Variation and uncertainty in the potential yield of Korean soybean under multi-model ensemble climate change scenarios

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Introduction

- Abnormal weather conditions caused by climate change (i.e., drought and high temperature) are often increased concerns about ensuring a safe growth and yield of the rainfed crops.
- Many studies on the growth and yield responses of future climate scenarios in the crop models have been actively studied recently.
- While various future climate change scenarios have been used in climate change impact assessments in many applications, concerns regarding uncertainty in the future climate scenarios predicted by climate models have increased.

Objectives & Study Areas

This study was carried out to

- Examine changes in yield and response of soybeans in crop growth models where the various future climate scenarios have been downscaled to reflect the topography of South Korea.
- Determine whether an MME approach can contribute to the assessment of the impacts of climatic uncertainty on the potential grain yields of soybeans under various future climate change scenarios.

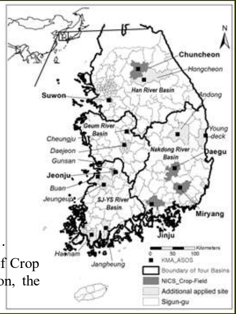

Fig. 1. Geographical locations of the six sites (bold letters and gray polygons) of NICS (National Institute of Crop Science) at which the genetic parameters of "Taegwang" were calibrated and validated. In addition, the locations of 10 sites (italic letters and hash polygons) for CROPGRO-Soybean simulation are shown.

Results

I. The reproducibility of the potential yield of soybeans under past climate change scenarios:

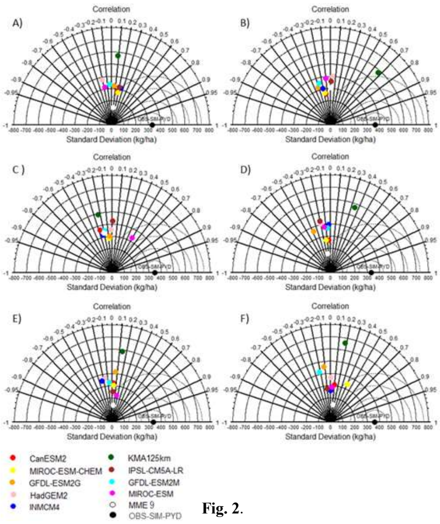

Fig. 2. The correlation coefficients versus the standard deviations for the potential yields (SIM-PYDs) of eight global climate models and one regional climate model (RCM), simulated from CROPGRO-Soybean at six stations (A: Daegu, B: Miryang, C: Jeonju, D: Jinju, E: Suwon, F: Chuncheon).

Figure 2 shows the standard deviations (SD) and the correlation coefficients of the predicted potential yield for the eight individual global climate models (GCMs) and one regional climate model (RCM) in all six sites during 1976 to 2005. As shown Figure 2, during the past period (1976-2005), the predicted potential yield for individual global climate models (GCMs) (individual-SIM-PYDs) did not reproduce the observation climate-based simulated potential yield (OBS-SIM-PYD) since the correlation between the individual-SIM-PYDs and OBS-SIM-PYD was low. However, the correlation between the individual-SIM-PYDs of regional climate model (RCM) and the OBS-SIM-PYD is higher than that of the individual-SIM-PYDs of GCMs.

As the number of GCMs participating in the multi-model ensemble (MME) increased, the root mean squared error (RMSE) decreased. In the other hand, the estimation error (e.g., RMSE) decreased as the number of GMCs included in the MME increased, but it did not decrease to zero.

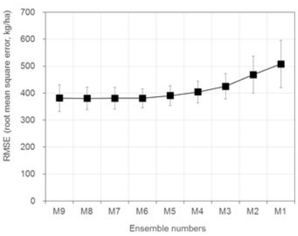

Fig. 4. The Root Mean Square Error (RMSE) versus the ensemble type (numbered M1-M8) for each individual climate models.

II. Changes and uncertainty of the potential yield of soybeans by multi-model ensemble:

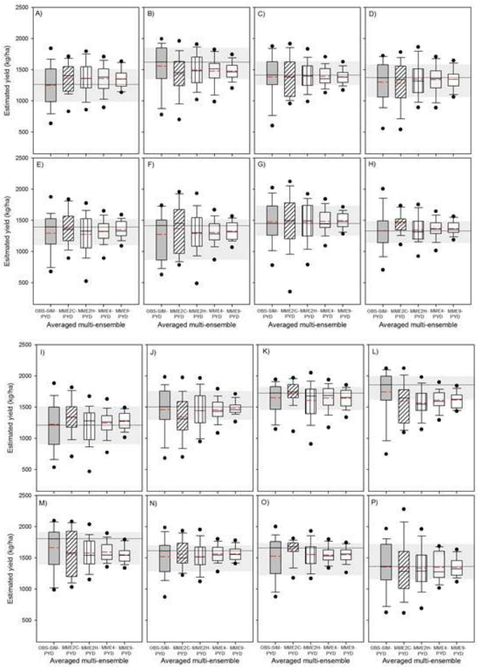

Fig. 3. Comparison of the mean potential yields averaged by applying four ensemble methods to each of 16 sites (A: Daegu B: Miryang, C: Jeonju, D: Jinju, E: Suwon, F: Chuncheon, G: Hongcheon, H: Andong, I: Cheungju, J: Daejeon, K: Gunsan, L: Buan, M: Jeungeup, N: Jangheung, O: Haenam, P: Youngdeck).

The way in which the potential yield averaged by MME represented variations in the observation climate-based predicted potential yields (OBS-SIM-PYD) is also important. Variation (e.g., IQR) s in the individual-SIM-PYDs during the past period (1976-2005) averaged by MME depending on the individual-SIM-PYDs of each single GCM included in the average were compared (Figure 3). Although the variation in individual-SIM-PYDs averaged by MME varied depending on the type and number of included climate models, generally the variance of MME2C-PYD and MME2H-PYD showed better reproducibility of the variance in the OBS-SIM-PYD than MME4-PYD or MME9-PYD. In order words, the mean of MME4-PYD or MME9-PYD seemed to be similar to the mean of OBS-SIM-PYD, but they were too averaged to have a small fluctuation range (i.e., IQR) and they could not effectively reproduce the variation of OBS-SIM-PYD (Chung et al., 2017).

Conclusion

- It could not be concluded that the multi-model ensemble (MME) approach reduced the uncertainty, but it did reduce the estimation error of the predicted potential yield of soybeans under future climate change scenarios.
- The MME approach is not suitable for the estimation of the potential yield during extreme or abnormal climate events due to the large error in the annual variation of the predicted potential yield.

Future work

Generate and analyze the spatial distribution of the relative change of soybean potential yields:

In most southern regions, the future potential soybean yields will be lower than at present, since in MME the relative change of the potential yields of soybean was expected to decrease in the near future under RCP4.5 and RCP8.5 scenarios at the most sites.

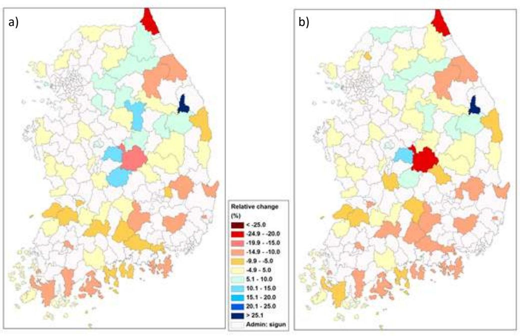

Fig. 6. Spatial distribution of the relative change of soybean potential yields in RCP4.5 (a) and RCP8.5 (b) during 2021-2050, respectively.

Acknowledgment:

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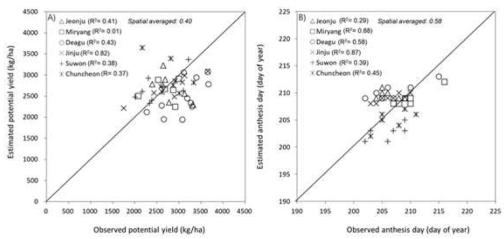
Methods and Materials

Crop model simulation:

- ***CROPGRO-Soybean (Hoogenboom et al., 2010)***: version 4.6
- ***Genetic parameters***: Kim et al. (2012).

Fig. 5. Comparison of predictability of the potential yield (A) and flowering time (B) based on genetic parameters of "Taegwang", from 2003 to 2013 at the 6 sites (Jinju, Suwon, Chuncheon, Daegu, Miryang, and Jeonju).



Climate input:

- ***Period***:
  - *Past*: 1981-2010 (2003-2010)
  - *Future*: 2021-2050
- ***Multi-climate scenarios***: eight scenarios of GCMs of CMIP5 and one scenario of RCM of Korean Meteorology Administration

Model	Origin	Country	Resolution
KMA-12km	Korea Meteorological Administation	Korea	12.5km x 12.5km
CanESM2	Canadian Centre for Climate Modeling and Analysis	Canada	2.8° x 2.8°
GFDL-ESM2G GFDL-ESM2M	NOAA/GFDL (Geophysical Fluid Dynamic Laboratory)	USA	2.5° x 2.0°
HadGEM2-CC	Meteorological Office Hadley Center	UK	1.88° x 1.25°
inmcm4	Institute for Numerical Mathematics	Russia	2° x 1.5°
IPSL-CM5A-LR	Institute Pierre Simon Laplace	France	3.75° x 1.8°
MIROC-ESM MIROC-ESM-CHEM	Atmosphere and Ocean Research Institute, National Institute for Environmental Studies, and Japan Agency for Marine-Earth Science and Technology	Japan	2.8° x 2.8°

Table 1. List of 8 individual Global Climate Models (GCMs) and one individual Regional Climate Model (RCM) used in this study.

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