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Profitability Analyses of Production Management Practices in a Ryegrass-Soybean Integrated System in Northeast Texas

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The effects of herbicide treatments, ryegrass clipping timings, and soybean harvest strategies on profitability are analyzed for the period 2021-23 in Northeast Texas. Soybean grain yield data from 2021-23, and soybean biomass dry weight data from 2023 were collected using a randomized block design. Results showed that annual ryegrass effectively suppressed weeds, with forage yields ranging from 251.39 lbs. to 1,752.06 lbs. per acre in 2022 depending on clipping time. Soybean grain yield averaged 625.99 lbs. per acre in 2021-23. Soybean biomass dry weight ranged from 2,336.48 lbs. to 5,632.80 lbs. per acre in 2023. Our findings suggest soybean production could be profitable for Texas farmers when integrating ryegrass hay production or cattle grazing into the system. Ryegrass as a cover crop also offers benefits such as weed control, soil health, additional forage production, and enhanced profits.

***Key words**:* Annual Ryegrass, Cover Crop, Economic Analysis, Forage, Grazing, Hay, Profit, Sensitivity Analysis; Soybeans

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There are several concerning trends and unsustainable issues in the American agricultural landscape. A major trend is the steadily declining cropland acreage, primarily driven by urbanization and development (Xie et al., 2023). According to the 2022 Census of Agriculture, (U.S. Department of Agriculture (USDA), 2024a), total area of cropland in the United States decreased 14.15%, from 445,324,765 acres to 382,356,350 acres from 2002 to 2022 within a 20-year span. Texas saw a 1.27% decline in farmland, from 127,036,184 acres to 125,417,325 acres from 2017 to 2022 (USDA, 2025; Tomascik, 2024); and an even larger 29.14% decline in acres harvested, from 17,595,330 acres to

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12,467,602 acres from 2017 to 2022 (USDA, 2024b), with approximately 77,000 acres harvested for soybean (USDA, 2024b). According to Xie et al. (2023), "Texas alone will see over 2 million acres of agricultural lands converted if its cities continue to grow at the existing pace." According to Gary Joiner, director of communications for the Texas Farm Bureau, the loss is attributed to development (Shofner, 2024). Other unsustainable issues in agriculture include the decline in production of today's conventional system (Francis et al., 2012), increased input usage, degraded soil quality, and limited essential resources such as fertilizers, fossil fuels, and water (Francis et al., 2012).

Crop rotation and cover crops, on the other hand, are examples of sustainable farming practices that can lower input costs while enhancing soil health and fertility. Common cover crops in Texas and the United States include winter cereals (rye, wheat, and oats) and a legume typically peas (Bowman and Wallander, 2021; Limon, 2025). Research on extended crop rotations, involving a forage legume like alfalfa for two or more years, indicates gains in yield preservation (Coulter et al., 2011). According to Chapagain, Lee, and Raizada (2020), "cover crop mixtures can be considered as a key tool for enhancing the multi-functionality, resiliency, and sustainability of cropping systems in temperate regions." The selection of dual-purpose crops creates a window for farmers to generate new sources of income. Other benefits of cover crops include improved soil health, reduced erosion, better soil moisture retention, protection of water quality, and decreased reliance on fertilizers, herbicides, and pesticides (Clark, 2012).

Although grass is not a popular cover crop in the United States (Bowman and Wallander, 2021), grass plays a key role in maintaining healthy soil (Ojija, 2024). Their deep roots loosen the soil, let water soak in, and reduce compaction and erosion. As grass grows and decays, organic matter improves soil structure, holds water, provides nutrients for plants, and provides food and shelter for other helpful organisms like worms and microbes. Annual ryegrass' thick roots break up compacted soil, add organic matter, capture leftover nitrogen for subsequent crops, create channels for air and water, and control erosion and weeds supporting a healthy soil life. By improving soil structure, saving nutrients, and reducing the need for chemicals, grasses help build stronger, more fertile soils for long-term farming.

Hay is an excellent feed source, and proper storage is essential for year-round livestock feed. Methods for storage include ensiling or plastic wrapping high moisture hay and haylage; bailing hay at less than 20% moisture for long-term stability; drying hay by forced air or chemical treatment to retain moisture content (between 20% and 35%), nutrients, and dry matter (Rotz and Shinners, 2007).

Ryegrass is an excellent hay choice due to its high nutritional contents. When compared to the perennial tall fescue system, the annual ryegrass system performs better because it produces larger animal weight gains, which leads to a higher revenue and net return (Islam et al., 2011). Annual ryegrass is compatible with warm-season perennial grass pastures, is easy to establish, and tolerates defoliation and stocking rates (Rouquette, Bransby, and Nelson, 1997). As a winter cover crop, annual ryegrass suppresses winter weeds and enhances soil conservation (Smith and Kallenbach, 2006). Cover crops also limit pests such as insects, nematodes, and disease organisms while decreasing reliance on fertilizers, herbicides, and pesticides (Clark, 2012). In addition to being environmentally sustainable, ryegrass also offers benefits such as fast growth during cooler months.

Soybeans are an excellent choice for high protein forage and are ideal for haying, ensiling, or grazing. Soybeans are economically viable and provide a nutrient-dense alternative to alfalfa forage. Although managing weeds and pests can be difficult, using prudent management techniques can help allay worries and make soybean forage a viable choice for producers looking for high-quality summer pasture (Blount et al., 2003). Soybeans for forage are harvested at the R7 stage (Wiederholt and Albrecht, 2003) to yield the best quality. In soybean growth, the R7 stage signifies beginning maturity, meaning one pod on the main stem has reached its mature color (tan or brown). Soybean forage is comparable in quality to alfalfa forage for dairy cows, providing substantial oil content (Wiederholt and Albrecht, 2003). Soybeans are harvested for forage when there are significant price fluctuations and poor seed yields.

Texas is an excellent state for hay production because of the extensive demand (Wallace, 2024) from dairies, horse owners, beef cattle operations, and other livestock markets. Although Texas is a leading hay producer, quantity demanded often exceeds quantity supplied, particularly following periods of drought, resulting in tight markets for ranchers (Russell, 2024). When pasture availability is low, many ranchers bring in hay from out of state to meet their livestock’s needs (Russell, 2024).

Good-quality hay is important for livestock because it gives them the nutrients they need to grow, stay healthy, and reproduce. Poor-quality hay, on the other hand, can cause weight loss, health problems, digestive issues, and even poisoning from things like nitrates. Feeding animals quality hay helps improve diet, increase feed intake, stay healthier, feel less stressed, and perform better.

With less arable land available and food demand rising, there is a need for creative solutions and reevaluation of traditional agricultural practices. “[D]rought and urbanization have a big impact on crop yield reduction as well as crop land cutback” (Ray, Fares, and Risch, 2018). Integrating innovative cropping systems such as soybean forage and ryegrass hay production presents a potential solution to mitigate current agricultural challenges. The objective of the study is to demonstrate alternative sustainable ryegrass-soybean management practices that can lead to sustainable land utilization, soil conservation, enhanced profitability, and improved forage quality for livestock feed.

Methodology and Data

The study uses data on soybean grain yield and plant height for the period 2021-23 from various soybean management practices. The data was collected by conducting experiments on a Leson clay soil in Greenville, Texas (33°9'59"N 96°9'51"W). Leson clay is moderately well drained, very high runoff, very low to moderately low permeability (0.00 to 0.06 in per hr.), with a maximum calcium carbonate content of 35%, a maximum gypsum content of 10%, nonsaline to slightly saline (0.0 to 4.0 mmhos per cm), a maximum sodium absorption ratio of 2.0, expansive under moist conditions and significantly cracky under dry conditions. Plots were established in December in fields with emerged volunteer annual ryegrass. Each plot measured 5 ft in width and 25 ft in length, replicated four times in a randomized block design. Plots were maintained without irrigation or fertilization. Herbicide treatments included Paraquat or Glyphosate, or in combination with residual herbicide active ingredients such as Atrazine, S-metolachlor, Metribuzin, Flumioxazin, Pyroxasulfone, and Carfentrazone. Forage treatments involved clipping in January to simulate grazing, and again in March or April to estimate forage biomass production. Prior to planting soybeans in April or June, all forage and cover crop plots were terminated with Glyphosate or Paraquat at least 2 weeks in advance. A post-emergent application of Glyphosate, S-metolachlor, and Dicamba, was applied to all soybean plots to control weeds until harvest. Soybean height data was collected on the same day the soybeans were harvested by measuring five plants per plot using a wooden ruler. Soybean plots were harvested in October with a plot combine. Soybean yield was determined after harvesting, with the grains stored in individual paper bags, then cleaned and weighed to estimate bushel per acre production. For both ryegrass and soybean forage, biomass weights were obtained and dried in paper bags to determine dry matter mass in kilograms. In 2023, soybeans were also harvested for forage in August. Height measurements and dry weight assessments were conducted on soybean plants harvested from 3-foot rows corresponding to each treatment, with samples collected by hand using a grass sickle at a 3-inch height.

The cost of custom rates such as seeding rate, herbicide flat rate ground application, crop production consulting services, round bales over 1500 lbs. full wrap, hauling hay (field to storage) and combine and hauling rates were obtained from Klose (2020) and then inflated from July 2020 dollars to December 2023 dollars using the Consumer Price Index (CPI) Inflation Calculator of the U.S. Bureau of Labor Statistics (2025). The cost of seeds and inoculant for seed, and herbicides such as Paraquat or Glyphosate, Surfactan, and Tavium plus surfactant were obtained from local dealers by the Integrated Pest Management (IPM) program specialist of the Texas A&M AgriLife Extension Service representative located in Commerce, Texas (Drake, 2024).

Results

Analysis of variance (ANOVA) and Tukey's mean comparisons of soybean yield across different treatments for the period 2021-23 were conducted using PROC GLM in Statistical Analysis System software (SAS) version 9.4. Soybean yield as the dependent variable while year and treatment (soybean management practices) as the class variables.

Table 1. Ryegrass-Soybean Yield Management Practices Evaluated.

Treatment	Description
1	Ryegrass cover cropping: Volunteer annual ryegrass plot establishment in late December, then ryegrass terminated with Glyphosate or Paraquat in early June (≈ 3-to-3.5-moth cover cropping) prior to soybean seeding in late June. Soybean grain harvested in late October.
2	Ryegrass cover cropping + ryegrass hay production: Volunteer annual ryegrass plot establishment in late December, then harvested as hay in early April, then ryegrass terminated with Glyphosate or Paraquat in early June prior to soybean seeding in late June. Soybean grain harvested in late October.
3	Ryegrass cover cropping + ryegrass grazing: Volunteer annual ryegrass plot establishment in late December, then ryegrass forage first cut in late January and second cut in late March or April (grazing simulation), then ryegrass terminated with an herbicide application in early June prior to seeding in late June. Soybean grain harvested in late October.
4	Glyphosate or Paraquat in December: Volunteer annual ryegrass plot establishment in late December, then ryegrass terminated with Glyphosate or Paraquat in late December (no cover cropping). Soybean seeding in late June and grain harvested in late October.
5	Glyphosate or Paraquat in February: Volunteer annual ryegrass plot establishment in late December, then ryegrass terminated with Glyphosate or Paraquat in early February (≈ 1-to-1.5-moth cover cropping). Soybean seeding in late June and grain harvested in late October.
6	Glyphosate or Paraquat in March: Volunteer annual ryegrass plot establishment in late December, then ryegrass terminated with Glyphosate or Paraquat in early March (≈ 2-to-2.5-moth cover cropping). Soybean seeding in late June and grain harvested in late October.
7	Glyphosate or Paraquat + Residual in December: Volunteer annual ryegrass plot establishment in late December, then ryegrass terminated with Glyphosate or Paraquat plus one or more residual herbicide in late December (no cover cropping). Soybean seeding in late June and grain harvested in late October.

Table 1 describes the ryegrass-soybean management practices evaluated. Treatments 5 (Glyphosate or Paraquat in February) and 7 (Glyphosate or Paraquat + residual in December) are the most common soybean management practices in Northeast Texas. Treatment 6 (Glyphosate or Paraquat in March) is an alternative practice with a different timing for farmers. Although ryegrass cover cropping (Treatments 1 through 3) is not common in Northeast Texas and in the United States (Bowman and Wallander, 2021), it is an innovative and sustainable management practice with a lot of potential since hay is big business in Texas. In addition, integrating ryegrass as a cover crop or as a forage (Treatments 1 through 3) into a soybean system is a conservation-regenerative management practice, which environmentally conscious consumers demand from producers. Conservation-regenerative practices are trending among environmentally conscious consumers and promoted by government conservation programs and multinational corporations (Archer Daniels Midland, 2025). For example, as a marketing strategy, multinational corporations are paying a premium for programs integrating conservation-regenerative practices.

Overall, for the period 2021-23, there were no statistical differences in soybean grain yield across treatments regardless of year as indicated by an F-statistic of 1.00 (p-value of

0.4224), but there were statistical differences in soybean yield across years regardless of treatment as indicated by an F-statistic of 224.48 (p-value less than 0.0001). Soybean grain yields in all three years were statistically different from each other at the 1% significance level using Tukey's studentized range (honestly significant difference) test. 2022 was statistically lower than in 2021 and 2023 at the 0.01 significance level. Soybean yield in 2022 was lower because of lower rainfall and late planting. Soybean grain yield for 2021 and 2023 were 3.05 and 11.04 bushels per acre while for the year 2022 it was 16.98 bushels per acre (Table 2).

Table 2. Tukey's Mean Comparisons for Soybean Grain Yield.

	Grain Yield (bushels per acre)			
Treatment	2021	2022	2023	Overall
1: Cover Cropping	16.93 A B	1.67 B	11.68 A	10.29
2: Hay Production	19.39 A B	2.37 A B	11.85 A	13.10
3: Grazing Simulation	22.61 A	2.31 A B	11.38 A	12.65
4: Herbicide in December	13.67 B	3.06 A B	9.86 A	9.08
5: Herbicide in February	17.35 A B	3.39 A B	9.63 A	10.45
6: Herbicide in March	20.03 A B	1.83 B	9.93 A	9.21
7: Herbicide + Residual in December	15.57 B	3.91 A	11.46 A	11.51
Overall	16.98	3.05	11.04	10.32

Note: Treatments with different letters within a year are statistically different at the 5% significance level.

Multiple mean comparison across treatments, within years, revealed there were statistical differences in soybean grain yield across treatments. Statistical differences in soybean yield across treatments were found in 2021 as indicated by an F-statistic of 3.16 (p-value = 0.0076) and in 2022 as indicated by an F-statistic of 6.99 (p-value < 0.0001), but not in 2023 as indicated by an F-statistic of 0.27 (p-value = 0.9488). Table 2 reports Tukey's Studentized Range (HSD) test results by year at the 5% significance level.

Treatment 6 (Glyphosate or Paraquat in March) exhibited the highest yield in 2021, but it was only statistically different from Treatments 5 (Glyphosate or Paraquat in December) and 8 (Glyphosate or Paraquat + Residual + Surfactant in December). Similarly, Treatment 7 (Glyphosate or Paraquat + Residual + Surfactant in December) achieved the highest yield in 2022, but it was only statistically different from Treatments 7 (Glyphosate or Paraquat in March) and 1 (cover cropping) at the 5% significance level. Last, Treatment 7 (Glyphosate or Paraquat + Residual + Surfactant in December) achieved the highest yield in 2023, but it was not statistically different from the other treatments at the 5% significance level.

When conditions to harvest soybeans as grain are poor, a farmer can harvest soybeans as hay, which may happen during hot dry summers in Northeast Texas. A linear regression model was estimated using data from 2023 to determine the relationship between soybean plant height and estimated biomass production, and to provide an effective way to predict dry weight biomass for alternative hay production when climatic conditions or soybean yield potential as seed are poor. Soybean biomass was estimated as a linear function of plant height; that is, $\widehat{Biomass}$ (lbs. per acre) = a × *Height* (inches), where "a" is the slope of the estimated regression line. The intercept was excluded to allow a direct contribution of plant height towards biomass. That is, no additional biomass for extremely small plants; or biomass production approaches zero as plant height also approaches zero.

A Pearson correlation analysis revealed a strong linear association between soybean plant height and biomass yield, statistically significant at the 1% level. Catchpole and Wheeler (1992) also found a strong linear correlation between soybean biomass and plant heigh. In addition, a highly significant F-statistic of 373.32 (p-value < 0.0001) confirmed the ability of plant height to predict biomass production. The model's predictive accuracy is enhanced by the absence of autocorrelation (DW = 2.046) and a substantial and statistically significant parameter estimate of 138.20 lbs. per acre per inch of height (p-value < 0.0001). The findings reveal that biomass output estimates range from 2,280.34 lbs. to 3,178.66 lbs. per acre in 2021, and from 2,625.85 lbs. to 4,146.08 lbs. per acre in 2022, that can be attributed to changes in plant height and environmental factors. Nguyen et al. (2022) also found a relationship between structural parameters, such as height and volume, and biomass. Table 3 reports the soybean biomass estimates based on this simple linear regression model.

Table 3. Soybean Forage Biomass Estimates Per Plant Height.

Plant Height (in.)	Estimated Biomass (lbs./ acre)
15	2,073.04
18	2,487.65
21	2,902.26
24	3,316.86
27	3,731.47
30	4,146.08
33	4,560.69
36	4,975.30
39	5,389.90
42	5,804.51

Note: $\widehat{Biomass}\ (lbs./acre) = 138.20 \times Height\ (inches)$.

Profitability Analyses

Several sensitivity analyses were conducted to assess the economic viability and profitability of the different soybean production management practices. Sensitivity analyses study how overall profitability varies when market prices, yield levels, and input costs vary. The result highlights scenarios of hay production, ryegrass grazing simulation, and soybean production that provide insight into determining the optimal management practice.

Table 4. Estimates of Costs and Earnings of Annual Ryegrass and Soybean Hay Production.

Description	Ryegrass Hay (U.S. Dollars)	Soybean Hay (U.S. Dollars)	Quantity
Costs			
Glyphosate	n.a.	$9.50	Per acre
Surfactan	n.a.	$0.10	Per acre
Seed	$19.00	$55.00	Per acre
Inoculant for Seed	n.a.	$4.00	Per acre
Seeding Rate	$57.60	$57.60	Per acre
Tavium (Dicamba + Dual)	n.a.	$24.04	Per acre
Herbicides Flat Rate Ground Application	$17.95	$17.95	Per acre
Round Bales over 1500 lbs. Full Wrap	$43.39	$91.11	Per 2,000 lbs.
Hauling Hay (Field to Storage)	$14.41	$30.27	Per 2,000 lbs.
Total Cost	$152.35	$289.57	Per acre
Hay Pricing	$140.00	$200.00	Per 2,000 lbs.
Total Production	2000	4,200	Lbs.
Total Revenue	$140.00	$420.00	Per acre
Loss	($12.35)	$130.43	Per acre

Note: Negative dollar amounts are in parentheses.

Tables 4 through 6 estimate costs and earnings in 2023 for selective ryegrass-soybean management production practices. Table 4 summarizes the costs and earnings from annual ryegrass and soybean hay production (for example, Treatment 2 for ryegrass production). Table 5 summarizes the costs and earnings from ryegrass cattle grazing (Treatment 3). Table 6 summarizes the costs and earnings from soybean harvested as grain when volunteer annual ryegrass is terminated with Glyphosate (for example, Treatments 5, 6, 7, or 8) prior to soybean seeding in April or June (Table 1) and a post-emergent application of Tavium® is applied to soybeans in the growth stage from emergence (cracking) to the R2 state (full flowering) usually around April or June. In practice, it can be applied at planting or 30 days after planting for end season weed control. Tavium® is a foliar systemic broadleaf Dicamba herbicide, ideally targeting small weeds (2-4 inches) for best results. Dicamba is an herbicide used to control broadleaf weed plants.

Table 5. Estimates of Costs and Earnings from Cattle Grazing Annual Ryegrass.

Description	U.S. Dollars	Quantity
Costs		
Ryegrass Seed	$19.00	Per 25 lb. per acre
Grass Seeding Rate	$57.60	Per acre
Herbicides Flat Rate Ground Application	$17.95	Per acre
Crop Production Consulting Services	$16.28	Per acre
Total Cost	$110.83	Per acre
Cattle Grazing Lease Contract	$0.60	Per lb. gain
Quantity of Dry Matter Produced		1000 lbs. per acre per 1 cycle
Cycles of Ryegrass		2 cycles
Calf Consumption Daily		15 lbs. (3% of weight)
Days of Occupancy		133 days
Pounds of Gain		2.5 lbs. per day
Weight Gain		333 lbs.
Total Revenue	$200.00	Per acre
Profit	$89.17	Per acre

Table 6. Costs and Earnings from Soybean Grain Production.

Description	U.S. Dollars	Quantity
Costs		
Glyphosate	$9.50	32 fl. oz per acre
Surfactan	$0.10	Per acre
Soybean Seed	$55.00	Per acre
Inoculant for Seed	$4.00	Per acre
Seeder Rate	$57.60	Per acre
Tavium (Dicamba + Dual)	$24.04	56.5 fl. oz per acre
Herbicide Flat Rate Ground Application	$17.95	Per acre
Combine and Hauling Rates	$50.79	Per acre
Total Cost	$218.98	Per acre
Soybean Price	$12.80	Per bushel
Total Production		11 bushels per acre
Total Revenue	$140.80	Per acre
Loss	($78.18)	Per acre

Note: Negative dollar amounts are in parentheses.

Tables 7 through 10 present the profitability analyses from various ryegrass-soybean production management practices. The tables estimate profits of the indicated enterprise. These analyses provide insight into making informed decisions.

Table 7 reports a sensitivity analysis of annual ryegrass hay production (for example, Treatment 2). The profitability scenario (Table 7) is conservative because the profit calculations account for seeding rate and seed price, which are unnecessary costs when annual ryegrass is already established. The dry matter levels in Table 7 are consistent with the level reported by Jensen, Asay, and Waldron (2001), who found yield levels for perennial ryegrass ranging from 1,400 lbs. to 3,300 lbs. A loss of $12.35 per acre is estimated when the ryegrass hay market price is $140 per short ton and 2,000 lbs. of ryegrass dry matter are produced (Table 4). The sensitivity analysis in Table 7 assumes the costs and earnings summarized in Table 4 vary with the level of production or market price of ryegrass hay, except for seeding rate, herbicides flat rate ground application, and ryegrass seed. In 2022, annual ryegrass dry matter production averaged about 1,000 lbs. per acre for one cycle (or 2,000 lbs. per acre in two cycles). The ryegrass hay market price of $140 per short ton in Northeast Texas was obtained from regional producers (Drake, 2024). According to the Texas Direct Hay Report in 2024, the low and high estimates in Central Texas for the asking prices of large round bales of Bermuda grass of good/premium quality were $150-$175 per bale and $300-$330 per bale. In 2024, profits were expected for Northeast Texas farmers for ryegrass hay market prices greater than or equal to $160 per short ton when 2,000 lbs. of ryegrass dry matter were produced (Table 7).

Table 7. Profitability Analysis from Seeded Annual Ryegrass Hay.

	Dry Matter Production (lbs. per acre)						
Hay Price ($/2,000 lbs.)	1,000	1,500	2,000	2,500	3,000	3,500	4,000
$100	($73.45)	($62.90)	($52.35)	($41.80)	($31.25)	($20.70)	($10.15)
$120	($63.45)	($47.90)	($32.35)	($16.80)	($1.25)	$14.30	$29.85
$140	($53.45)	($32.90)	($12.35)	$8.20	$28.75	$49.30	$69.85
$160	($43.45)	($17.90)	$7.65	$33.20	$58.75	$84.30	$109.85
$180	($33.45)	($2.90)	$27.65	$58.20	$88.75	$119.30	$149.85
$200	($23.45)	$12.10	$47.65	$83.20	$118.75	$154.30	$189.85
$220	($13.45)	$27.10	$67.65	$108.20	$148.75	$189.30	$229.85
$240	($3.45)	$42.10	$87.65	$133.20	$178.75	$224.30	$269.85
$260	$6.55	$57.10	$107.65	$158.20	$208.75	$259.30	$309.85
$280	$16.55	$72.10	$127.65	$183.20	$238.75	$294.30	$349.85
$300	$26.55	$87.10	$147.65	$208.20	$268.75	$329.30	$389.85

Note: Profit ($/acre) calculations reported inside the table. Negative dollar amounts are in parentheses.

Table 8. Profitability Analysis from Seeded Annual Ryegrass Grazing Simulation.

	Dry Matter Production (lbs.)						
Grazing Rate ($/lb.)	500	1,000	1,500	2,000	2,500	3,000	3,500
$0.40	($77.50)	($44.16)	($10.83)	$22.50	$55.84	$89.17	$122.50
$0.45	($73.33)	($35.83)	$1.67	$39.17	$76.67	$114.17	$151.67
$0.50	($69.16)	($27.50)	$14.17	$55.84	$97.50	$139.17	$180.84
$0.55	($65.00)	($19.16)	$26.67	$72.50	$118.34	$164.17	$210.00
$0.60	($60.83)	($10.83)	$39.17	$89.17	$139.17	$189.17	$239.17
$0.65	($56.66)	($2.50)	$51.67	$105.84	$160.00	$214.17	$268.34
$0.70	($52.50)	$5.84	$64.17	$122.50	$180.84	$239.17	$297.50
$0.75	($48.33)	$14.17	$76.67	$139.17	$201.67	$264.17	$326.67
$0.80	($44.16)	$22.50	$89.17	$155.84	$222.50	$289.17	$355.84
$0.85	($40.00)	$30.84	$101.67	$172.50	$243.34	$314.17	$385.00

Note: Profit ($/acre) calculations reported inside the table. Negative dollar amounts are in parentheses.

Similarly, Table 8 reports a sensitivity analysis of grazing annual ryegrass (for example, Treatment 3). A profit of $89.17 per acre is expected when the grazing rate is $0.60 per lb. and 2,000 lbs. of dry matter are produced. Table 8 reports profit scenarios under various grazing rates and dry matter production levels. The sensitivity analysis in Table 8 assumes the revenues summarized in Table 5 vary with the level of production or the cattle grazing lease contract while keeping the costs constant.

Table 9 reports a sensitivity analysis of soybean grain production; profit estimates are provided at various soybean prices and yield levels. The sensitivity analysis in Table 9 assumes the costs and earnings summarized in Table 6 are fixed, except for soybean price and soybean production. Overall, during 2021-23, soybean yield averaged about 11 bu. per acre (regardless of treatment and year) (Table 2). A loss of $78.18 per acre is expected when the soybean price is $12.80 per bu. and soybean yield is 11 bu. per acre. The soybean market price of $12.80 per bu. in 2024 in Northeast Texas was obtained from regional producers (Drake, 2024). According to the Weekly Cash Price Report of Extension Economics Unit (2025), Texas A&M AgriLife Extension Service, soybean cash prices in North Texas averaged $11.48 per bu. in 2021 and $13.72 per bu. in 2022. For the period 2021-24, soybean prices in the Eastern Texas Panhandle averaged $12.01 per bu. in 2021, reached a max of $14.41 per bu. in 2022, then decreased to $13.26 per bu. in 2023, then decreased again to $9.78 per bu. in 2024 (Extension Economics Unit, 2025). A decreasing trend in soybean prices is expected to exacerbate the loss per acre from soybean grain production in Northeast Texas (Table 9). Poor soybean prices in Northeast Texas suggest favors harvesting soybeans as forage.

Table 9. Profitability Analysis from Soybean Grain Production.

	Soybean Grain Production (bu. per acre)						
Soybean Price ($/bu.)	**3.00**	**7.00**	**11.00**	**13.00**	**15.00**	**17.00**	**18.00**
$10.0	($188.98)	($148.98)	($108.98)	($88.98)	($68.98)	($48.98)	($38.98)
$10.5	($187.48)	($145.48)	($103.48)	($82.48)	($61.48)	($40.48)	($29.98)
$11.0	($185.98)	($141.98)	($97.98)	($75.98)	($53.98)	($31.98)	($20.98)
$11.5	($184.48)	($138.48)	($92.48)	($69.48)	($46.48)	($23.48)	($11.98)
$12.0	($182.98)	($134.98)	($86.98)	($62.98)	($38.98)	($14.98)	($2.98)
$12.5	($181.48)	($131.48)	($81.48)	($56.48)	($31.48)	($6.48)	$6.02
$12.8	($180.58)	($129.38)	($78.18)	($52.58)	($26.98)	($1.38)	$11.42
$13.0	($179.98)	($127.98)	($75.98)	($49.98)	($23.98)	$2.02	$15.02
$13.5	($178.48)	($124.48)	($70.48)	($43.48)	($16.48)	$10.52	$24.02
$14.0	($176.98)	($120.98)	($64.98)	($36.98)	($8.98)	$19.02	$33.02

Note: Profit ($/acre) calculations reported inside the table. Negative dollar amounts are in parentheses.

Soybean yield averaged about 17 bu. per acre in 2021, about 3 bu. per acre in 2022, and about 13 bu. per acre in 2023 (Table 2). At a price of $12.8 per bu., a loss of $1.38 per acre was expected with a yield level of 17 bu. per acre in 2021, a loss of $180.58 per acre with a yield level 3 bu. per acre in 2022, and a loss of $52.58 per acre with a yield level of 13 bu. per acre in 2023 (Table 9). At a price of $12.8 per bu., a profit of $11.42 is expected when soybean grain yield reaches 18 bu. per acre (Table 9).

For the period 2021-23, soybean yield averaged 10.29, 13.10, 12.65, 9.08, 10.45, 9.21, and 11.151 bu. per acre for Treatments 1 through 7 (Table 2), respectively. All these soybean yield levels would have resulted in a loss (Table 9). However, in an integrated ryegrass-soybean system, Treatment 2 was expected to result in a loss of $12.35 per acre from ryegrass hay production when ryegrass hay market price is $140 per short ton (Table 4) plus a loss of $52.58 per acre from soybean production when soybean market price is $12.8 (Table 9), for a combined loss of $64.93 per acre. Likewise, Treatment 3 will receive a profit of $89.17 per acre from ryegrass grazing when the cattle grazing lease contract is $0.60 per lb. gain (Table 5) plus a loss of about $52.58 per acre for soybean production when soybean market price is $12.8 (Table 9), for a combined profit of $36.59 per acre. In a ryegrass-soybean integrated system, it is possible that ryegrass may result in profit while soybean grain production may result in a loss or vice versa. That is, in an integrated system, one enterprise may help offset the loss of the other enterprise. Integrated systems maximize the use of resources, minimize waste, and may enhance overall productivity and sustainability.

Table 10. Profitability Analysis from Soybean Hay Production.

Soybean Hay Price ($/2,000 lbs.)	Soybean Hay Production (lbs. per acre)						
	1,500	2,000	3,000	4,200	5,000	6,000	7,000
$100	($136.54)	($125.99)	($104.89)	($79.57)	($62.69)	($41.59)	($20.49)
$120	($121.54)	($105.99)	($74.89)	($37.57)	($12.69)	$18.41	$49.51
$140	($106.54)	($85.99)	($44.89)	$4.43	$37.31	$78.41	$119.51
$160	($91.54)	($65.99)	($14.89)	$46.43	$87.31	$138.41	$189.51
$180	($76.54)	($45.99)	$15.11	$88.43	$137.31	$198.41	$259.51
$200	($61.54)	($25.99)	$45.11	$130.43	$187.31	$258.41	$329.51
$220	($46.54)	($5.99)	$75.11	$172.43	$237.31	$318.41	$399.51
$240	($31.54)	$14.01	$105.11	$214.43	$287.31	$378.41	$469.51
$260	($16.54)	$34.01	$135.11	$256.43	$337.31	$438.41	$539.51
$280	($1.54)	$54.01	$165.11	$298.43	$387.31	$498.41	$609.51
$300	$13.46	$74.01	$195.11	$340.43	$437.31	$558.41	$679.51

Note: Profit ($/acre) calculations reported inside the table. Negative dollar amounts are in parentheses.

Table 10 reports a sensitivity analysis of soybean hay production. Table 10 estimates profits at various soybean hay prices and soybean hay production levels. Table 10 assumes the costs and earnings for soybean hay production summarized in Table 4 are fixed, except for soybean hay market price and the cost of baling and hauling hay vary with the level of soybean hay production. In 2023, soybean dry matter weight ranged from 2,336.48 lbs. to 5,632.80 lbs. per acre and averaged 4,204 lbs. per acre. At a soybean hay market price of $200 per short ton and a hay dry matter production level of 4,200 lbs. per acre, profits are estimated to be $130.43 per acre (Table 4). The soybean hay market price of $200 per short ton in Northeast Texas was obtained from regional producers (Drake, 2024). According to the Texas Direct Hay Report in late 2024 (October-December), the asking price for ground alfalfa of fair/good quality, delivered to a feedlot, in the Texas Panhandle, was $200-$235 per ton. In 2024, profits were expected for Northeast Texas farmers for soybean hay market prices greater than or equal to $140 per short ton when 4,200 lbs. of soybean dry matter are produced (Table 10). While hay price plays a significant role, maximizing production efficiency is equally critical for profitability.

Soybeans are harvested for forage when seed market price or seed yields do not meet expectations. The farmer has about 30 days after the pods are set, in practice somewhere between the R3 stage (beginning pod) and the R4 stage (full pod), to determine the grain or forage yield and decide which one is more profitable. Many times, the decision is influenced by crop insurance if the farmer insured the soybean crop.

Table 3 estimates dry matter weight (lbs. per acre) for various plant heights. That is, for a specific plant height, the production level can be estimated using Table 3, which can then be found in Table 10 to obtain a profit estimate for an expected seed market price, holding the costs mentioned earlier for soybean hay production in Table 4 constant. For example, 2022 was a below-average year in terms of soybean yield (Table 2); however, soybean plant heights at harvest ranged from about 17 to 30 inches and averaged 24 inches. At 24 inches tall, the expected biomass production is 3,317 lbs. per acre which, at a soybean hay market price of $200 per bu., is expected to generate a profit of slightly above $45.11 per acre (Table 10). Matching yield potential with expected market prices is key to estimating income potential.

In summary, among the ryegrass-soybean management practices evaluated, ryegrass cattle grazing (Tables 5 and 8) and soybean hay production (Table 6 and 10) were most likely profitable under the levels of production, market prices, and estimated costs considered in the analysis. The fact that cattle grazing is likely to be profitable highlights the importance of integrated systems; while the fact that soybean hay production is also likely to be profitable emphasizes the importance of harvesting soybean as hay when conditions to harvest it as grain are poor.

Summary and Conclusion

This study investigated the economic feasibility of integrating soybean forage into a no-till annual ryegrass production system in Northeast Texas. The research utilized a randomized block design to evaluate the effects of herbicide treatments, ryegrass clipping timings, and soybean harvest strategies on profitability. The findings revealed that ryegrass effectively suppressed weeds. Depending on the planting date, clipping time, and rainfall, ryegrass forage yields ranged from 251.39 lbs. to 1,752.06 lbs. per acre in

2022 while soybean forage yields averaged 625.99 lbs. per acre in 2021-23. Sensitivity analyses reported profitability scenarios depending on target yields and market prices.

The study concluded that integrating soybean forage into ryegrass systems is economically viable, offering farmers dual benefits of enhanced weed control and additional income from forage sales. The study supports producers selecting suitable management practices and in making informed decisions. In addition, an integrated ryegrass-soybean system employs conservation-regenerative management practices and may help to diversify income and enhance resilience to environmental and market fluctuations.

The results unveil promising outcomes for the integration of annual ryegrass cover cropping in no-till soybean systems during the offseason. Various herbicide, forage, and cover crop treatments effectively controlled fall annual ryegrass and other broadleaf weeds, with sustained suppression observed for up to 120 days after the initial application. Notably, cover crop and forage treatments not only controlled weeds but also provided suppression of fall broadleaf and spring weeds, highlighting the dual benefits of these approaches. Ryegrass cattle grazing and soybean hay production were found to be most likely profitable; one stresses the importance of integrated systems while the other highlights options for soybean farmers under poor market conditions.

Cooperative extension service applied research and demonstrations play critical roles in promoting these systems to achieve broader sustainability goals. Future research should expand this study's scope to other geographic regions and soil types, explore the integration of livestock grazing with soybean forage systems, and conduct long-term economic analyses under variable market conditions. Additionally, further studies on the digestibility and nutritional value of soybean forage for livestock could strengthen its adoption as an alternative to traditional forage crops. The performance of these integrated systems under extreme weather conditions also warrants investigation to enhance resilience in the face of climate change. Innovative cropping systems are crucial to address agricultural challenges, combining economic profitability with environmental sustainability, and to provide strong foundations for future explorations of integrated forage production systems.

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