Landscape level carbon, water balances and agricultural production in mountainous terrain of the Haean Basin, South Korea

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Introduction
Atmosphere, Climate
Topography

Land-use

Yield of Crops and Water Use

Carbon and Water Balance

Input data – Radiation, Temperature, Humidity and Topographic information

Process-based Spatial Simulation Model (PIXGRO)

Prediction

Gross Primary Production (GPP), Ecosystem Respiration (Reco), Net Ecosystem CO$_2$ (NEE), Water Use and Yield of Crops

Calibration and Validation

Seasonal Change in Biomass

Measurement of Gas Exchange Fluxes
Atmosphere, Climate
Topography

Ecophysiological Process

Yield of Crops and Water Use

Process-based Spatial Simulation Model (PIXGRO)

Gross Primary Production (GPP), Ecosystem Respiration (Reco), Net Ecosystem CO₂ (NEE), Water Use and Yield of Crops

Land-use

Linkage

Measurement of Gas Exchange Fluxes

Input data – Radiation, Temperature, Humidity and Topographic Information

Predication

Prediction and Validation

Land Surface Fluxes

Seasonal Change in Biomass

Water Use
Materials and Methods
Site Description

Korean Peninsula

DMZ Seoul

Soyang Watershed

Haean Catchment
Simulation Model PIXGRO

**Input**
- Meteorological drivers (Hourly)
  - Radiation
  - Temperature
  - Precipitation
  - CO₂
- Land and Soil
  - Soil Data Base
  - DEM
  - Land Cover
  - Fertilizer Use
  - MODIS 250m

**PROXEL\textsubscript{NEE}**
- Canopy processes
  - Leaf Energy Balance
  - Gross Primary Production (GPP)
  - Canopy Conductance
  - Transpiration Rate, ET

**Fluxes**
- LAI
- Flux Summary
  - Woody Vegetation
  - Carbon Uptake
  - Leaf Respiration
  - Microbial plus Wood and Root Respiration
  - Soil CO₂ Efflux
  - ET

**Output**
- Total Biomass
  - Leaf Weight
  - Stem Weight
  - Root Weight
  - Grain Weight
  - Transpiration
  - Crop Stage
  - WUE, NUE
- Photosynthesis (GPP)
- Respiration (Reco)
- NEE
- Water Use and Soil Water Status

**CGRO**
- Growth & Development
  - (Grass, Tundra Wetlands, Crops)
  - Carbon Uptake
  - Whole Plant Respiration
  - Growth Allocation
  - Nutrient Uptake
  - Phenology & Development

**Water stress factor**

**Soil Stores**
2009: CO$_2$ chamber measurement and yield survey were processed for 5 dominating crops, e.g., rice, potato, radish, cabbage and bean.
Spatial Framework
### Needed Key Parameters of PIXGRO

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Definition</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>$J_{max}$</td>
<td>Electron transport capacity at 25 °C</td>
<td>21.7</td>
<td>µmol m(^{-2}) s(^{-1})</td>
</tr>
<tr>
<td>$Vc_{max}$</td>
<td>Carboxylation capacity at 25 °C</td>
<td></td>
<td>µmol m(^{-2}) s(^{-1})</td>
</tr>
<tr>
<td>$Rd$</td>
<td>Respiratory capacity at 25 °C</td>
<td>2.1</td>
<td>µmol m(^{-2}) s(^{-1})</td>
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<tr>
<td>$E$</td>
<td>Growth respiration/conversion factor</td>
<td>0.7</td>
<td>g (tissue) /g (CH(_2)O)</td>
</tr>
<tr>
<td>$K_m$</td>
<td>Maintenance respiration constant</td>
<td>0.0006</td>
<td>g CH(_2)O / g tissue-h</td>
</tr>
<tr>
<td>$B$</td>
<td>Maintenance respiration coefficient</td>
<td>0.0693</td>
<td>°C(^{-1})</td>
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<tr>
<td>SLA</td>
<td>Specific leaf area</td>
<td>200</td>
<td>cm(^2)/g</td>
</tr>
<tr>
<td>V</td>
<td>Leaf area senescence factor</td>
<td>0.0005</td>
<td>cm(^2)/hr</td>
</tr>
<tr>
<td><strong>Phenophase threshold</strong></td>
<td>Planting</td>
<td></td>
<td>°C day above 0 °C</td>
</tr>
<tr>
<td></td>
<td>Flowering</td>
<td></td>
<td>°C day above 0 °C</td>
</tr>
<tr>
<td></td>
<td>Graining</td>
<td></td>
<td>°C day above 0 °C</td>
</tr>
<tr>
<td></td>
<td>Dormancy</td>
<td></td>
<td>°C day above 0 °C</td>
</tr>
<tr>
<td><strong>Partitioning coefficients</strong></td>
<td>Biomass partitioning coefficients of leaves, stems, roots and grain</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Measurement of Gas Exchange Fluxes

Validation via chamber and (in development) eddy covariance flux measurements
Hypothesized seasonal change in the physiological parameter, $V_{c_{\text{uptake}}}$, based on flux measurements at other sites (CARBOEUROPE)

Key parameter for the PROXEL sub-model of PIXGRO for root crops and rice

Methods can be applied to all crops and ecosystem types
Application of Measurement

Eddy covariance system
CO₂ flux measurement

Statistical Analysis

NEE
R_{eco}

GPP

V_{cuptake}

Model inversion

Agricultural land use SIMULATION for Haean

Crop biomass
LAI

Biomass
LAI_{max}
Etc.

Biomass partitioning coefficient
Phenophase threshold

Phenology date

OUTPUT

- Total Biomass
- Leaf Weight
- Stem Weight
- Root Weight
- Grain Weight
- Transpiration

- Photosynthesis (GPP)
- Respiration (Reco)
- NEE
- Water Use and Soil Water Status
Results
**Crop Biomass**

- **Max LAI**
  - Rice: 2.83
  - Cabbage: 7.21
  - Bean: 5.99

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- **Rice Biomass (%)**
  - Leaves
  - Root
  - Stem
  - Grain

- **Cabbage Biomass (%)**
  - Leave
  - Yellow
  - Root
  - Stem

- **Bean Biomass (%)**
  - Green
  - Root
  - Stem
  - Bean

**HARVEST!**
Root Crop

Max LAI
Potato  2.31
Radish  4.29
Seasonal course in maximum exchange rates

Rice

Cabbage

Radish

Bean

Mean GPP

Reco

NEE

138 188 238

-16 -12 -8 -4 0 4 8 12 16

Mean GPP

Reco

NEE

138 158 178 198

-25 -20 -15 -10 0 10 15 20 25

Mean GPP

Reco

NEE

138 188 238

-25 -20 -15 -10 0 5 10 15 20 25
The partition coefficient

\[ \frac{dW_{p_i}}{dt} = \eta_{p_i} \frac{dW}{dt} \]

\( \eta_p \) the partition coefficient

\( i \) 5 crops (bean, cabbage, potato, radish and rice)
Daily Outputs for Haean

Initial Version Daily Output at Landscape Level: Haean-myun DOY 213 (August 1)
Conclusions and Ongoing Work
• **Field Experiment provides**
  – crop yield, biomass, LAI
  – agricultural land surface fluxes
  – database of model parameters

• **PIXGRO provides**
  – a useful landscape level tool
  – a simple mechanistically-based approach
  – opportunities for validation of process interactions at several scales
• Ongoing work

  – To extend the spatially explicit simulation of yield to include many crops
  – To estimate services derived from at least 10 land use types
  – To include influences with respect to management
  – To derive key parameters using model inversion
  – To calculate spatial parameters through remote sensing
  – To develop and evaluate scenarios of expected global change in the Haean basin
Thank you