THE ECONOMICS OF COVER CROP BIOMASS FOR CORN AND COTTON

Trent A. Morton[1*], Jason S. Bergtold[1], and Andrew J. Price[1]
[1]USDA-ARS, National Soil Dynamics Laboratory, 411 S. Donahue Dr. Auburn, AL 36832
[*]Corresponding author's e-mail address: tmorton@ars.usda.gov

ABSTRACT

The inclusion of cover crops into cropping systems brings both direct and indirect costs and benefits to the farm. A myriad of studies have examined the economic benefits of cover crops in multiple cropping systems by comparing them to systems without cover crops. To date, economic research pertaining to the economic impact of the level of cover crop biomass has yet to be examined. Thus, the purpose of this paper was to assess the economic impact of different amounts of biomass associated with growing high residue cover crops in a corn-cotton conservation tillage system. An experiment examining planting and termination dates of cover crops and its effects on cover crop biomass, cash crop yields and weed suppression in corn-cotton conservation systems was conducted at two sites in Alabama and one site in Florida. A mathematical model incorporating the direct and indirect effects of cover crops, such as weed suppression and provision of nitrogen to the soil, was estimated using the experimental data. Findings suggest that rye and crimson clover cover crops used in a conservation tillage system can, in fact, be profitable to a farmer if managed properly and if economically viable levels of biomass are obtained from the cover crops. Taking into account potential cost savings, the minimum amount of cover crop biomass needed to be profitable for rye prior to cotton was 4,897 lbs per acre and for crimson clover prior to corn was 2,680 lbs per acre.

INTRODUCTION

Most cotton (*Gossypium hirsutum)* and corn (*Zea Mays* L.) producers in the Southeast have customarily grown their crops utilizing conventional tillage methods. However, as a result of soil degradation and other problems caused by conventional tillage, many farmers have shifted their practices to include conservation tillage systems such as no-till or reduced tillage along with the addition of a winter cover crop.

The inclusion of cover crops in cropping systems brings both direct and indirect costs and benefits. Cover crops can help alleviate drought stress by increasing infiltration rates and soil moisture content. In addition, cover crops can improve soil quality by helping to relieve soil compaction, improve soil organic matter and reduce soil erosion (Reeves, 1994; Sustainable Agriculture Network, 1998). Other benefits can include weed suppression, protecting water quality, increasing nutrient cycling efficiency, and potentially improving cash crop productivity. Costs of using cover crops can include increased direct costs for planting and management, loss in crop revenue if cover crops interfere with cash crop production (e.g. hair-pinning), slow soil warming, and difficulties in predicting N mineralization (Snapp et al., 2005). All of these elements have the potential to increase or decrease yields and the profitability of crop enterprises.

Many studies have examined the costs and benefits of cover crops. However, the purpose of this paper is to assess the economic impact of the amount of biomass or residue associated with growing high residue cover crops in conservation tillage systems. Mathematical models were developed to quantify the amount of rye (*Secale cereale* L.) and crimson clover (*Trifolium Incarnatum* L.) biomass required for cotton and corn enterprises to be economically viable when a cover crop is planted. In addition, economically optimal planting and termination dates for these cover crops were determined.

MATERIALS AND METHODS

The Experiment and Data

An ongoing corn-cotton conservation tillage system experiment examining different planting and termination dates for winter cover crops was established at two locations in Alabama and one location in Florida, beginning in 2003. For the purpose of this paper, only the 2005 data from the experimental site at the E.V. Smith Research and Extension Center near Shorter, AL was used. This portion of the experiment is located on a Coastal Plain soil type (sandy loam), which required in-row sub-soiling prior to planting to disrupt soil compaction with minimal disturbance of the soil surface. The cropping system was a corn-cotton rotation with winter cover crops planted and terminated prior to the cash crop. Rye was planted preceding cotton; and crimson clover was planted preceding corn, both with a no-till grain drill. Five planting dates were examined for each cover crop based on the first average frost date of the year. The planting dates were: 4 weeks prior to average frost, 2 weeks prior to average frost, at average frost, 2 weeks after average frost, and 4 weeks after average frost. A mechanical roller with crimping bars was used in combination with herbicides to terminate the cover crops. Four different termination dates where examined prior to spring planting. The termination dates were 4, 3, 2, and 1 week(s) prior to spring planting. All planting and termination dates were subject to weather conditions, therefore, some dates varied slightly. The experimental set-up was as a strip plot design with planting dates along vertical strips and termination dates along horizontal strips across three replications for both corn and cotton. Each plot was 4-rows in width and both corn and cotton were present each year.

Cover crop biomass samples were taken, at termination of the cover crop, within a ¼ m^2 area randomly chosen inside each plot. Weed biomass samples were taken in a ¼ m^2 area randomly chosen within each plot 3 to 4 weeks after planting of the cash crop. Cash crop plant stands were taken along 10 ft. sections randomly chosen from the rows within the plots. Percent of ground cover provided by residue was measured using digital photographs of a ¼ m^2 area within each plot overlaid with three randomly generated dot screens for each treatment. Each dot intersecting residue in the photograph was then counted and the total number of dots for each dot screen was averaged to determine the percentage of cover (Morrison, et. al.). Yield data was obtained from harvesting the center two rows of each plot with a plot combine and a 2-row cotton picker. The bags were then weighed from every plot of each crop and the yield data was generated from the weights.

Economic Methodology

The primary objective of most farming operations is to maximize profit. Thus, for simplicity, we assume producers are profit maximizers and are risk-neutral. In addition, stochastic conditions, such as weather, are assumed to be known a priori. Based on these assumptions, a farmer who considers planting a winter cover crop will plant that cover if the gain in revenue from planting and managing the cover to achieve a level of biomass *r* is greater than or equal to the cost of the cover crop minus savings. That is, if:

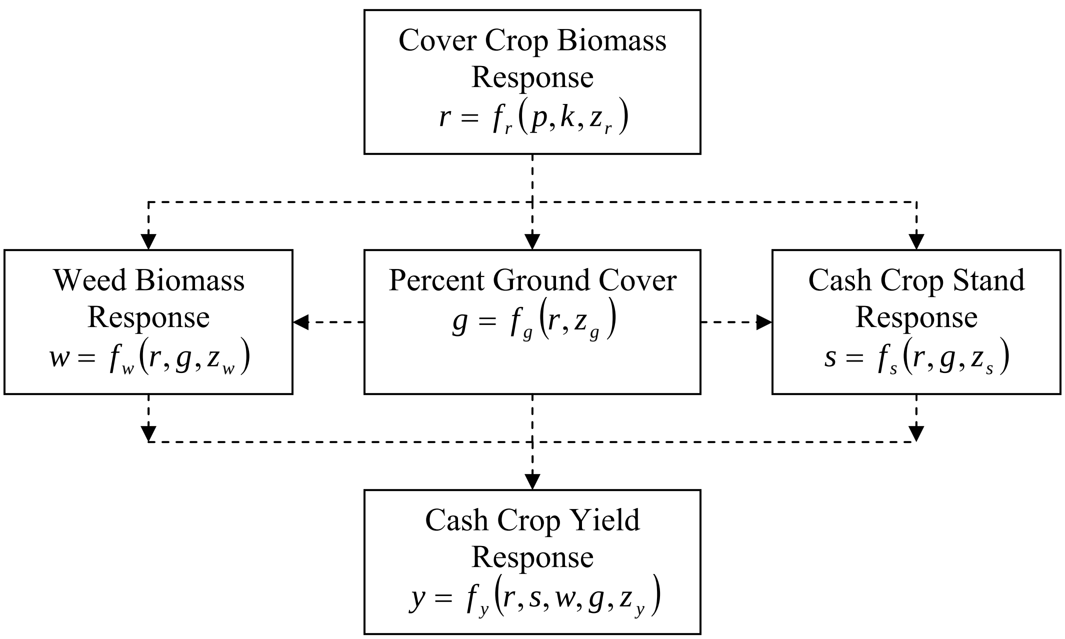
$$p \cdot \Delta y(r) \geq c(r) \tag{1}$$

where, p is the price of the cash crop, $\Delta y(r)$ is the change in cash crop yield for a given level of r, r is cover crop biomass, and $c(r)$ is a cost function that captures the cost of and potential savings from using a winter cover crop for a given level of biomass r.[2]

Empirical Model

To estimate $\Delta y(r)$ and incorporate potential indirect effects on cash crop yields from increased levels of biomass (r), the cash crop production model presented in Figure 1 was estimated based on the experimental set-up and data available. The weed response (w), percent ground cover (g), and cash crop stand (s) response functions where included to incorporate the potential indirect effects that different levels of cover crop biomass may have on cash crop yields. The rye and clover biomass response functions were based on plant dates (p) and termination dates (k) of the cover crops.

Initially, to estimate the cash crop yield response function, weed biomass, cash crop stand, and percent ground cover response functions were examined with different functional forms. These included linear, semi-log, quadratic, higher-order polynomial expansions, and translog (Chambers, 1988). The models with the best adjusted R^2 and mean-square errors where chosen



Note: z_i, $i = r,w,g,s,y$ are other relevant variables for the respective response function.

Figure 1. Cash Crop Production Model.

to use for further analysis. Models were estimated in SAS using the MIXED procedure to account for random effects due to experimental replications (Little et al., 1996). The functional

[2] Condition (1) is equivalent to the condition that the marginal revenue from obtaining a specified level of cover crop biomass be greater than or equal to the marginal cost.

form for the percent ground cover function was based on the function used by Steiner et al (2000), and was estimated is SAS using the NLMIXED procedure following a similar procedure used by Knezevic, et al. (2002) to estimate critical periods for weed control. The cover crop biomass response functions were estimated in SAS using the MIXED procedure as ANOVA models with fixed effects for plant date/kill date combinations and random effects for replications. The functional forms used for the economic analyses in the paper for each of the cash crop models are presented in Table 1.

Given that $\Delta y = \partial y = \frac{\partial f_y}{\partial r}\partial r$, condition (1) can be rewritten to incorporate the cash crop production model in figure 1, because cash crop yield can be made to be explicitly a function of *r* by substituting the weed biomass, percent ground cover, and cash crop stand response functions into the cash crop yield response function. Then:

$$\frac{\partial y}{\partial r} = \frac{\partial f_y}{\partial_r} + \frac{\partial f_y}{\partial_s}\left[\frac{\partial f_s}{\partial r} + \frac{\partial f_s}{\partial g}\frac{\partial f_g}{\partial r}\right] + \frac{\partial f_y}{\partial w}\left[\frac{\partial f_w}{\partial r} + \frac{\partial f_w}{\partial g}\frac{\partial f_g}{\partial r}\right] + \frac{\partial f_y}{\partial g}\frac{\partial f_g}{\partial r}, \tag{2}$$

given z_i, $i = r, w, g, s, y$ are strictly exogenous to the system.[3] Condition (2) was used to derive revenue curves with MATLAB for each cash crop (see figures 2 and 3). These revenue curves were then used for economic analyses and determining economically viable levels of cover crop biomass using condition (1). The cost function, $c(r)$ is a fixed amount, given the level of biomass produced was determined by different planting and termination dates of the cover crop, which did not change the cost of using a winter cover crop. This is not likely always the case given different levels of nitrogen and/or seeding rates may have achieved the same objective and would have been variable. The cost function includes cost savings from potential reduced use of herbicide due to weed suppression and fertilizers for the cash crop due to the nitrogen equivalence of legumes.

RESULTS AND DISCUSSION

The functional forms and estimates for each of the response functions for both the corn and cotton models are provided in Table 1.[4] The functional forms varied for each response function from the translog the for cotton yield response function, higher order polynomial functions for weed biomass, and linear or quadratic for the rest. R^2 values ranged from 0.20-0.60 and mean square error estimates were the lowest for the models examined. Using the response functions in table 1, crop revenue curves, equal to $p \cdot \Delta y$, were derived using condition (2) (see in figures 2 and 3).

[3] Given a second order translog function was used for the cash crop yield response for the cotton model, $\frac{\partial y}{\partial r} = y\frac{\partial \ln(y)}{\partial r}$.

[4] The results for the rye biomass response functions are not presented due to space limitations, but are available for the authors upon request.

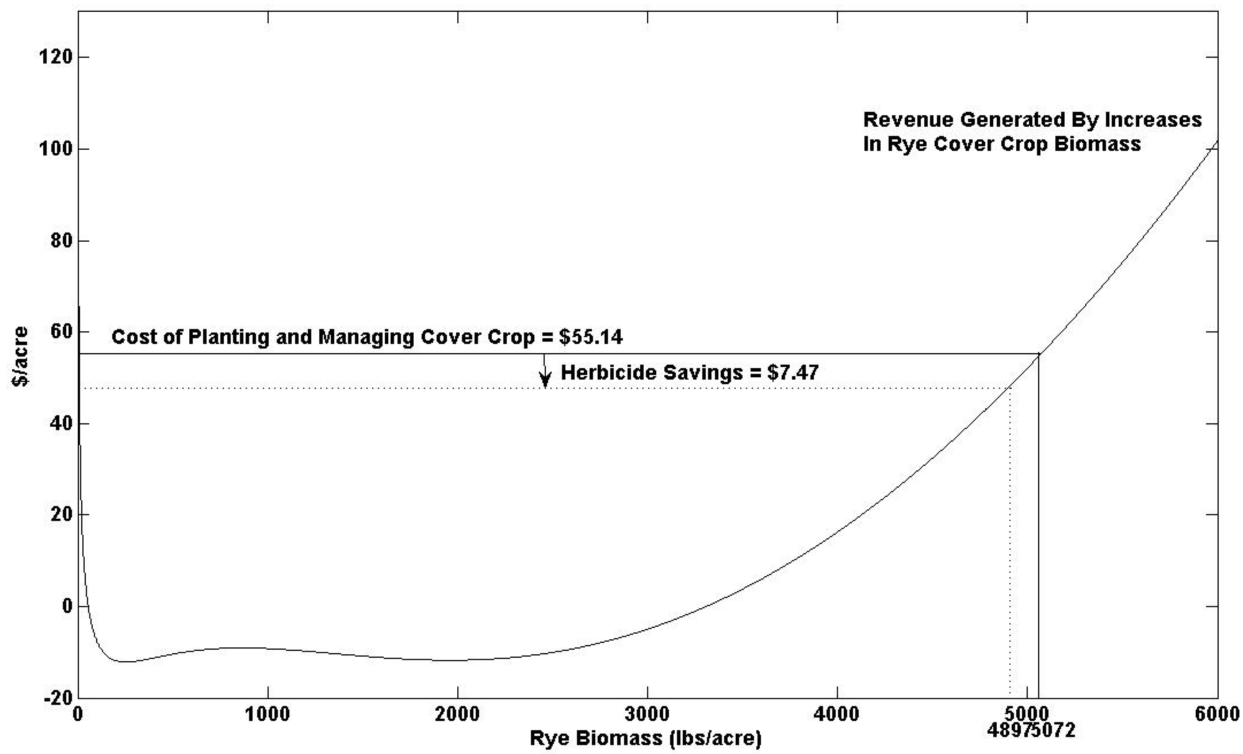


Figure 2: Cotton Revenue Curve for Different Levels of Rye Biomass.

Figure 2 provides a graphical representation of the crop revenue curve for cotton. If only the cost of planting and managing the cover crop is considered, condition (1) is satisfied at equality when 5072 lbs of rye biomass per acre are produced. That is, the change in revenue from 5072 lbs of rye biomass per acre is equal to the cost of planting and managing the rye cover crop. This is the minimum amount of cover crop biomass needed to make it economically viable to plant. If we take into account the weed suppression benefits of the cover crop and forego using a pre-emergence herbicide, then cost savings in the amount of $7.47 per acre can be realized, effectively reducing the economic costs of the cover crop. Taking account of this savings reduces the minimum amount of biomass needed to 4,897 lbs per acre.

Figure 3 provides a graphical representation of the crop revenue curve for corn. The figure shows that condition (1) is met with equality when 4,968 lbs. of crimson clover biomass per acre is produced. Again, this is a minimum for economic viability of using the cover crop. By taking into account pre-emergence herbicide savings, the economic costs of the cover crop can be reduced by $7.47 requiring that only 4,029 lbs. of crimson clover biomass per acre be produced. For simplicity, we assumed that the nitrogen equivalence provided by the crimson clover was linearly related to the amount of biomass produced. At 5,000 lbs of clover biomass per acre, N equivalence was conservatively assumed to be 60 lbs per acre, equal to $22.20 in N savings for the proceeding cash crop. Taking the cost savings of the N equivalence into account reduces the minimum amount of crimson clover biomass needed to 2680 lbs per acre.

Figure 4 illustrates the optimal planting and termination dates of rye and crimson clover for achieving maximum levels of biomass. Surface plots were estimated using SAS. Using the estimated cover crop biomass functions, we determined economically viable planting dates and

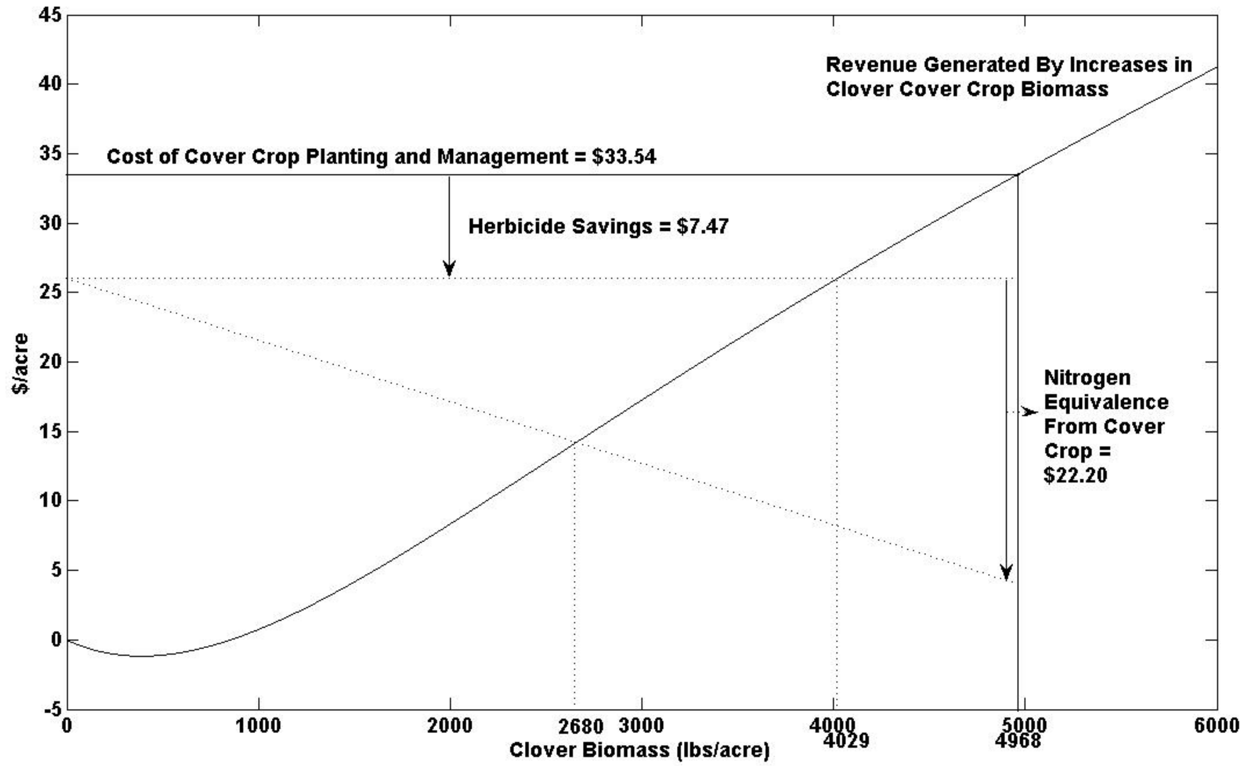
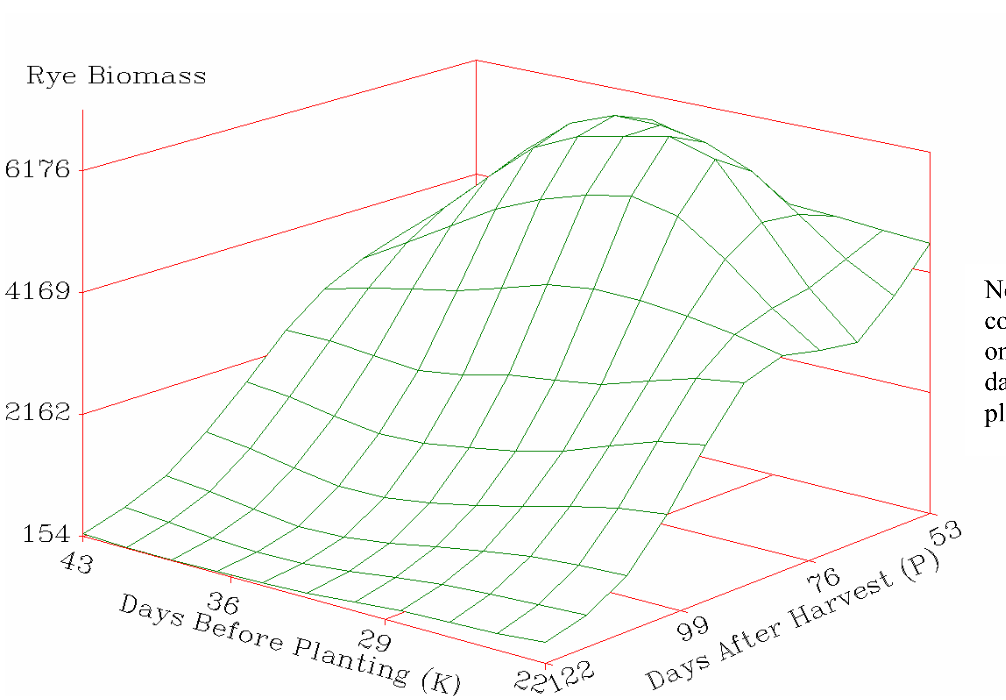


Figure 3: Corn Revenue Curve for Different Levels of Clover Biomass.



Note: Harvest date corresponds to corn harvest on 08/16/2004 and planting date corresponds to cotton planting on 05/02/2005.

Figure 4: Rye Biomass Response Surface to Plant and Termination Date.

termination dates for rye and crimson clover in central Alabama. In order to achieve profitable levels of rye biomass, rye needs to be planted approximately 9-10 weeks after the corn harvest (*p*2) and terminated 4 weeks before cotton is planted (*k*3). Crimson clover needs to be planted approximately 4 weeks after cotton is harvested (*p*2). The termination dates were found to be insignificant for crimson clover, therefore any of the termination dates would suffice.

CONCLUSIONS

The inclusion of cover crops into cropping systems brings both direct and indirect costs and benefits to the farm. The purpose of this paper was to assess the economic impact of different levels of biomass associated with growing high residue cover crops used as an element of a conservation tillage system. The data suggests that rye and crimson clover cover crops used in a conservation tillage system can, in fact, be profitable to a farmer if managed properly and if economically viable levels of biomass are obtained from the cover crops.

REFERENCES

Chambers, R.G. 1983. *Applied Production Analysis: A Dual Approach*. Cambridge, UK: Cambridge University Press. 326 p.

Knezevic, Stevan Z., Sean P. Evans, Erin E. Blankenship, Rene C. Van Acker, and John L. Lindquist. 2002. Critical Period for Weed Control: the Concept and Data Analysis. *Weed Science*. 50:773-786.

Littell, R.C., G.A. Milliken, W.W. Stroup and R.D. Wolfinger. 1996. *SAS System for Mixed Models*. Cary, NC.: SAS Institute Inc. pp.1-29.

Morrison Jr., J.E., F.W. Chichester, D.E. Escobar. 1989. Measurement of Residue Cover with Dot Screens. *Journal of Soil and Water Conservation*. 44:542-544.

Reeves, D.W. 1994. Cover Crops and Rotations. In Advances in Soil Science: Crop Residue Management. (J.L. Hartfield and B.A. Stewart, eds.) Boca Raton, FL: Lewis Publishers, CRC Press Inc. pp. 125-172.

Snapp, S.S., S.M. Swinton, R. Labarta, D. Mutch, J.R. Black, R. Leep, J. Nyiraneza, and K. O'Neil. 2005. Evaluating Cover Crops for Benefits, Costs and Performance within Cropping Niches. *Agronomy Journal*. 97:322-332.

Steiner, J.L., H.H. Schromberg, P.W. Unger, and J. Cresap. 2000. Biomass and Residue Cover Relationships of Fresh and Decomposing Small Grain Residue. *Soil Science Society of America Journal*. 64:2109-2114.

Sustainable Agriculture Network. 1998. Managing Cover Crop Profitability, 2nd edition. Handbook Series Book 3. Berlington, VT: Sustainable Agriculture Productions.

Table 1. Estimated Response Functions for Cash Crop Production Models

Corn		Cotton	
Response	**Functional Form**	**Response**	**Functional Form**
Yield[1]	$y = 53.00 - 0.15w + 16.09s + 0.02y_{-1} + 0.0027w^2$	Yield[1]	$\ln(y) = 10.12 - 0.15\ln(r) - 2.03\ln(w) + 0.70\ln(r_{-1}) + 0.02\ln(w)^2 + 0.12\ln(s)^2 + 0.02\ln(r)\ln(r_{-1}) + 0.02\ln(w)\ln(r_{-1}) + 0.32\ln(w)\ln(y_{-1}) - 0.18\ln(r_{-1})\ln(y_{-1})$
Plant Stand	$s = 2.03 + 0.00005r - 0.32g$	Plant Stand	$s = 4.33 - 0.00029r - 0.00000004r^2 + 0.000019rg^2$
Weed Biomass	$w = 42.66 - 0.02r + 109.03g$	Weed Biomass	$w = 11930 - 2484.28\ln(r) - 19099g + 2934.24g^2 + 23.70\ln(r)^3 - 3.33g^3 + 5216.52\ln(r)g - 460.13\ln(r)^2 g$
Percent Cover	$g = 1 - \exp(-0.85 - 0.00061r)$	Percent Cover	$g = 1 - \exp(-1.48 - 0.00049r)$

Note: The ANOVA table for the cover crop biomass response function is not shown, but is available from the authors upon request. Graphical representations are presented in Figure 4.

[1] The variable y_{-1} represents crop yields from the previous year. For corn, this would be prior cotton yield; and for cotton, this would be prior corn yield, due to the two-year cotton-corn rotation used in the experiment. Likewise, the variable r_{-1} is cover crop biomass from the previous year, which would be rye if clover is planted before corn and clover if rye is planted before cotton.