Grantee Information

Project Title:	Web-based Decision Support Tool for Cover Crop Management
Institution:	University of Illinois
Primary Investigator:	Jonathan Coppess
NREC Project #	2017-3-360574-222

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:

Have you encountered any issues related to this project?   ☒ Yes   ☐ No
If you answered "yes" please explain:
See below, subsequent detailed final report.

Have you reached any conclusions related to this project that you would like to highlight?   ☒ Yes   ☐ No
If you answered "yes" please explain:
See below, subsequent detailed final report.

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 below, subsequent detailed final report.

Additional Notes:

See below.

2018 FINAL REPORT
Grantee: Jonathan Coppess, University of Illinois
NREC Project: 2017-3-360574-222; Web-based Decision Support Tool for Cover Crop
Management

The following is the 2018 final report for NREC project #2017-3-360574-222, for the development of a web-based decision support tool for cover crop management.

(1) Project Management

The following is a summary of the budget for this project based on a recent report from the University's sponsored programs office data. It covers expenditures and obligations from the beginning of the project through December 31, 2018.

Item	Budget Authority	Activity	Commitments/Obligated	Available Balance
NCSA	$214,405	$156,907	$2,846	$54,652
ACES	$ 53,103	$ 54,816	$ 654	($2,366)
Totals	$267,508	$211,723	$3,500	$52,286

(2) Tool Development Progress

In 2018, we made significant progress on developing the web-based cover crop management tool prototype, particularly as concerns the design and implementation of the web tool frontend and backend service. A primary focus this year has been on establishing the user interface in the web tool to allow users to add/modify/remove farm practice information for their farms, save that data to a *PostgreSQL* database, and use the farm data as input to the *DSSAT* crop model. The development team worked with a web designer at NCSA to review the first version of the prototype and work through the application requirements to help create mockups of the user interface (UI), including a design for the *MyFarm* UI that farmers would use to add a field and modify the farm practice data associated with the field. Mockups (Figure 1) consisted of visual designs of the UI and cascading style sheets (CSS) to provide a consistent look and feel across the application and to ensure an intuitive user interface.
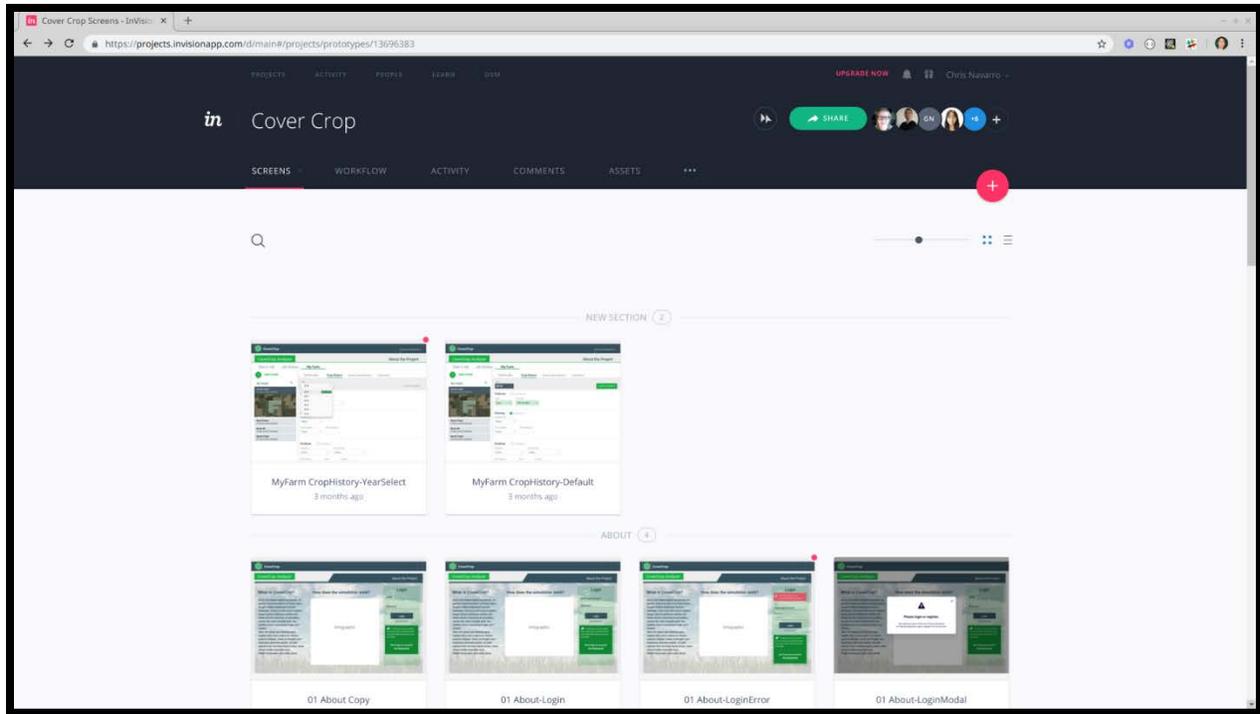
Figure 1. A screenshot of the InDesign interface showing some of the designs created for the web application.

Input from the web designer was used to create the next version of the web application. We developed a login page and registration page for users to register and securely log into the application. The secure login leverages the user management built into the workflow manager, *DataWolf*, which can be configured to use user/password login, Light Directory Access Protocol (LDAP), etc. to provide a secure login. When a user first logs in to the application, they are taken directly to the map, which now centers on user-defined farms or defaults to central Illinois if the user has no defined farms. After logging in, users can use the *MyFarm* interface to add a farm to their profile (Figure 2). When a farm is defined, it is initially populated with some default data. Users can then use the *MyFarm* UI to add/modify farm practice data for each year. This includes modifying fertilizer application (amount, how it's applied, etc.), adding new fertilizer events, modify planting information—distribution, row spacing, depth, date planted, date harvested and tillage information.
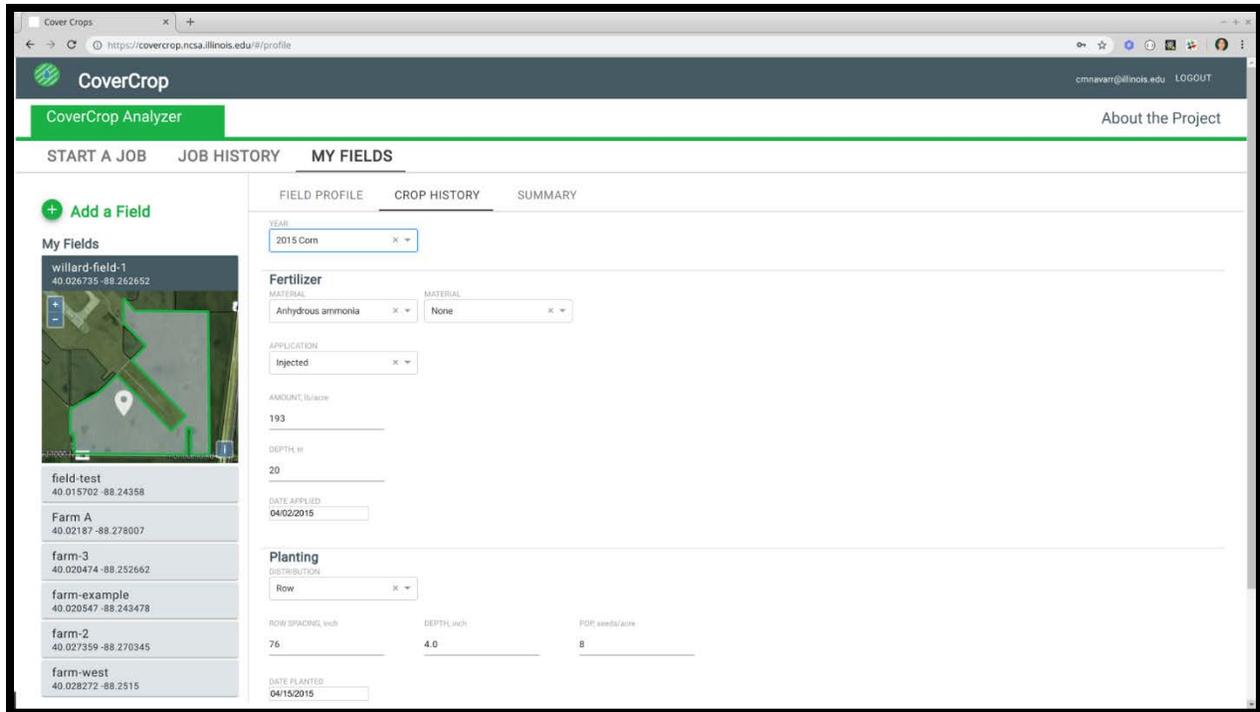
Figure 2. A screenshot of the My Farm page depicting how users can manage their fields.

Users can also go to the Summary page to see all the available data for their farm and download it in *SQX* format using the download button on the page. While working on the *MyFarm* UI changes, which required significant time to design and develop so that it would be functional for farmers, we also added support for a generic *SQX* template file. This intermediate step allowed farmers to perform "What If" scenarios to see how a cover crop could impact a field for any winter/spring season (e.g. the impact of adding a cover crop for winter 2015 through spring 2016). This work included adding a *Python* tool to the workflow to handle running *DSSAT* with either their *MyFarm* data or using the template to generate example data to run what-if cover crop scenarios for different years to evaluate the impact of a cover crop. On the run model page for launching *DSSAT* jobs, we have also added a selection box for selecting a cover crop cultivar (currently only cereal rye), which will be expanded in the future. After running a job, the user is taken to the job history page where they can see the results of the last model run as well as browse through the previous model runs. In addition, the graphs are clipped to show the selected establishment and termination dates from the model run page; a design that we continue to work with in order to provide usable information to the farmer.

The frontend changes for saving user's farm practice data required that we design a Service Layer to save the changes made in the web tool between user sessions. The development team spent time designing a Representational State Transfer (REST) Application Programming Interface (API), referred to as a *RESTful API*, to communicate changes made in the web application to the backend so that the changes can be stored for a user's farm and retrieved later. The following table provides example endpoints included:

Cover Crop Web Application API Definitions		
Route	**Method**	**Description**
/userfield	POST	Add a new farm to the user profile
/userfield	GET	Get a list of user's defined farms
/users/{username}/CLUs/{clu_id}/experiment_file_json	PATCH	Modify JSON format experiment file associated with a username and CLU.
/users/{username}/CLUs/{clu_id}/experiment_file_json	GET	Get experiment file associated with a username and CLU in JSON format
/users/{username}/CLUs/{clu_id}/experiment_file_json	POST	Add a JSON format experiment file to a CLU for a user. Optionally add the default JSON format experiment file to the field if the request body is empty.
/users/{username}/CLUs/{clu_id}/experiment_file_sqx	GET	Get experiment file in SQX format
/soils	GET	Get soil information for field

We developed API endpoints for creating, reading and updating *JSON* (JavaScript Object Notation) format experiment file based on user input. *JSON* is human-readable text consisting of key-value pairs for transmitting data objects and was chosen after researching available tools that could be leveraged. For this purpose, we leveraged the *Agricultural Model Intercomparison and Improvement Project* (AgMIP) JSON format (http://research.agmip.org/display/dev/JSON+Data+Objects). The service has *API*s to convert the *JSON* format experiment file to *DSSAT*'s *SQX* file for the purpose of displaying in the web application as well as a *PATCH* endpoint to make changes to the farm practice data associated with a field, obtain field soil information, etc. We found an existing tool called *AgMIP QuadUI* (http://tools.agmip.org/quadui.php) that could convert the *DSSAT* model data from *SQX* (DSSAT format) to *JSON* (web format). This would allow the web application to communicate changes in *JSON* format to the service to modify the experiment file and the *QuadUI* tool could convert the *JSON* data to *SQX* for model runs. In addition, the *QuadUI* tool can convert to several other formats, which could be potentially leveraged with other models.

Figure 3 is from a demonstration run of the tool for a field south of the Champaign-Willard airport for a cereal rye cover crop established in late October 2018 with expected termination in late April 2019. As discussed below, a growing focus of the work is on calibration of the *DSSAT* model. We are increasing our collaboration with other NREC-funded researchers to use research

data for model calibration. We also continue to troubleshoot issues with *DSSAT* as it operates in the web environment compared with actual data and validation/verification runs between the web-based system and the stand-alone model.
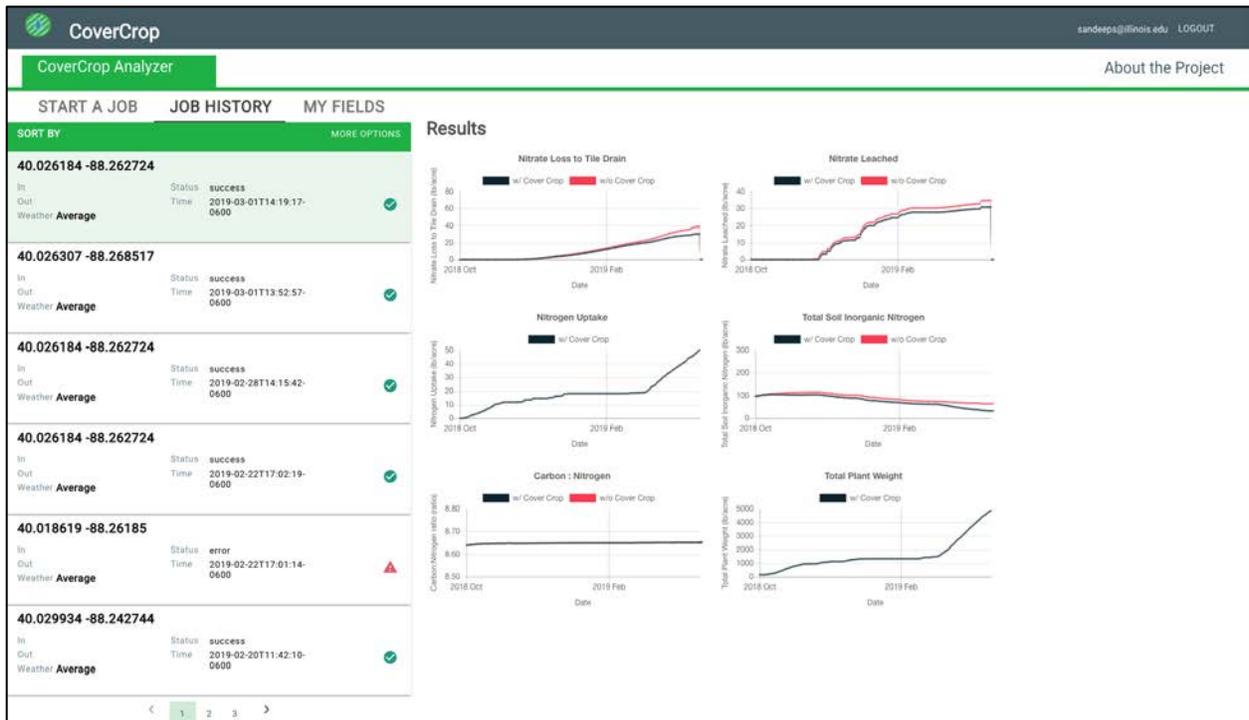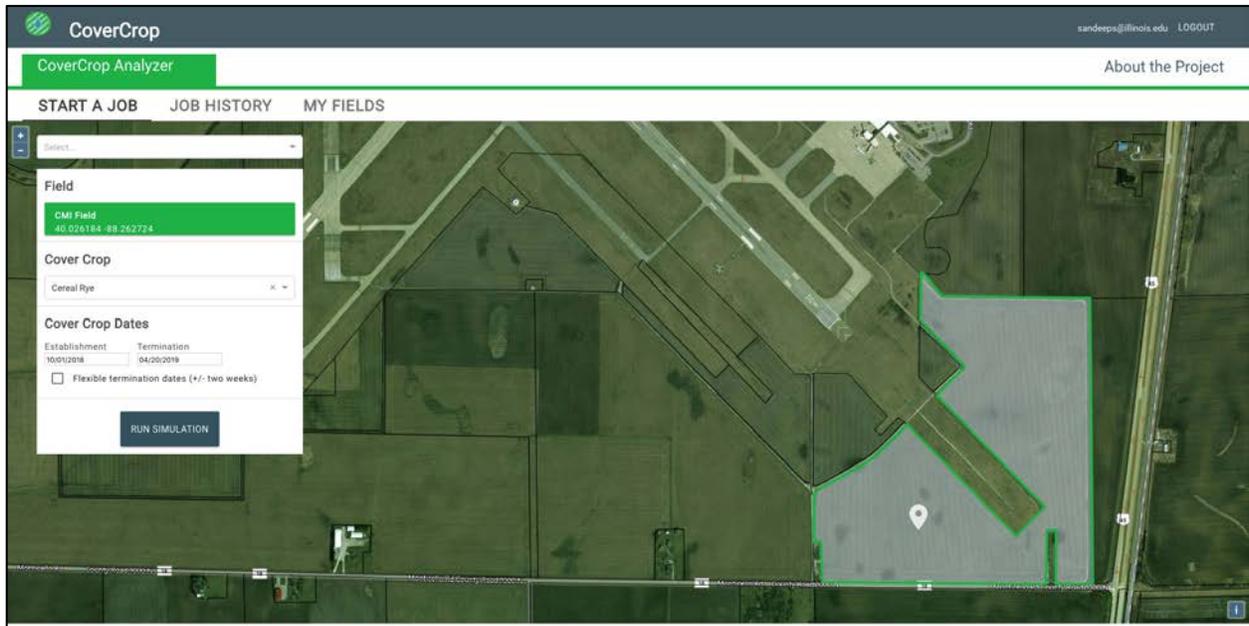

Figure 3. Screenshots of the web application showing user selection of inputs and the job history page showing the output of corresponding DSSAT simulation in the form of plots.

(3) Modeling, Research and Outreach

A priority in the last year was advancing tool development to a point that enabled calibration of the *DSSAT* model and verification of its projections and outputs. In summary, we prepared the calibration procedure for *DSSAT* used by the web application, including soil nitrogen and water dynamics along with crop biomass and yield component. These are visualized outputs from the web application. Specifically, we worked on calibration and validation using observed experimental data provided by Dr. Shalamar Armstrong.

In further detail, the procedure to calibrate the model used by the web application is based on previous research for soil nitrogen and water dynamics along with crop biomass and yield. The calibration process is based on what is known as the "hit and trail" method (Thorpe et al., 2007). The method involves changing each parameter at a time within a certain allowable range. With each change, we run the model and check all significant results that have occurred in the simulated crop growth; analyzing the sensitivity of each parameter on different components of the model. This calibration method includes sensitivity analysis for each parameter responsible for the changes in crop growth simulated outputs. For example, there might be a few parameters simulated by the model which are more sensitive to crop growth, others might be less sensitive. Generally, we work with the highly sensitive parameters based on graphical comparisons of the data, as well as statistical evaluation between observed and simulated data. To date, the observed datasets used for calibration are from the experiments conducted by Dr. Shalamar Armstrong at the Illinois State University Teaching and Agricultural Research Farm, Lexington, Illinois. We are seeking additional data sets from NREC-funded researchers and farmers.

Important results of the calibration and validation process include more than improving the web application, but also provide important revisions or modifications to the *DSSAT* model. For example our work led to revised genotype coefficients of the wheat growth model in *DSSAT*. Importantly, wheat is a proxy for cereal rye as a cover crop in the model. One aspect of our work will be to improve the model so that it is more accurate for cereal rye as a cover crop, and this outcome was one aspect of it. Through the web application, the DSSAT model can better simulate crop growth.

One specific issue we uncovered and modified concerned survival and plant development at very low temperatures during winter; cereal rye, for example, can survive lower temperature extremes better than wheat (Li et al., 2008). Winter wheat has a higher hibernation and killing temperature as compared to cereal rye. The rye and winter wheat are very similar plants; winter wheat has been used by researchers as proxy for cereal rye in cover crop research. As such, winter wheat makes for an adequate proxy in *DSSAT*, but it can be improved upon for cover crop purposes. Because cereal rye is more tolerant of extreme cold temperatures than winter wheat, it can survive and continue to develop at lower temperatures. Based on this work, we modified the genotype coefficients in *DSSAT*, updating the wheat model to better simulate cereal rye in a cover cropping practice.

References:

Li, L., Malone, R. W., Ma, L., Kaspar, T. C., Jaynes, D. B., Saseendran, S. A., ... & Ahuja, L. R. (2008). "Winter cover crop effects on nitrate leaching in subsurface drainage as simulated by RZWQM-DSSAT." *Transactions of the ASABE*, 51(5), 1575-1583.

Thorp, K. R., Malone, R. W., & Jaynes, D. B. (2007). "Simulating long-term effects of nitrogen fertilizer application rates on corn yield and nitrogen dynamics." *Transactions of the ASABE*, 50(4), 1287-1303.