AGU Fall Meeting – 2018 (GC43I-1656)

Comparison of two spatial implementations of a crop model using remotely sensed observations over southeastern United States

Vikalp Mishra[1,2], Walter Lee Ellenburg[1,2], Kel Markert[1,2], Sarva T. Pulla[1]

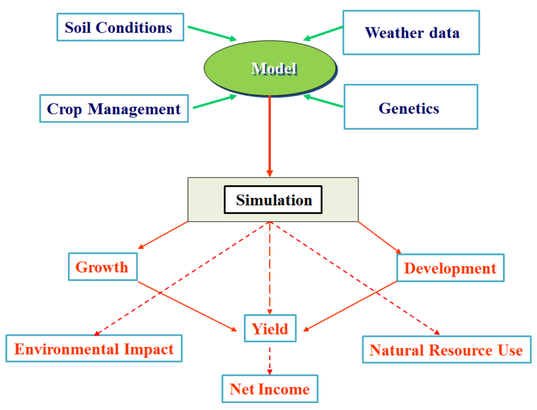
Global food security is one of the most pressing issues of the current century, particularly for developing nations. Agricultural simulation models can be a key component in testing new technologies, seeds and cultivars etc. However, inaccurate input information, model related errors and the mode of implementation can also add to model uncertainties. In this study, the crop model is implemented in two separate fashions: a) gridded (GriDSSAT model) and b) using random spatial ensembles (RHEAS model). This is done in the Southeastern US to evaluate and understand the model performance over a region data availabilities. Once the model performance is assessed, multiple satellite based earth observation parameters such as soil moisture, vegetation index etc. can be assimilated into crop models to reduce input and model related uncertainties particularly in data limited regions. In this study, the National Agricultural Statistical Services (NASS) reported yield data at county levels are used for comparison and validation purposes. The GriDSSAT model estimation of corn yields in comparison with the reported NASS yields showed an overall RMSD of nearly 3720 (kg/ha) whereas RMSD for the RHEAS model implementation was 3550 (kg/ha). Overall the GriDSSAT model had negative bias of nearly 2400 kg/ha (except for 2013) while RHEAS had a slight positive bias of 400 kg/ha (approx.).

Study Area and Setup

- For this research, 3 states were selected from Southeastern U.S. where GriDSSAT runs operationally,including:
  - Alabama (AL)
  - Georgia (GA)
  - South Carolina (SC)
- Crop yields were compared at county levels
- NASS county mean yields served as 'ground truth' for this study.
- Corn crop was selected in this study since it's one of the most water intensive crops and can represent the optimum water use by a crop in the region
- The region typically has low irrigation activities (except parts of GA). Therefore both models were run without irrigation.

GriDSSAT

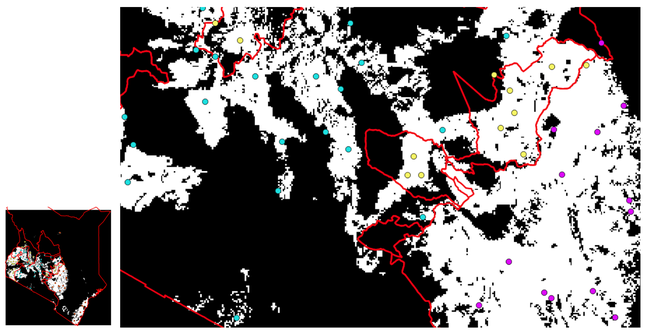
- Gridded DSSAT (Decision Support System for AgroTechnology Transfer) model, currently operational over Southeastern U.S. (Study area + Florida).
- The model operates at ~4.7 km resolution and is calibrated with localized crop management information such as cultivars, fertilization type, amount and time etc.
- Model uses top 3 agricultural soils of the county for simulations.
- GriDSSAT is forced with high resolution and quite reliable weather information from NCEP stage IV precipitation data, temperature and solar radiation from reanalysis(?)
- GriDSSAT is a deterministic model



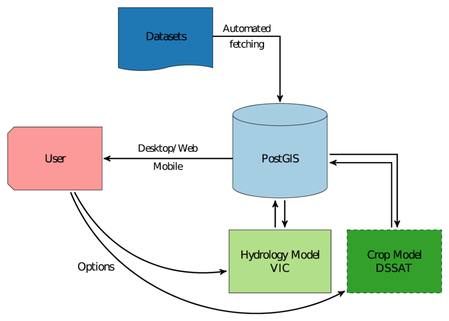
Simplified Schematic of the DSSAT crop model working

RHEAS

- Probabilistic coupled hydrologic (Variable Infiltration Capacity: VIC) and crop model (DSSAT) framework.
- The framework is capable of simulating both the hydrologic and crop model component simultaneously over specified geometry (grid, county, state, region etc.)
- RHEAS is populated with 1-km resolution global soil data from WISE soil database.
- Apart from global soils, the RHEAS by default is forced with coarse resolution global datasets such as NCEP at 25 Km (for temperatures).
- The model is capable of performing 'data assimilations' using popular filters like Kalman Filter and its variants.
- Various outputs from hydrology model can be used to force/assimilate the crop model - solar radiation is forced in crop model in this case. But parameters like Soil moisture can be assimilated into crop model too.
- The framework is also capable of assimilating satellite derived products into hydrologic model as well such as soil moisture/Leaf area index etc.
- The framework is based on probabilistic approach: such that based on the model is run over the specified number of ensembles for the study area. The points are selected at random and aggregated to represent the overall crop growth and yield estimates.



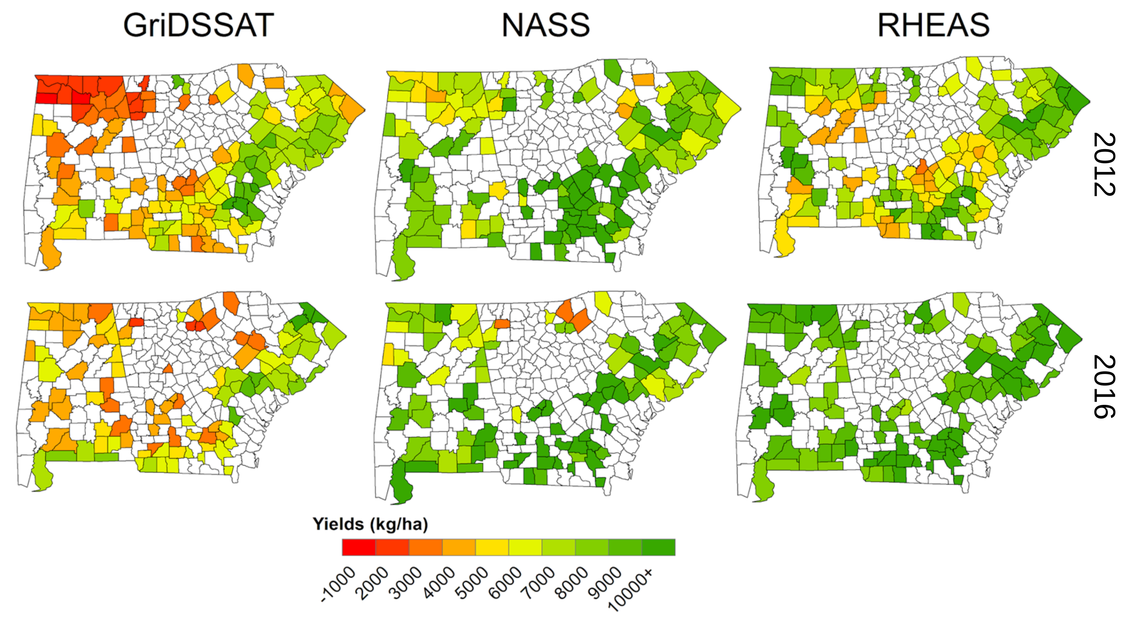
The above image is the Crop Mask over Kenya. The dark region represents non-agricultural area and the white region represent agricultural area. The colored points represent the random points that were selected in the probabilistic approach

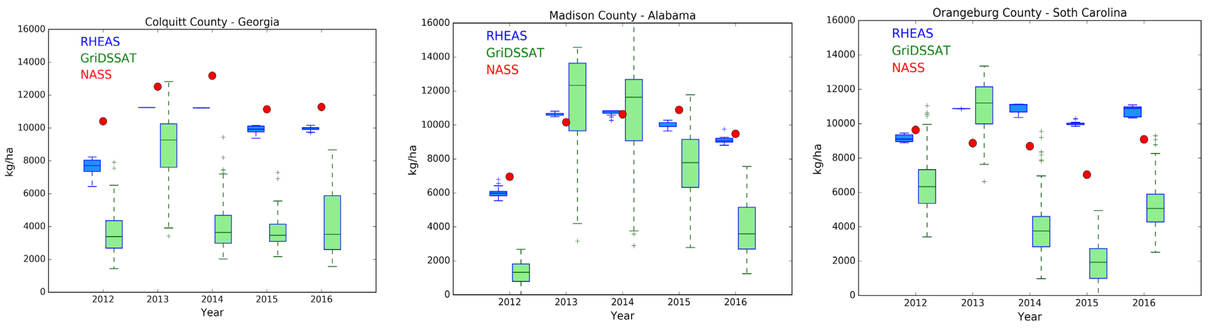


Simplified Schematic of the RHEAS Software Architecture

Results

Yield comparison for two years (2012 and 2016) as an example of model results. Only corn producing counties (170) were used in this comparisons. The GriDSSAT model implementation corn yields in comparison with the reported NASS yields showed an overall RMSD of nearly 3720 (kg/ha) whereas RMSD for RHEAS model implementation was 3550 (kg/ha). Overall the GriDSSAT model had negative bias of nearly 2400 kg/ha (except for 2013) while RHEAS had a slight positive bias of 400 kg/ha (approx.).



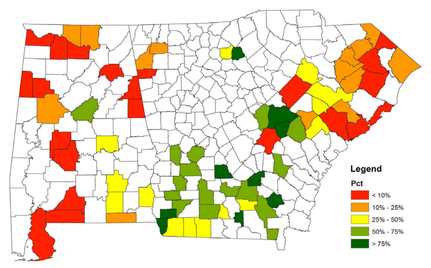


The boxplot shows the comparison b/w model yields and NASS reported yields. The red dots are NASS yields for a county whereas boxplot show the spread of yields of all the grids within a county for GriDSSAT model run and 30 ensemble members for RHEAS.

Overall correlations are 0.35 (GriDSSAT vs NASS) and 0.11 (RHEAS vs NASS). Nearly 78% counties had positive correlations for GriDSSAT, whereas, only 57% counties had positive correlations for RHEAS

2012 was a significant drought in North Alabama that GriDSSAT captures, however, when using NASS statistics, irrigated yields may influence the NASS estimates.

2012 NASS Percent Irrigation (Corn)



Conclusion

- The DSSAT module through RHEAS framework produced fairly realistic estimates of the yield in the Southeast United States. But the model underperformed during extreme conditions. Whereas in comparison the well-calibrated GriDSSAT model generally performed below par.
- There is a big difference in model performance for counties with significant irrigation (Colquitt) and negligible (Orangeburg). For moderate irrigated region both model performed comparable (except for dry years like 2012)
- Assimilating parameters like Soil moisture into RHEAS could produce better yield estimates.

[1]NASA-SERVIR, Marshall Space Flight Center, Huntsville, AL
[2]Earth System Science Center, University of Alabama in Huntsville, AL
Contact: Vikalp Mishra, 320 Sparkman Drive, Huntsville, AL 35805**,** vikalp.mishra@nasa.gov