Understanding on utilization of weather and climate data with Agricultural model

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최악의 가뭄에 고온현상까지 겹치면서 농작물 피해가 속출하는 등 본격적인 영농철을 맞은 농촌에 비상이 걸렸다. 30일 오후 여주의 한 들녘에서 고온현상과 물 부족으로 인해 발작들이 타들어 가고 있다. 임열수기자 pplys@kyeongin.com
Climate Change

- Climate Variation
  - Uncertainty
- Long-term Climate
  - Adaptation
  - Mitigation
- Impact Assessment
  - Sensitivity
  - Vulnerability

Sustainable Development
Agriculture

- Farms, Fields, Crops, Livestocks...
- Food Security
Soil Plant Atmosphere

• Soil – Plant – Atmosphere Continuum (SPAC)
  - normally mentioned SPAC is the Pathway for water moving from soil through plant to the atmosphere
Environment: **temporal & spatial**

- Planting > Growing > Harvesting

- Local Environment
Weather Station

- where crops are grown
Synoptic Weather Observation

- Local Weather / Climate
  - Representative sites
  - Issues: homogenous terrains/land cover vs. various terrains/land cover
Terrain, Landuse

- Terrain : Land cover
  - Plain < Homogenous
  - Mountain (Highland) area, Urban < Complex, Various
Homogenous

• Synoptic weather station
  - isothermal line
Various

• Mountain/Highland
  - various weather/climate; agro-, mountain- climate
  - not directly use synoptic weather/climate data
Local Weather

- where crops are grown, or where trees are grown
Climate Models

• Observation
  - synoptic weather stations

• Future Climate
  - forecasting models

Synoptic weather station maps of each countries (average distance over 50km, 100km)
Local/Site-Specific Environment

- Site-specific climate: topography, vegetation, land cover
  - distance, elevation,
  - slope effect,
  - heat island effect, cold air drainage effect etc.

- **Downscaling methods**
  - temporal
  - spatial
Models

- Climatic forecasting information produced in climate models

- need Application models in other sectors
  - Agricultural models
  - Hydrological models
  - Various models ... etc.
Issues / Concerns

• When Applied to Other Models of Fields
  - using climate prediction information as input information

• Its Uncertainties
  - systematic
  - **downscaling**
Uncertainty of Downscaling

- Model Evaluation

Source: Dr. Eum Hyung-Ill’s research
## Uncertainty of Downscaling

### Evaluation Framework

<table>
<thead>
<tr>
<th>Criteria</th>
<th>PRCP Evaluation method</th>
<th>TMAX Evaluation method</th>
<th>TMIN Evaluation method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time-series Related (Criteria 1)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PRCPSTOT SDII</td>
<td>Distance of RMSEs from the perfect value</td>
<td>Distance of RMSEs from the perfect value</td>
<td>Distance of RMSEs from the perfect value</td>
</tr>
<tr>
<td>Tau, annual average</td>
<td>RMSE of tau between observed and simulated values</td>
<td>Tau, annual average</td>
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<tr>
<td>Distributed Related (Criteria 2)</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Distribution of values</td>
<td>K-S D statistic</td>
<td>Distribution of values</td>
<td>K-S D statistic</td>
</tr>
<tr>
<td>Multi-day Persistence (Criteria 3)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CDD &amp; CWD</td>
<td>WSDI</td>
<td>CSDI</td>
<td></td>
</tr>
<tr>
<td>Extremes (Criteria 4)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rx5day Rx1day R95pTOT R99pTOT</td>
<td>Distance of RMSEs from the perfect value</td>
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<td>Spatial structure (Criteria 5)</td>
<td></td>
<td></td>
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<tr>
<td>Spatial correlation between stations</td>
<td>RMSE of spatial correlations between observed and simulated values</td>
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*Source: Dr. Eum Hyung-II’s research*
Uncertainty of Downscaling

- PRCP
- TMAX
- TMIN

Source: Dr. Eum Hyung-Il’s research
Agro-Climatology:
Agro-Climatic information

• Provide important information for cropping calendar (farming activities)
  - sowing/planting,
  - irrigation/spray schedule,
  - harvest crop

• Added value
  - to produce information to manage agricultural ecosystem
• Growing Degree Days (GDD)
  - is a weather-based indicator for assessing crop development.

  - is a calculation used by crop producers that is a measure of heat accumulation used to predict plant and pest development rates such as the date that a crop reaches maturity (source: in google search).
Agro-Climatic Index: GDD

• GDD by calculating from daily temperature data

\[ \text{GDD} = \frac{(T_{\text{max}} - T_{\text{min}})}{2} - T_{\text{base}} \]

- \( T_{\text{max}} \): daily Maximum Temperature
- \( T_{\text{min}} \): daily Minimum Temperature
- \( T_{\text{base}} \): base temperature which a crop starts growth
Agro-Climatic Index: GDD

- GDD by calculating with monthly temperature data

\[
GDD = N \times \left( \frac{T_{\text{max}} - T_{\text{min}}}{2} \right) - T_{\text{base}} + L \times \sigma \times \sqrt{N}
\]

- \( N \) : the number of month
- \( T_{\text{max}} \) : monthly Maximum Temperature
- \( T_{\text{min}} \) : monthly Minimum Temperature
- \( T_{\text{base}} \) : base temperature which a crop starts growth
- \( L \) : constant
- \( \sigma \) : the standard deviation of the monthly Average temperature
Agro-Climatic Index: GDD

- 8 GCMs and one RCM used in the calculation of GDD

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</tr>
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<td></td>
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</tbody>
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Agro-Climatic Index: GDD

• $T_{\text{base}}$: 5°C GDD by calculating from daily temperature data

Probability density function (up) and boxplot (down) of growing degree days (right) and plant period (left) on base temperature 5°C under each GCM during 1976-2005. In each box plot, horizontal lines represent, from left to right, the 10th percentile, 25th percentile, median, 75th percentile and 90th percentile of calculations on each climate sets (from observed to each 8 individual GCM and one RCM).

Agro-Climatic Index: GDD

- $T_{base}$: $5^\circ$C  GDD by calculating from daily temperature data

Crop Model:
*Growth and Development Stage, Potential yield*
Agricultural Models

- Soil models
  - roots

- Crop models
  - phonological/genetic

- Pest/Disease models

Climate/Weather Data

Crop

Soil

Pest/Disease
Crop models

- DSSAT package
  - various crops
  - even vegetables and fruit crops
Crop models

• Crops
  - Cereal crops: Rice, Maize,
  - Legume crops: Soybean, Peanut ...
  - Root crops: Potato, Taro ...

• Potential Yield
Objectives of Case Study-1

• High temperature Impacts on Growth Stages
  - (Obs.1) Assess the reproducibility of temperature on each growth stage and growth periods
  - (Obs.2) Assess the impact of high temperature on yield of soybean?
Materials and Methods of Case Study

• CROPGROW-Soybean
  - Cultivars: TaeGwang (medium-late maturity)
  - Genetics information from GenCalc
  - Applied sites: Jeonju and Miryang + 14 fields

• Critical growth stages
  - Vegetative: before flowering
  - Reproductive: after flowering

• Criteria abnormal temperature on each growth stage
Genetic Information

- **TaeGwang (medium and late maturity)**
  - Korean soybean cultivar

<table>
<thead>
<tr>
<th>CSDL</th>
<th>PPSEN</th>
<th>EM-FL</th>
<th>FL-SH</th>
<th>FL-SD</th>
<th>SD-PM</th>
<th>FL-LF</th>
<th>LFMAX</th>
<th>SLAVR</th>
<th>SIZLF</th>
<th>XFRT</th>
<th>WTPSD</th>
<th>SFDUR</th>
<th>SDPDV</th>
<th>PODUR</th>
<th>THRSH</th>
<th>SDPRO</th>
<th>SDLIP</th>
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</thead>
<tbody>
<tr>
<td>12.70</td>
<td>0.32</td>
<td>18.71</td>
<td>4.92</td>
<td>9.52</td>
<td>35.84</td>
<td>9.56</td>
<td>1.03</td>
<td>350.00</td>
<td>300.00</td>
<td>1.00</td>
<td>0.19</td>
<td>10.10</td>
<td>1.35</td>
<td>29.28</td>
<td>78.00</td>
<td>0.40</td>
<td>0.20</td>
</tr>
</tbody>
</table>

\[ y = 1.1843x - 9.4399 \]
\[ R^2 = 0.9213 \]

\[ y = 0.8204x - 324.48 \]
\[ R^2 = 0.4581 \]
Genetic Information

- Evaluation genetic properties of TaeGwang
  - 16 sites

![Graph A](image1.png)

- Spatial averaged: 0.40
  - Jeonju ($R^2 = 0.41$)
  - Miryang ($R^2 = 0.01$)
  - Deagu ($R^2 = 0.43$)
  - Jinju ($R^2 = 0.82$)
  - Suwon ($R^2 = 0.38$)
  - Chuncheon ($R = 0.37$)

![Graph B](image2.png)

- Spatial averaged: 0.58
  - Jeonju ($R^2 = 0.29$)
  - Miryang ($R^2 = 0.88$)
  - Deagu ($R^2 = 0.58$)
  - Jinju ($R^2 = 0.87$)
  - Suwon ($R^2 = 0.39$)
  - Chuncheon ($R^2 = 0.45$)
Growth Stage of Soybean

- Growing season: timing of planting, flowering, pod development, and seed filling
### Criteria abnormal temperature

- **Critical growth stages**

<table>
<thead>
<tr>
<th>Crop</th>
<th>Base Temp.</th>
<th>Vegetation period</th>
<th>Reproduction period</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soybean</td>
<td>10</td>
<td>25-30 (DT), 19-24 (NT)</td>
<td>26-32 (DT), 22-27 (NT)</td>
</tr>
</tbody>
</table>

*(Holmberg, 1973; Gibson and Mullen, 1996)*
Abnormal temperature

- before and after Anthesis

![Graphs showing temperature differences before and after Anthesis for Jeonju and Miryang.](image-url)
Impact on growth period

- During Vegetative stage

Within 4~5 days

![Graph showing duration of growth stages]

- Planting to Anthesis
  - Not high temp.
- Planting to Anthesis
  - High Temp.

O: Miryang
X: Jeonju

duration in days
Impact on growth period

- During Reproductive stage

14~16 days (two weeks)
Summary (Obs.1.)

- Period of vegetation stages (before flowering) is shortened

- Reproductive stages is also shortened, especially high temperatures occur in the period of R4(R3) to R6, and it’s shorter, and also affects decreasing yield
  - 1.5°C ~ 2.0°C compared with criteria temperature
Yield Components (Obs.2)

- How much the impact of high (abnormal) temperature on yield of soybean?
Shift growth stages

• Planting Season
  - May to June

Range: one month or 1.5 month
Shift growth stages

- **Shift Planting time**: easy way to avoid extreme case, such as high temperature or no rainy days (i.e., conditions in which crops can not grow/cultivate well)

- In the case of Korean soybean, usually plant June 10 in the southern region
  - shift (+/-) 5 days (shorten / delay)
  - for example,
    - shorten – May 25, June 5 with based on June 10
    - delay – June 15 etc...
Results

- Relative change on yield planted at June 10

Apply to future climate scenarios

• Compare two cases:
  - Occurrence of high temperature during critical periods Vs.
  - Just common temperature as Normal year

• Future Climate Scenarios
  - a preliminary result of KMA-125km
Results

• Relative change on a yield component in Normal vs. High temperature
Results

• Relative change on yield planted at June 10

Miryang

Jeonju

RCP45 (2021-2050)

RCP85 (2021-2050)
Summary (Obs.2.)

- by shortening the planting time, it is possible to avoid the decrease of the yield of soybean by avoiding the high temperature during critical growth stage (e.g., grain filling period)

- more negative impact on delay of the planting time
Multi Model Ensemble Simulation: Reproducibility of yield in CROP Model
Objectives of Case Study-2

• Multi Models Ensemble Simulation
  - (Obs.3)
  evaluate yield reproducibility, & investigate appropriate ensemble averaging method to average the predicted yields from various climate models, & build database for multi models ensemble simulation of crop model
## Climate (Weather) Information

- **9 Scenarios**
  - 8 GCMs
  - 1 RCM
- **Quantile mapping**

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Reproducibility of yield

- Reproduce
  - past climate/weather at the growth stages necessary to analyze in more detail whether the downscaled climate data from GCMs during the major crop growth periods reproduced the observed climate accurately enough, and to evaluate the plant responses in the crop model.
Multi Model Ensemble Methods

- MME types
  - 4 types
  -

Number of participating

- Number of participating in MME simulation
  - the estimation error decreased as the number of GMCs included in the MME increased
the mean of the MME4 averaged potential yields or the MME9 averaged potential yields were similar to the OBS-SIM-PYD, but the range of variations (interquartile range) of the predicted potential yield was small and showed the typical features of the statistical method, so that the potential yield could not be predicted for any given climate change scenario, such as high temperature events.

necessary to provide information on the type and number of individual GCMs that can reduce the estimation error by as much as possible, rather than including arbitrarily large numbers of GCMs in the MME.
Additional

- Multi-range climate information

Source: http://slideplayer.com/slide/1447561/
Project Overview

Forecast mixing in daily time-step (S2S and Seasonal)

Hydrology (watershed modeling)

Agriculture (Crop modeling)

Drought forecast using seasonal forecast (EDI)

Risk components for Risk Assessment Framework

Remote Sensing

S2S Forecast

Seasonal Forecast

Climate Change

Drought forecast using machine learning and R/S (SPI, ...)

Drought forecast information & weights for models

Down-scaling
Crop modeling (S2S)

2) Assessment critical growth stages of crop from S2S Information
   - in cropping season: 1~2 weeks (within 7 ~ 15 days)
   - 3 critical periods (e.g., 1~2 weeks after sowing or planting, flowering period and grain filling period during reproductive period. Those periods are within 7~15 days)
multi-disciplinary research

- breeding
- plant physiology
- crop modeling
- socioeconomics
- hydrology modeling results

Chung et al., 2014: Modeling the effect of a heat wave on maize production in the USA and its implications on food in the developing world. *Weather and Climate Extr* 6, 67-77.
(doi: 10.1016/j.wace.2014.07.002)
Thank you so much for attention