high</td>
<td>435 14,508</td>
</tr>
</tbody>
</table>

CH$_4$ CH$_4$ GWP (GgCH$_4$/C/y) (GgCO$_2$/y)
DNDC vs IPCC

DNDC MODELED METHANE EMISSION

IPCC (BASED ON RS CROPPING/WATER MGMT)
- Red areas: communes with higher DNDC modeled methane emissions.
- Blue areas: communes with higher IPCC modeled methane emissions.
- Process models captures differences in drivers.
- Inform mitigation strategies and targeting.
Next Steps: MRV Demonstration Thai Binh Province (with MARD IAE)

- GHG measurements for 2 rice growing seasons, 11 sites per season (from 8 districts), each of sites will have 3 treatments: 66 sets of treatment-seasons of GHG (CH₄ and N₂O) measurements.

- Collect rice crop development: 99 sites with rice crop development and water table depth (AWD) measured at least every 10 days for 2 cropping seasons.

- Dense time series of SAR images: Sentinel-1A,B (6 day repeat) and TerraSAR-X (3 images per 11 day repeat) to map water management, crop growth and yields.

- DNDC validation and uncertainty

- Refined SAR processing algorithms for field level management mapping at site to provincial scale.
Continuous vs. AWD Flood Management

Cycle Time ~ 5 to 8 d

Slide from Joe Massey (MSU)
Summary

- PALSAR-2, Sentinel-1, Landsat 8 fusion high LULC accuracy
  - Multitemporal required for mapping rice attributes
  - Suite of parameters: extent, hydroperiod, intensity, calendar
- RRD GHG footprint characterized through integration of EO data and DNDC with uncertainty characterized
- Integrated RiceDSS and DNDC model provides template scalable platform for rice GHG MRV for tracking INDC progress.
- Next steps: Thai Binh study 2017 with MARD IAE
  - Mapping AWD with high temporal frequency SAR
  - Validate rice MRV system for Red River Delta
  - Expand collaborations, tech transfer RiceDSS platform/system
Thank you!
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Questions?

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