ASSESSING THE FEASIBILITY OF GROWING COVER CROPS IN COTTON PRODUCTION SYSTEMS OF THE TEXAS ROLLING PLAINS

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Abstract

There has been an increasing interest to grow cover crops in the Texas Rolling Plain (TRP) region, mainly to build soil health. However, there are also concerns that growing cover crops could potentially reduce soil moisture, and thereby affect subsequent cash crop yield. Previous field studies from this region demonstrated mixed results with some showing a reduction in cash crop yields due to growing of cover crops and others indicating no significant impact of cover crops on subsequent cotton lint yields. The objectives of this study were to evaluate the CROPGRO-Cotton and CERES-Wheat modules within the Cropping System Model (CSM) of the Decision Support System for Agrotechnology Transfer (DSSAT) for the TRP region, and use the evaluated model for assessing the long-term effects of growing winter wheat as a cover crop on seed cotton yield under irrigated and dryland conditions. The above two modules were calibrated using the measured data on soil moisture and crop yield from four treatments namely (i) cotton without cover crop under irrigated conditions (CwC-I) (ii) cotton with cover crop (winter wheat) - irrigated (CWC-I) (iii) cotton without cover crop - dryland (CwC-D) and (iv) cotton with cover crop - dryland (CWC-D) at the Texas A&M AgriLife Research Station at Chillicothe during the period from 2011 to 2015. A well calibrated CSM-CROPGRO-Cotton and CSM-CROPSIM-CERES-Wheat modules were established for the TRP region. The degree of agreement (*d)* between the CROPGRO-Cotton simulated and measured seed cotton yield was 0.95 during both calibration and validation periods whereas the coefficient of determination (r^2) was 0.99 during calibration and 0.95 during validation. For the above ground biomass predictions by the CERES-Wheat model, *d* and *r* were 0.91 and 0.76, respectively during the calibration period, and 0.84 and 0.53, respectively during the validation period. Results from the long-term (2000-2015) simulations indicated that there was no statistically significant reduction in seed cotton yields due to growing of cover crops.

Introduction

The Texas Rolling Plains (TRP) is predominately made up of monoculture cropping systems with cotton and wheat accounting for over one million hectares. In the recent times, there has been an increasing interest to grow cover crops in this region, mainly to build soil health. Cover crop is a transition crop between two production systems and it has the potential of providing multiple benefits such as preventing soil erosion, improving soil physical and biological properties, suppling nutrients, suppressing weeds, improving the availability of soil water and breaking pest cycles. Many researches emphasized that cover crops help in increasing soil organic matter, increasing infiltration rate and enhancing nitrogen fertilizer use efficiency (Bordovsky et al., 1999; Veenstra et al., 2007; Li et al., 2008). In contrast, several other researchers (Balkcom et al., 2007; Dabney et al., 2001) reported a potential disadvantage of reducing soil moisture to the subsequent cash crops due to growing of cover crops in winter. Previous field studies from the TRP and Texas High Plains (THP) regions demonstrated mixed results with some showing a reduction in cash crop yields due to growing of cover crops (Baughman et al., 2007; Dozier et al., 2008; Keeling et al., 1996) and others indicating no significant impact of cover crops on subsequent cotton lint yields (DeLaune et al., 2012; Sij et al., 2004). In view of these mixed results, there is a need to evaluate the long-term effects of growing cover crops in winter on subsequent cotton crop yield. The Decision Support System for Agrotechnology Transfer (DSSAT) Cropping System Model (CSM) is very useful for this purpose.

The DSSAT CSM has been widely used for various applications across the world (Adhikari et al., 2016; Jones et al., 2003; Modala et al., 2015; Thorp et al., 2010). For example, Salmerón et al. (2014) used the DSSAT CSM to evaluate the impact of cover crop-maize rotation on nitrogen leaching for a range of soil types and irrigation management practices in Spain. Recently, Adhikari et al. (2016) used the CSM-CROPGRO-Cotton model to simulate the future (2041-2070) seed cotton yields in the THP region under increasing and constant atmospheric CO_2 concentration scenarios. Similarly, the CSM-CROPSIM-CERES (Crop Estimation through Resource and Environment Synthesis)-Wheat model has also been used by many researchers (Lobell and Ortiz-Monasterio, 2006; Thorp et al., 2010) for various water management studies in wheat in different geographic locations of the world. The objectives of this study were to evaluate the CROPGRO-Cotton and CERES-Wheat modules within the DSSAT CSM for the THP region using measured data from the cover crop (winter wheat-cotton) experiments at the Texas A&M AgriLife Research Station at Chillicothe, and to assess the long-term effects of growing winter wheat as a cover crop on seed cotton yield under irrigated and dryland conditions using the evaluated modules.

Materials and Methods

An outline of the methodology followed in this study is shown in Figure 1. The CSM-CROPGRO-Cotton and CSM-CROPSIM-CERES-Wheat modules, which are included in the DSSAT CSM, were used in sequence this study. These two modules were calibrated and validated using the measured soil moisture and crop yield data collected during the period from 2011 to 2015 from four different cover crop treatments at the Texas A&M AgriLife Research Station at Chillicothe in the TRP. The four treatments consists of: (i) cotton without cover crop under irrigated conditions (CwC-I) (ii) cotton with cover crop (winter wheat) - irrigated (CWC-I) (iii) cotton without cover crop - dryland (CwC-D) and, (iv) cotton with cover crop - dryland (CWC-D). The soil type in the experimental field is Grandfield fine sandy loam (*Fine-loamy, mixed, superactive, thermic Typic Haplustalfs*), which is characterized as a well drained soil that is suitable for cotton and grain sorghum cultivation (USDA, 2008). Some of the important soil related parameters required for the DSSAT-CSM include soil texture, bulk density, pH, soil organic carbon, saturated hydraulic conductivity. Daily weather parameters required by the model such as the maximum and minimum temperature, solar radiation, precipitation, dew point and wind speed were obtained from the Texas High Plain Evapotranspiration Network (TXHPET) weather station at Chillicothe for the period from 2000 to 2015 (Porter et al., 2005).

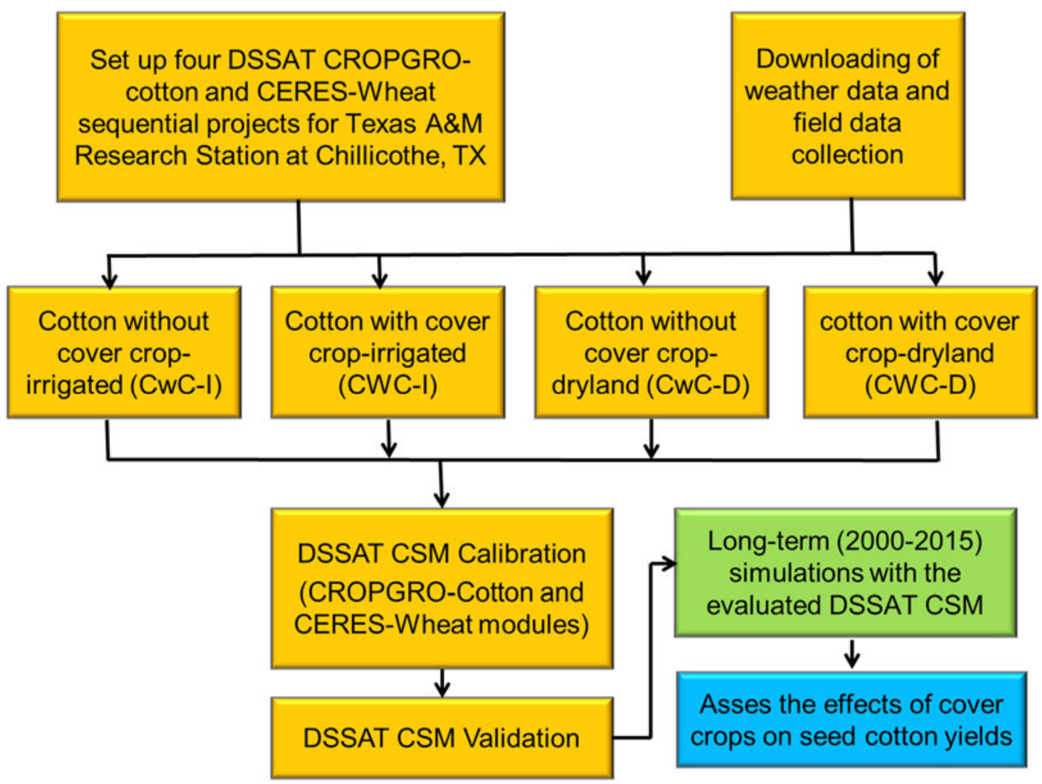

Figure 1. Flow chart showing the methodology adopted in this study

Measured seed cotton yield data from the CWC-I, CwC-I, CWC-D and CwC-D treatments during the 2013 and 2014 growing seasons were used to calibrate and validate the CSM-CROPGRO-Cotton model for crop yield prediction, respectively. Similarly, the measured winter wheat aboveground biomass data from the CWC-D treatment during the

2011-2012 growing season and the CWC-I and CWC-D treatments during the 2012-2013 growing season were used to calibrate the CSM-CROPSIM-CERES-Wheat model. The winter wheat aboveground biomass data from CWC-I, CWC-D treatments during the 2013-2014 and 2014-2015 growing seasons were used to validate the CSM-CROPSIM-CERES-Wheat model. The measured soil moisture data from 0-20, 20-40, 40-60, 60-80 and 80-140 cm soil profile depths over the period from 3 DOY 2013 to 298 DOY 2013, and from 315 DOY 2013 to 255 DOY 2015 were also used during the CROPGRO-Cotton and CERES-Wheat modules' calibration and validation, respectively.

Various cultivar and ecotype parameters that govern the crop growth and development, crop phenology and crop yield for cotton and winter wheat were adjusted manually to improve the model simulation. The model calibration was carried out in there steps. Initially, the simulated dates of the onset of various cotton and wheat phenological stages were compared with the generally observed dates in the study area. Second, simulated daily soil moisture content in 0-20, 20-40, 40-60, 60-80 and 80-140 cm soil profiles was compared with the measured soil moisture content. Finally, the simulated seed cotton yield and above ground biomass of wheat were compared with the observed seed cotton yield and above ground biomass of wheat, respectively. The effect of each adjusted sensitive parameters in the cotton and wheat cultivar and ecotype files on the model performance were observed by four statistics such as the coefficient of determination (r^2) (Legates and McCabe, 1999), root mean square error (*RMSE*), index of agreement (*d*) (Willmott et al., 1985), and percent error (*PE*). Finally, the evaluated CROPGRO-Cotton and CERES-Wheat modules were used in sequence to simulate the effect of growing cover crops on seed cotton yield for the period of 2000-2015 under irrigated and dryland conditions.

Results and Discussion

A total of seventeen cotton cultivar and ecotype parameters were adjusted during the CSM-CROPGRO-Cotton model calibration and eleven winter wheat cultivar and ecotype parameters were adjusted during the CSM-CROPSIM-CERES-Wheat model calibration. The simulated dates of onset of various phenological stages such as the emergence, anthesis, and maturity by both cotton and winter wheat modules were within the ranges observed in the study region during the model calibration and validation periods. While the observed data on cotton phenological stages was obtained from Robertson et al. (2007), the same for winter wheat was obtained from field measurements at the Texas A&M Research Station at Chillicothe, except on a few occasions. A close agreement was found between the simulated and measured soil moisture in 0-20, 20-40, 40-60, 60-80 and 80-140 cm soil profiles under the CwC-I, CWC-I, CwC-D and CWC-D treatments. A sample time series comparison of simulated and observed soil moisture in 60-80 cm soil profile in the CWC-I treatment is shown in Figure 2.

The CSM-CROPGRO-Cotton model simulated seed cotton yield matched reasonably well with the measured data from the CwC-I, CWC-I CwC-D and CWC-D treatments during both calibration as well as validation periods (Table 1). The model performance statistics such as r^2, *RMSE*, *d* and *PE* achieved during the model calibration and validation are also presented in Table 1.The *PE* in seed cotton yield prediction ranged between -46.2% and 20.6% during the calibration period and between -15% and 13.9% during the validation period. The *d* during both calibration and validation periods was 0.95 where as r^2 was 0.99 during calibration and 0.95 during validation. In general, the CSM-CROPGRO-Cotton model over predicted seed cotton yield under the irrigated conditions (CWC-I, CwC-I) and under predicted it under the dryland conditions during both model calibration and validation periods. Similarly, the CSM-CROPSIM-CERES-Wheat model simulated above ground wheat biomass also matched well with the observed data under both irrigated and dryland conditions during the model calibration and validation periods (Table 2). The model performance statistics for the CSM-CROPSIM-CERES-Wheat model calibration and validation periods are also presented in Table 2. The *PE* in winter wheat aboveground biomass yield prediction ranged between -17.1% and 18.2% during the model calibration period and between -27.9% and 26.8% during the validation period. The *d* and *r* were 0.91 and 0.76, respectively during the model calibration period, and 0.84 and 0.53, respectively during the validation period.

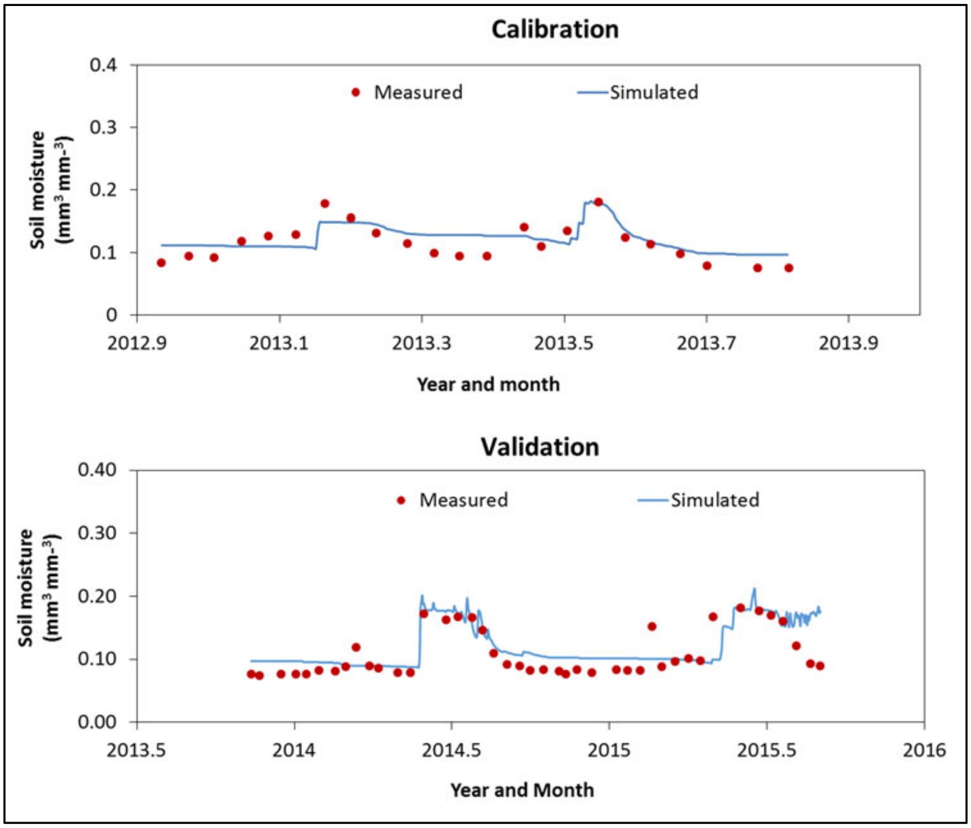

Figure 2. Comparison of simulated and measured soil moisture in the 60-80 cm depth soil profile in the cotton with cover crop-irrigated (CWC-I) treatment.

Table 1. Model performance statistics during calibration and validation of the CROPGRO-Cotton module. Treatment acronyms: cotton without cover crop - irrigated (CwC-I), cotton with cover crop - irrigated (CWC-I), cotton without cover crop - dryland (CwC-D) and cotton with cover crop - dryland (CWC-D).

Year	Treatments	Seed cotton yield (kg/ha)		*PE*	*RMSE* (Kg/ha)	*d*	r^2
		Measured	Simulated				
Calibration period							
2013	CWC-I	2752	3316	20.5	6.4	0.95	0.99
2013	CwC-I	2862	3547	23.9			
2013	CWC-D	1334	718	-46.2			
2013	CwC-D	1123	732	-34.8			
Validation period							
2014	CWC-I	3500	3989	13.9	5.4	0.95	0.95
2014	CwC-I	3148	4054	28.8			
2014	CWC-D	1413	1380	-2.4			
2014	CwC-D	1648	1401	-15			

Where *PE* is percent error, *RMSE* is root mean square error, *d* is index of agreement and r^2 is coefficient of determination

Table 2. Model performance statistics during calibration and validation of the CERES-Wheat module. Treatment acronym CWC-I stands for cotton with cover crop (winter wheat)–irrigated, and CWC-D for cotton with cover crop-dryland

Year/ Season	Treatments	Above ground biomass (kg/ha)		*PE*	*RMSE* (kg/ha)	*d*	r^2
		Measured	Simulated				
Calibration period							
2012-2013	CWC-I	1995	1653	-17.1			
2011-2012	CWC-D	2540	2427	-4.4	4.2	0.91	0.76
2012-2013	CWC-D	1352	1598	18.2			
Validation period							
2013-2014	CWC-I	1231	984	-20.1			
2014-2015	CWC-I	2614	1885	-27.9			
2013-2014	CWC-D	893	1107	23.9	7.1	0.84	0.53
2014-2015	CWC-D	1947	2469	26.8			

Where *PE* is percent error, *RMSE* is root mean square error, *d* is index of agreement and r^2 is coefficient of determination

The calibrated cotton and wheat modules were used to run long term (2000-2015) simulations of four cover crop treatments considered in this study. The simulated average (2000-2015) seed cotton yield under four treatments (CwC-I, CWC-I CwC-D, CWC-D) is presented in Figure 3. No significant differences were observed between with- and without cover crop treatments under dryland and irrigated systems (Figure 3). In general, about 6% decrease in seed cotton yield was predicted in case of the cotton treatments with cover crops when compared to those without a cover crop under irrigated conditions. In contrast, under dryland conditions, the simulated seed cotton yield was about 6% higher for the treatments with cover crops compared to those without cover crops. These results imply that growing winter wheat as a cover crop in the cotton production systems in the TRP region could potentially help to increase the seed cotton yield under dryland conditions.

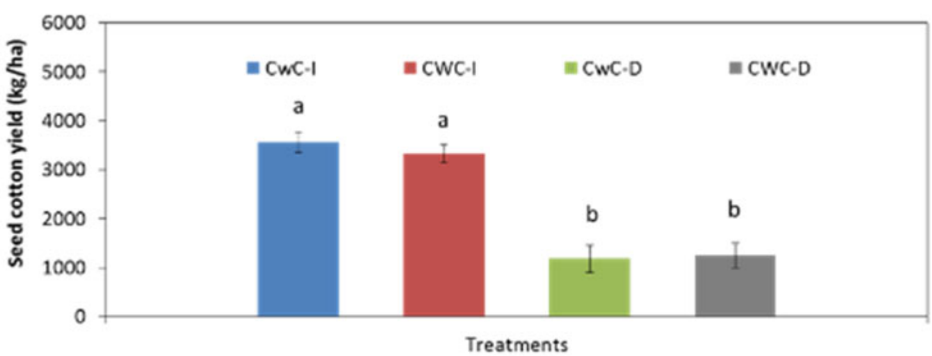

Figure 3. Comparison of simulated long term average (2000-2015) seed cotton yield in four different treatments: cotton without cover crop-irrigated (CwC-I), cotton with cover crop-irrigated (CWC-I), cotton without cover crop-dryland (CwC-D) and cotton with cover crop-dryland (CWC-D)

Summary

Well calibrated CSM-CROPGRO-Cotton and CSM-CROPSIM-CERES-Wheat modules were established for the TRP region using the observed soil moisture and crop yield data from the recent cover crop experiments at the Texas A&M AgriLife Research Station at Chillicothe. The calibrated model demonstrated the potential to reasonably simulate soil moisture, seed cotton yield and above ground biomass of wheat in the CwC-I, CWC-I, CwC-D and CWC-D treatments. The calibrated modules were used to simulate the long term (2000-2015) seed cotton yield under different cover crop treatments. No significant difference in simulated average (2000-2015) seed cotton yield between the CwC-I and CwC-D; and CWC-I and CWC-D treatments, was found. However, about 6% lower seed cotton yield was predicted under CWC-I treatments compared to CwC-I treatments, and about 6% higher yield under CWD-D treatments compared to CwC-D treatments. These results imply that growing winter wheat as a cover crop in the TRP cotton production systems could potentially increase the seed cotton yield under dryland conditions.

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