Complex Terrain and Ecological Heterogeneity (TERRECO): Evaluating Ecosystem Services in Mountainous Landscapes

Energy and CO$_2$ exchange between agro-ecosystems and the atmosphere over a complex terrain in Korea

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Objectives

• Eddy-covariance technique ~ complex terrain
  – Site selection and footprint analysis
  – Data quality control
  – Gap-filling

• Energy and CO$_2$ exchange over croplands at Haean
  – Monsoon
  – Length of growing season

• Input or validation for models
Field campaign 2010

Biomass sampling
Turbulence measurement
Rice growing
Potato growing

Land use 2009 (Q:2010?)
Cabbage
Ochard
Others
Ginseng
Potato
Bean
Radish
Rice

Yanggu County Office (2010)
Eddy-covariance

\[ F = \overline{w'x'} \]
Biometric measurements
Automatic Weather Stations (AWS)

Solar radiation
Temperature
Humidity

Rice field
Precipitation
Wind speed
Wind rose

Potato field
Precipitation
Wind speed
Wind rose
Footprint

Potato field  Rice field
Data flow

Weather station

High frequency (20 Hz) data of wind, temperature, H₂O, CO₂

Instrument error code (AGC)

Energy and CO₂ fluxes

Spike check

Quality controlled fluxes

Gap-filling

Fluxes without gaps

Footprint

# Mauder and Foken (2004)

# Göckede et al. (2008)
Data flow (what’s new)
Quality control

<table>
<thead>
<tr>
<th>Steps</th>
<th>Period 1</th>
<th>Period 2</th>
<th>Period 3</th>
<th>Overall</th>
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</thead>
<tbody>
<tr>
<td>w/CO$_2$ threshold check</td>
<td>99.6%</td>
<td>99.9%</td>
<td>99.7%</td>
<td>99.7%</td>
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<tr>
<td>Instrument error check</td>
<td>86.8%</td>
<td>70.9%</td>
<td>72.0%</td>
<td>78.0%</td>
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<tr>
<td>w/CO$_2$ spike check</td>
<td>86.2%</td>
<td>68.9%</td>
<td>70.1%</td>
<td>76.6%</td>
</tr>
<tr>
<td>NEE Threshold check</td>
<td>86.2%</td>
<td>68.9%</td>
<td>70.1%</td>
<td>76.6%</td>
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<tr>
<td>NEE quality flag check*</td>
<td>82.1%</td>
<td>68.4%</td>
<td>68.0%</td>
<td>74.1%</td>
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<tr>
<td>NEE spike check</td>
<td>78.6%</td>
<td>65.1%</td>
<td>63.9%</td>
<td>70.5%</td>
</tr>
</tbody>
</table>

* data with quality flag of 7, 8, 9 were rejected (Foken and Wichura, 1996; Foken et al., 2004).
Gaps
### Gap-filling strategy for CO$_2$ flux

<table>
<thead>
<tr>
<th></th>
<th>Daytime</th>
<th>Nighttime</th>
</tr>
</thead>
<tbody>
<tr>
<td>$R_{eco}$</td>
<td></td>
<td>gaps</td>
</tr>
<tr>
<td>NEE</td>
<td>Measured and gaps</td>
<td>Measured and gaps</td>
</tr>
<tr>
<td>GPP</td>
<td>$GPP = NEE - R_{eco}$</td>
<td>0</td>
</tr>
</tbody>
</table>
Gap-filling strategy for CO$_2$ flux

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<td>Measured and gaps</td>
<td>NEE = $R_{eco}$</td>
</tr>
<tr>
<td>GPP</td>
<td>$GPP = NEE - R_{eco}$</td>
<td>0</td>
</tr>
</tbody>
</table>

\[
F_d = \frac{\alpha R_g \beta}{\alpha R_g + \beta} + \gamma \\
F_{R,eco} = F_{R,10} e^{E_0[(1/(283.15-T_0))-(1/(T-T_0))]} \\
\]

# Michaelis and Menton, 1913; 
# Falge et al., 2001

# Lloyd and Taylor, 1994; 
# Falge et al., 2001

# Lindner, 2011

# Ruppert et al., 2006
Light response curve

Daytime NEE [micromol/m2 s] ~ Rg (global radiation) [W / m2]

- All data
- Conventional temperature classification
- Conventional temporal classification
- Our new LAI approach
## Gap-filling

<table>
<thead>
<tr>
<th>Models</th>
<th>Temperature bins</th>
<th>LAI factor*</th>
<th>Day bins</th>
<th>VPD bins</th>
<th>VPD factor**</th>
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<tbody>
<tr>
<td>1-T</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
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<tr>
<td>2-D</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
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<tr>
<td>3-T-L</td>
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<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
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<tr>
<td>4-T-L-Vf</td>
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<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
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<tr>
<td>5-L-Vb</td>
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<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>6-L-Vb-Vf</td>
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<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>7-D-L-Vf</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
</tbody>
</table>

* $Fd$ was replaced with $Fd^* = Fd / LAI$

** An exponential function was introduced (# Lasslop et al., 2010).
Performances of gap-filling models: daytime

NEE

# Taylor (2001)

E: Nash–Sutcliffe model efficiency coefficient
d: index of agreement
Fluxes: observed

Potato field

Rice field

NEE

Latent heat flux

Sensible heat flux
Fluxes: gap-filled

Potato field

Rice field

NEE

Latent heat flux

Sensible heat flux
Residuals

Fig. 5. Retrieval LAI for two potato fields (P2 and P3) with different calendars. Phenological observations are indicated on top. P2 has a longer cycle than P3; emergence is earlier and harvest is later than for P2. E stands for Emergence, VD for Vegetative Development, F for Flowering, PG for Potato Growing, R for Ripening as Rt for Harvest.

# González-Sanpedro et al. (2008)
Mean diurnal cycle

Potato field

Rice field

(Graphs showing the diurnal cycle for VPD, NEE-Obs, and other variables for Potato and Rice fields.)
Daily mean

- Daily, potato field
- Daily, rice field
Cumulative

Potato field

Rice field
Comparison with chamber measurement

**Co-worker: Steve Lindner**

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**Potato field**

**Rice field**
Comparison of WRF model with observations

Co-worker: Dr. Jea-Chul Kim, Dr. Adrei Serafimovich

![Map of Fichtelgebirge, Germany](image1)

![Map of Heaen, South Korea](image2)

![Graph of Latent Heat Flux for DE-F](image3)

![Graph of Latent Heat Flux for DE-M](image4)

![Graph of Latent Heat Flux for OBS and WRF](image5)

Red: OBS  
Blue: WRF
Conclusion

- Eddy-covariance technique ~ complex terrain
- Gap-filling
- CO2 flux
  - Mid-season depression
  - Late-season source at potato farm
- Further co-operation work
• Zhao, P. et al., 2011. Documentation of the Observation Period, May 12th to Nov. 8th, 2010, Haean, South Korea, Universität Bayreuth, Abt. Mikrometeorologie, Print, ISSN 1614-8916, Arbeitsergebnisse 45.


• Zhao P., Lee B., Lindner S., Lüers J., Tenhunen J., Foken T., *in plan*: Influence of monsoon and crop management on CO2 uptake over farmlands in South Korea
Thank you for your attention.