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Economic Impacts of Cover Crops for a Missouri Wheat–Corn–Soybean Rotation

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Abstract: In the United States, agricultural production using row-crop farming has reduced crop diversity. Repeated growing of the same crop in a field reduces soil productivity and increases pests, disease infestations, and weed growth. These negative effects can be mitigated by rotating cash crops with cover crops. Cover crops can improve soil's physical, chemical, and biological properties, provide ground cover, and sequester soil carbon. This study examines the economic profitability for a four-year wheat–corn–soybean study with cover crops by conducting a field experiment involving a control (without cover crops) at the Soil Health Farm in Chariton County, MO, USA. Our findings suggested that economic profitability of the cash crop is negatively affected by the cover crop during the first two years but were positive in the fourth year. The rotation with cover crops obtained the same profit as in the control group if revenue from the cash crop increased by 35% or the cost of the cover crop decreased by 26% in the first year, depending on the cost of seeding the cover crop and terminating it. This study provides insights for policymakers on ways to improve the economic efficiency of cost-share conservation programs.

Keywords: green manure; costs; benefits; net present value; revenue; wheat–corn–soybean rotation; yields

1. Introduction

In the United States, agricultural production is dominated by row-crop farming—approximately 85% of the nation's farmland is devoted to growing corn, soybeans, and wheat [1]. Row-crop farming has doubled yields for soybeans and wheat, and tripled yields for corn over the past 60 years [2]. However, it relies heavily on pesticides and fertilizers, which have many negative environmental impacts [3], including reduced soil productivity, increased pests, disease infestations, and weed growth [4–6]. Furthermore, agricultural nonpoint-source pollution (run-off of chemicals, nutrients, and sediment) is the leading cause of decreased water quality in the United States [7]. Approximately 50% of losses of nitrogen (N) and phosphorus (P) from agricultural areas occurs during fallow periods when the land is bare [8,9].

Rotating cash crops such as corn, wheat, and soybeans with cover crops including legumes, grasses, and forbs provides many ecological benefits. The cover crops are planted mostly to protect and conserve the soil between cash crops [10]. The resulting ground cover conserves the soil by reducing erosion, and improves soil quality by providing organic matter and biological activity, reduces the amount of pollution entering water bodies, and controls harmful insects [11,12].

The benefits of a cover crop rotation for the soils' physical, chemical, and biological properties may have some positive impacts on the yield of cash crops [13,14]. Some researchers reported that the cover crop rotation was associated with a yield increase (e.g., Raper et al. [15], Werblow [16]). However, the increases in yield varied with the type of cover crop used. For instance, Tonitto et al. [17] found that non-legume cover crops did not improve the yield of cash crops. In contrast, Sainju et al. [18] found that legume cover crops of hairy vetch and crimson clover had a greater effect on tomato fruit yields than a rye cover crop.

Farmers are interested in the benefits of cover crops, but, so far, their adoption of the practice has been limited in Missouri and many other states [11,19]. A survey of 3500 farmers in Illinois, Indiana, Iowa, and Minnesota was conducted in 2006, and its result indicated that only 18% of the farmers had used cover crops before and 11% had planted cover crops sometime in the preceding five years [20]. Recently, the rate of adoption of cover crops has increased. A more recent survey (in 2015) of farmers in Montana found that approximately 30% had grown cover crops [21].

The agricultural literature has identified several reasons for limited adoption of cover crops. Some factors are associated with biological and operational constraints. For instance, Miller et al. [22] found that adoption of cover crops would increase if planting cover crops can greatly reduce the use of fertilizer (50% less). The economic profitability is also one important factor [23,24]. In a survey by Singer et al. [20], more than half of the farmers indicated that they would plant cover crops if a cost-sharing program was available. Miller et al. [22] suggested that cash crop yields and cover crop seed and planting costs affect the adoption of cover crops. Costs associated with cover crop adoption are mainly determined by the establishment costs. Labarta et al. [25] had indicated that cover crop establishment costs may be 11 times than the establishment costs of grasses. Schnitkey et al. [26] has estimated the establishment costs of cover crops to be $50.90 per hectare ($20.60 per acre), which includes $32.37 per hectare ($13.10 per acre) drilling costs and $18.53 per hectare ($7.5 per acre) seed costs. Swanson et al. [27] also estimated cover crop establishment cost of cereal rye and cereal rye/hairy vetch blend to be $70.18 per hectare ($28.40 per acre) and $143.94 per hectare ($58.25 per acre), respectively.

However, the economic profitability of applying a cover crop in cash crops are not clear; studies done so far have produced inconsistent results. According to the results of the 2015–2016 cover crop survey of more than 2000 U.S. farmers [16], only one-third of the farmers who had used cover crops before reported an increase in profit as a result. The majority indicated either no change in their profit or lacked data to estimate their profit. A case study was conducted at Stoneville, Mississippi in 1999 and 2001 to examine the impacts of cover crops on economic returns [28]. It found that rotating soybean production with a rye cover crop over a three-year period was less profitable than production without a cover crop. Cash crop economic profits are determined by economic revenues and costs. Cover crops may increase cash crop yields, and thus lead to increased economic revenues. However, these increased revenues may not be compensated by the additional costs associated with the use of cover crops. This may lead to decreased economic profits by applying cover crops. Other studies have suggested that use of a cover crop can reduce profits in the short term but show a positive return in the long term due to improved soil health. According to a recent case study conducted by the Natural Resources Conservation Service (NRCS) in 2015 in Missouri [29], adding a cover crop to a corn–soybean rotation had a negative economy for farmers in the short term, but could potentially benefit farmers economically in the long term.

Few studies have made direct economic comparisons of a cover crop treatment with a control. This study examines the impacts of including cover crops in rotation with cash crops in Missouri on cash crop yields and farmers' net profits over a four-year period with a no-cover crop control. In Missouri, 66% of the state's land is used for agriculture and the state ranks the second in terms of number of farms (99,171 farms in 2012) [30]. Corn, soybean, and wheat make up more than 55% of the crops produced in Missouri. Corn–soybean rotation is most common in Missouri, but research findings suggested a higher yield for soybean following wheat [31–33].

The objectives of the study were to (a) explore the impacts of cover crop practices on cash crop yields, (b) estimate the annual cost and revenue for producing cash crops in Missouri, (c) compare the economic profitability of a wheat–corn–soybean rotation with and without a cover crop over a four-year period, and (d) estimate farmers' economic profitability under different levels of cover crop costs and cash crop sales revenues.

2. Materials and Methods

This study was conducted at the NRCS Soil Health Farm in Chariton County, north-central Missouri (Figure 1, 39°30′12″ N and 92°43′29″ W). In Chariton County, approximately 70% of the farmland is planted with crops and the size of an average farm is 147 hectares (363 acres) [34]. Annual average temperature is 12 °C (54 °F), and mean temperatures in July is 30 °C (86 °F). The 30-year average precipitation is 101 cm (40 inches), and this area receives ~28 cm (11 inches) of snow per year [35].

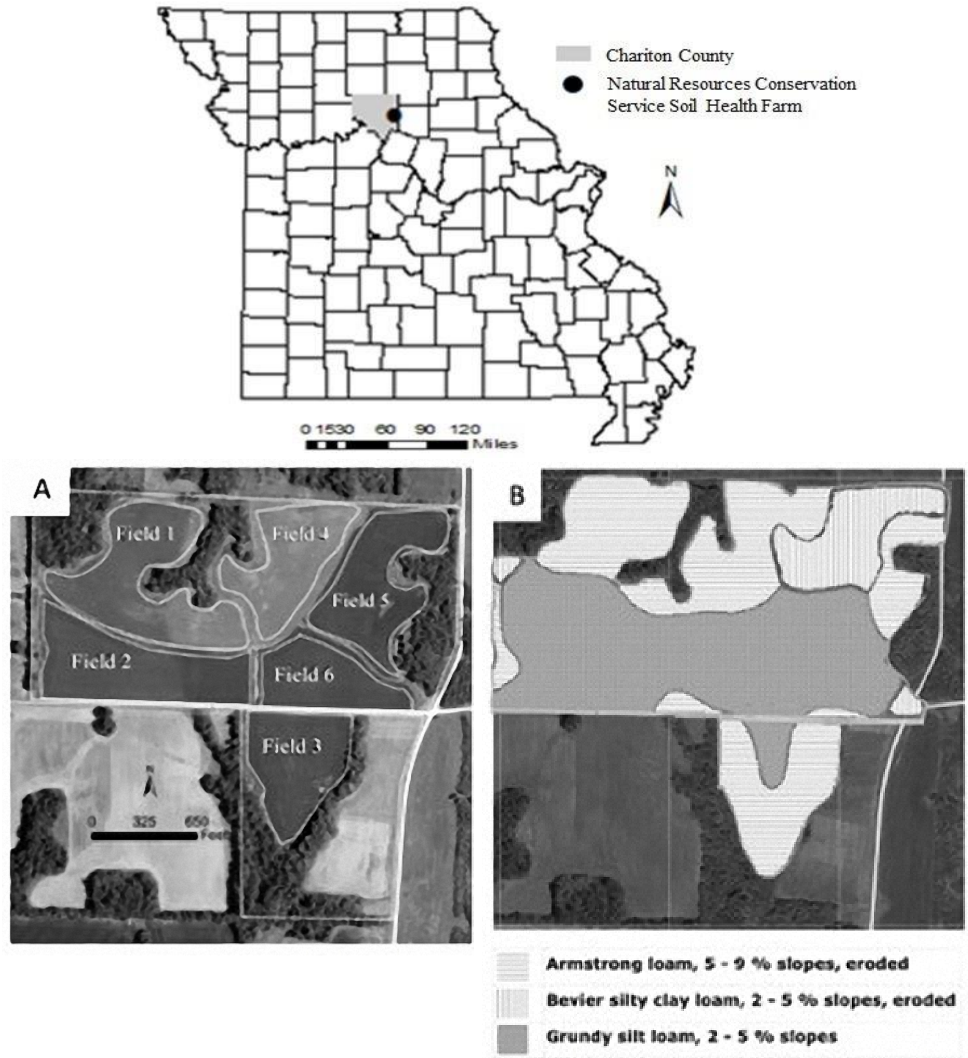

Figure 1. Location of Natural Resources Conservation Service's Soil Health Farm (39°30′12″ N and 92°43′29″ W) in Chariton County, Missouri. (**A**) Google Earth imagery and outlines of research fields and (**B**) major soil types.

The study area is 26.3 hectares (64.9 acres), which was divided into six fields (Table 1). These fields were planted with soybeans, corn, and wheat—three of the top four crops acreages produced in Chariton County [34]. Soils in Fields 1 and 4 are primarily Armstrong loam, 5–9% slopes, eroded (fine, smectitic, mesic Aquertic Hapludalfs). Soils in Fields 2 and 6 are primarily Grundy silt loam, 2–5% slopes (fine, smectitic, mesic Aquertic Argiudolls). Soils in Field 3 are Armstrong loam and Grundy silt loam. Field 5 has three types of soil including: Grundy silt loam, Armstrong loam and Bevier silty clay loam (Fine, smectitic, mesic Aeric Vertic Epiaqualfs). Of these soils, Grundy silt loam has the highest crop productivity (e.g., soybeans and corns) and Armstrong clay loam has the lowest according to Crop Productivity Index [36].

Table 1. Cash crops planted to the six fields from 2012 to 2016.

Cash Crops		Planting Year				
Field	**Size in Hectares (Acres)**	**2012**	**2013**	**2014**	**2015**	**2016**
1	5.5 (13.7)	Wheat	Corn	Soybeans	Corn	Soybeans
2	5.3 (13.1)	Wheat	Soybeans	Corn	None *	Corn
4	4.1 (10.1)	Wheat	Corn	Soybeans	Wheat	Corn
5	4.5 (11.0)	Wheat	Soybeans	Corn	None *	Wheat
6	3.0 (7.5)	Wheat	Soybeans	Corn	None *	Soybeans
3 (Control Field)	3.8 (9.5)	Wheat	Soybeans	Corn	None *	Corn

* In 2015, soybeans could not be planted by the final planting date as planned because of rain.

In 2011, the study area had been planted with winter wheat. Yield and cost information for the six fields before the initiation of this project were not available. To prepare for this study, the fields were treated in September 2012 with three herbicides—Quest, Roundup Weathermax—and 2-4D Ester. In 2013, cash crops were planted (Table 1). The treatments consisted of Fields 1, 2, 4, 5, and 6, planted to a mixed-seed cover crop after the cash crop was harvested. Field 3 was used as the control and was never planted with a cover crop. Only Field 3 had primary tillage, other fields use no-tillage. To compare the economics of the cover crop rotation system with the control system over the four-year period, the cash crop sequence in Field 2 followed the planting sequence of Field 3.

The cover crop mix used in this study was of legumes and non-legumes because mixed cover crops are more effective than single-species cover crops in improving soil health and nutrient supplies [37]. The mixed cover crops, on average, had a higher ratio of non-legumes (Appendix A), and included annual rye (*Lolium multiflorum L.*), buckwheat (*Fagopyrum esculentum L.*), cereal rye (*Secale cereale L.*), cowpea (*Vigna unguiculata L.*), crimson clover (*Trifolium incarnatum L.*), hairy vetch (*Vicia villosa Roth.*), oats (*Avena sativa L.*), radishes (*Raphanus sativus L.*), sorghum (*Sorghum bicolor L.*), sunflowers (*Helianthus annuus L.*), sunn hemp (*Crotalaria juncea L.*), sweet clover (*Melilotus officinalis L.*), turnips (*Brassica rapa L.*), triticale (*Triticosecale*), and winter peas (*Pisum sativum L.*). Cover crops were planted after wheat harvest.

To analyze the profitability of including a cover crop in the rotation, the study collected cost and revenue information. Costs include the costs of producing the cash crop and the costs of planting, maintaining, and terminating the cover crop. The cost of production of the cash crop included work required to establish the fields, seed purchases, the cost to buy and apply fertilizers and pesticides, and inputs of labor and resources for harvesting. Corn (N, P, K) and soybean (P, K) fertilizer was applied each year during the study according to soil test recommendations to provide sufficient nutrients for crop growth. The control field required additional tillage for seedbed preparation. The cost of the cover crop consisted of the cost of purchasing and planting the seeds, and of terminating the cover crop. In 2013, the cover crop was planted via aerial broadcast; thereafter, planting was done using a seed drill. The herbicides used to terminate the cover were applied by spraying. The analysis omits other costs, such as income taxes, to simplify the analysis and make the most direct comparison between the control and the cover crop treatments. Revenue was determined by the crop yield and the market price at the time of harvest. Average prices for cash crops and cover crops used in this research are presented in Appendix B.

The cost and revenue data for 2013, 2014, and 2015 were compounded into 2016 dollars using prices received indexes for crops retrieved from United States Department of Agriculture National Agricultural Statistics Service [38] and were used to compute the annual cost, annual revenue, annual net revenue (annual revenue minus annual cost) and benefit–cost ratios (BCRs) for the cash crops. Negative annual net revenue from the cash crop was denoted by a BCR of less than 1.0 and positive net revenue by a BCR of more than 1.0 [39]. In addition, the net present value of Fields 2 and 3 for 2013 through 2016 were calculated as part of the comparison of the economic effects of cover crops. This is because time has effects on the costs and revenues (e.g., inflation), and comparing costs and revenues as they appear is misleading. A discount rate of 5% was used to discount costs and revenues in 2014, 2015, and 2016 to their actual values in 2013 following Adusumilli et al. [40].

To evaluate the impacts of cover crop costs and cash crop yields on profitability, annual BCRs were calculated under different levels of cover crop costs and cash crop yields for Field 2. Levels of cover crops were set to be 55%, 60%, 65%, . . . , 85%, 90%, and 95% of the actual cover crop costs. Levels of cash crop yields were set to be 105%, 110%, 115%, . . . , 140%, 145% and 150% of the actual yields. The results were further compared to the BCR for the control (Field 3). These comparisons also identified the level of cover crop cost or cash crop yield at which point total revenue covered the total cost.

3. Results and Discussion

3.1. Annual Yields, Costs and Benefits

Cash crop yields, annual costs, revenues and net revenues, and benefit–cost ratios for the treatment and control fields are provided in Table 2. In 2015, soybeans could not be planted by the final planting date because of rain. We found an estimated RUSLE2 (Revised Universal Soil Loss Equation 2) [41] reduction in soil erosion from 37 t/ha (15 t/ac) compared to 27 t/ha (11 t/ac) when using cover crop in our corn–soybean rotation. Thus, cover crops reduce soil erosion to 73% of that from a corn–soybean rotation without using cover crops. This is less than reported by Langdale et al. [42], where soil erosion was reduced to 12–27% when cover crops were used. A possible explanation for this difference is that our research fields may have different geographic and biophysical characteristics (e.g., soil type, rainfall, and slope gradient and length) with the fields at Langdale et al.'s study.

The comparison between Fields 2 and 3 showed that average annual yield per hectare (acre) of the control field was less than the average yield of the treatment fields (Table 2). This finding agrees with others (e.g., [43,44]). A field-based comparison over six years in Fort Valley, Georgia [18], for example, indicated that tomato yields were positively affected by the use of cover crops, and a national survey [16] identified an average increase of 20.0% in yields for corn and 2.8% in yields for soybeans after use of a cover crop. Our analysis also showed that cover crops have a positive impact on the annual revenue of the cash crops (Table 2).

In terms of annual costs, the control field has the lowest total cost. The annual cost of the cover crop varied with the seeding and termination methods. Aerial broadcast seeding used in 2013 costed $139.88 per hectare ($56.61 per acre). Given the irregular shape and relatively small size of the fields, our aerial application costs were inflated. Thus, we used average commercial aerial application price in Missouri ($26.46 per hectare or $10.71 per acre) as a proxy to calculate the cover crop seeding costs occurred in 2013. Drill seeding cost only $44.67 per hectare ($18.08 per acre), a figure that is comparable to other studies (e.g., $50.90 per hectare from [26]). The annual cost of cover crops over our study period ranged from $78.88 to $154.86 per hectare ($31.92 to $62.67 per acre) with an average cost of $109.74 per hectare ($44.43 per acre). Cover crop costs may depend on many factors such as: cover crop species used, seeding rate, cover crop planting method, among many others [26,27]. Our costs are comparable to results from other studies, such as [45], which found average annual costs of $140.85 to $168.03 per hectare. Cost differences between treatment and control groups were mainly from costs associated with purchasing cover crop seeds, planting and terminating cover crops, and cash crop planting and management. For instance, in 2013, the treatment group had higher herbicide cost ($57.77/ha or $23.38/ac higher) and fertilizer cost ($118.73/ha or $48.05/ac higher) compared to the control. Higher fertilizer cost may be due to the highly eroded soils with very thin top soils, and poor cover crop growth in 2013. Herbicide cost was $166.15/ha ($67.24/ac) higher in the treatment group compared to the control in 2014. However, in 2016, the control had a higher pesticide cost ($61.90/ha or $25.05/ac higher) compared to the treatment group. This suggests that cover crops may provide some pest control benefits and reduce pesticide costs.

The results for annual net revenue, also shown in Table 2, are mixed. In 2013, the net annual revenues from the treatment group were positive. However, net revenues from corn production in 2014 and wheat production in 2015 and 2016 were negative, likely as a result of a greater supply of corn and wheat, and depressed prices and sales revenue in those years [46]. Annual net revenues of the control also exceeded that of the treatment fields in 2013 and 2014. In 2013, annual net revenue from soybeans in the treatment fields was less compared to the control. In 2014, the net revenue for the treatment fields planted to corn were negative and the control revenue was higher. In 2016, the net revenue from corn from the treatment group was higher than revenue from corn from the control. This result indicates that investing in the additional cost of a cover crop may pay dividends after a few years by improving the soil quality. Additional economic data are needed to determine the long-term economic impacts of cover crops. In terms of policy concerns, cost-share programs aimed at increasing farmers' use of cover crops and sustainable agricultural practices may need to extend the duration of that assistance. Short-term payments are essential to encourage adoption of cover crops; however, long-term assistance may promote the continuous use of cover crops. On the other hand, the duration of support provided may depend on the potential profitability of the cash crop.

Similar trends were observed for the annual BCRs (Table 2). Corn production in 2014, wheat production in 2015 and 2016, and corn production in 2016 in the control have BCRs less than 1.0, pointing to economic losses for these crops. The BCR for the control exceeded the BCR for Field 2 in 2013 and 2014, indicating a greater economic return in the absence of a cover crop. However, in 2016, the BCR for Field 2 exceeded the BCR for the control field.

Table 2. Cash crop yields, annual costs, revenues, and net revenues, and benefit–cost ratios for the treatment and control fields.

Yields, Costs, Revenues, and Benefit-Cost Ratios	Field 1	Field 2	Field 4	Field 5	Field 6	Field 3 (Control Field)	Differences between Fields 2&3
				2013			
Cash Crop	Corn	Soybean	Corn	Soybean	Soybean	Soybean	
Yield (Bushels/acre)	115.77	24.50	115.77	24.50	24.50	22.37	2.13
Cost ($/acre)	$393.03	$237.64	$393.03	$236.41	$236.16	$160.29	$77.35
Cover Crops	$62.67	$40.69	$62.67	$40.69	$40.69	$0.00	$40.69
Cash Crops	$330.35	$196.95	$330.35	$195.72	$195.47	$160.29	$36.66
Revenue ($/acre)	$572.16	$439.33	$572.16	$439.33	$439.33	$401.13	$38.20
Net revenue ($/acre)	$179.13	$201.69	$179.13	$202.92	$203.17	$240.84	−$39.15
Benefit–cost ratio	1.46	1.86	1.46	1.86	1.86	2.50	N/A
				2014			
Cash Crop	Soybean	Corn	Soybean	Corn	Corn	Corn	
Yield (Bushels/acre)	47.77	207.89	47.77	207.89	207.89	192.48	15.41
Cost ($/acre)	$351.07	$547.26	$351.07	$547.26	$547.26	$419.48	$127.78
Cover Crops	$53.62	$57.06	$53.62	$57.06	$57.06	$0.00	$57.06
Cash Crops	$297.45	$490.20	$297.45	$490.20	$490.20	$419.48	$70.72
Revenue ($/acre)	$435.02	$546.62	$435.02	$546.62	$546.62	$420.91	$125.71
Net revenue ($/acre)	$83.96	−$0.64	$83.96	−$0.64	−$0.64	$1.43	−$2.07
Benefit–cost ratio	1.24	0.99	1.24	0.99	0.99	1.00	N/A

Table 2. *Cont.*

Yields, Costs, Revenues, and Benefit-Cost Ratios	Field 1	Field 2	Field 4	Field 5	Field 6	Field 3 (Control Field)	Differences between Fields 2&3
2015							
Cash Crop	Corn	Soybean	Wheat	Soybean	Soybean	Soybean	
Yield (Bushels/acre)	102.8	N/A	44.09	N/A	N/A	N/A	N/A
Cost ($/acre)	$347.57	N/A	$280.63	N/A	N/A	N/A	N/A
Cover Crops	$31.92	$31.92	$31.92	$31.92	$31.92	N/A	N/A
Cash Crops	$315.65	N/A	$248.71	N/A	N/A	N/A	N/A
Revenue ($/acre)	$367.25	N/A	$197.13	N/A	N/A	N/A	N/A
Net revenue ($/acre)	$19.68	N/A	−$83.50	N/A	N/A	N/A	N/A
Benefit–cost ratio	1.06	N/A	0.70	N/A	N/A	N/A	N/A
2016							
Cash Crop	Soybean	Corn	Corn	Wheat	Soybean	Corn	
Yield (Bushels/acre)	58.60	128.08	128.08	33.32	58.60	108.23	19.85
Cost ($/acre)	$228.93	$353.03	$353.03	$174.97	$228.93	$332.40	$20.63
Cover Crops	$40.62	$40.62	$40.62	$40.62	$40.62	$0.00	$40.62
Cash Crops	$188.31	$312.41	$312.41	$134.35	$188.31	$332.40	−$19.99
Revenue ($/acre)	$534.44	$389.45	$389.45	$150.63	$534.44	$329.09	$60.36
Net revenue ($/acre)	$305.51	$36.42	$36.42	−$24.34	$305.51	−$3.31	$39.73
Benefit–cost ratio	2.33	1.10	1.10	0.86	2.33	0.99	N/A

Average yield, cost, revenue and net revenue for corn, soybean, and wheat production over the experiment period are provided in Table 3. The control and the treatment fields had similar average yields of corn, but the treatment fields had a higher soybean yield. However, the treatment fields obtained a lower net revenue from soybean production compared to the control, but a higher net revenue for the corn production.

Table 3. Average yield, cost, revenue, and net revenue for corn, soybean, and wheat over the experiment period (2013–2016).

Field	Cash Crop	Yield (Bushels/Acre)	Cost ($/Acre)	Revenue ($/Acre)	Net Revenue ($/Acre)
Fields 1, 2, 4, 5, & 6	Corn	151.77	$447.70	$509.01	$61.31
	Soybean	40.89	$267.17	$465.27	$198.10
	Wheat	38.71	$227.80	$173.88	−$53.92
Field 3 (Control Field)	Corn	150.36	$375.94	$375.00	−$0.94
	Soybean	22.37	$160.29	$401.13	$240.84
	Wheat	N/A	N/A	N/A	N/A

To compare the profitability of a wheat–soybean–corn rotation system over four years with and without the cover crop, we calculated net present values and four-year BCRs for treatment Field 2 and control Field 3, and found that the treatment field was less profitable than the control field. Field 2 had a net present value of $178.30 per hectare ($72.16 per acre) and a four-year BCR of 1.24 while Field 3 had a net present value of $254.53 per hectare ($103.00 per acre) and a four-year BCR of 1.36. This suggests that wheat–soybean–corn rotation system with cover crops may not be as profitable as the one without cover crops in the short term (four years in our case). Given data constraints, long-term economic profitability for the rotation system cannot be estimated.

3.2. Simulated Benefit–Cost Ratios

In our analysis, simulations produced a series of BCRs based on different values for the cost of the cover crop and the yields of the cash crops for Field 2 by using the 2013 and 2014 data. The 2016 data are excluded from the discussion because the BCRs for Field 2 were greater than 1.0 and greater than the BCR for Field 3. The results of the simulations showed that a decrease in the cost of the cover crop or an increase in the revenue lead to an increase in the BCR.

In 2013, BCR of Field 2 was greater than 1.0 under the given cover crop costs and cash crop revenues, but to match the profitability of the control field, the cover crop cost would have to be reduced by 26% with all other things being equal. In 2014, the BCR of Field 2 reaches 1.0 if the cover crop cost was decreased by 0.5%. Thus, for the treatment group to reach the breakeven point, the cost of the cover crop must be reduced by more than 26% in the first year.

The results of the simulations using different sales revenue levels suggest that an increase in revenue leads to an increase in the BCRs. In 2013, revenue from Field 2 would have to increase 35% to match the profitability of the control field. In 2014, the BCR of Field 2 reaches 1.0 when the cash crop revenue increases by just 0.5%.

These findings suggest that changes may be needed in the designing of future conservation incentive programs from an economic perspective. Some current programs use a flat rate to calculate cost-shares for farmers for planting cover crops. The Environmental Quality Incentive Program, for example, provides a flat rate per acre to farmers who participate the program. Our results proposed two ways of compensating farmers' short-term economic losses associated with establishing a cover crop rotation by either share the costs or provide a monetary incentive based on farmer's cash crop revenues. For example, to promote cover crop adoption in Missouri, relative policies can (1) share some of the cost of the cover crop (depending on the seeding and termination methods used for the cover crop and the number of years of cover crop used) or (2) provide a certain amount of money (which could be a portion of cash crop revenues) to farmers to compensate them for the cost of the cover crop.

4. Conclusions

This field and simulation study of the economic effects of cover crops on cash crop production was conducted at NRCS's Soil Health Farm in Chariton County, Missouri. The study compared the annual economic profitability of production of corn, wheat, and soybeans with and without a cover crop in the rotation by examining the cost of the cover crop, the cost of the cash crop, revenues generated by the cash crop, and the cash crop yields. The differences in yield found may have been related to differences among soils. However, net revenue was reduced in the short term because of the additional cost associated with the cover crop. Over a longer term, use of a cover crop may lead to an increase in revenue from the cash crop relative to production without the cover crop as the cover crop can reduce soil erosion and improve infiltration and soil health.

This study was short term of four years. Longer-term studies are needed to explore the economic impacts of cover crops on cash crops more fully. Our results indicate that including a cover crop in the rotation system may produce benefits such as improved soil and water quality and enhanced nutrient cycling in as little as four years, and those benefits are likely to have a cumulative positive impact on the yield of the cash crop in the long term.

The results of this study provide insight for policymakers involved in implementing financial assistance programs. In the short term, the cost associated with the cover crop has a negative economic impact on cash crop production that may be replaced with a positive impact in subsequent years because of improved soil health and yields. A better understanding of the long-term economics of cover crops can assist policymakers in designing financial incentive programs that provide adequate support and efficiently use the resources available.

Extension and educational programs are also needed to improve the cover crop adoption. Programs should explain benefits and potential risks associated with cover crop use [19]. Workshops at the Farmers Union or other farmers' groups can help promote cover crop adoption. Peer effects may positively affect the use of cover crops. Farmers can learn about cover crop economic and environmental benefits and associated technology from their peers in the same agricultural group [47]. Well-designed financial assistance programs and tailored extension and educational programs are both important in improving the use of cover crops.

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Appendix A

Table A1. Description of Cover Crop Mixes Used at the Chariton County Soil Health Farm by Field.

Year	Field 1 (%)	Field 2 (%)	Field 4 (%)	Field 5 (%)	Field 6 (%)
2012	Sorghum-Sudan (35)	Sorghum-Sudan (35)	Cereal Rye (25)	Cereal Rye (50)	Cereal Rye (50)
	Buckwheat (15)	Buckwheat (15)	Cowpea (25)	Pearl millet (15)	Cowpea (50)
	Cowpea (10)	Cowpea (10)	Pearl millet (15)	Triticale (10)	
	Cereal Rye (5)	Cereal Rye (5)	Triticale (10)	Turnip (3.5)	
	Annual Sweet Clover (10)	Sweet Clover (10)	Turnip (3.5)	Crimson Clover (2.5)	
	Radish (5)	Radish (5)	Crimson Clover (2.5)	Buckwheat (5)	
	Sunn Hemp (2.5)	Sunn Hemp (2.5)	Buckwheat (5)	Winter Pea (10)	
	Sorghum Sudan (15)	Sorghum Sudan (15)	Winter Pea (10)	Red Clover (4)	
	Barley (2.5)	Barley (2.5)	Red Clover (4)		
2013	Peas (25)	Peas (25)	Hairy Vetch (5)	Oats (16.5)	Hairy Vetch (10)
	Radish (25)	Radish (25)	Winter Pea (25)	Rapeseed (16.5)	Winter Pea (50)
	Rye (5)	Rye (5)	Cowpea (10)	Yellow Mustard (17)	Cowpea (20)
	Hairy Vetch (12.5)	Hairy Vetch (12.5)	Crimson Clover (1)	Rye (7.5)	Crimson Clover (2)
	Winter Pea (7.5)	Winter Pea (7.5)	Sorghum Sudan (1)	Hairy Vetch (42.5)	Sorghum Sudan (2)
	Radish (5)	Radish (5)	Annual Rye (0.5)		Annual Rye (1)
	Cowpea (7.5)	Cowpea (7.5)	Oats (1)		Oats (2)
	Turnip (5)	Turnip (5)	Radish (2)		Radish (4)
	Sorghum Sudan (2.5)	Sorghum Sudan (2.5)	Rye (7.5)		Buckwheat (6)
	Annual Sweet Clover (5)	Annual Sweet Clover (5)	Hairy Vetch (42.5)		Sunflower (2)
			Buckwheat (2)		Turnip (1)
			Sunflower (2)		
			Turnip (0.5)		
2014	Triticale (50)	Cereal Rye (50)	Wheat (100)	Triticale (75)	Barley (75)
	Barley (50)	Triticale (20)		Wheat (25)	Wheat (25)
		Barley (20)			
		Wheat (10)			

Table A1. *Cont.*

Year	Field 1 (%)	Field 2 (%)	Field 4 (%)	Field 5 (%)	Field 6 (%)
2015	Barley (20) Cereal Rye (40) Triticale (40)	Oat (20) Cereal Rye (40) Triticale (40)	Oat (20) Rapeseed (15) Hairy Vetch (50) Crimson Clover (10) Winter Pea (15)	Wheat (100)	Winter Oats (20) Cereal Rye (40) Triticale (40)
2016	Oat (50) Cereal Rye (25) Triticale (25)	Cereal Rye (35) Triticale (35) Barley (30)	Triticale (60) Wheat (40)	Black Oat (10) Buckwheat (10) Cowpea (30) Sunn Hemp (5) Radish (10) Turnips (5) Canola (10) Crimson Clover (10) Hairy Vetch (10)	Wheat (100)

Appendix B

Table A2. (**a**) Average Prices for Cash Crops and (**b**) Cover Crops Used in Estimating the Economic Benefits and Costs in this Study.

(**a**)

	Soybean ($/bu)	Corn ($/bu)	Wheat ($/bu)
2013	15.83	9.31	N/A
2014	10.05	2.13	N/A
2015	N/A	3.78	4.38
2016	9.12	3.04	4.52

(**b**)

Cover Crop	Price ($/lb)
Annual Rye	$0.60
Buckwheat	$0.75
Cereal Rye	$0.28
Cowpea	$0.85
Crimson Clover	$1.10
Hairy Vetch	$2.05
Oats	$0.42
Radishes	$1.95
Sorghum	$0.90
Sunflowers	$0.60
Sunn Hemp	$1.80
Sweet Clover	$2.00
Turnips	$2.00
Triticale	$0.35
Winter Peas	$0.55

References

1. USDA NASS (United States Department of Agriculture, National Agricultural Statistics Service). Crop Production 2016 Summary. 2017. Available online: http://usda.mannlib.cornell.edu/usda/current/CropProdSu/CropProdSu-01-12-2017.pdf (accessed on 11 November 2018).
2. Sassenrath, G.F.; Heilman, P.; Luschei, E.; Bennett, G.L.; Fitzgerald, G.; Klesius, P.; Tracy, W.; Williford, J.R.; Zimba, P.V. Technology, complexity and change in agricultural production systems. *Renew. Agric. Food Syst.* **2008**, *23*, 285–295. [CrossRef]
3. McDaniel, T.V.; Martin, P.A.; Struger, J.; Sherry, J.; Marvin, C.H.; McMaster, M.E.; Clarence, S.; Tetreault, G. Potential endocrine disruption of sexual development in free ranging male northern leopard frogs (*Rana pipiens*) and green frogs (*Rana clamitans*) from areas of intensive row crop agriculture. *Aquat. Toxicol.* **2008**, *88*, 230–242. [CrossRef] [PubMed]
4. Porter, P.M.; Lauer, J.G.; Lueschen, W.E.; Ford, J.H.; Hoverstad, T.R.; Oplinger, E.S.; Crookston, R.K. Environment affects the corn and soybean rotation effect. *Agron. J.* **1997**, *89*, 442–448. [CrossRef]

5. Kremer, R.J. Growth suppression of annual weeds by deleterious rhizobacteria integrated with cover crops. In Proceedings of the Xth International Symposium on Biological Control of Weeds, Bozeman, MT, USA, 4–14 July 1999; Spencer, N.R., Ed.; Montana State University: Bozeman, MT, USA, 2000; pp. 931–940.
6. Uchino, H.; Iwama, K.; Jitsuyama, Y.; Ichiyama, K.; Sugiura, E.; Yudate, T. Stable characteristics of cover crops for weed suppression in organic farming systems. *Plant Prod. Sci.* **2011**, *14*, 75–85. [CrossRef]
7. Environmental Protection Agency. Nonpoint Source: Agriculture. 2016. Available online: https://www.epa.gov/nps/nonpoint-source-agriculture (accessed on 11 November 2018).
8. Udawatta, R.P.; Motavalli, P.P.; Garrett, H.E. Phosphorus loss and runoff characteristics in three adjacent agricultural watersheds with claypan soils. *J. Environ. Qual.* **2004**, *33*, 1709–1719. [CrossRef]
9. Udawatta, R.P.; Motavalli, P.P.; Garrett, H.E.; Krstansky, J.J. Nitrogen losses in runoff from three adjacent agricultural watersheds with claypan soils. *Agric. Ecosyst. Environ.* **2006**, *117*, 39–48. [CrossRef]
10. USDA NRCS (United States Department of Agriculture, Natural Resources Conservation Service). Cover Crop. 2011. Available online: https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1046845.pdf (accessed on 11 November 2018).
11. Delgado, J.A.; Gantzer, C.J. The 4Rs for cover crops and other advances in cover crop management for environmental quality. *J. Soil Water Conserv.* **2015**, *70*, 142A–145A. [CrossRef]
12. Bowman, G.; Shirley, C.; Cramer, C. *Managing Cover Crops Profitably*; Sustainable Agriculture Network Handbook Series Book; Sustainable Agriculture Research and Education Program: College Park, MD, USA, 1998; Volume 3, pp. 22–23.
13. Kabir, Z.; Koide, R.T. The effect of dandelion or a cover crop on mycorrhiza inoculum potential, soil aggregation and yield of maize. *Agric. Ecosyst. Environ.* **2000**, *78*, 167–174. [CrossRef]
14. Kabir, Z.; Koide, R.T. Effect of autumn and winter mycorrhizal cover crops on soil properties, nutrient uptake and yield of sweet corn in Pennsylvania, USA. *Plant Soil* **2002**, *238*, 205–215. [CrossRef]
15. Raper, R.L.; Reeves, D.W.; Burmester, C.H.; Schwab, E.B. Tillage depth, tillage timing, and cover crop effects on cotton yield, soil strength, and tillage energy requirements. *Appl. Eng. Agric.* **2000**, *16*, 379–386. [CrossRef]
16. Werblow, S. Annual Report 2015–2016 Cover Crop Survey. 2016. Available online: http://www.sare.org/Learning-Center/From-the-Field/North-Central-SARE-From-the-Field/2016-Covercrop-Survey-Analysis (accessed on 11 November 2018).
17. Tonitto, C.; David, M.B.; Drinkwater, L.E. Replacing bare fallows with cover crops in fertilizer-intensive cropping systems: A meta-analysis of crop yield and N dynamics. *Agric. Ecosyst. Environ.* **2006**, *112*, 58–72. [CrossRef]
18. Sainju, U.M.; Singh, B.P.; Whitehead, W.F. Comparison of the effects of cover crops and nitrogen fertilization on tomato yield, root growth, and soil properties. *Sci. Hortic.* **2001**, *91*, 201–214. [CrossRef]
19. Arbuckle, J.G.; Roesch-McNally, G. Cover crop adoption in Iowa: The role of perceived practice characteristics. *J. Soil Water Conserv.* **2015**, *70*, 418–429. [CrossRef]
20. Singer, J.W.; Nusser, S.M.; Alf, C.J. Are cover crops being used in the US Corn Belt? *J. Soil Water Conserv.* **2007**, *62*, 353–358.
21. Jones, C.A.; Miller, P.R.; Zabinski, C.; Kurnick, R.; Olson-Rutz, K. Cover Crop Decision Making: Information Sources and Barriers/Incentives for Adoption based on a Montana Producer Survey. 2015. Available online: https://scisoc.confex.com/crops/2015am/webprogram/Paper95075.html (accessed on 11 November 2018).
22. Miller, L.; Chin, J.; Zook, K. Policy Opportunities to Increase cover Crop Adoption on North Carolina Farms: A Report for the Union of Concerned Scientists. Master's Thesis, School of Environment of Duke University, Durham, NC, USA, 2012. Available online: https://dukespace.lib.duke.edu/dspace/bitstream/handle/10161/5308/Zook_Miller_Chin.pdf?sequence=3 (accessed on 11 November 2018).
23. Stivers-Young, L.J.; Tucker, F.A. Cover cropping practices of vegetable producers in western New York. *HortTechnology* **1999**, *9*, 459–465. [CrossRef]
24. Mallory, E.B.; Posner, J.L.; Baldock, J.O. Performance, economics, and adoption of cover crops in Wisconsin cash grain rotations: On-farm trials. *Am. J. Altern. Agric.* **1998**, *13*, 2–11. [CrossRef]
25. Labarta, R.; Swinton, S.M.; Black, J.R.; Snapp, S.; Leep, R. *Economic Analysis Approaches to Potato-Based Integrated Crop Sys-Tems: Issues and Methods*; Staff Paper 02–32; Department of Agricultural Economics, Michigan State University: East Lansing, MI, USA, 2002.

26. Schnitkey, G.; Coppess, J.; Paulson, N. Costs and benefits of cover crops: An example with cereal rye. *Farmdoc Daily* **2016**, *6*, 126. Available online: http://farmdocdaily.illinois.edu/2016/07/costs-and-benefits-of-covercrops-example.html (accessed on 11 November 2018).
27. Swanson, K.; Schnitkey, G.; Coppess, J. Understanding Budget Implications of Cover Crops. *Farmdoc Daily* **2018**, *8*, 119.
28. Reddy, K.N. Impact of rye cover crop and herbicides on weeds, yield, and net return in narrow-row transgenic and conventional soybean (*Glycine max*). *Weed Technol.* **2003**, *17*, 28–35. [CrossRef]
29. Cartwright, L. Adding Cover Crops for Seed Production to a Corn/Soybean Rotation—Missouri Cover Crop Economics Case Study 1. 2015. Available online: https://efotg.sc.egov.usda.gov/references/Public/MO/CS1_AddingCoverCropstoCornSoybeanRotation_March2015Final.pdf (accessed on 10 January 2018).
30. United States Department of Agriculture, Census of Agriculture. Census of Agriculture, 2012 Census Volume 1, Chapter 1: State Level Data. 2013. Available online: https://www.agcensus.usda.gov/Publications/2012/Full_Report/Volume_1,_Chapter_1_State_Level/Missouri/st29_1_001_001.pdf (accessed on 11 November 2018).
31. Helsel, R.Z.; Minor, H.C. Soybean Production in Missouri. 1993. Available online: https://extension2.missouri.edu/g4410 (accessed on 11 November 2018).
32. Dunn, D. Soil Fertility in a Wheat/Soybean/Corn Rotation. Available online: http://extension.missouri.edu/scott/documents/Ag/Fall-Crop-Presentaiton/SoilFertilityWheat-Dunn_2014.pdf (accessed on 11 November 2018).
33. Tomer, M.D.; James, D.E.; Sandoval-Green, C.M.J. Agricultural conservation planning framework: 3. land use and field boundary database development and structure. *J. Environ. Qual.* **2017**, *46*, 676–686. [CrossRef]
34. United States Department of Agriculture, Census of Agriculture. County Profile: Chariton County, Missouri. 2013. Available online: https://www.agcensus.usda.gov/Publications/2012/Online_Resources/County_Profiles/Missouri/cp29041.pdf (accessed on 11 November 2018).
35. Midwestern Regional Climate Center. Midwest Climate: Climate Summaries. 2015. Available online: http://mrcc.isws.illinois.edu/ (accessed on 11 November 2018).
36. USDA NRCS (United States Department of Agriculture, Natural Resources Conservation Service). Web Soil Survey. 2017. Available online: https://websoilsurvey.sc.egov.usda.gov/App/WebSoilSurvey.aspx (accessed on 11 November 2018).
37. Snapp, S.S.; Swinton, S.M.; Labarta, R.; Mutch, D.; Black, J.R.; Leep, R.; Nyiraneza, J.; O'Neil, K. Evaluating cover crops for benefits, costs and performance within cropping system niches. *Agron. J.* **2005**, *97*, 322–332.
38. USDA NASS (United States Department of Agriculture, National Agricultural Statistics Service). Prices Paid Surveys and Indexes. 2017. Available online: https://www.nass.usda.gov/Surveys/Guide_to_NASS_Surveys/Prices_Paid_and_Prices_Paid_Indexes/ (accessed on 11 November 2018).
39. Klemperer, W.D. *Forest Resource Economics and Finance*; McGraw-Hill Inc.: New York, NY, USA, 1996.
40. Adusumilli, N.; Davis, S.; Fromme, D. Financial evaluation of irrigation efficiency improvement practices in row crop production in Louisiana. In Proceedings of the 2016 Annual Meeting, San Antonio, TX, USA, 6–9 February 2016; Southern Agricultural Economics Association: San Antonio, TX, USA, 2016; No. 229791.
41. USDA NRCS (United States Department of Agriculture, Natural Resources Conservation Service). *Revised Universal Soil Loss Equation, Version 2 (RUSLE2) Official NRCS Database*; NRCS: Washington, DC, USA, 2018. Available online: http://fargo.nserl.purdue.edu/rusle2_dataweb/RUSLE2_Index.htm (accessed on 11 November 2018).
42. Langdale, G.W.; Blevins, R.L.; Karlen, D.L.; McCool, D.K.; Nearing, M.A.; Skidmore, E.L.; Thomas, A.W.; Tyler, D.D.; Williams, J.R. Cover crop effects on soil erosion by wind and water. In *Cover Crops for Clean Water: The Proceedings of an International Conference, West Tennessee Experiment Station, April 9–11, 1991, Jackson, Tennessee*; Soil and Water Conservation Society: Jackson, TN, USA, 1991; pp. 15–22.
43. Hively, W.; Cox, W.J. Interseeding cover crops into soybean and subsequent corn yields. *Agron. J.* **2001**, *93*, 308–313. [CrossRef]
44. Fageria, N.K.; Baligar, V.C.; Bailey, B.A. Role of cover crops in improving soil and row crop productivity. *Commun. Soil Sci. Plant Anal.* **2005**, *36*, 2733–2757. [CrossRef]
45. Tyndall, J.; Bowman, T. *Iowa Nutrient Reduction Strategy Best Management Practice Cost Overview Series: Cover Crops*; Department of Ecology & Natural Resource Management, Iowa State University: Ames, IA, USA, 2016; Available online: http://www.nrem.iastate.edu/bmpcosttools/files/page/files/2016%20Cost%20Sheet%20for%20Cereal%20Rye%20Cover%20Crop.pdf (accessed on 11 November 2018).

46. University of Illinois. Revenue and Costs for Corn, Soybeans, Wheat, and Double-Crop Soybeans, Actual for 2010 through 2015, Projected 2016 and 2017. 2017. Available online: http://www.farmdoc.illinois.edu/manage/actual_projected_costs.pdf (accessed on 11 November 2018).
47. Songsermsawas, T.; Baylis, K.R.; Chhatre, A. Effects of Peers on Agricultural Productivity in Rural Northern India (No. 327-2016-12722). 2014. Available online: https://ageconsearch.umn.edu/record/170168/files/Songsermsawas_AAEA_2014.pdf (accessed on 18 April 2018).