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Risk and returns from grazing beef cattle on warm-season grasses in Tennessee

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Abstract

Beef cattle production in the southeastern United States is forage-based, relying primarily on tall fescue (*Schedonorus arundinaceus* [Schreb.] Dumort; TF). While TF has many desirable characteristics for forage, physiological traits can create forage management challenges for producers during the summer. Managing forage production is necessary for producers to maximize profits and reduce feed costs. A possible way to extend grazing in this region is to use warm-season grasses (WSGs) during summer to complement tall fescue. Therefore, the objective of this study is to compare the profitability and risk associated with grazing beef stocker cattle on five WSGs: a combination of big bluestem (*Andropogon gerardi* Vitman) and indiangrass (*Sorghastrum nutans* L.; BI), switchgrass (*Panicum virgatum* L.; SG), eastern gamagrass, (*Tripsacum dactyloides*; EG), bermudagrass (*Cynodon dactylon* L.; BG), and crabgrass (*Digitaria sanguinalis*; CG). Data comes from a 3-yr (2014–2016) grazing experiment at two locations in Tennessee. The results show that CG had the lowest expected net returns to grazing due to its high production cost, and a profit-maximizing and risk averse producer would select grazing SG relative to the other forages. The study extends the literature by comparing the profitability and risk of native WSGs (BI, SG, EG), traditional WSG (BG), and annual WSG (CG). Furthermore, these results will be important in educating southeastern US beef cattle producers on using WSGs.

1 | INTRODUCTION

Beef cattle production in the southeastern United States is a forage-based mixture of cow-calf production and stocker operations (McBride & Mathews, 2011). Tall fescue (*Schedonorus arundinaceus* [Schreb.] Dumort; TF) is the most common pasture and hay in this region because it is adaptable, easy to establish, and persistent under adverse conditions (Stuedemann & Hoveland, 1988; Wolf et al., 1979). While TF grows from March to May as well as from September to November, physiological characteristics of TF can be problematic during the summer for beef cattle producers (Volenec & Nelson, 2007). Thus, managing forage production throughout the year to reduce the need for mechanically harvested feedstuffs is critical when trying to maximize profits, but also challenging.

Most TF planted prior to 1980 is infected with an endophytic fungus (Roberts & Andrae, 2004). During summer, cattle grazing endophyte-infected TF can be affected by fescue

Abbreviations: AP, Ames Plantation Research and Education Center; BG, bermudagrass; BI, big bluestem and indiangrass mixture; CG, crabgrass; EG, eastern gamagrass; HR, Highland Rim Research and Education Center; PLS, pure live seed; SG, switchgrass; TF, tall fescue; WSG, warm-season grass.

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toxicity causing cattle to have elevated body temperature, lower conception rates, reduced average daily gain, and failure to shed winter coat (Looper et al., 2010; Roberts & Andrae, 2004). These biological effects are estimated to result in over one billion dollars in lost revenue per year to cattle producers (Smith et al., 2012). Along with the negative effect of fescue toxicity, decreased forage yield and quality during the summer presents another hurdle for cattle producers. In a continuous grazing system, the most common producer practices to deal with diminished summer TF growth are to provide cattle with supplemental feedstuffs, reduce stocking rate, or obtain more grazing land.

Another possible solution to this problem is to rotate cattle to warm-season grasses (WSGs) during summer. WSGs break dormancy in late March and early April, grow vigorously from mid-May through mid-summer, with fall dormancy typically occurring in October (Keyser et al., 2011). Including WSGs in a grazing system could increase grazing days and help improve TF pastures by allowing them to rest during summer months (Anderson, Rasby, Klopfeinstein, & Clark, 2005; Jordan, Erickson, Klopfenstein, Adams, & Milton, 1999; Moore, White, Hintz, Patrick, & Brummer, 2004; Shain, Klopfenstein, Stock, Vieselmeyer, & Erickson, 2005). Following a spring-calving season (i.e., Jan. through mid-Mar.), cows are typically bred in May and June (Campbell, Backus, Dixon, Carlisle, & Waller, 2013). Nutritional needs for spring-calving cows to produce milk for growing calves, maintain body condition, and rebreed are peaking when TF growth is declining and WSGs growth is peaking (Bagley et al., 1987). Therefore, incorporating a WSG in the southeastern United States would fit the production cycle of spring-calving cows. These forages would also help feed spring-born heifer calves that were being retained and developed for cow replacement. WSGs would provide these replacement heifers with forage at the time of breeding. Furthermore, for fall-calving herds, which is also common in this region, calves are born in September and October and are weaned in April or May. A WSG could give producers the opportunity to retain ownership of their calves post-weaning and sell at a heavier weight at the end of summer. A WSG could also boost forage availability during the last trimester of the fall-calving cows, which has been shown to affect calf performance (Lewis, Griffith, Boyer, & Rhinehart, 2016).

For these reasons, several studies have analyzed animal performance on WSGs in the southeastern United States, and have found that steers grazing WSGs have positive gains (Backus et al., 2017; Burns & Fischer, 2013; Burns, Mochrie, & Timothy, 1984; Lowe et al., 2015, 2016). However, only a few existing studies have examined the profitability of grazing WSG. Lowe et al. (2015) analyzed animal performance and profitability of grazing beef steers across several native WSGs in Tennessee and found that grazing steers on WSGs would have positive partial net returns to grazing. These net returns to grazing ranged from a low of $244 to $852 ha^{-1}, depending on WSG species and grazing management. Similarly, animal performance and economics of grazing bred heifers on WSG have proven favorable with cost of gain as low as $0.14 kg^{-1} for switchgrass (*Panicum virgatum* L.; SG) pasture and $0.18 kg^{-1} when a combination of big bluestem (*Andropogon gerardi* Vitman) and indiangrass (*Sorghastrum nutans* L.; BI) was grazed (Keyser et al., 2016). Furthermore, costs for dairy heifers grazing SG and a BI blend were $0.38 and $0.65 head^{-1} d^{-1}, which are lower than the $1.89 head^{-1} d^{-1} that was estimated for using harvested commodity feeds (Lowe et al., 2016).

Core Ideas

- Crabgrass production cost was the highest
- Grazing switchgrass had less variability
- Switchgrass had the highest average net returns

While these studies provide insight into the potential profitability of grazing WSGs, more research is needed to determine the WSG species or mixtures that would best suit the southeastern United States. These studies only analyzed native WSGs, but further analysis is needed to compare the profitability of using native WSGs to other commonly used WSG options for southeastern United States, such as crabgrass (*Digitaria sanguinalis*; CG) and bermudagrass (*Cynodon dactylon* L.; BG). Previous studies have compared animal performance and forage production of annual WSGs and native WSGs (Tracy, Maughan, Post, & Faulkner, 2010), as well as BG with native WSGs (Burns & Fischer, 2013; Burns et al., 1984) in the southeastern United States. However, these studies did not compare the profitability of grazing these forages. Another benefit of using WSGs is that these grasses are both more drought and heat tolerant than cool-season grasses (Brown, 1999). Producers could also be mitigating forage production risk associated with summer drought by grazing a WSG, but to date, no studies have conducted a risk analysis on grazing WSGs.

The objective of this study was to analyze the profitability and risk associated with grazing beef stocker cattle on five WSGs in Tennessee. The hypothesis was there are no differences in the profitability of using native WSGs and commonly used WSG options for grazing stocker cattle in the southeastern United States. Partial budgeting was used to test differences in net returns to grazing, and a simulation analysis with stochastic prices and beef yields was conducted to evaluate risk. Results from this study could have a major effect on the Tennessee agricultural economy. The beef cattle industry in Tennessee is consistently the highest grossing sector of the state's agricultural industry (USDA, 2012). In 2012, total sales of cattle and calves was $735.5 million, which accounted for approximately 28% of Tennessee's agricultural income (USDA, 2012). Furthermore, these results also have implications for producers across southeastern United States that primarily rely on TF for forage production.

2 | MATERIALS AND METHODS

2.1 | Experimental design

Animal performance data was collected from a WSG grazing experiment located at Ames Plantation in Grand Junction, TN (AP; 35°6′ N, 89°13′ W) and Highland Rim Research and Education Center in Springfield, TN (HR; 36°28′ N, 86°50′ W) from 2014 to 2016. Memphis silt loam, Loring silt loam, and Lexingtion silt loam were the primary soils at AP, and HR soils were classified as a Dickson fine-silty loam, siliceous, semiactive, thermic glossic fragiudults (22% clay, 70% silt, 8% sand). The experiment was a randomized complete block design where the WSG grazing treatments included BI, SG, eastern gamagrass, (*Tripsacum dactyloides*; EG), BG, and CG. The experimental unit was 1.2-ha paddocks, and each treatment was replicated three times. Since EG was only grazed at AP, which results in an incomplete block analysis, there were a total of 81 paddocks in this experiment ([3 Years with 3 Replications] with 5 Treatments at the AP location and [3 Years with 3 Replications] with 4 Grasses at the HR location).

The native WSGs (BI, SG, and EG) were established in 2008 at both locations and more information about these paddocks can be found in Backus et al. (2017). BG was seeded in May 2013 at both locations. However, due to winter-kill, BG was re-established at HR in 2014. Crabgrass was seeded yearly at both locations. Both BG and CG were planted in a prepared seedbed, disking followed by cultipacking, at both locations. Bermudagrass was seeded at a rate of 17 kg pure live seed (PLS) ha^{-1}, and CG was seed at a rate of 7 kg PLS ha^{-1} at AP. At HR, BG was seeded at a rate of 10 kg PLS ha^{-1}, and CG was seeded at a rate of 8 kg PLS ha^{-1}. All pastures received 67 kg ha^{-1} of nitrogen (N) following green-up, and phosphorus (P) and potassium (K) levels were adjusted per soil test to maintain a medium level of these two nutrients. At AP, 67 kg ha^{-1} of P was applied and no additional K. Pastures at HR were amended with 33 to 67 kg ha^{-1} P and 67 to 135 kg ha^{-1} of K, depending on individual pastures. Rainfall and temperature were collected at each site annually (Table 1). Grazing duration varied by year and was often influenced by rainfall and temperature. All paddocks were burned at the end of the grazing.

2.2 | Grazing management

At both locations, we used put-and-take grazing method (Backus et al., 2017; Lowe et al., 2015) with four testers (weaned heifers) and a variable number of grazers based on forage availability. Forages canopy height targets were 60 to 76 cm for SG, 40 to 46 cm for BI, and 45 to 60 cm for EG, and 7 to 20 cm for BG and CG. Testers were randomly assigned to pastures based on body mass. Prior to grazing, testers were fed an equilibration ration to decrease initial body weight variability from variation in gut fill (Backus et al., 2017; Lowe et al., 2015, 2016). This ration contained 12.9% crude protein and 27.2% crude fiber and consisted of citrus pulp, cottonseed hulls, dried distillers grains, molasses, and soyhulls. Heifers were fed the equilibration diet at 2.25% of body weight over 4 d. On the fourth day, heifers were fed and weighed in the morning. The morning of the next day heifers were weighed, but not fed, and turned out on their assigned paddocks. The average body weight on those 2 d was the starting body weight. At termination of grazing for each species, heifers were again fed the equilibration diet using the same protocol as initiation of grazing. The average stocking, which included the testers and grazers, were five for BI, seven for BG, seven for CG, eight for EG, and seven for SG (Zechiel, 2017). The put-and-take grazing system is necessary for comparison of total gains across WSGs, however, this type of system is not common practice among producers. Thus, the experimental data will likely reflect higher gains than what producers would likely achieve.

Testers at AP were weighed an average of 237 kg (227, 243, and 240 kg for 2014, 2015, and 2016; respectively). BI, SG, and EG were grazed an average of 94 d over the 3 yr (13 May–4 Aug. 2014, 8 May–17 Aug. 2015, and 6 May–12 Aug. 2016). Heifers grazed BG and CG an average of 72 d (6 June–18 Aug., 5 June–17 Aug., and 3 June–12 Aug. for 2014, 2015, and 2016, respectively).

At HR, fall-born dairy–beef cross heifers were grazed in 2014, while in 2015 and 2016, beef heifers were used. Grazing of BI and SG averaged 101 d (16 May–8 Aug., 15 May–31 Aug., and 12 May–29 Aug. for 2014, 2015, and 2016, respectively). Due to establishment failure in 2013, BG was not grazed at HR in 2014. Otherwise, grazing BG and CG averaged 70 d (20 June–8 Aug., 12 June–31 Aug., and 9 June–31 Aug. for 2014, 2015, and 2016, respectively). Heifers at HR had been backgrounded for at least 45 d prior to initiation of the study. Heifer starting weights averaged 242 kg (202, 274, and 249 kg for 2014, 2015, and 2016, respectively). Table 2 shows the summary statistics of total gains by forage and locations.

Heifer care and management was conducted under UTK-IACUC Protocol No. 2258–0414 approved on 14 April 2014 by the Institutional Animal Care and Use Committee.

TABLE 1 Average daily temperature and total rainfall during grazing months by location and year

	2014		2015		2016		3-yr Average	
	Temp.[a]	Rainfall	Temp.	Rainfall	Temp.	Rainfall	Temp.	Rainfall
Month	°C	cm	°C	cm	°C	cm	°C	cm
Ames Plantation								
May	21	11	21	11	19	15	20	12
June	25	30	26	24	26	3	26	19
July	24	25	27	11	28	10	26	15
Aug.	26	10	25	10	27	13	26	11
May–Aug.	24	76	25	55	25	41	57	14
Highland Rim								
May	21	5	21	9	18	20	20	11
June	25	0	25	11	26	10	25	7
July	24	7	27	15	27	25	26	16
Aug.	26	14	24	3	27	8	26	9
May-Aug.	24	27	24	39	25	62	24	43

[a]Source: NOAA, Grand Junction, and Springfield TN weather station.

TABLE 2 Summary statistics of total gains (kg ha^{-1}) by forage and location

Location and pasture	Median	Mean	Standard deviation	Minimum	Maximum
Ames Plantation					
Big bluestem/indiangrass	205	231	70	164	333
Switchgrass	276	289	97	158	446
Eastern gamagrass	181	240	127	88	418
Bermudagrass	132	140	51	69	236
Crabgrass	148	159	55	80	266
Highland Rim					
Big bluestem/indiangrass	278	286	96	120	405
Switchgrass	376	342	76	243	424
Bermudagrass	302	296	50	228	356
Crabgrass	275	242	87	115	342

2.3 | Budgeting

Enterprise budgets were developed to calculate estimated establishment and production costs for each forage. For the perennial forages, a 10-yr production horizon with no grazing in the establishment year was assumed, which is typical for this region (Boyer, Tyler, Roberts, English, & Larson, 2012, 2014; Lowe et al., 2015; Zhou, Boyer, Larson, & Lieb, 2014). Total establishment and production costs of native warm-season grasses were calculated following previous studies (Boyer, Griffith, Roberts, Savoy, & Leib, 2014; Keyser et al., 2016; Lowe et al., 2015, 2016; McFarlane, Boyer, & Mulliniks, 2018). Establishment costs, which included seed, fertilizer, herbicide, machinery, and labor, were annualized over the pasture production life using a discount rate of 5.5% (Boyer et al., 2012, 2014; Lowe et al., 2015; McFarlane et al., 2018; Zhou et al., 2014). Establishing perennial forages has been shown to be more difficult than annual WSG forages (Tracy et al., 2010). Therefore, a 10% re-establishment cost was assumed for all perennial forages to account for the risk of failed establishment (Boyer et al., 2012, 2014; Lowe et al., 2015; McFarlane et al., 2018). The annualized establishment costs were combined with the annual operating expenses, which included fertilizer, herbicides, and other routine maintenance. The annuity equivalent formula was used to calculate the annualized establishment costs for each WSG into perpetuity. The complete budgets are provided as supplemental material. Estimated total annualized pasture costs are in 2017 dollars (Table 3). Of the forages in this analysis, CG had the highest total annual pasture cost due to replanting every year, and SG had the lowest total annual pasture cost. Seed costs is shown to be a major contributor to the cost of production.

Prices for Tennessee heifers ranging from 272 to 317 kg^{-1} were collected from the United States Department of Agriculture Agricultural Marketing Service (USDA AMS, 2017)

TABLE 3 Annualized establishment costs and annual operating expenses (\$ ha^{-1}) for each forage type

Pasture	Annualized establishment cost	Annual operating expenses	Total expense
Big bluestem/ indiangrass	\$94.37	\$353.05	\$447.89
Switchgrass	\$75.88	\$342.32	\$418.20
Eastern gamagrass	\$115.75	\$342.32	\$458.07
Bermudagrass	\$81.26	\$342.32	\$423.57
Crabgrass	–	\$538.60	\$538.60

from 2000 to 2017 and adjusted into 2017 dollars using the Consumer Price Index from the United States Bureau of Labor Statistics (2017). The average heifer price was \$2.68 kg^{-1} with a minimum of \$2.08 and maximum of \$4.47 kg^{-1} (USDA AMS, 2017). These prices were used to estimate the revenue of heifer calves being sold at the end of each summer.

2.4 | Profitability analysis

We used partial budgeting to approximate net returns for grazing stocker cattle on the five WSGs in this experiment. Partial budgeting approach only considers the costs that are different across the different WSGs, allowing for a straightforward comparison of grazing the WSGs in this experiment. We assume animal maintenance and production costs are the same across forages, as well as the foregone revenue the producer could receive from selling the calf at weaning (i.e., the opportunity cost of retaining ownership). However, the establishment and production costs for the different WSG forages will vary. Therefore, we estimated partial net returns to grazing only considering the cost of the different WSGs. Revenue received from a stocker operation would be from the sold total gains for beef produced over the summer. This approach is similar to the approach in Lowe et al. (2015), and the producer's expected net returns to grazing the WSGs is expressed as:

$$E\left(\pi_i\right) = p_i E\left(y_i\right) - \mathrm{EC}_i - \mathrm{PC}_i \quad (1)$$

where π_i is the expected annual net returns (\$ ha^{-1}) for grazing the ith WGS (i = BI, SG, EG, BG, and CG.); p_i is the average price of stocker calves (\$ kg^{-1}); γ_i is the total gains put on during the grazing period by the stocker calves (kg ha^{-1}); EC_i is annualized pasture establishment cost of each pasture (\$ ha^{-1}); and PC_i is the annual production cost for the pasture (\$ ha^{-1}). The estimated partial net returns do not completely reflect the profitability of grazing WSGs, but this analysis will determine which WSGs would be preferred.

We assumed the cattle producer would select the WSG treatment that maximizes profits to grazing. We followed analysis for a randomized incomplete block design because EG was only used at one location (Zechiel, 2017). A mixed model was used to evaluate the effects of each WSG treatment on expected net returns to grazing (SAS Institute, 2004). Year, location, and pasture were considered random effects. Means were separated using Fisher's Least Significant Differences ($P < 0.05$). The null hypothesis is partial net returns to grazing are not different across the WSG treatments.

2.5 | Simulation and risk analysis

Retaining stocker cattle to graze incurs risk due to variability in prices and beef gains (Tang, Lewis, Lambert, Griffith, & Boyer, 2017). Risk can be incorporated in this analysis by consider the expected net returns as well as the variability of those net returns. This information could affect producers' selection of WSGs to graze. To include price and production risk in the producers' decision-making framework, we established a Monte Carlo simulation model to estimate distributions of net returns by WSG treatment. Total beef gains for heifers were randomly drawn from a Gray, Richardson, Klose, and Schumann (GRKS) distribution following Henry et al. (2016). The GRKS distribution is valuable when limited information is available about the distribution, since it only requires the minimum, midpoint, and maximum values as the bounds (Richardson, 2006). The GRKS distribution is a two-piece normal distribution with 50% of the observations below the midpoint and 2.5% below the minimum value, while 50% of the observations are above the midpoint and 2.5% above the maximum value (Richardson, 2006). Price for heifer calves that were purchased and sold were randomly drawn from an empirical distribution derived using the Tennessee price data from 2000 to 2017. Simulation and Econometrics to Analyze Risk (SIMETAR) was used to develop the distributions and perform the simulations (Richardson et al., 2008). A total of 5000 breakeven price observations were simulated for each of the forage-based heifer development systems.

We use stochastic dominance to compare the simulated cumulative distribution function of net returns for each WSG treatment. For a treatment to be first-degree stochastic dominant, the scenario with CDF F dominates another scenario with CDF G if $F(\pi) \leq G(\pi) \forall \pi$ (Chavas, 2004). If first-degree stochastic dominance does not find a clear preferred treatment, second-degree stochastic dominance is used, which adds the restriction that producers are risk averse (Chavas, 2004). Second-degree stochastic dominance states the scenario with CDF F dominates another scenario with CDF G if G if $\int F(\pi) d\pi \leq \int G(\pi) d\pi \forall \pi$ (Chavas, 2004). Stochastic dominance is an effective method of conducting a risk analysis of different production practices (Henry et al., 2016).

3 | RESULTS AND DISCUSSION

3.1 | Statistical analysis

The null hypothesis is rejected at the 0.05 probability level that partial net returns to grazing were not different across WSG treatments (Table 4). Expected partial net returns to grazing were, on average, highest for SG (\$430 ha^{-1}) and lowest, on average, for CG (\$3 ha^{-1}). Expected net return to grazing CG was not different from grazing BG, but was lower than the grazing all other forages ($P \leq 0.05$). Grazing BG produced expected partial net returns that were not different ($P \leq 0.05$) from grazing BI and EG; however, partial net returns to grazing BG was lower than grazing SG ($P \leq 0.05$). Similarly, grazing SG resulted in a higher expected partial net return than grazing BI ($P \leq 0.05$). Partial net returns to grazing EG was not different from the partial net returns to grazing SG ($P \leq 0.05$).

Tracy et al. (2010) showed no difference in animal performance from grazing annual WSGs and native WSGs; however, they noted that the annual cost of establishing annual WSGs was higher than the native WSGs because of the repeated establishment of the annual WSGs. This higher costs of production explains why partial net returns for grazing CG were lower than grazing native WSGs. Results from grazing BG indicate that a producer would be indifferent between grazing BG and BI, EG, or CG, despite the fact that the total cost of production for BG was lower than these other forages. Among the native WSGs, SG was more profitable than grazing BI, which matches what Lowe et al. (2015) observed. For EG, the results indicate that there were no differences in net returns to grazing BI and SG, which also match what Lowe et al. (2015) found. Eastern gamagrass was more expensive to produce than BI and SG, but the results imply that larger beef yields on EG produced higher revenue that was greater than the higher cost of production for EG (Zechiel, 2017). Overall, the results indicate that a risk neutral, profit-maximizer would select to graze SG, and that grazing native WSGs would be economically competitive with grazing traditional WSGs (i.e., BG and CG).

It is important to note the economics of grazing stocker cattle on WSGs, or any retained ownership decision, is dependent on several factors, such as feed costs and cattle prices. Historically, cattle prices per unit decrease as stocker cattle weights increases; however, this decrease can be affected by feed costs (Tang et al., 2017). Higher feed costs can increase cattle prices for heavier animals, thus increasing the demand for extending grazing days to increase the weight of feeder cattle. Therefore, prices are a key market signal when considering extending grazing days with WSGs.

TABLE 4 Parameter Estimates from the analysis of variance (ANOVA) for pasture effects on expected net returns by forage (\$ ha^{-1})

Pasture	Fixed effects	Expected net returns
Intercept	429.75	
Big bluestem/indiangrass	−181.70*	\$248b[a]
Switchgrass	–	\$430c
Eastern gamagrass	−144.89	\$285b,c
Bermudagrass	−319.88***	\$110a,b
Crabgrass	−426.89***	\$3a

[a]For each column, if letters are the same across treatments and locations then values in the column are not different at the 0.05 level.

*Significant at the 0.05 probability level

***Significant at the 0.001 probability level

3.2 | Risk analysis

Considering the variation in prices and beef gains, we found that SG was dominant over all other WSG pastures by second-degree stochastic dominance (Figure 1). We can conclude that both a risk-averse and profit-maximizing producer would select to graze SG over all other WSG pastures. This result suggests that SG is a viable alternative to grazing BG and CG. The higher stocking density results in greater total gains ha^{-1} and makes SG a profitable forage with minimal risk. This finding is important to share with southeastern US producers that are interested in planting and grazing WSGs.

Less than 3% of all simulated partial net returns to grazing SG were less than zero, and there was a 76% chance of having partial net returns to grazing above \$240 ha^{-1} (Figure 2). The highest probability of having zero partial net returns was found for CG (59%), thus, there was only a 41% chance than partial net returns to grazing CG were greater than zero. Interestingly, the probability of partial net returns to grazing being less than zero was the next highest for EG (38%). This is explained by the high variation in beef gains for grazing EG

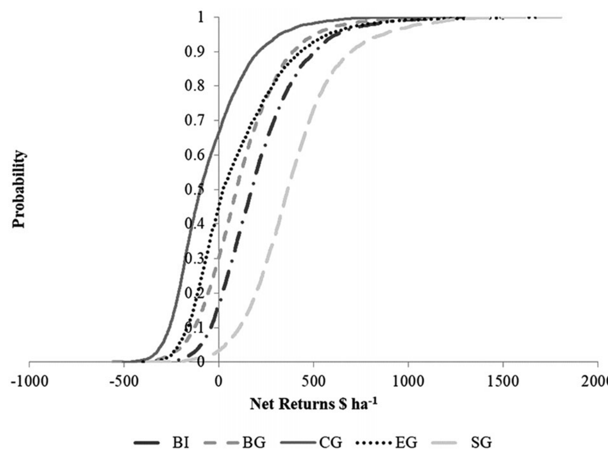

FIGURE 1 Cumulative distribution function of the net returns (\$ ha^{-1}) by pasture type. BI, big bluestem and indiangrass mixture; BG, bermudagrass; CG, crabgrass; EG, eastern gamagrass; SG, switchgrass

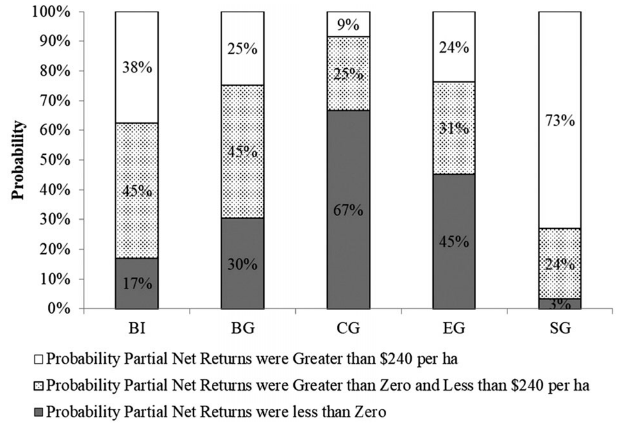

FIGURE 2 Probability of Net Returns being less than zero (shown in dark gray), between zero and \$240 ha^{-1} (shown in dotted), and greater than \$240 ha^{-1} (shown in white). BI, big bluestem and indiangrass mixture; BG, bermudagrass; CG, crabgrass; EG, eastern gamagrass; SG, switchgrass

(see Table 2) and the higher cost of production (see Table 3). For BG, there was a slightly higher probability of generating partial net returns to grazing below zero (26%) than for BI (13%). Figure 2 further demonstrates the risk associated with grazing each of these WGS.

4 | CONCLUSIONS

Managing forage production in a beef-cattle operation throughout the year to limit feeding mechanically-harvested feedstuffs is vital for producers to maximize profits. However, this is also a very challenging task. Beef cattle production in the southeastern United States primarily relies on TF for hay and pasture, but TF has certain physiological characteristics that can cause problems for cattle producers during summer (Volenec & Nelson, 2007). One possible solution to this problem is to graze WSGs during summer. While several studies have examined animal performance on WSGs in the southeastern United States, only a few studies have compared the profitability of these forages (Backus et al., 2017; Burns & Fischer, 2013; Burns et al., 1984; Lowe et al., 2015, 2016). More research is needed to determine WSG species or mixtures that best fit the southeastern United States.

Therefore, we analyzed the profitability and risk associated with grazing beef stocker cattle on five WSGs based on a three year (2014–2016) grazing experiment at two locations in Tennessee. The WSGs included in this study were BI, SG, EG, BG, and CG. This study extends the literature by comparing the profitability of native WSGs (BI, SG, EG), traditional WSG (BG), and annual WSG (CG). Moreover, a simulation was established to compare the risk associated with grazing each of these forages.

The results show that CG, while popular with producers, had the lowest expected net returns to grazing due to its high production cost when planted annually. However, in practice, producers typically do not reseed CG on an annual basis. Thus, future research is needed to determine beef gains when CG is reseeded every year, every other year, and every third year. The profitability of grazing BG was comparable with grazing two of the native WSGs (BI and EG) but grazing SG was the most profitable and had the lowest risk exposure. A shortcoming of this study is the experiment did not include TF as a control or check to common producer practice. Future research is need to compare WSG grazing systems to traditional TF grazing systems.

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REFERENCES

Anderson, R. V., Rasby, R. J., Klopfeinstein, T. J., & Clark, R. T. (2005). An evaluation of production and economic efficiency of two beef systems from calving to slaughter. *Journal of Animal Science*, *83*, 694–704.

Backus, W. M., Waller, J. C., Bates, G. E., Harper, C. A., Saxton, A., McIntosh, D. W., … Keyser, P. D. (2017). Management of native warm-season grasses for beef cattle and biomass production in the Mid-South USA. *Journal of Animal Science*, *95*, 3143–3153.

Bagley, C. P., Carpenter, J. C., Feazel, J. I., Hembry, F. G., Huffman, D. C., & Koonce, K. L. (1987). Influence of calving season and stocking rate on beef cow-calf productivity. *Journal of Animal Science*, *64*, 687–694. https://doi.org/10.2527/jas1987.643687x

Boyer, C. N., Griffith, A. P., Roberts, R. K., Savoy, H. J., & Leib, B. G. (2014). Probability of exceeding toxic nitrate levels in bermudagrass hay: Implications for net returns. *Journal of the American Society*, Farm Managers and Rural Appraisers, 25–40.

Boyer, C. N., Tyler, D. D., Roberts, R. K., English, B. C., & Larson, J. A. (2012). Switchgrass yield response functions and profit-maximizing nitrogen rates on four landscapes in Tennessee. *Agronomy Journal*, *104*(6), 1579–1588. https://doi.org/10.2134/agronj2012.0179

Brown, R. H. (1999). Agronomic implications of C4 photosynthesis. In R. F. Sage & R. K. Monson (Eds.), *C4 Plant Biology* (pp. 473–507). San Diego, CA: Academic Press.

Burns, J. C., Mochrie, R. D., & Timothy, D. H. (1984). Steer performance from two perennial pennisetum species, switchgrass, and a fescue- 'coastal' bermudagrass system. *Agronomy Journal*, *76*, 795–800. https://doi.org/10.2134/agronj1984.00021962007600050020x

Burns, J. C., & Fisher, D. S. (2013). Steer performance and pasture productivity among five perennial warm-season grasses. *Agronomy Journal*, *105*(1), 113–123. https://doi.org/10.2134/agronj2012.0142

Campbell, B. T., Backus, W. M., Dixon, C. M., Carlisle, R. J., & Waller, J. C. (2013). A comparison of spring- and fall-calving beef herds grazing tall fescue. *The Professional Animal Scientist*, *29*, 172–178. https://doi.org/10.15232/S1080-7446(15)30216-3

Chavas, J. P. (2004). *Risk analysis in theory and practice*. San Diego, CA: Elsevier.

Henry, G. W., Boyer, C. N., Griffith, A. P., Larson, J. A., Smith, S. A., & Lewis, K. E. (2016). Risk and returns of spring and fall calving beef cattle in Tennessee. *Journal of Agricultural and Applied Economics*, *48*(3), 257–278. https://doi.org/10.1017/aae.2016.11

Jordan, D. J., Erickson, G. E., Klopfenstein, T. J., Adams, D. C., & Milton, T. (1999). Steer performance within summer grazing systems. Nebraska Beef Cattle Reports. Paper 409.

Keyser, P., Bates, G., Waller, J., Harper, C., & Doxon, E. (2011). Economic Implications of Growing Native Warm-Season Grasses for Forage in the Mid-South (SP731-E).

Keyser, P. D., Holcomb, E. D., Lituma, C. M., Bates, G. E., Waller, J. C., Boyer, C. N., & Mulliniks, J. T. (2016). Forage attributes and animal performance from native grass inter-seeded with red clover. *Agronomy Journal*, *108*, 373–383. https://doi.org/10.2134/agronj2015.0198

Lewis, K. E., Griffith, A. P., Boyer, C. N., & Rhinehart, J. (2016). Does prepartum supplemental feed impact beef cattle profitability through finishing. *Journal of Agricultural and Applied Economics*, *48*(2), 173–191. https://doi.org/10.1017/aae.2016.9

Looper, M. L., Reiter, S. T., Williamson, B. C., Sales, M. A., Hallford, D. M., & Rosenkrans, C. F. (2010). Effects of body condition on measures of intramuscular and rump fat, endocrine factors, and calving rate of beef cows grazing common bermudagrass or endophyte-infected tall fescue. *Journal of Animal Science*, *88*(12), 4133–4141. https://doi.org/10.2527/jas.2010-3192

Lowe, J. K., II, Boyer, C. N., Griffith, A. P., Keyser, P., Bates, G. E., Waller, M., & Backus, W. M. (2015). Profitability of beef and biomass production from native warm season grasses in Tennessee. *Agronomy Journal*, *107*, 1733–1740. https://doi.org/10.2134/agronj15.0083

Lowe, J. K., II, Boyer, C. N., Griffith, A. P., Waller, J. C., Bates, G. E., Keyser, P. D., … Holcomb, E. D. (2016). The cost of feeding bred dairy heifers on native warm-season grasses and harvested feedstuffs. *Journal of Dairy Science*, *99*(1), 634–643. https://doi.org/10.3168/jds.2015-9475

McFarlane, Z. D., Boyer, C. N., & Mulliniks, T. (2018). Profitability of developing heifers on stockpiled winter forages. *Journal of Applied Farm Economics*, *2*(2), 1.

McBride, W. D., & Mathews, K., Jr. (2011). The diverse structure and organization of US beef cow-calf farms. EIB-73. *U.S. Department of Agriculture Economic Research Service*, Washington, DC: U.S. Department of Agriculture.

Moore, K. J., White, T. A., Hintz, R. L., Patrick, P. K., & Brummer, E. C. (2004). Forages and pasture management. *Agronomy Journal*, *96*, 1103–1111. https://doi.org/10.2134/agronj2004.1103

Richardson, J. W. (2006). Simulation for applied risk management. Unnumbered staff report, Department of Agricultural Economics, Agricultural and Food Policy Center, Texas A&M University, College Station, Texas.

Richardson, J. W., Schumann, K. D., & Feldman, P. A. (2008). SIMETAR Simulation for Excel to Analyze Risk. *Department of Agricultural Economics, Agricultural and Food Policy Center*, Texas A&M University, College Station, Texas.

Roberts, C., & Andrae, J. (2004). Tall fescue toxicosis and management. *Crop Manage*, *3*(1). https://doi.org/10.1094/CM-2004-0427-01-MG

SAS Institute Inc. (2004). *SAS OnlineDoc 9.2*. Cary, NC: SAS Institute Inc.

Shain, D. H., Klopfenstein, T. J., Stock, R. A., Vieselmeyer, B. A., & Erickson, G. E. (2005). Evaluation of grazing alternate summer and fall forages in extensive beef cattle production systems. *The Professional Animal Scientist*, *21*, 390–402. https://doi.org/10.15232/S1080-7446(15)31237-7

Smith, S. A., Caldwell, J. D., Popp, M. P., Coffey, K. P., Jennings, J. A., Savin, M. C., & Rosenkrans, C. F. (2012). Tall fescue toxicosis mitigation strategies: Comparisons of cow-calf returns in spring- and fall-calving herds. *Journal of Agricultural and Applied Economics*, *44*(4), 577–592. https://doi.org/10.1017/S1074070800024123

Stuedemann, J. A., & Hoveland, C. S. (1988). Fescue endophyte: History and impact on animal agriculture. *Journal of Production Agriculture*, *1*(1), 39–44. https://doi.org/10.2134/jpa1988.0039

Tang, M., Lewis, K. E., Lambert, D. M., Griffith, A. P., & Boyer, C. N. (2017). Beef cattle retained ownership and profitability in Tennessee. *Journal of Agricultural and Applied Economics*, *49*(4), 571–591. https://doi.org/10.1017/aae.2017.12

Tracy, B. F., Maughan, M., Post, N., & Faulkner, D. B. (2010). Integrating annual and perennial warm-season grasses in a temperate grazing system. *Crop Science*, *50*, 2171–2177. https://doi.org/10.2135/cropsci2010.02.0110

United States Bureau of Labor Statistics. (2017). Consumer Price Index, BLS-CPI. Retrieved from http://www.bls.gov/cpi/ (accessed 2 Feb. 2018).

USDA. (2012). Census of Agriculture-Tennessee. Retrieved from http://www.agcensus.usda.gov/Publications/2012/Full_Report/Volume_1,_Chapter_1_State_Level/Tennessee/

United States Department of Agriculture Agricultural Marketing Service. (2017). Feeder and Replacement Cattle Auctions. Retrieved from https://www.ams.usda.gov/market-news/feeder-and-replacement-cattle-auctions#Tennessee (accessed February 2016).

Volenec, J. J., and Nelson, C. J. (2007). Physiology of Forage Plants. In R. F. Barnes et al. (Eds.), *Forages: The Science of Grassland Agriculture* (Vol. *II*, pp. 37–52). Vol Aimes, IA: R.F. Blackwell Publishing.

Wolf, D. D., Brown, R. H., & Blaser, R. E. 1979. Physiology of Growth and Development. In: R. C. Buckner & L. P. Bush (Eds.), Tall Fescue. Am. Soc. Agron., Madison, WI. 75–93.

Zechiel, K. E. (2017). Coping with drought in beef cattle production: Innovation through optimal warm-season forage systems. M.S. Thesis, Department of Animal Science, University of Tennessee, Knoxville.

Zhou, X. V., Boyer, C. N., Larson, J. A., & Lieb, B. G. (2014). Breakeven cost of irrigating bermudagrass, tall fescue, and orchardgrass hay production in Tennessee. *Agronomy Journal*, *106*, 2227–2234. https://doi.org/10.2134/agronj14.0221

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