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Letter

Potential Yield of Soybean with Climate Change in Ethiopia

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LETTER

In the southern regions of Ethiopia, soybeans have been cultivated using a double cropping system, with soybeans planted after winter and spring crops such as winter barley, garlic, and onions. Recently, due to climate change, soybeans have been cultivated as summer crops, alongside potatoes and cabbages. However, concerns for the safe growth and yield of crops have been increasing due to the increased frequency of extreme weather events, such as heat waves and droughts.

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. Climate change data produced from the Global Climate Model (GCM) may only be suitable for analyzing changes in the average atmospheric characteristics at synoptic scales due to the low spatial resolutions (200 to 400 km) and simplifications of physical processes. To overcome the limitations of the spatial resolution of the GCM, and to produce more detailed climate information, dynamic downscaling methods uses Regional Climate Models (RCM) that can take into account the physical processes of a particular area have been developed. As another way to resolve this uncertainty, a few methods have been developed. One such method is a bias correction method that corrects for the systematic bias between GCMs by comparing past climate change scenarios predicted by GCMs with observational data from the same period to evaluate whether GCM that have already been developed can reproduce past climates. Models that apply spatial downscaling to make predictions at the national scale are currently being developed, using the statistical multi-criteria selection method of GCM or RCM data. Another method that is used in climate science to reduce uncertainty and produce reliable future climate change data is the multi-model ensemble (MME) approach, a method that combines climate information from more than one GCM. MME simulation, that uses more than one crop growth model, is also currently applied to the evaluation of crop productivity in agriculture research.

This study used DSSAT (Decision Support System for Agrotechnology Transfer), a software package that can simulate the growth of various crops by use of the same input/output files, and is one of the most widely used crop growth models worldwide. Beans such as peanuts and soybeans are simulated by the DSSAT CROPGRO growth model. CROPGRO can simulate the growth of soybeans and the balance of carbon and nitrogen within agricultural systems (such as uptake, fixation, and formation by the soil system) by inputting daily weather conditions to the model. All soil information required for DSSAT soil input parameters was taken from the precision digital soil map produced by the National Institute of Agricultural Science (NAS). This map provides detailed information on the physical and chemical properties of the soil texture. Information from DSSAT soil profiles regarding the locations of the 16 ASOS weather stations was extracted from the digital map for use in this study.

The simulation period of CROPGRO-Soybean for past climate change scenarios was from 1976 to 2005. This period was chosen because the future climate change scenarios used by CMIP5 in this study had been forecast since 2006, and we then selected the 30 year period from 1976 to 2005 of past climate change scenarios for this analysis. For projections from 2006 to 2100, the near future period used in this study was set from 2021 to 2050. The coefficient of determination (R2) and root mean squared error (RMSE) were calculated to validate the impact on the potential yields of the genetic parameters of Taegwang. The potential yield of Taegwang estimated from the observed weather data for the past period (1976-2005) was used as the observation climate-based simulated potential yield (OBS-SIM-PYD) for this analysis. The potential yields of Taegwang predicted by the past and future climate change scenarios of eight individual GCMs and one RCM were also used as the simulated potential yields for individual GCMs (individual-SIM-PYDs). The interquartile range (IQR) of individual-SIM-PYD for the past 30 years from 1976 to 2005 was calculated. The IQR can be obtained by subtracting the first quartile from the 3rd quartile. The prediction for the anthesis day and potential yield in Jinju during 2003-2013 proved reliable since the Taegwang genetic parameters of Kim were constructed using data from Jinju. Given that soybeans are sensitive to day length, the predictions of the anthesis day for Miryang and Daegu were accurate, as these two sites are geographically close to Jinju and hence have similar day lengths. In contrast with the accurate prediction of the anthesis day in Miryang, the prediction of the

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potential yield was not accurate. We were not able to determine whether the prediction of the potential yield was not accurate due to insufficient observed yield data from the Mirayng site. However, as mentioned in the Introduction, it could be suggested that, due to the lack of existing case studies of crop model in Ethiopia not enough genetic parameters or high quality observation data are available for the calibration and validation of input parameters for crop modeling.