IMPACT OF CLIMATE CHANGE USING CRAFT: A CASE STUDY FOR WEST AFRICA

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INTRODUCTION

- The CGIAR research program on Climate Change, Agriculture and Food Security Program's (CCAFS) Regional Agricultural Forecasting Toolbox (CRAFT) is a framework for multi-scale spatial gridded simulations using an ensemble of crop models. The toolbox facilitates studies on the potential impact of climate change on crop production for a region in addition to other capabilities such as the regional in-season yield forecasting and risk assessment.
- CRAFT can be used to generate and conduct multiple simulation scenarios, maps, and interactive visualizations using a crop engine that can run the crop simulation models DSSAT, APSIM, and SARRA-H, in concert with the Climate Predictability Tool (CPT) for probabilistic seasonal climate forecasts.

OBJECTIVES

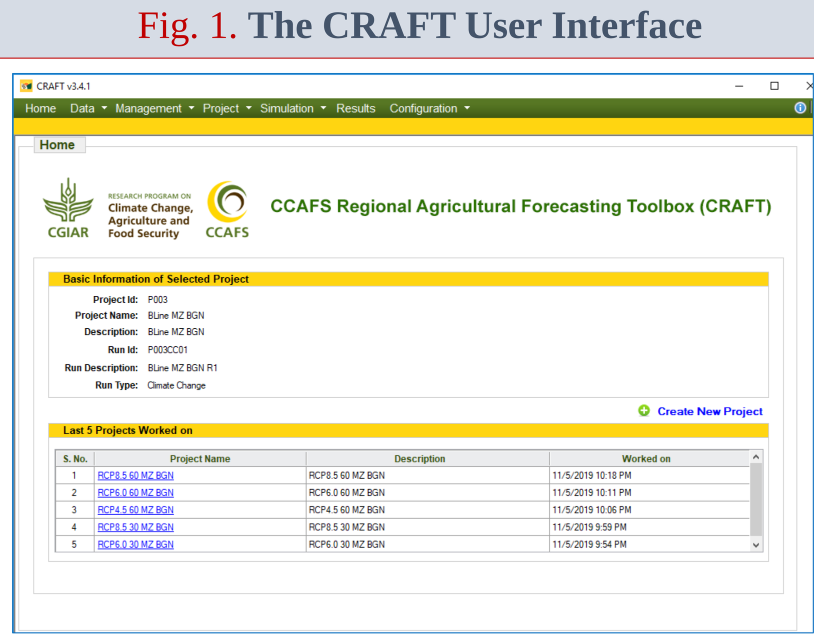
One of the main applications of CRAFT is to address food security under a changing climate. The objective of this study were:

- To prepare gridded data sets for soil, weather, crop and its management as key inputs into CRAFT for reproducing historical yields both spatially and temporally.
- To determine the impact of climate change for the near-term (2020-2040) and the midcentury (2050-2070) periods under the RCPs 4.5, 6.0, and 8.5 on cereal crop yield in the West Africa.

CRAFT

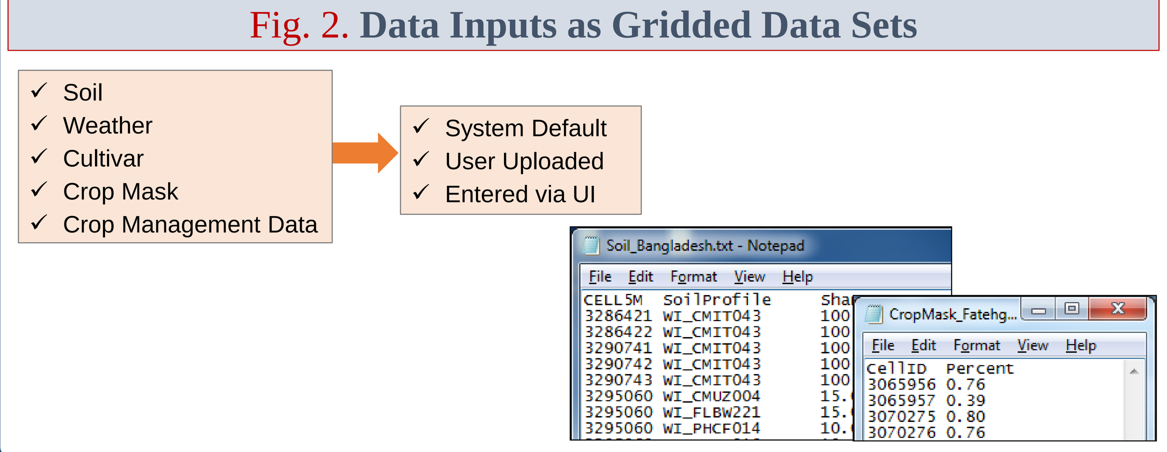
- Climate Change, Agriculture and Food Security (CCAFS) Regional Agricultural Forecasting Toolbox (CRAFT) includes the client application with a user-friendly interface (Fig. 1) and the database implementation.

Fig. 1. The CRAFT User Interface



- CRAFT is designed to use gridded data schemes for spatial variability through the use of two predefined reference grids of 5 and 30 arc minute resolutions. Using schematization, three spatial scales are considered at a country, state/province, and district levels.
- The input data must be prepared as shape files and masked datasets using GIS and uploaded into the database (Fig. 2).

Fig. 2. Data Inputs as Gridded Data Sets



MODEL AND INPUTS

- The simulations were conducted with the CRAFT crop engine that included the DSSAT Cropping System Simulation model (CSM).
- The input data were prepared as GIS shape files and masked datasets at a 5 arc-minute (0.083°) resolution and were uploaded into the CRAFT database.
- Initial conditions included root weight: 50 kg/ha; total residue: 50 kg/ha; N residue: 0.4%; incorporation depth: 5 cm; available water: 15%; initial N: 5 kg/ha.
- Crop mask was created for the maize hybrid Obatampa; the simulations conducted with the CSM-CERES-Maize model.
- Planting: dry seed in rows at an average population of 5 plant/m^2; a row spacing of 75 cm; a planting depth of 5 cm and the earliest planting on June 12.
- There was one fertilizer application of 50 kg N/ha at 17-26 days after sowing (*DAP*).

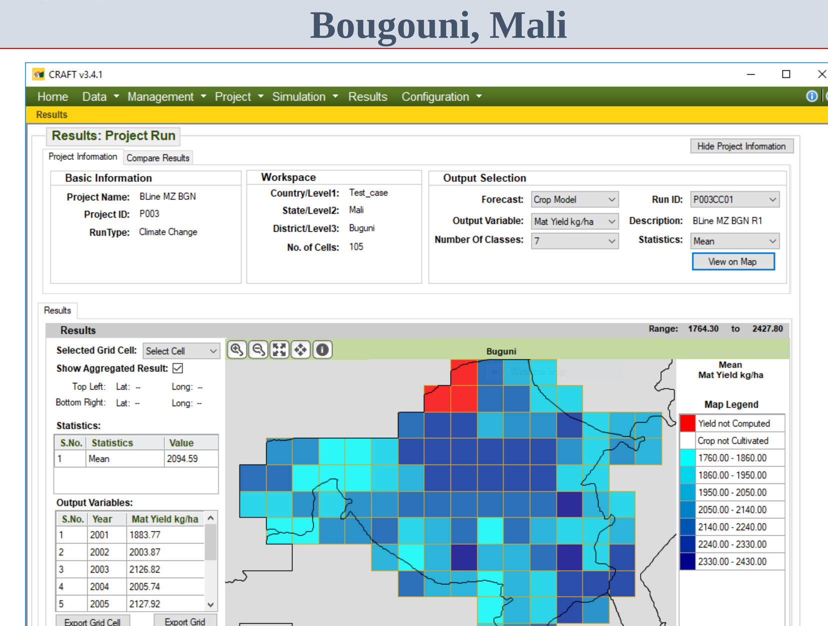
Weather and Soil Data

- Daily climate data (min and max temperature, rainfall, and radiation) on future weather projections from an ensemble of three GCMs (GISS-E2-H, MIROC5, NorESM1-M) generated by MarkSim weather file generator (web version for IPCC AR5 data - CMIP5) for 3 RCPs (4.5, 6.0, and 8.5) were prepared for Mali in West Africa. One set of weather data was used per a 5 arc-minute grid cell.
- Soil mask was based on soil profiles from the AfSIS soil database version 1.0 of the International Soil Reference and Information Centre (ISRIC) in Wageningen, The Netherlands, which was developed for the project "Globally integrated-Africa Soil Information Service (AfSIS)". One dominant soil profile was considered per a grid cell.

CASE STUDIES

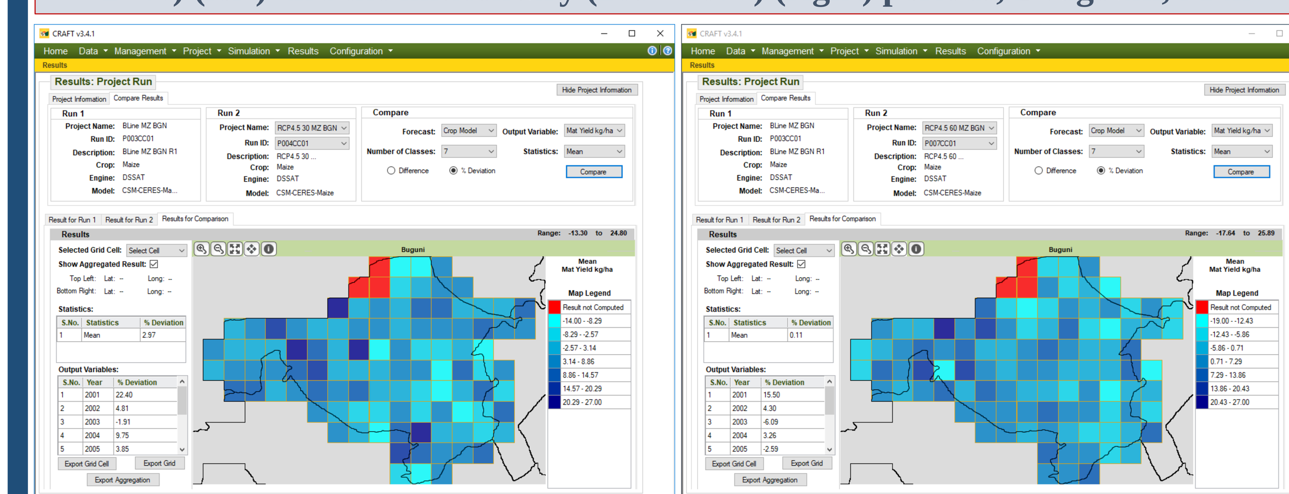
- Results for one region of Bougouni, Mali (105 cells) and for maize crop are provided below.
- Estimation of a long-term mean and variability of simulated historical maize yield (1991 - 2010) as a base line and its comparison to the observed yield time series showed the regional yield (observed in average 1971 kg/ha) was well simulated with a mean absolute error (*MAE*) - 150 kg/ha, standard error (*SD*) - 183 kg/ha, and relative error (*ER*) - 7.6 % (Fig. 3).

Fig. 3. Aggregated Simulated Maize Yield as a Baseline (1991-2010), Bougouni, Mali



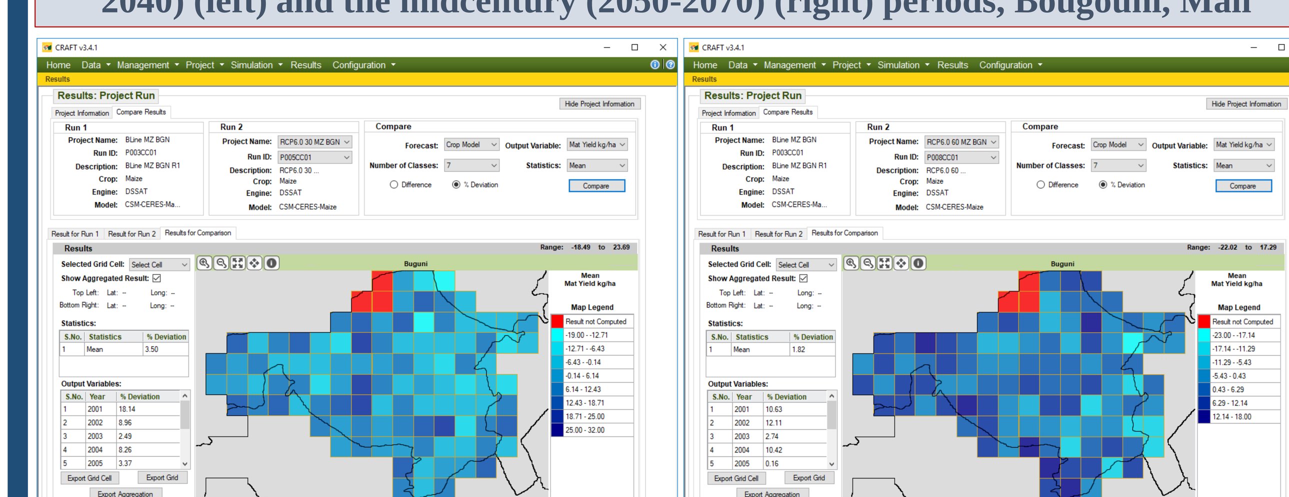
- Simulated values of a long-term (1991 - 2010) mean and variability of the evapotranspiration (*ET*, mm) and leaf area index (*LAI*) were 484 mm and 443-530 mm, 2.66 and 2.36 - 2.86, respectively.
- Climate change impact assessment for the near-term (2020-2040) and the midcentury (2050-2070) periods under the RCPs 4.5, 6.0, and 8.5 on regional maize yield for the entire evaluation period showed the following:
- Regional average yield increased by 3% for the RCP4.5 scenario in the near-term period, but its spatial variability over the area was from -14 to +27% (Fig. 4, left). The increasing tendency was negligible (0.11%) for midcentury period (Fig. 4, right), but again it has clear spatial variability of the impact.

Fig. 4. Deviation of the yield (%) from baseline for RCP4.5 in the near-term (2020-2040) (left) and the midcentury (2050-2070) (right) periods, Bougouni, Mali



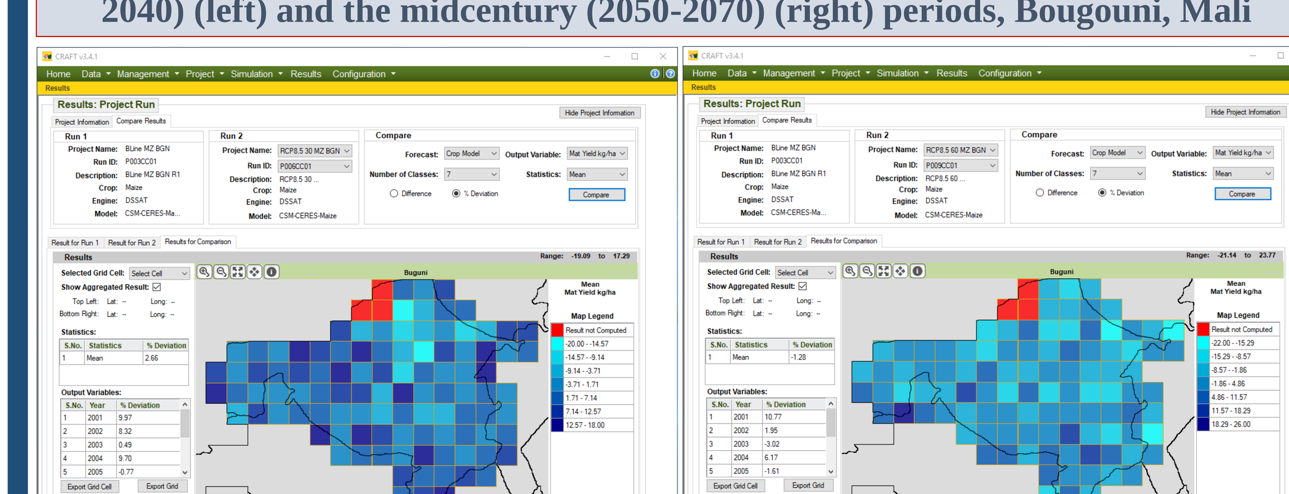
- For the RCP6.0 scenario average regional yield also increased in the near-term period and in more extant (3.5%) (Fig. 5, left), but in less extent (1.8%) for the midcentury (Fig. 5, right) compared to the base line yield.

Fig. 5. Deviation of the yield (%) from baseline for RCP6.0 in the near-term (2020-2040) (left) and the midcentury (2050-2070) (right) periods, Bougouni, Mali



- For the RCP8.5 scenario average regional yield increased for the near-term period by 2.7% (Fig. 6, left), but there were areas with extremely high decrease in yield up to 15-20%. For the midcentury the yield decreased by 1.3% (Fig. 6, right) compared to the base line yield, although in some areas yield increased by 18-26%.

Fig. 6. Deviation of the yield (%) from baseline for RCP8.5 in near-term (2020-2040) (left) and the midcentury (2050-2070) (right) periods, Bougouni, Mali



- Despite the general positive tendencies over the study region climate change impact showed clear spatial distribution with various magnitudes from negative to positive impact on the final yield. In some case negative effect of decreasing yield reached the level of 15-25%.

CONCLUSIONS

- CRAFT with the gridded data sets allowed evaluation of climate change impact on long-term yield over the region and well captured spatial distribution of this impact.
- Comparison capability between different projects and runs implemented in CRAFT showed that it well suited for visualization a wide range of spatial and temporal variability of the final simulation results.

FUTURE WORK

- Extending the simulation for entire study region that consists of four (Benin, Burkina Faso, Ghana, and Mali) West African countries.
- Considering other cereal crops such as sorghum and pearl millet.
- Applying other crop models integrated in CRAFT according an ensemble approach to crop modeling.