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Is Harvesting Cover Crops for Hay Profitable When Planting Corn and Soybean in Tennessee?

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Abstract: Winter cover crops can improve the soil's moisture-holding capacity, reduce soil water evaporation, and mitigate water-induced soil erosion; however, economic studies show mixed results on cover crop impacts on profits. One way to potentially increase the profits from planting cover crops is to harvest the cover crop for hay. The objective of this study was to determine the profitability of planting and harvesting cover crops when planting corn (*Zea mays*) or soybean (*Glycine max* (L.) Merr.) as a cash crop. We determined the difference in net returns among 15 cover crop species when planted before corn and soybeans. We then calculated the breakeven hay price if the cover crop was harvested. Data were collected from an experiment in Tennessee, from 2017 to 2019, at two locations. There was no difference in net returns across cover crop treatments for both corn and soybeans, thus indicating that planting a cover crop does not reduce profits. The breakeven prices for harvesting cover crops suggest that this system would not likely be profitable for corn but might be profitable if planting soybeans, depending on labor availability and local demand for hay.

Keywords: corn; cover crops; economics; soybeans

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Citation: Duncan, H.; Eicher, J.; Bracey, W.M.; Sykes, V.R.; Boyer, C.N.; Yin, F.; Bates, G.E.; Butler, D.M.; Willette, A.R. Is Harvesting Cover Crops for Hay Profitable When Planting Corn and Soybean in Tennessee? *Agronomy* **2022**, *12*, 1353. https://doi.org/10.3390/agronomy12061353

Academic Editor: David W. Archer

Received: 15 December 2021
Accepted: 28 May 2022
Published: 1 June 2022

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1. Introduction

A global challenge associated with crop production is minimizing water-induced soil erosion without reducing producer profits. This challenge is especially difficult for crop production in the Mid-South United States on sandy or silty soils, which are more vulnerable to soil erosion [1,2]. Researchers and producers in this region have been long interested in evaluating practices that could reduce soil erosion without reducing producer profits [3,4]. Planting winter cover crops is one practice that can potentially mitigate soil erosion by increasing soil surface biomass. Winter cover crops can help retain nutrients in soils that are otherwise lost due to leaching or runoff, improve the soil's moisture-holding capacity, reduce soil water evaporation, and mitigate water-induced soil erosion [3–7].

Despite the environmental benefits of using winter cover crops, producer implementation of these practices is low across the United States [8–11]. Less than 2% of all United States cropland (2.75 million ha) was planted with winter cover crops during 2010/2011 [9]. In 2017, the percent of cropland that planted cover crops grew to be about 4.8% [12]. Inconsistent findings on the profitability of planting cover crops may explain slow adoption rates [2–4,8]. Cover crops could increase producer net returns through higher yields and reduced nitrogen (N) fertilizer costs with legume cover crop species, but establishment and termination of the cover crop increase costs.

Studies have found that legume cover crops can reduce N fertilizer costs relative to not using cover crops or non-legume cover crops [13–15]. However, the impacts of planting legume and non-legume cover crop species on net returns have shown mixed results [16]. A recent study showed that a profit-maximizing producer would not plant a cover crop in upland cotton (*Gossypium hirsutum* L.) production, despite the legume cover crops reducing N fertilizer rates [16]. Most of this work in this area of the United States has focused on cotton production and used a limited amount of cover crop species [13,16–19]. A few studies have looked at the profitability of using cover crops in continuous corn production and found that cover crops can lower N rates and increase yields [3,20,21]. However, these results are likely related to the climate in these regions [3]. More research is needed on the impact of a wide variety of cover crop species on corn (*Zea mays*) and soybean (*Glycine max* (L.) Merr.) profitability in the Mid-South.

Furthermore, several cover crop species could fit well into a Mid-South dual-use cover cropping system where the cover crop is harvested for hay [22,23]. These cover crops contain important forage nutritive value characteristics, such as high dry matter content, crude protein, and total digestible nutrients [24]. Therefore, a producer could harvest the cover crop for hay; however, an important economic question to answer is what the breakeven price for the cover crop hay is. That is, what price does the producer need for the hay to sell it for a profit? Knowing this information would provide insight into economic feasibility of a dual-purpose cover crop system. It would also provide producers an economic incentive to plant cover crops, knowing the hay production could be profitable.

The purpose of this study was to evaluate profitability of planting and/or harvesting cover crops when planting corn and soybeans as a cash crop. Specifically, we determined the difference in net returns among 15 cover crops when planted before corn and soybeans. We calculated the cost to plant each species of cover crop, cost of corn and soybean production, forage harvest cost, and forage income levels to determine the species and season that had the most profitability. Our objectives were to determine (1) changes in net returns with planting a cover crop in corn or soybean systems, and (2) when a cover crop is planted, determine the breakeven hay price to harvest and market the cover crop as hay.

2. Materials and Methods

2.1. Data

Plots were established at two University of Tennessee AgResearch and Education centers: Plant Sciences Unit of the East Tennessee AgResearch and Education Center (ETREC) in Knoxville, Tennessee (35.892495, −83.959613) and Middle Tennessee AgResearch and Education Center (MTREC) in Spring Hill, Tennessee (35.721164, −86.964894). The soil type at ETREC is Sequatchie loam (fine-loamy, siliceous, semiactive, thermic Humic Hapludult) and at MTREC is Maury silt loam (fine, mixed, active, mesic Typic Paleudalf). Treatments were a factorial design with fifteen cover crop species and a no-cover control evaluated under two management systems. One management system was defined as single-use, where the cover crop was chemically terminated and left as residue before cash-crop planting. The other system is defined as dual-use, where cover-crop residue was mechanically harvested then chemically terminated prior to cash crop planting. This was repeated under two different cover-crop planting/harvesting times, resulting from different cash-crop rotations, corn/cover crop–soybean and soybean/cover crop–corn, and was repeated over two growing seasons (fall 2017 through spring 2019).

Cover crops were seeded at rates recommended by University of Tennessee Extension for forage production (see Reference [24]; Table 1). Cover crops included arrowleaf clover (*Trifolium vesiculosum* Savi), crimson clover (*T. incarnatum*), red clover (*T. pratense*), common vetch (*Vicia sativa*), hairy vetch (*V. villosa*), woolypod vetch (V. villosa), winter pea (*Pisum sativum*), barley (*Hordeum vulgare*), oats (*Avena sativa*), triticale (*X Triticosecale*), cereal rye (*Secale cereale*), winter wheat (*Triticum aestivum*), canola (*Brassica napus*), forage radish (*Raphanus sativus*), and turnip (*B. rapa*). Table 1 also shows the average cost of the cover crop seeds, which were collected from local seed providers.

Table 1. Seeding rate and cost of cover crop.

Cover Crop	Seeding Rate kg ha^{-1}	\$ kg^{-1}	Total Cost \$ ha^{-1}†
Barley	168	$1.10	$185
Clover Arrowleaf	11	$2.18	$24
Clover Crimson	28	$2.65	$74
Clover Red	11	$2.25	$25
Canola	9	$3.53	$32
Cereal Rye	168	$0.66	$111
Hairy Vetch	34	$4.63	$156
Oat	168	$0.75	$126
Pea	56	$1.63	$91
Radish	17	$2.43	$41
Triticale	168	$0.79	$133
Turnip	7	$1.98	$13
Vetch Woolypod	34	$5.56	$187
Vetch Common	34	$2.56	$86
Wheat	202	$0.62	$125

† The cost associated with planting the cover crop was \$35.6 ha^{-1}, and forage harvest cost was \$82.4 ha^{-1}. Seed costs were averaged from quotes provided by multiple local seed providers.

Cover crop plots planted before corn were established in late October of each year. Forage harvest occurred in mid-April, and plots were terminated shortly after. Corn was planted in these plots in mid-April and harvested in mid-September. Cover-crop plots preceding soybeans were established in late-September to early-October. Forage harvest occurred in mid-April, and plots were terminated shortly after. Soybean was planted in these plots in mid-May and harvested in late September to late October. The planting date, harvest dates, and input (e.g., fertilizer and chemicals) application followed University of Tennessee Extension recommendations and were consistent across treatments. Exact planting and harvest dates, as well as crop varieties, can be found in Bracey [25,26]. Plots were arranged in a randomized complete block design with three replicates. Plots were planted 3.1 m $\times$ 9.1 m and were trimmed to 7.5 m length at ETREC and 8.2 m at MTREC. Table 2 shows the average corn and soybean yields as affected by cover crop harvest across all years and locations. The average corn yield for Tennessee is 11,432 kg ha^{-1}, which is 115 kg ha^{-1} less than what the average was in these data [27]. The average soybean yield in these data was 205 kg ha^{-1} higher than the Tennessee average of 3232 kg ha^{-1} [27].

Forage harvest for ETREC and MTREC occurred in late-March, before corn planting; and in late-April, before soybean planting. Cover crop biomass from one randomly selected 0.09 m^2 area of each plot was sampled at a height of 5 cm. These samples were weighed, dried at 55 °C for 72 h, and reweighed to determine total forage dry biomass. Table 3 shows the average total forage yield when harvested prior to corn and soybean planting across all years and locations. For more details of the experiment, exact dates, cover crop varieties, forage quality data, and soil-quality data, please refer to the data in Bracey [25,26]. Perception was average relative to the last 25 years within the timeframe of the study [28].

The calculated cost for corn production per acre is \$1554 ha^{-1}. Soybean production calculated cost was \$1111.5 ha^{-1} [29]. The cost associated with planting the cover crop was \$35.6 ha^{-1}, and forage harvest cost was \$82.4 ha^{-1} [30]. Cover crop seed cost is shown in Table 1 for each cover crop species. The estimated price for corn was \$107.95 Mg^{-1}, and the soybean estimated price was \$299.37 Mg^{-1}. All prices were adjusted to 2021 dollars, using the Implicit Gross Domestic Product Price Deflator [31].

Table 2. Average corn and soybean yield (kg ha^{-1}) for forage and non-forage harvested treatments across years and locations.

	Corn			Soybean		
Cover Crop	**Forage**	**Non-Forage**	**Difference in Forage and Non-Forage**	**Forage**	**Non-Forage**	**Difference in Forage and Non-Forage**
Barley	11,848	11,436	412	3158	3338	(181)
Clover Arrowleaf	11,239	10,811	428	3222	3436	(214)
Clover Crimson	11,699	11,451	248	3284	3526	(241)
Clover Red	12,102	11,417	685	3365	3223	142
Canola	11,143	12,182	(1039)	3249	3041	208
Cereal Rye	11,589	11,625	(36)	3184	3180	4
Hairy Vetch	11,780	11,601	179	3182	3218	(37)
No Cover	11,186	10,952	235	3184	3327	(143)
Oat	11,818	11,292	526	3306	3541	(235)
Pea	10,492	12,061	(1569)	3013	3125	(112)
Radish	10,817	11,965	(1149)	3237	3202	34
Triticale	11,227	11,921	(694)	3085	3336	(250)
Turnip	11,838	12,993	(1155)	3230	3211	18
Vetch Woolypod	11,200	11,970	(769)	2997	3330	(333)
Vetch Common	10,610	11,328	(717)	2883	3232	(349)
Wheat	12,276	11,681	595	3238	3325	(87)
Average	11,429	11,668	(239)	3176	3287	(111)

Table 3. Average forage yields for the cover crops by succeeding cash crop across all years (2018 and 2019) and Locations (Knoxville, TN, USA; and Spring Hill, TN, USA).

Cover Crop	Forage Followed by Corn	Forage Followed by Soybeans
Barley	901	2431
Clover Arrowleaf	528	1272
Clover Crimson	815	4565
Clover Red	973	1567
Canola	1208	2864
Cereal Rye	1141	3040
Hairy Vetch	1069	3068
No Cover	802	492
Oat	1464	3350
Pea	1028	3289
Radish	582	675
Triticale	1310	3418
Turnip	945	2468
Vetch Woolypod	891	3239
Vetch Common	768	1612
Wheat	1466	3896
Average	901	2431

2.2. Net Returns

Net returns were calculated for corn and soybean production, using enterprise budgets. Net returns are the revenue from the cash crop (corn or soybeans) minus the production expenses. Previous studies have used enterprise budgets to analyze the profitability of cover crops [14–19]. We assume that the producers are profit maximizers and would select to plant cover crops and the preferred cover crop species with the highest net returns. As discussed above, producers choosing to adopt cover crops have additional costs of planting and terminating the cover crops; thus, higher revenue through increased yields is needed to pay for these additional costs. In this calculation, we assume the traditional approach of cover crop systems that cover crops are not harvested for revenue before planting the cash crop. Mathematically, the net returns are calculated as follows:

$$\max_{\lambda,i} NR_{ji} = p_j y_{ji} - c_j - \lambda(w_i r_i - k) \quad (1)$$

where NR_{ji} is the net returns (\$ ha^{-1}) for crop j (j = corn or soybeans) and cover crop species i (i = 1, . . . ,15); p_j is the price (\$ kg^{-1}) for crop j; y_{ji} is the crop yield in kg ha^{-1}; c_j is the total production cost of planting the cash crop j; λ is an indicator variable equal to one if crop cover is planted, and it is zero if otherwise; w_i is the cost of seed for cover crop in \$ kg^{-1}; r_i is the seeding rate for the cover crop; and k is the is the cost of planting the cover crop. Therefore, a profit maximizing producer would choose to plant a cover crop (λ) and the cover crop species (i) that maximizes net returns.

2.3. Breakeven Price of Cover Crop Hay

Next, we set up a different economic framework, assuming a corn or soybean producer planted a cover crop. This framework was established to determine the breakeven price of hay a producer would need to harvest their cover crop for hay. That is, a producer has a cover crop planted and determines if he/she should terminate it and plant the cash crop or harvest the cover crop for hay. Profitability is determined by the value of the cover crop hay in a given year. Thus, we investigated this breakeven price. In this scenario, a producer has a cost of planting the cover crop that is shown in Equation (1) and will terminate the cover crop regardless of whether it is harvested for hay or terminated by other means. Thus, a producer would have the added costs of harvesting the cover crop for hay. This means the breakeven price of harvesting the cover crop for hay would be the total cost of harvesting divided by the hay yield or $P_{ij}^{BE} = \theta / f_{ij}$, where P_{ij}^{BE} is the breakeven price in \$ kg^{-1}, θ is the cost of harvesting the cover crop for hay in \$ ha^{-1}, and f_{ij} is the forage yield from the cover crop in kg ha^{-1}.

2.4. Statistical Analysis

Two statistical models were estimated. The first was with net returns as the dependent variable, and the second was with the breakeven hay price as the other dependent variable. For the net returns model, the cash crop yield observations that were not harvested for forage were used, and the fixed effects included cover crop species. We estimate net returns models for corn and soybeans separately. For the breakeven price of hay model, only forage observations where cover crops were harvested for hay were included, and the forage yield observations with no cover crop planted were deleted. Fixed effects for this model included cover crop species, the crop planted after the cover crops, and the interaction of these variables. In both models, random effects were location, replication, and year. We tested for heteroskedasticity and failed to reject the null hypothesis that errors were heteroskedastic. A statistical analysis was performed by using PROC MIXED in SAS 9.4, and Fisher's Protected LSD was used to find mean separations [32]. A p-value of less than 0.05 was used to determine statistical significance.

3. Results

3.1. Net Returns

Table 4 shows the parameter estimates for the ANOVA analysis of net returns for corn and soybeans across the cover crop species. Wheat was dropped from the ANOVA analysis; thus, the parameters were interpreted relative to the net returns to wheat cover crop. The results show that there was not a statistical difference across the cover crop treatment for corn and soybeans. This indicates that a corn or soybean producer's net returns would not statistically vary between planting a cover crop and not planting a cover crop. The reported p-values are for the estimate being different than zero.

Table 4. Parameter estimates from corn and soybean ANOVA analysis across cover crop species.

	Corn		Soybeans	
Species	**Net Returns †**	***p*-Values**	**Net Returns ‡**	***p*-Values**
Intercept	225.55	0.589	72.30	0.812
Barley	−101.65	0.638	−68.55	0.440
Clover Arrowleaf	−45.06	0.835	172.61	0.053
Clover Crimson	−0.28	0.999	103.65	0.270
Clover Red	55.31	0.798	57.89	0.505
Canola	176.59	0.414	−21.79	0.802
Cereal Rye	4.02	0.985	−45.18	0.603
Hairy Vetch	−44.50	0.837	−74.32	0.392
No Cover	2.89	0.989	125.33	0.150
Oat	−66.34	0.759	85.80	0.323
Pea	96.52	0.655	−47.89	0.581
Radish	131.26	0.543	34.10	0.694
Triticale	31.26	0.885	−4.69	0.957
Turnip	294.28	0.195	65.24	0.452
Vetch Woolypod	−14.03	0.948	−60.38	0.487
Vetch Common	−20.39	0.925	0.82	0.993
Wheat	-	-	-	-
F-Statistics (*p*-value)	-	0.9771	-	0.1404
Observations	193	-	191	-

† Cost for corn production per acre is \$1554 ha^{-1}, and estimated price for corn was \$107.95 Mg^{-1}; ‡ soybean production calculated cost was \$1111.5 ha^{-1}, and soybean estimated price was \$299.37 Mg^{-1}.

While the results are not statistically different, numeric differences in net returns are discussed. If a producer wanted to plant a cover crop species before planting corn, turnips resulted in the higher net returns on average (\$225 + \$294 = \$519 ha^{-1}). Turnips had the lowest cost to plant, and corn yields also had the third highest average yield. Canola and radish had the next highest net return, on average, of (\$176 + \$225 = \$402) \$402 and \$357 ha^{-1}, respectively. These two cover crops also had low costs for establishment. The no-cover-crop treatment before corn had an average net return of \$228 ha^{-1}, which ranked seventh among the 15 cover crop treatments. Planting barley prior to corn had the lowest average net returns of \$124 ha^{-1}, which had the second highest cost of establishment. If a producer was planting soybeans, arrowleaf clover had the highest net return of \$244 ha^{-1} on average. Again, barley resulted in a low average net returns (\$4 ha^{-1}) before planting soybeans but was not the lowest; the lowest was hairy vetch (−\$2 ha^{-1}). If a soybean producer decided to not plant a cover crop, his/her estimated net return would be \$198 ha^{-1}, which was the second highest net returns, on average, when soybeans were being planted.

Pairwise comparisons were made between cover crop species for both corn and soybeans. The results showed no difference in cover crop treatments across corn, but, for soybeans, there were several differences. Net returns from planting arrowleaf clover before soybeans were higher than hairy vetch, barley, woolypod vetch, winter pea, cereal rye, canola, and triticale. The no-cover-crop treatment had higher net returns than winter pea, barley, hairy vetch, and woolypod vetch. There was no difference in no cover crop and the highest average net returns treatment of arrowleaf clover.

3.2. Breakeven Price

Table 5 shows the ANOVA statistics from breakeven price for hay analysis. Breakeven prices were different among cover crop species and succeeding cash crop. Table 6 shows the average breakeven price for hay across the cover crop treatment and cash crops. The average breakeven price for hay was lower when planting cover crops before planting soybeans. This can be explained by the forage having a longer time to grow and produce more mass to harvest during the long cover crop season prior to planting soybeans, compared to the short cover crop season prior to planting corn. Two recent studies in Tennessee found that the yield-maximizing planting date for corn was at the end of March and the midto late-May for soybeans [33,34]. Therefore, when a producer is planting soybeans, there would be approximately one and a half to two months of additional growth for the cover crop before harvesting.

Table 5. ANOVA results for the breakeven price of hay.

Effect	F-Value	Prob > F
Cover Crop Species	2.33	0.0044
Crop	14.75	0.0001
Cover Crop Species x Crop	1.82	0.0351

Table 6. Breakeven forage price for cover crop hay harvest before planting corn and soybeans across cover crop species in \$ Mg^{-1} (n = 358).

	Breakeven Price \$ Mg^{-1} †	
Cover Crop Species	**Before Planting Soybean**	**Before Planting Corn**
Barley	\$57 [a,b]	\$129 [a]
Clover Arrowleaf	\$188 [c]	\$413 [a,b]
Clover Crimson	\$26 [a]	\$182 [a,b]
Clover Red	\$67 [a,b]	\$635 [a,b]
Canola	\$77 [a,b]	\$1113 [b]
Cereal Rye	\$43 [a]	\$101 [a]
Hairy Vetch	\$22 [a]	\$125 [a]
Oat	\$35 [a]	\$84 [a]
Pea	\$32 [a]	\$128 [a]
Radish	\$136 [b,c]	\$290 [a,b]
Triticale	\$37 [a]	\$91 [a]
Turnip	\$61 [a,b]	\$170 [a]
Vetch Woolypod	\$40 [a]	\$116 [a]
Vetch Common	\$95 [a,b]	\$192 [a,b]
Wheat	\$29 [a]	\$77 [a]

† Means followed by the same letter do not differ statistically at the $p < 0.05$ level.

We collected hay-price data for this region to compare these breakeven prices to historic hay prices from 2012 to 2019 during the months (March, April, and May) when these forages will be harvested for hay [35]. The average price for good-quality hay was \$108 Mg^{-1} (or \$119 ton^{-1}). Good-quality hay prices were selected based on hay-quality data found in Bracey [25,26]. Given these historical hay prices, the results show that harvesting a cover crop for hay prior to planting corn would likely never be profitable at the breakeven prices. Perhaps by harvesting wheat, oats, or triticale prior to planting corn, a producer might break even if he/she can get \$77 Mg^{-1} (or \$70 ton^{-1}), \$84 Mg^{-1} (or \$76 ton^{-1}), and \$83 Mg^{-1} (or \$91 ton^{-1}), respectively. However, for a soybean producer, the breakeven price was much lower than for a corn producer. There are several possible cover crops that would have a breakeven price lower than the average hay price during this time. The only two cover crops with average breakeven prices higher than the average hay price were arrowleaf clover and radish. The lowest breakeven price, when planting soybeans after the cover crops, was wheat at \$22 Mg^{-1} (or \$20 ton^{-1}), followed by wheat at \$27 Mg^{-1} (or \$26 ton^{-1}).

While harvesting certain cover crops prior to planting soybeans might be profitable for hay production, there are several production restrictions a producer would need to consider. The producer would need to also consider labor requirements that could occur on a field. The producer would also need to consider hay storage depending on their field size.

4. Conclusions

The purpose of this study was to determine the profitability to plant and/or harvest cover crops preceding a corn or soybean cash crop. We calculated differences in net returns among 15 cover crop species when planted before corn or soybeans. We calculated the cost to plant each species of cover crop, cost of corn or soybean production, forage harvest cost, and forage income levels to determine the species and cash crop that had the greatest profitability. These calculations allow corn and soybean producers to do a cost-benefit analysis of planting a cover crop versus not planting a cover. The data allow for an economic analysis of planting different cover crop species, while analyzing the estimated net return for the crop and the breakeven forage price.

We found no statistical difference in net returns between planting a cover crop versus no cover crop across the different species and seasons. This analysis did not include the value of harvesting the forage as a hay. However, we can conclude that, if the producer did want to plant a cover crop, the highest net return per acre for corn would be following radish, while the lowest average net returns would be following barley. For soybean, the highest net returns were following arrowleaf clover, and the lowest net returns were following hairy vetch. If harvesting the cover crop before planting corn, wheat had the lowest breakeven price. The cover crop species with the lowest breakeven price before planting soybeans was hairy vetch. Planting a cover crop to maximize profits from forage production would likely reduce the net returns to corn. The breakeven cost of harvesting the cover crop as a forage followed by planting corn would likely be higher than the value of the forage. The breakeven prices for harvesting cover crops for hay was lower than the average hay prices when planting soybeans, indicating that harvesting the cover crop for hay could increase net returns when planting soybeans. It is important to note that these findings will vary depending on labor and machinery constraints, as well as local hay demand.

This study is not without limitations. We do not consider potential N credits in the legume cover crops. That is, this study does not consider varying N fixation rates across cover crop species to consider the N cost savings from the legume cover crops. Moreover, harvesting cover crops would remove residue, which would have otherwise potentially acted to suppress weeds and reduce herbicide applications. Reductions in N or herbicide applications could also help cover crops' profitability but is outside the scope of this analysis. The short-term nature of this study also does not consider long-term soil health benefits from cover crops. Harvesting cover crops would leave aboveground stubble and underground root mass and, therefore, would likely not completely negate soil health building benefits. However, the removal of residue could have an impact on the rate of soil health improvement over the long term. Future research examining long-term impacts of this practice would be useful in providing a clearer picture of sustainability. Future research might also consider analyzing the profitability of grazing beef cattle or dairy cattle on winter cover crops instead of harvesting for hay. Producers might be able to increase revenue by leasing cover crops for grazing or purchasing feeder cattle to graze.

Author Contributions: H.D., J.E. and C.N.B. analyzed the economic data and wrote the paper; W.M.B. and V.R.S. analyzed the agronomic data; W.M.B., A.R.W., V.R.S., G.E.B., F.Y. and D.M.B. conceived and designed the experiment; V.R.S. supervised the experiment and secured funding. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the United Soybean Board, grant number 1820-172-0132-A, the Tennessee Soybean Promotion Board, grant number 19-154-P and 20-154-R and the USDA National Institute of Food and Agriculture, hatch project 1017613.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Conflicts of Interest: Authors declare no conflict of interest.

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