2019 Final Report Summary Sheet

Grantee Information

Project Title: Web-based Cover Crop Decision Support Tool

Institution: University of Illinois at Urbana-Champaign, College of ACES; NCSA

Primary Investigator: Jonathan Coppess

NREC Project # 2017-3-360574

[redacted]

Is your project on target from an IMPLEMENTATION standpoint? ☒ **Yes** ☐ **No**

If you answered "no" please explain:

Is your project on target from a BUDGET standpoint? ☒ **Yes** ☐ **No**

If you answered "no" please explain:

Based on what you know today, will you meet the objectives of your project on-time and on-budget? ☐ **Yes** ☒ **No**

If you answered "no" please explain:

While the tool development has progressed somewhat slower than anticipated, it has remained on-budget and reasonably on-time. The biggest challenge for this project has been accessing the data necessary for calibration and validation/verification of the model.

Have you encountered any issues related to this project? ☒ **Yes** ☐ **No**

If you answered "yes" please explain:

As mentioned above, the biggest issue is having sufficient data from experiments/research and actual farmer experience to properly calibrate the model in the tool and verify its outputs.

Have you reached any conclusions related to this project that you would like to highlight? ☐ **Yes** ☒ **No**

If you answered "yes" please explain:

Have you completed any outreach activities related this project? Or do you have any activities planned? ☒ **Yes** ☐ **No**

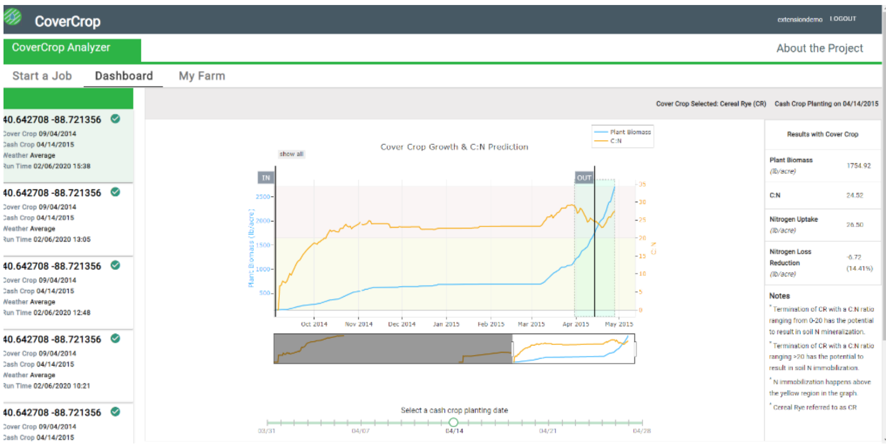
If you answered "yes" please explain and provide details for any upcoming outreach:

See outreach details below.

Summary of the Project

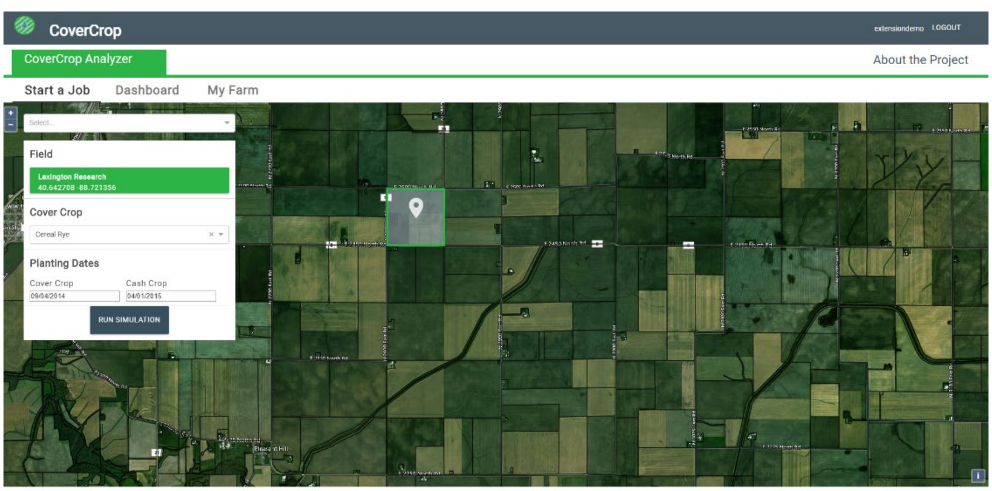
Figure 1 is the most recent image of the cover crop decision support tool dashboard. This is the key visualization of the output of data produced by the complex DSSAT model estimating cover crop performance in the research fields in Lexington, Illinois. The key dashboard outputs for the user include the estimated biomass in the field based upon crop growth, weather, and soils from the SSURGO database; estimated nitrogen uptake in the cover crop; and the estimated reduction in nitrogen lost from the field. The dashboard also provides the carbon-to-nitrogen (C:N) ration for the crop, while helps inform the user of the potential for soil N mineralization based on estimated termination dates and commercial crop planting.

Figure 1. Cover Crop Tool, Dashboard



The visualized output in the dashboard is the product of running DSSAT in the web environment using information for actual fields; data input by the user, such as management, as well as weather and soil data. The user begins by selecting an actual field from a mapping tool, as demonstrated in Figure 2.

Figure 2. Cover Crop Tool, Start Job



Figures 1 and 2 show the tool development to date and a visual summary of the progress of this project. In short, the dashboard represents an effort at placing advanced scientific research in the hands of the farmer, researcher, educator or policymaker using advanced computing technology. A video demonstration of the tool in operation is also included with this report.

The following is the complete 2019 Final report for NREC project **#2017-3-360574-222**, for the development of a web-based decision support tool for cover crop management.

(1) Tool and Model Calibration

Cereal rye as a cover crop has proved to be one of the most efficient methods for reducing reduce nitrate loss from tile drainage without any allelopathic effect on the cash crops, i.e., corn and soybean. The complex DSSAT model, however, does not specifically include a model to simulate the growth of cereal rye. Because cereal rye and winter wheat are very similar crops, the winter wheat model has been used to simulate cereal rye. Specifically, winter wheat is used as a proxy for cover crop cereal rye using the CERES-wheat model contained in DSSAT. One key difference between the two crops is hibernation and cold killing temperature. Cereal rye has a lower hibernation and killing temperature as compared to winter wheat. To address this difference and improve DSSAT's ability to simulate cereal rye as a cover crop, we modified the coefficients related to temperatures as indicated in the following table.

Temperature Coefficients	**Description**	**Wheat**	**Rye**
TKFH	Temperature at which killed when fully hardened (°C)	-15	-25
TKLF	Temp.at which leaves start to be killed (°C)	-10	-25

Web based cover crop tool calibration for cereal rye biomass was performed based on a trial and error method using the modified CERES-wheat model in DSSAT. Initial calibration used observed data and results from the research of Dr. Shalamar Armstrong and experiments conducted at Illinois State University Teaching and Agricultural Research Farm in Lexington Illinois. Soil information was obtained from the SSURGO database at USDA which is used by the web tool; soils were 721A-Drummer and Elpaso (silty clay loam soil). The following information is from Dr. Armstrong's experiments.

<table>
<tr><th colspan="2">Crop</th><th colspan="2">Planting</th><th>Harvesting</th></tr>
<tr><td colspan="2">2014 Rye/Fallow</td><td colspan="2">Sep 4, 2014</td><td>Apr 16, 2015</td></tr>
<tr><td colspan="2">2015 Corn</td><td colspan="2">Apr 30, 2015</td><td>Sep 23, 2015</td></tr>
<tr><td colspan="2">2015 Rye/Fallow</td><td colspan="2">Sep 5, 2015</td><td>Apr 16, 2016</td></tr>
<tr><td colspan="2">2016 Soybean</td><td colspan="2">May 14, 2016</td><td>Oct 21, 2016</td></tr>
<tr><td colspan="2">2016 Rye/Fallow</td><td colspan="2">Sep 15, 2016</td><td>Apr 12, 2017</td></tr>
<tr><td colspan="2">2017 Corn</td><td colspan="2">Apr 25, 2017</td><td>Oct 9, 2017</td></tr>
<tr><td colspan="2">2017 Rye/Fallow</td><td colspan="2">Sep 15, 2017</td><td>Apr 12, 2018</td></tr>
<tr><td colspan="2">2018 Soybean</td><td colspan="2">May 7, 2018</td><td>Sep 28, 2018</td></tr>
<tr><td colspan="2">2018 Rye/Fallow</td><td colspan="2">Sep 6, 2018</td><td>Apr 24, 2019</td></tr>
<tr><td colspan="2">2019 Corn</td><td colspan="2">May 20, 2019</td><td>Oct 15, 2019</td></tr>
<tr><td colspan="5"><u>Treatments:</u></td></tr>
<tr><th>FCC</th><th>FN</th><th>SCC</th><th>SN</th><th>ZC</th></tr>
<tr><td>With cover crop</td><td>Without cover crop</td><td>With cover crop</td><td>Without cover crop</td><td rowspan="2">Zero control</td></tr>
<tr><td colspan="2">Fall Dominated Split N Application</td><td colspan="2">Spring dominated split N application</td></tr>
</table>

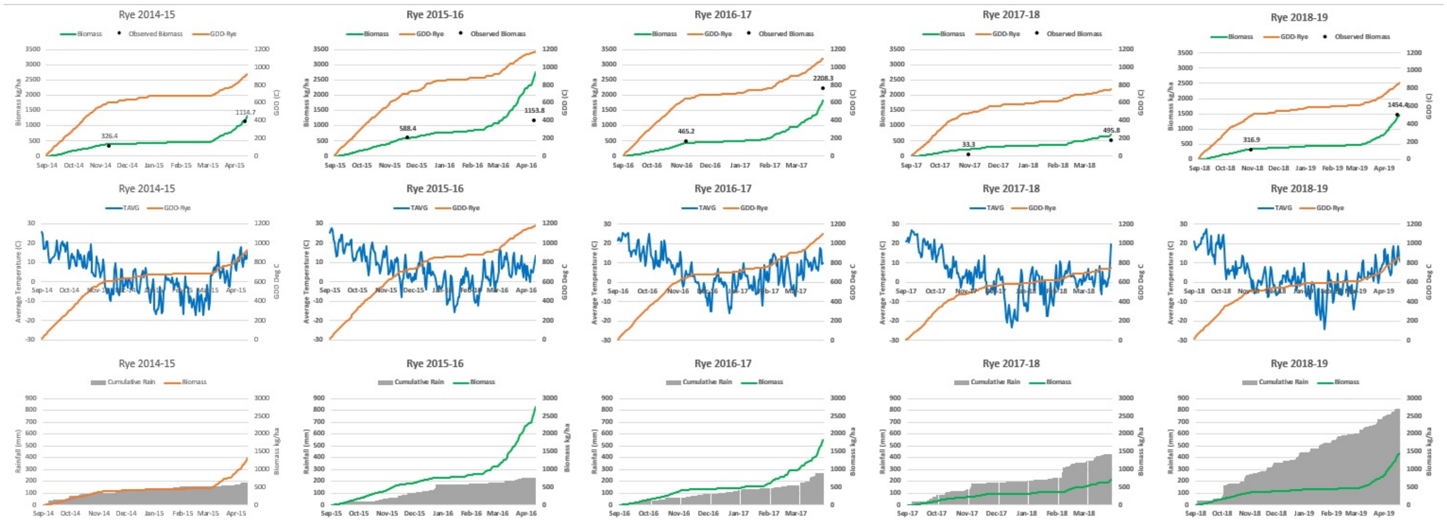


Figure 3. Updated Calibration Results

DSSAT contains both Genotype and Ecotype parameters in the CERES-Wheat model. Genotypes depend on different cultivars, whereas, the ecotype parameters are based mostly on environmental factors for crop growth. Since cereal rye is differs from winter wheat, the genotype parameters were found not to be sensitive to cereal rye growth. Therefore we are calibrating the model to assume that winter wheat is growing under different environmental factors, i.e., to calibrate with the ecotype parameters. On performing sensitivity analysis, we found the ecotype parameters to be very sensitive. On changing a few parameters related to photosynthetic radiation use efficiency and leaf production/growth, we were able to perform the calibration for 2014-15, 2015-16 and 2016-17 and validated for 2017-18 and 2018-19.

The observed biomass for year 2014-15, 2015-16 and 2016-17 were 1114, 1153, and 2208 kg/ha, respectively, whereas the simulated biomass for these years are 1216, 2671, and 1819 kg/ha. Upon further analysis, we found that the observed biomass for years 2014-15 and 2016-17 were close with simulated biomass of cereal rye; however, there was a big difference between simulated and observed biomass of the year 2015-16. The main reason for this difference was the inclusion of radish in the winter cover crop mix used for the field study. In the field experiments, the cereal rye and radish were planted together with the split of 92% and 8%, respectively. Since 2015-16 had the warmer winter compared to other two years, there was a significant radish growth which limited the growth of cereal rye in the spring reducing the observed cereal biomass. The observed and simulated cereal rye biomass were compared with growing degree days, average temperature and cumulative rainfall to determine the reasoning behind the huge simulated biomass in 2015-16; the results are in Figure 3.

The validation results for year 2017-18 and 2018-19 were compared. The observed cereal rye biomass was found to be 496 and 1454 kg/ha, whereas, the simulated biomass for these years, respectively, were 706 and 1421 kg/ha. These results seem quite close to each other; therefore, we have confidence that that the model is sufficiently calibrated for the specific experiment (FCC) at this stage of development. Now, the other part of this research is to estimate the cereal C:N, as it is provides important data points for understanding the growth, impact and, ultimately, the termination of cereal rye. For that it was assumed earlier that plant carbon is roughly 40% of the total cereal rye biomass and since DSSAT simulates the plant nitrogen results, the plant C:N can easily be calculated. Currently, the work on plant C:N estimation and its relationship with the soil nitrogen pool, soil moisture and temperature are in progress. The preliminary results on plant C:N ratio and soil nitrogen pool along with soil moisture and temperature can be seen in Figure 4 for year 2014-15 and 2015-16. Later on, the calibration/validation on other experiments on the different fields with different management conditions will be performed to optimize the web-tool for Illinois conditions.

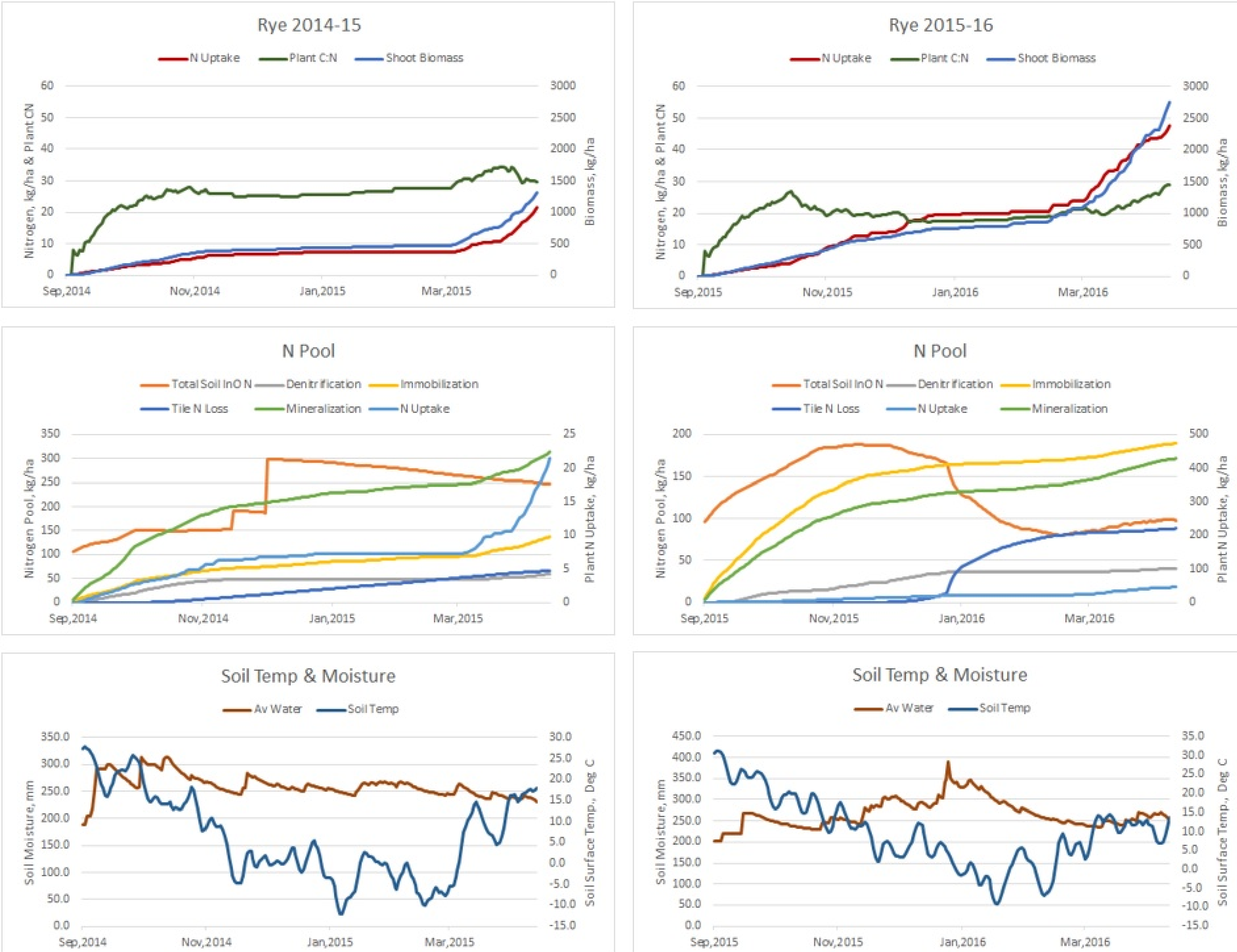


Figure 4. Additional Calibration Results

(2) Tool Development Progress

Tool development progressed significantly during 2019 and has effectively reached beta release stage (subject to calibration/verification), with development highlights as follows:

- *Tool Revisions and Fixes*. Operating DSSAT in the web environment requires a continuous set of treatments for the simulation to work properly. The development team made progress revising tool operation to allow for filling gaps in the experiment file between crops or activities on the farm; gaps to be filled with fallow as users make changes to their field's treatment data. In addition, we fixed the default experiment JSON document by removing duplicate entries and fixed a bug related to using incorrect cultivar ID for fallow. We also fixed bugs related to the "Run Simulation" button that was not responding to user click and in the graphs page related to dates not aligning properly between with and without cover crop scenario. We noticed that Nitrate Loss and Nitrate Leached graphs were showing a drop off between termination of fallow and the next cash crop. This was fixed and in both the termination dates for with and without cover crop scenario align such as the drop off doesn't occur.

- *Web Service Updates*. Updated the web service to include cultivar details in the planting event JSON body and to allow the user to handle the addition and deletion of new farming events, enabling user to add or delete treatment entries like fertilizer application, tillage, to a crop field from the backend. We also added the feature to set fertilizer field to "None" from the user interface, allowing users to delete a fertilizer application entry from his/her field, if needed. In addition, we downloaded the 2019 weather data from the Illinois State Water Survey and updated our database to include it so we have all weather data through 2019. We added a CHANGELOG to the web service repository so as to keep track of the code changes in a better way, as well as a delete endpoint to the web service to remove a field from the user's profile and upgraded package dependencies in the web application. We created a fork of the DSSAT Translator (https://github.com/agmip/translator-dssat), updated it so that we can support more than 9 treatments in the experiment file. This enables us to have long running experiment setups that can have many more treatments. We have started using this fork of the DSSAT Translator for converting the DSSAT experiment file from SQX to JSON format and vice versa. Previously, we were using the AgMIP QuadUI for this purpose. With this change, we will also have more control over custom changes that might be needed for this project. We have also set up automated builds for this fork using GitHub Actions. The improved DSSAT Translator is also available for public use. Finally, we also fixed some bugs in the backend service that were identified during this time.

- *User Interface*. We developed code to display cover crop history on the My Farm page, as well as for the user interface and the web service to enable updating planting and harvesting events, tillage event details (including modifications to information on the fields in the profile) and the ability to add multiple fertilizer events. We made progress on updating the user interface to include the feature to add a new crop to the user's field. We updated the user interface and web service to fix the download experiment file URL in the My Farm Summary page so that a user can download the DSSAT sequence file (SQX) associated with the field by clicking on the Download icon on the My Farm Summary page. The My Farm Summary page also now includes tillage details. Figure 4 provides the latest version of the My Farm page and Figure 5 is a series of multiple images for My Farm User Inputs and data entry. Finally, we have started an initial implementation of the Dashboard, the most recent version is shown in the images below. We have also improved the Start a Job page so users can specify the cover crop planting date and the cash crop planting date and the DSSAT model automatically runs using +/- two weeks. This will allow users to use the recently added Dashboard to understand how allowing the cover crop to grow longer can impact the results. The Dashboard includes a graph visualizing cover crop growth and C:N prediction over time along with a table that shows Plant Biomass, C:N ratio, Nitrogen Uptake, and Nitrogen Loss Reduction. Users can use the slider bar at the bottom of the page to see how allowing the cover crop to grow longer impacts the Nitrogen Loss Reduction.

(3) Budget and Management

The following is a summary of the budget through December of 2019 for this project.

2019 Final Report: Budget Summary									
	1/1/17 - 12/31/17		1/1/18 -12/31/18		1/1/19 - 12/31/19		TOTAL ITD DEC 2019	
	Budget	Expense	Budget	Expense	Budget	Expense	Budget	Expense
Budg Pool (Investment Income)	68.23	-	1,105.78	-	1,230.66	-	2,404.67	-
Transportation Services	-	-	-	-	-	104.40	-	104.40
Services	9,845.00	492.28	10,638.00	18,077.02	-	2,109.02	20,483.00	20,678.32
Indirect Costs Pool	13,557.00	4,350.30	13,060.00	15,291.23	7,830.00	8,786.54	34,447.00	28,428.07
Academic Salary	77,665.00	27,198.78	84,333.00	73,887.46	57,441.00	55,500.56	219,439.00	156,586.80
Assistant Salary	-	-	-	16,594.45	-	-	-	16,594.45
Wages	-	808.75	-	568.75	-	-	-	1,377.50
Benefit Costs	34,522.00	10,656.19	22,587.00	28,506.91	13,035.00	21,371.46	70,144.00	60,534.56
TOTAL	**135,657.23**	**43,506.30**	**131,723.78**	**152,925.82**	**79,536.66**	**87,871.98**	**346,917.67**	**284,304.10**
Coppess Acct (ACE)	23,655.23	13,518.28	29,320.78	41,297.85	40,383.66	249.34	93,359.67	55,065.47
Navarro Acct (NCSA)	112,002.00	29,988.02	102,403.00	111,627.97	39,153.00	87,622.64	253,558.00	229,238.63
	135,657.23	**43,506.30**	**131,723.78**	**152,925.82**	**79,536.66**	**87,871.98**	**346,917.67**	**284,304.10**

(4) Outreach and Publication Updates

During 2019, we showcased the cover crop management web application at the Engineering Open House at the University of Illinois on March 8, 2019. We submitted a full-paper titled "Extensible Framework for Analysis of Farm Practices and Programs" to the PEARC19 (Practice and Experience in Advanced Research Computing) Conference (https://www.pearc19.pearc.org/), which was presented at the conference on July 31, 2019. This paper is available through the ACM Digital Library (https://dl.acm.org/doi/abs/10.1145/3332186.3337063). In addition, we demonstrated the tool and discussed the project at the Universities Council on Water Resources (UCOWR) annual meeting in Utah, June 12, 2019 (https://ucowr.org/2019-conference/). We also presented the project and demonstrated the tool in February 2020 at the Midwest Cover Crop Council meeting and at NREC Live.