CROP MODEL BASED SPATIAL YIELD FORECASTING USING CRAFT: CASE STUDY FOR GHANA

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INTRODUCTION

- The CCAFS Regional Agricultural Forecasting Toolbox (CRAFT) is a platform to provide a one-stop access to gridded crop modeling and yield forecasting along with risk analysis and climate impact studies at spatial resolutions of 5 and 30 arc-minutes (https://craft.dssat.net/).
- It is designed as an adaptable software platform to produce multiple simulation scenarios, maps, and interactive visualizations using a crop engine that can run the pre-installed crop models in concert with the Climate Predictability Tool (CPT) for seasonal climate forecasts.
- Integrating crop modeling with climate forecast in CRAFT, including gridded data and simulations offers new insights into regional yield forecasting.

OBJECTIVES

- To evaluate CRAFT for simulating the spatial distribution of maize yield under rainfed conditions of West Africa, particularly in the northern Ghana.
- To apply CRAFT for forecasting water limited regional maize yield in the major maize-growing regions in Ghana.

MODEL AND INPUTS

- The simulations with CRAFT were conducted with the DSSAT crop engine.
- CRAFT is designed to use gridded data to account for spatial variability through the reference grid.
- Input data were prepared as GIS shape files and masked datasets at a 5 arc-minute (0.083°) spatial resolution and were uploaded into the database.

Daily Weather

- Gridded daily weather data included maximum and minimum daily air temperatures, rainfall and solar radiation (1992-2021) and sources were:
- Maximum and minimum daily air temperatures and rainfall from 17 weather stations of the Ghana Meteorological Agency (GMet).
- Maximum and minimum daily air temperatures, Daily solar radiation by NASA POWER (World Wide Energy Resources).
- Daily total rainfall by CHIRPS (Climate Hazards Infrared Precipitation with Stations).

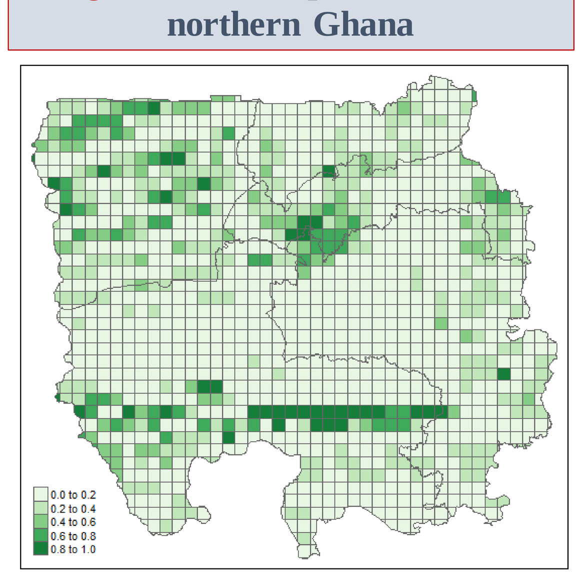
Soil Data

- Soil characteristics (soil physical, hydraulic, and chemical properties) for each soil horizon up to a depth of 2 m were obtained from the International Soil Reference Information Centre (ISRIC) soil grids database and the Harvest Choice generic soil profiles (HC27). Both datasets has a high spatial resolution of 5 arc-minutes.

Crop Management

- Crop mask of maize (source the Ministry of Agriculture of Ghana) included calibrated for that region maize variety Obatanpa from the DSSAT maize varietal dataset (Fig. 1). Values of mask are share per grid cell (0-1).

Fig. 1. Maize crop mask for the northern Ghana



- Planting: method - dry seed; distribution – rows; population on average - 4 plant/m^2; row spacing - 75 cm; planting depth - 7 cm. Planting dates were calculated from CHIRPS data on seasonal and annual rainfall.
- Fertilizer application: Number of application - 1; application - 14 days after sowing (*DAP*); amount - 60 kg N/ha at 10 cm depth.

Simulation Setup

- One weather dataset and one soil profile for each individual grid cell.
- Initial conditions: root weight - 100 kg/ha; total residue - 250 kg/ha; N residue - 0.8%; incorporation depth - 5 cm; available water - 25%; initial N - 8 kg/ha.

CASE STUDIES

Yield Spatial Variability

- The spatial extent of this study was the northern part in Ghana consisting of five regions.
- An estimation of long-term mean and variability of simulated maize yield for was conducted using time series of regional-level maize yield data (1992 - 2021).

Yield Forecast

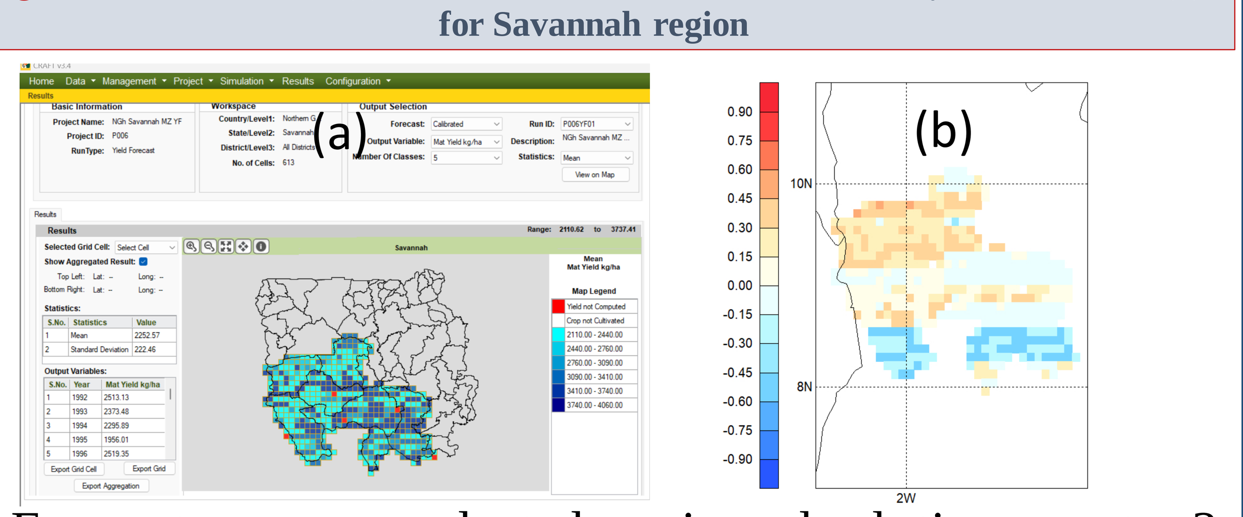
Yield forecasting with CRAFT uses the following steps:

- Simulate yield with current year of weather data through the forecast date, complemented by past year of weather data through harvest for each historical year.
- Simulated yield values serve as a predictand and provide a mean and distribution.
- The current year forecast is a result of fitting the predictand and the current predictor (SST) to the statistical model by CPT and train the model over years (29).
- Yield forecasting in CRAFT is conducted after optional detrending and calibration procedures.

Yield Forecast for the Savannah region

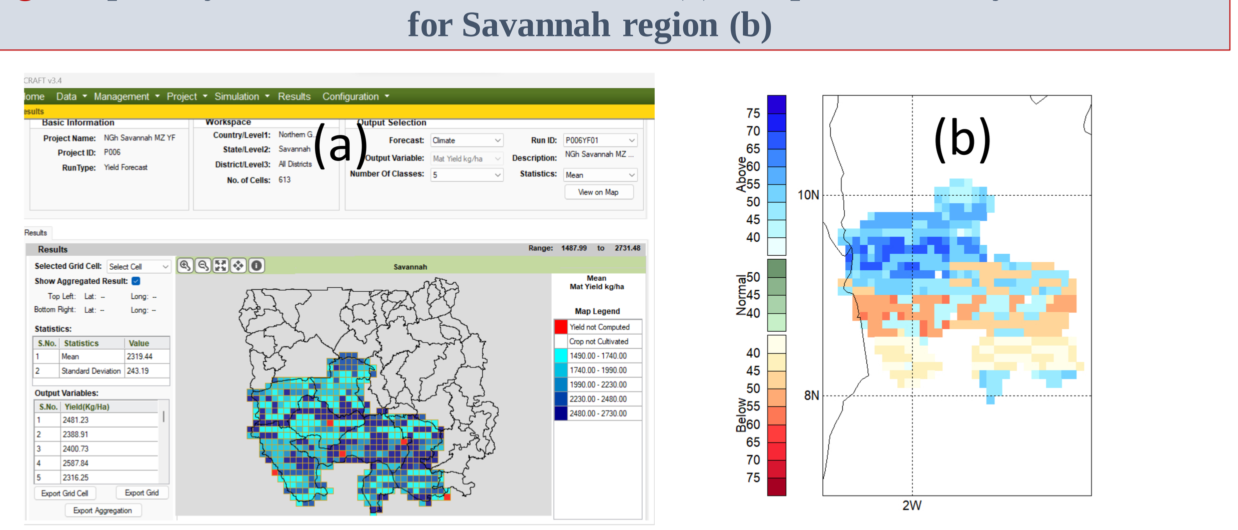
- After detrending yield values (1992-2020) calibration run was conducted (Fig. 2a) for the Savannah region (613 grid cells). The best SST predictor was selected based on correlation between SST and yield values (Fig. 2 b).

Fig. 2 Yield calibration (a) and Pearson's correlation between yield and SSTs (b) for Savannah region



- Forecasts were conducted various lead time up to 3 months. The forecast for June 15, 2021, is demonstrated for the Savannah region (Fig. 3a). The selected predictor (SST) was for May-June-July(MJJ). Regional yield forecast was 2216 kg/ha with an error of 269 kg/ha or 13.8% compared to reported one. From the forecast results probabilistic yield forecast can be derived (Fig. 3b)

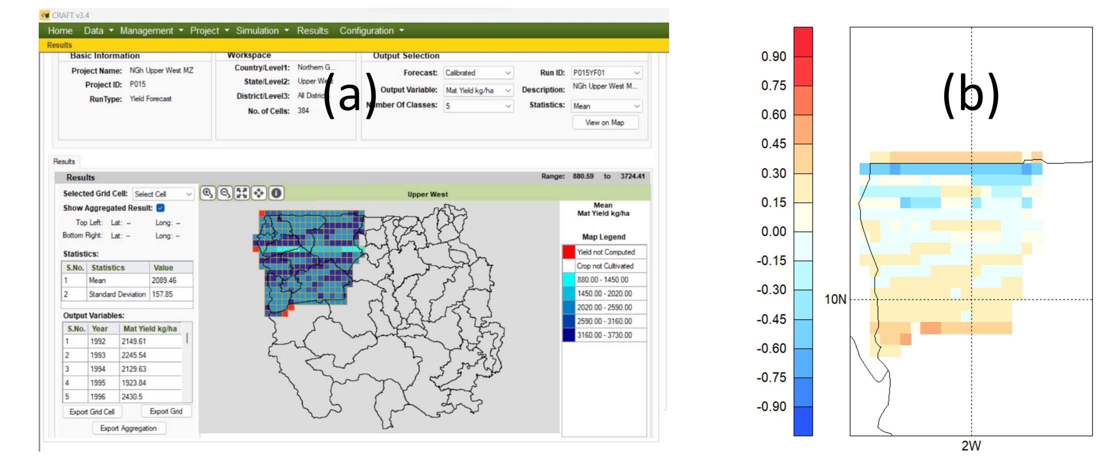
Fig. 3. Spatial yield forecast on 2021 June 15 (a) and probabilistic yield forecast for Savannah region (b)



Yield Forecast for the Upper West region

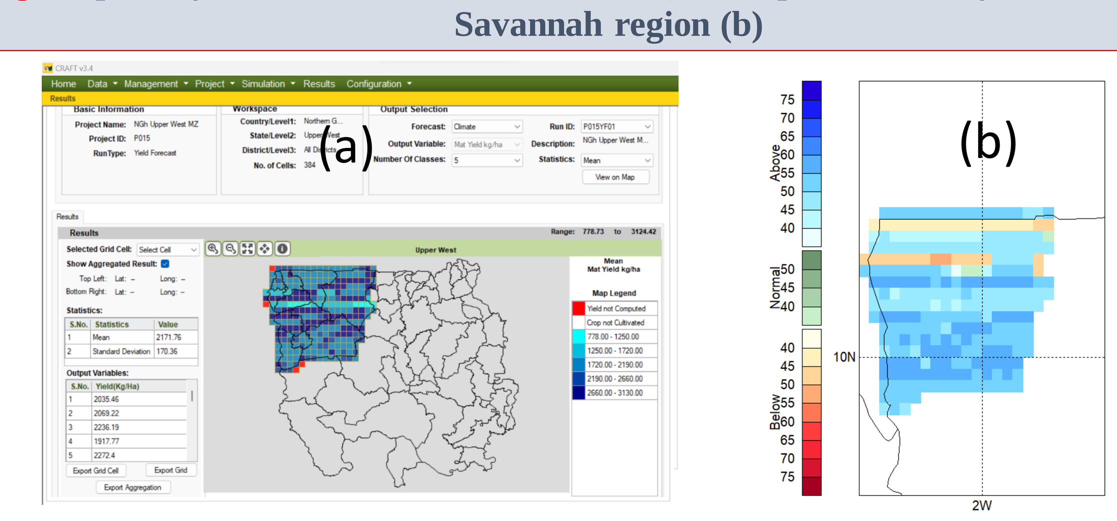
- After detrending yield values (1992-2020) calibration run was conducted (Fig. 4a) for the Upper West region (384 grid cells). The best SST predictor was selected based on correlation between SST and yield values (Fig. 4b).

Fig. 4 Yield calibration (a) and Pearson's correlation between yield and SSTs (b) for Upper West region



- Forecasts were conducted various lead time up to 3 months. The forecast for June 15, 2021, is demonstrated for the Upper West region (Fig. 5a). The selected predictor (SST) was for May-June-July(MJJ). Regional yield forecast was 2287 kg/ha with an error of 123 kg/ha or 5.4% compared to reported one. From the forecast results probabilistic yield forecast was derived (Fig. 5b)

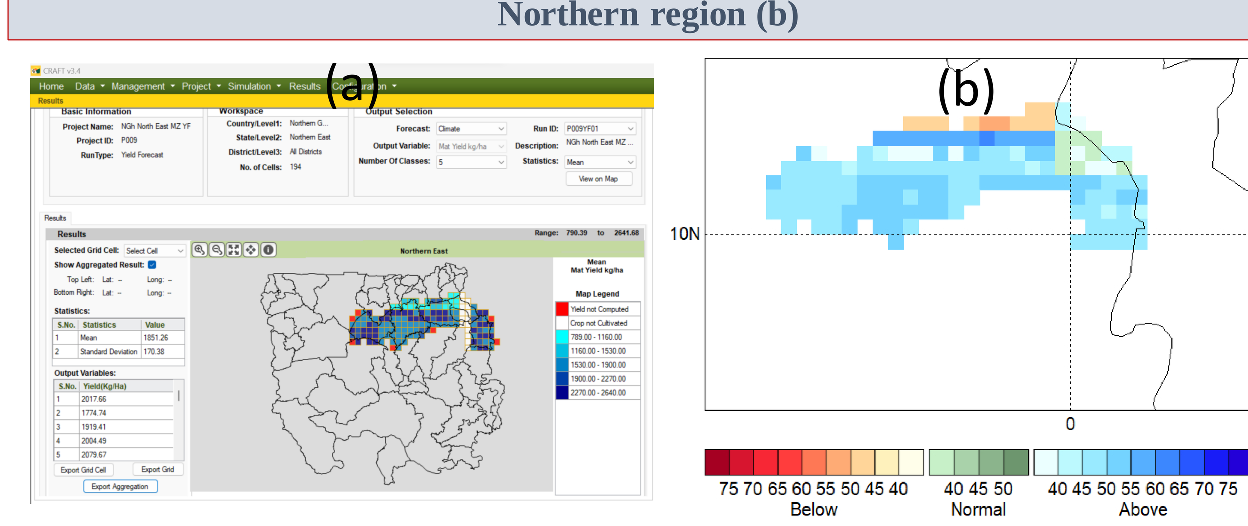
Fig. 5 Spatial yield forecast on 2021 June 15 (a) and probabilistic yield forecast for Savannah region (b)



Yield Forecast for the North East region

- The forecast for June 15, 2021, is demonstrated for the North East region (Fig. 6a). The selected predictor (SST) was for May-June-July(MJJ). Regional yield forecast was 1840 kg/ha with an error of 212 kg/ha or 11.5% compared to reported one. From the forecast results probabilistic yield forecast was derived (Fig. 6b)

Fig. 6 Spatial yield forecast on 2021 June 15 (a) and probabilistic yield forecast for Northern region (b)



CONCLUSIONS

- The study showed that the regional maize yield forecast error using SSTs in the most cases in the northern Ghana did not exceed 15% with the lead time up to three months.
- The present study introduces a promising approach for operationally monitoring regional crop growth and predicting yield based on combination of crop model and climate forecast.
- Successful application of this approach at regional scale depends on various digital databases used as the crop model inputs.

Reference and Funding

- Shelia, V., Hansen, J., Sharda, J., Porter, C., Aggarwal, P., Wilkerson, C.J., Hoogenboom, G., 2019. A multi-scale and multi-model gridded framework for forecasting crop production, risk analysis, and climate change impact studies. Environ. Modeling & Software. 115, 144-154.

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