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Profitability of Beef and Biomass Production from Native Warm-Season Grasses in Tennessee

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ABSTRACT

Native warm-season grasses (NWSGs) have demonstrated potential to reduce summer forage variability, and furthermore, there has been growing interest in the use of NWSGs as lignocellulosic biomass crops. The objective of this research was to determine if there was a difference in net returns for full-season summer grazing beef steers (Bos taurus) on three NWSGs. Additionally, the expected price for biomass that a beef producer would need to break even between using the dual-purpose early-season grazing and biomass system and the full-season grazing system was calculated for these three NWSGs. Weaned beef steers grazed switchgrass (*Panicum virgatum* L.) (SG), a big bluestem (*Andropogon gerardi* Vitman) and indiangrass [*Sorghastrum nutans* (L.) Nash] mixture (BBIG), and eastern gamagrass [*Tripsacum dactyloides* (L.) L.] at Grand Junction (AP) and Highland Rim (HR), TN, from 2010 to 2012. The dual-purpose grazing occurred for 30 d beginning in early May, with subsequent growth harvested as biomass post-dormancy, and full-season grazing occurred for 90 d beginning in early May. Budgets were developed for each NWSG to calculate net returns, and mixed models were used to determine differences in beef yield and net returns across each NWSG and location. Expected yield and net returns to full-season grazing were not different among NWSGs at AP. However, net returns to full-season grazing were higher for BBIG than SG at HR. A profit-maximizing, risk-neutral individual would increase net returns by grazing any of the NWSGs over marketing calves at weaning. The breakeven biomass prices ranged between US$10 and US$98 Mg^{-1} depending on the NWSG and location.

For most of the southeastern United States, beef cattle production consists of a mixture of cow-calf operations and stocker operations. The primary pasture forage used by these operations is tall fescue [*Schedonorus arundinaceus* (Schreb.) Dumort., formerly *Festuca arundinacea* Schreb.], a cool-season grass (Keyser et al., 2011). Tall fescue has peak production in spring and fall, but physiological characteristics commonly present during the summer grazing months can negatively impact cattle performance and profitability (Volenec and Nelson, 2007; Smith et al., 2012). During summer, cattle grazing endophyte-infected tall fescue are likely to be impacted by fescue toxicity, which can result in elevated body temperature, lower conception rates, reduced average daily gain (ADG), and failure to shed their winter coat (Roberts and Andrae, 2004; Looper et al., 2010), thus lowering profits for cow-calf operators by reducing conception rates of cows and decreasing profits for stocker cattle by reducing ADG. Smith et al. (2012) estimated fescue toxicosis results in annual losses of more than US$1 billion to cattle producers.

A possible solution to this problem is to rotate cows, heifer development, and stocker cattle to NWSGs during summer when the impacts of toxicosis are typically greatest. Several studies have analyzed animal performance on NWSGs, but fewer studies have directly compared animal performance on NWSGs. In Nebraska, Krueger and Curtis (1979) found ADG for yearling steers to be 0.93 kg d^{-1} when grazing switchgrass (SG), 0.70 kg d^{-1} when grazing big bluestem (BB), and 1.08 kg d^{-1} when grazing indiangrass (IG), with total beef gains of 146 kg ha^{-1} on SG, 138 kg ha^{-1} on BB, and 119 kg ha^{-1} on IG. In Iowa, Moore et al. (2004) evaluated SG and BB as a complement to grazing weaned calves on bromegrass (*Bromus inermis* Leyss.) and found no difference in animal performance between BB and SG.

In the southeastern United States, Burns et al. (1984) found that the ADG for steers grazing SG during summer was 66% higher than for steers grazing a sequence of tall fescue and Coastal bermudagrass (*Cynodon dactylon* L.) in North Carolina. In fact, steers grazing SG yielded 322 kg ha^{-1} before the Coastal bermudagrass pasture was available to graze. More recently, Burns and Fisher (2013) compared ADG and total beef yield of steers grazing monocultures of eastern gamagrass (EG), SG, and BB in North Carolina during the summer

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Abbreviations: ADG, average daily gain; AP, Ames Plantation Research and Education Center; BB, big bluestem; BBIG, big bluestem and indiangrass mixture; EG, eastern gamagrass; HR, Highland Rim Research and Education Center; IG, indiangrass; NWSG, native warm-season grass; SG, switchgrass.

months. Steers grazing EG gained 0.87 kg d^{-1} with a total beef yield of 752 kg ha^{-1}, steers grazing BB gained 1.08 kg d^{-1} with a total beef yield of 732 kg ha^{-1}, and steers grazing SG gained 0.91 kg d^{-1} with a total beef yield of 839 kg ha^{-1}; total beef yield did not differ among the NWSGs.

The economic research on grazing NWSGs has primarily focused on the cost of production, but little is known about the profitability of grazing NWSGs. Research suggests that grazing NWSGs could decrease the cost of production by extending grazing days in stocker operations (Jordan et al., 1999; Anderson et al., 2005; Shain et al., 2005). However, if NWSGs are being used to grow stocker cattle before marketing, the potential for cattle prices to decrease during the grazing period is an important consideration in any evaluation of profitability. This is especially true given the fact that the market price of stocker and feeder cattle decreases as the animals increase in weight. Thus, a stocker producer grazing NWSGs during the summer months has a heavier animal to market and could receive a lower price per kilogram at that time, which makes it difficult to determine if the value of the beef yield from grazing during the summer months was greater than the decrease in price per kilogram. Phillips et al. (2004) found that calves grazing native range grass in Oklahoma increased net returns to producers by 33% per head relative to being placed in a confinement feedlot after winter wheat (*Triticum aestivum* L.) grazing. However, there is little known regarding the profitability of grazing NWSG in the southeastern United States; thus, such analysis would make a unique contribution to the literature and provide an important framework for decision making by stocker cattle producers in this region.

Furthermore, the use of NWSGs is not exclusive to cattle production. In recent years, there has been growing interest in the use of NWSGs as a lignocellulosic biomass crop (Hallam et al., 2001; Mulkey et al., 2008; Heggenstaller et al., 2009; Griffith et al., 2011; Hong et al., 2013). Several NWSGs such as SG, BB, IG, and EG have been compared to determine the NWSG with the lowest cost of production (i.e., breakeven price of biomass) (Hallam et al., 2001; Griffith et al., 2011; Hong et al., 2013). Currently, there is no market for biomass in the southeastern United States, but if a market develops, there is a possibility that beef producers could use a dual-purpose biomass and grazing system to maximize profits. In the dual-purpose system, NWSGs would be grazed for a short period early in the growing season, with a biomass harvest after dormancy (Mosali et al., 2013).

Mosali et al. (2013) studied SG in a dual-purpose early-season grazing–biomass production system and reported that such a system could allow stocker cattle to remain on forage for a longer period of time before entering the feedlot, resulting in greater gains, and produce a biomass harvest annually on the same pastures. While Mosali et al. (2013) provided valuable insight into the management of a dual-purpose grazing–biomass system, the research was limited to SG. Moreover, the question remains, at what price of biomass would a beef producer be better off using the dual-purpose system instead of full-season grazing of NWSGs?

The objectives of this research were to determine if there was a difference in expected net returns for full-season grazing beef steers (i.e., stocker operation) in Tennessee on SG, a mixture of BB and IG (BBIG), and EG at two locations. Additionally, the expected beef yield and biomass production data were collected for a dual-purpose early-season grazing and biomass system. The expected price for biomass that a beef producer would need to break even between using the dual-purpose system and the full-season grazing system was calculated for these three NWSGs at two locations. Results from this study provide information for cow-calf and stocker cattle producers to make more profitable summer grazing decisions as well as insight into a dual-purpose grazing–biomass production system.

MATERIALS AND METHODS

Experimental Data

Animal performance and forage data were collected from Ames Plantation (AP) in Grand Junction, TN (35°6′ N, 89°13′ W) and Highland Rim Research and Education Center (HR) in Springfield, TN (36°28′ N, 86°50′ W) from 2010 to 2012. Soils at AP were Memphis silt loam (a fine-silty, mixed, active, thermic Typic Hapludalf), Loring silt loam (a fine-silty, mixed, active, thermic Oxyaquic Fragiudalf), and Lexington silt loam (a fine-silty, mixed, active, thermic Ultic Hapludalf); soils at HR were classified as a Dickson loam (a fine-silty, siliceous, semiactive, thermic Glossic Fragiudult with 22% clay, 70% silt, and 8% sand) with a pH of about 6. The NWSG grazing treatments were set up as a completely randomized block design with three replications of each treatment. Experimental units consisted of paddocks 1.214 ha in size and were established in 2008 at both sites. The NWSG grazing treatments at AP included SG, BBIG, and EG, and the NWSGs grazed at HR included BBIG and SG. Before no-till planting, glyphosate [*N*-(phosphonomethyl)glycine] was applied to treatment areas for cleanup in the spring of 2008. Switchgrass was seeded at a rate of 6.72 kg pure live seed (PLS) ha^{-1}, BBIG was planted at a ratio of 65:35 and a rate of 10.08 kg PLS ha^{-1}, and EG was seeded at a rate of 13.45 kg PLS ha^{-1}. Cultivars used were for each NWSG were Alamo for SG, OZ-70 for BB, Rumsey for IG, and Pete for EG. Paddocks were fertilized in April of each year, with rates determined from soil samples. At AP, all paddocks received 67 kg N ha^{-1} and 90 kg P ha^{-1}, with a few paddocks receiving 45 kg K ha^{-1} in 2010. In 2011 and 2012, all paddocks were fertilized with 67 kg N ha^{-1} and 45 or 67 kg K ha^{-1}, depending on the soil sample recommendations. At HR, 67 kg N ha^{-1} was applied to all paddocks in 2010 and 2011. In 2012, paddocks received either 67 kg N ha^{-1} and 100 kg P ha^{-1}; 67 kg N ha^{-1}, 100 kg P ha^{-1}, and 100 kg K ha^{-1}; or 67 kg N ha^{-1}, 67 kg P ha^{-1}, and 100 kg K ha^{-1}.

At each location, this experiment was conducted for two grazing periods: (i) early-season grazing and (ii) full-season grazing. A total of 45 observations were collected for the early-season grazing and a total of 45 observations were collected for the full-season grazing. The early-season grazing period concluded approximately 30 d from the initiation of grazing, and biomass was harvested post-dormancy. In early November, 10 0.25-m^2 sample sites were randomly selected in each paddock. Forage height was measured in centimeters at each sample site and the forage clipped with gasoline-powered hedge trimmers at 2.54 cm. The full-season grazing period was terminated approximately 90 d from the initiation of grazing. Table 1 shows rainfall and temperatures by year and location. Grazing duration varied by year, often due to rainfall and temperature.

Table 1. Average daily temperature (temp.) and total rainfall during grazing months by location and year.

Month	2010		2011		2012		3-yr Avg.	
	Temp.†	Rainfall	Temp.	Rainfall	Temp.	Rainfall	Temp.	Rainfall
	°C	cm	°C	cm	°C	cm	°C	cm
				Ames Plantation				
May	21.91	34.29	19.93	13.41	22.02	5.31	21.29	17.67
June	27.62	1.45	26.54	8.74	24.18	10.06	26.11	6.75
July	28.05	22.71	28.20	7.54	27.79	8.56	28.01	12.94
Aug.	28.32	6.05	27.00	5.31	25.86	6.07	27.06	5.81
May–Aug.	26.48	64.5	25.41	35.00	24.96	30.0	25.62	43.17
				Highland Rim				
May	20.47	26.26	18.63	13.21	21.51	20.02	20.20	19.83
June	26.23	9.58	25.71	12.88	23.31	2.82	25.08	8.43
July	27.40	3.33	27.23	7.14	27.55	19.35	27.39	9.94
Aug.	27.10	7.39	25.72	5.08	24.13	7.21	25.65	6.56
May–Aug.	25.30	46.56	24.32	38.31	24.13	49.4	24.58	44.76

† Source: NOAA, Grand Junction and Springfield, TN, weather stations.

Animal Management

Tennessee Livestock Producers (Columbia, TN) provided 109, 145, and 168 weaned beef steers for the experiment in 2010, 2011, and 2012. Before arriving at AP and HR, the steers were backgrounded for 42 d at the Tennessee Livestock Producers cattle facility to alleviate symptoms of marketing and shipping stress. The animals that were used in this study were m1 and m2 feeder cattle grade beef steers, predominantly all black hided, with some continental breed influenced steers being present.

A continuous grazing system with a variable stocking rate was utilized in this experiment. Each paddock contained four tester steers with a variable number of grazer animals dependent on the forage availability of the NWSG. Each year, steers were sorted from lightest to heaviest and the steers in the middle of the group were considered as testers. For full-season grazing, paddocks were stocked with grazers to maintain a stand height between 38.1 and 45.72 cm for BBIG, and grazers were used on the SG and EG paddocks to maintain a stand height between 60.96 and 76.2 cm. When forage growth was higher than the target height, grazers were added to the paddock, and when forage growth was within the desired range, grazers were removed. In 2010, the initial stocking rate included four tester steers, with one grazer per BBIG paddock and two grazers for each SG and EG paddock at HR and AP. In 2011, the initial stocking rate included four testers plus five grazer animals per SG paddock, one per BBIG paddock, and six per EG paddock at HR and AP. In 2012, there were four tester animals along with four grazer animals for each SG and EG paddock and one grazer per BBIG paddock at HR and AP. The number of grazers at the initial stocking was increased in 2011 and 2012 due to early forage production in SG and EG. The total grazing period for all 3 yr ranged from mid-May to early August.

For early-season grazing, grazer animals were used to maintain a stand height between 20.32 and 25.4 cm for all NWSG treatments. Similar to the full-season grazing, when forage growth was higher than the target height, grazers were added to the paddock, and when forage growth was within the desired range, grazers were removed. The initial stocking rate included four testers plus three grazers per BBIG paddock and four grazers for each SG and EG paddock in 2010 at AP and HR. In 2011, the initial stocking rate included four testers plus seven grazer animals per SG paddock, four grazers per BBIG paddock, and eight grazers per EG paddock at each location. In 2012, there were four testers plus eight grazer animals for each SG and EG paddock, and four testers plus four grazers per BBIG paddock at both locations.

Table 2 shows the dates of grazing, the average beginning weight, and the weight range for beef steers in the experiment by year and location. Steers were placed on a stuffer diet before and after entering the paddocks. This diet was used to regulate gut fill without adding weight to the animals, allowing a more accurate measurement of gain than traditional methods such as averaging weights from multiple days. With this diet, steers were fed at 2.0% body weight 5 d pre- and post- grazing. The stuffer diet ration both before and after entering the paddock consisted of cottonseed hulls, soy hulls, citrus pulp, distillers dried grains, and molasses, which was 12.9% crude protein and 27.2% crude fiber. The "on-pasture" weight was the average of weights from the last 2 d of the stuffer diet before grazing, and the "off-pasture" weight was the average of the last 2 d of a 5-d stuffer diet following the grazing period. The ADG was calculated using differences in beginning and ending weights of the testers divided by the number of days the tester steers were grazing. Table 3 shows the ADG and animal unit days by year, location, and treatment. The ADG was multiplied by the total number of grazing days for the tester and grazer animals to find the total beef yield.

Budgeting

Enterprise budgets were used to estimate establishment and operational costs for grazing SG, EG, and BBIG. A 10-yr production horizon was assumed (Duffy, 2007; Griffith et al., 2011; Haque et al., 2009; Khanna et al., 2008; Mooney et al., 2009), with no grazing occurring in the establishment year. Total establishment and production costs of NWSGs were calculated following the University of Tennessee switchgrass budget (University of Tennessee, Department of Agricultural and Resource Economics, 2009). The establishment costs included seed, herbicide, fertilizer, labor, and machinery and were annualized across the life of the pasture using a discount rate of 5.5% (University of Tennessee, Department of Agricultural and Resource Economics, 2009; US Department of Labor, 2013). The annualized establishment cost was added to annual

Table 2. Dates of grazing and beginning weight of beef steers for full-season and early-season grazing periods.

Grazing period	On date	Off date	Year	Min. weight	Max. weight	Avg. weight
				kg		
			Ames Plantation			
Full season	28 May	9 Aug.	2010	247.61	291.15	267.57
	4 May	9 Aug.	2011	219.94	287.07	256.00
	14 Apr.	27 July	2012	233.55	273.00	250.89
Early season	28 May	28 June	2010	245.39	293.93	268.47
	4 May	6 June	2011	232.46	278.50	258.79
	14 Apr.	21 May	2012	215.00	274.42	253.30
			Highland Rim			
Full season	7 May	9 Aug.	2010	244.03	295.28	269.08
	6 May	29 Aug.	2011	251.28	278.95	265.08
	27 Apr.	20 Aug.	2012	255.37	291.20	276.24
Early season	7 May	7 June	2010	250.84	298.46	267.92
	6 May	6 June	2011	249.02	283.04	264.99
	27 Apr.	29 May	2012	263.54	294.38	277.71

operational costs and annual land rent to calculate the total annual cost of production during a 10-yr useful life. To account for the risk of failed establishment, a 10% re-establishment cost was assumed in the budget.

Based on contemporary prices observed in Tennessee in 2013, seed costs were assumed to be US\$36.72 kg^{-1} for BB, US\$50.05 kg^{-1} for IG, US\$51.26 kg^{-1} for EG, and US\$28.58 kg^{-1} for SG. Average fertilizer prices were calculated from 2010 to 2012 as US\$0.59 kg^{-1} N, US\$0.77 kg^{-1} P, and US\$0.83 kg^{-1} K (National Agricultural Statistics Service, 2013). Fertilizer rates were based on the University of Tennessee switchgrass recommendations for grazing NWSG and were used for both full- and early-season grazing treatments. The annual fertilizer applications were 67 kg N ha^{-1}, 34 kg P ha^{-1}, and 34 kg K ha^{-1}. Estimated total annualized pasture costs were based on 2012 US dollars and are shown in Table 4.

In the dual-purpose production system, the biomass was harvested post-dormancy; therefore, the cost of harvesting biomass was included in the early-season grazing budgets. The harvest costs were based on budgets from Griffith et al. (2011) and Boyer et al. (2013). Mowing and raking costs were assumed to be US\$21.04 ha^{-1} and US\$9.59 ha^{-1}, respectively. Baling and staging costs were US\$14.64 and US\$4.50 per bale, respectively. Harvest costs were included in Table 3 for the dual-purpose grazing–biomass production system.

The average prices for 272.1- to 317.45-kg steers in Tennessee in the month of May from 2002 to 2011 (McKinley and Griffith, 2012) were used to reflect the purchase price of steers to graze NWSG or the opportunity cost of grazing steers on NWSG instead of marketing them at the beginning of the grazing period. The average price for 272.1- to 317.45-kg steers in Tennessee for the month of August, 2002 to 2011, was used to reflect the marketing price of beef steers after full-season grazing (McKinley and Griffith, 2012). Prices for the same weight class were used for the purchase and sale price because the cattle represented in this study did not gain enough weight during the grazing period to exceed the upper end of the range on average. Prices were adjusted for inflation during the summer grazing period, and the average price

Table 3. Expected average daily gain and animal unit day for early- and full-season grazing with weaned beef steers on three native warm-season grass (NSWG) forages at two locations in Tennessee, 2010–2012.

	Early-season grazing		Full-season grazing	
NSWG†	Avg. daily gain	Animal unit days‡	Avg. daily gain	Animal unit days
	kg	d	kg	d
		Ames Plantation		
SG	1.14	234	0.56	467
BBIG	1.23	175	0.82	279
EG	0.84	254	0.48	508
		Highland Rim		
SG	0.88	211	0.79	510
BBIG	1.09	161	0.96	359

† BBIG, big bluestem and indiangrass; EG, eastern gamagrass; SG, switchgrass.

‡ Animal unit days are calculated as (total steer grazing days × 0.68) + (total heifer grazing days × 0.84) + cow grazing days.

Table 4. Total annualized pasture costs for establishing and maintaining native warm-season grass (NSWG) pastures consisting of a big bluestem–indiangrass mix (BBIG), eastern gamagrass (EG), or switchgrass (SG) during a 10-yr useful life.

Pasture costs	BBIG	EG	SG
		US\$ ha^{-1}	
Establishment costs			
NWSG seed†	417.17	689.45	192.51
Establishment‡	517.51	517.51	574.00
Risk of re-establishment§	93.47	120.70	76.65
Total	1028.14	1327.65	843.16
Annualized establishment	136.40	176.14	111.86
Operational costs			
Fertilizer	195.95	195.95	195.95
Mowing	21.04	21.04	21.04
Land rent	51.87	51.87	51.87
Total annual pasture cost	405.26	445.00	380.72

† Seed cost was US\$36.72 kg^{-1} for big bluestem, US\$50.05 kg^{-1} for indiangrass, US\$51.26 kg^{-1} for eastern gamagrass, and US\$28.58 kg^{-1} for switchgrass.

‡ Other establishment costs include herbicide, machinery, land rent for the establishment year, labor, and fixed costs such as depreciation on equipment and total interest (University of Tennessee, Department of Agricultural and Resource Economics, 2009).

§ Total NWSG establishment costs include a 10% risk of failed establishment that will result in replanting.

of beef was US$2.56 kg^{-1} in May and US$2.58 kg^{-1} in August. For early-season grazing, the average price for 272.1- to 317.45-kg steers in Tennessee for the month of June from 2002 to 2011 (McKinley and Griffith, 2012) was used to reflect the marketing price of beef steers for early-season grazing. Prices were adjusted for inflation, and the average price of beef was US$2.56 kg^{-1} in June. We assumed that the steers were marketed immediately after being removed from pasture for both early- and full-season grazing. The average "on-pasture" weight (264 kg) and price (US$2.56 kg^{-1}) were used to find the interest expense (US$ ha^{-1}) of holding the four tester steers for 90 d in the full-season grazing and 30 d in the early-season grazing instead of selling them at weaning. We assumed an annual interest rate of 5.5%.

Economic Framework

For producers who traditionally market their calves after a short weaning period, the decision to graze NWSG can be framed as a profit-maximizing decision. Expected net returns to the pasture can be calculated by determining the difference in the value of beef yield and the pasture cost associated with producing the beef yield. In addition to pasture cost, the producer must also consider the opportunity cost of grazing steers on NWSG instead of marketing them at the beginning of the grazing period. The producer's expected net returns to full-season grazing NWSG is expressed as

$$\mathrm{E}\left(\mathrm{NR}_i^{\mathrm{f}}\right) = \mathrm{E}\left[\left(p_{\mathrm{m}}^{\mathrm{f}} w_i^{\mathrm{f}} - p_{\mathrm{p}} w_{\mathrm{p}}\right) - \mathrm{AEC}_i - \mathrm{OC}_i - \mathrm{LR} - I^{\mathrm{f}}\right] \quad [1]$$

where $\mathrm{E}(\mathrm{NR}_i^{\mathrm{f}})$ is expected annual net returns (US$ ha^{-1}) for full-season grazing (f) in the ith ($i = 1, \ldots, 3$) NWSG treatment; $p_{\mathrm{m}}^{\mathrm{f}}$ is the marketing price of beef (US$ kg^{-1}) at the end of the full-season grazing period; w_i^{f} is the final weight (kg ha^{-1}) of the steers when sold at the end of the full-season grazing period from the ith NWSG treatment; p_{p} is the purchase price of beef steers (US$ kg^{-1}) at the beginning of the grazing period; w_{p} is the purchase weight (kg ha^{-1}) at the beginning of the grazing period for the ith NWSG treatment; AEC_i is annualized pasture establishment cost (US$ ha^{-1}) for the ith NWSG treatment; OC_i is the annual operational pasture cost (US$ ha^{-1}), including pasture maintenance, mowing, and fertilizer; LR is the annual land rent (US$ ha^{-1}); and I^{f} is the annual interest expense (US$ ha^{-1}) for full-season grazing. The opportunity cost of grazing the steers during the summer months instead of marketing them at the beginning of the grazing period is represented by ($p_{\mathrm{p}} w_{\mathrm{p}}$) and the interest expense for holding the four steers for an additional 90 d.

Currently, there is no biomass market in the southeastern United States; therefore, the price of biomass as an energy feedstock has not been established. However, we estimated the price of biomass that a beef producer would need to receive to remove cattle from pasture and harvest the NWSGs for biomass. This price of biomass indicates the price where a producer would receive greater expected net returns using a dual-purpose system than full-season grazing of NWSGs. To find the breakeven price of biomass, expected net returns were calculated by determining the difference in the value of the beef yield plus the value of the biomass harvest minus the pasture and harvest costs associated with producing that beef yield and biomass yield along with the opportunity cost of grazing instead of marketing the calves at the beginning of the grazing period. The annual expected net returns to early-season grazing and a biomass harvest for each NWSG can be calculated as

$$\mathrm{E}\left(\mathrm{NR}_i^{\mathrm{e}}\right) = \mathrm{E}\left[\left(p_{\mathrm{m}}^{\mathrm{e}} w_i^{\mathrm{e}} - p_{\mathrm{p}} w_{\mathrm{p}}\right) + p_i^{\mathrm{bm}} z_i - \mathrm{AEC}_i - \mathrm{OC}_i - \mathrm{LR} - I^{\mathrm{e}} - h\left(z_i\right)\right] \quad [2]$$

where $\mathrm{E}(\mathrm{NR}_i^{\mathrm{e}})$ is the annual expected net return (US$ ha^{-1}) for early-season grazing (e) in the ith NWSG treatment; $p_{\mathrm{m}}^{\mathrm{e}}$ is the marketing price of beef (US$ kg^{-1}) at the end of the early-season grazing period; w_i^{e} is the final weight (kg ha^{-1}) of the steers when sold at the end of the early-season grazing period for the ith NWSG treatment; p_i^{bm} is the price of biomass (US$ Mg^{-1}); z_i is the biomass yield (Mg ha^{-1}) for the ith NWSG treatment; I^{e} is the annual interest expense (US$ ha^{-1}) for early-season grazing; and $h(z_i)$ is the harvest cost (US$ ha^{-1}) for the ith NWSG treatment, where the harvest cost is a function of yield.

Because p_i^{bm} is unknown, Eq. [2] was set equal to the expected net returns to full-season grazing (Eq. [1]) and was rearranged to solve for the price of biomass. Solving the equation for p_i^{bm} provides the breakeven price of biomass required for beef producers to generate the same net return to early-season grazing and biomass harvest as full-season grazing. This is expressed as

$$\mathrm{E}\left(p_i^{\mathrm{bm}}\right) = \mathrm{E}\left[\frac{p_{\mathrm{m}}^{\mathrm{f}} w_i^{\mathrm{f}} - p_{\mathrm{m}}^{\mathrm{e}} w_i^{\mathrm{e}} - I^{\mathrm{f}} + I^{\mathrm{e}} + h\left(z_i\right)}{z_i}\right] \quad [3]$$

The NWSG that results in the lowest breakeven price of biomass will probably be the NWSG that has the greatest chance of being used by beef producers in a dual-purpose system.

Statistical Methods

Mixed models were used to perform an ANOVA on the effects of each NWSG treatment and location on the expected beef yield for early- and full-season grazing, net returns to full-season grazing, and biomass yield. A random effect was included for year variability such as stochastic weather events. The expected beef yield model was estimated for both early- and full-season grazing periods, and is expressed as

$$\mathrm{BY}_{til} = \gamma_0 + D_l + \sum_{i=1}^{3-1} \gamma_i I_i + \sum_{i=1}^{3-1} \beta_{il} I_{il} D_{il} + v_t + \varepsilon_{til} \quad [4]$$

where BY_{til} is the beef yield (kg ha^{-1}) at time t for grazing the ith NWSG treatment and lth location; γ_0 is the intercept coefficient for the ith NWSG treatment; D_l is an indicator variable for the lth location; γ_i is the coefficient for the ith NWSG treatment; I_i is an indicator variable for the ith NWSG treatment; β_{il} is the coefficient for the interaction term for the ith NWSG treatment and the lth location; $v_t \sim N(0,\sigma_v^2)$ is the year random effect; and $\varepsilon_{til} \sim N(0,\sigma_\varepsilon^2)$ is a random error term. The null hypothesis was that beef yield was not different across NWSG treatments and between locations.

To determine the NWSG that produces the highest net returns to grazing, expected net returns for full-season grazing were compared across NWSGs and locations. A mixed model with a random effect for year was estimated to test for differences in expected net returns for full-season grazing across NWSG treatments and locations, which is expressed as

$$NR_{til} = \gamma_0 + D_l + \sum_{i=1}^{3-1} \gamma_i I_i + \sum_{i=1}^{3-1} \beta_{il} I_{il} D_{il} + v_t + \varepsilon_{til} \quad [5]$$

where NR_{til} is the net returns (US\$ ha^{-1}) at time t for full-season grazing the ith NWSG treatment and lth location. The null hypothesis was that expected net returns were not different across NWSG treatments and between locations.

A mixed model was used to estimate the fixed effects of NWSG and location on expected biomass yield. A random effect was included for year variability such as stochastic weather events. This model is expressed as

$$y_{til} = \gamma_0 + D_l + \sum_{i=1}^{3-1} \gamma_i I_i + \sum_{i=1}^{3-1} \beta_{il} I_{il} D_{il} + v_t + \varepsilon_{til} \quad [6]$$

where y_{til} is the yield (Mg ha^{-1}) at time t for the ith NWSG treatment and lth location. The null hypothesis was that biomass yields were not different across NWSG treatments and between locations. The MIXED procedure in SAS 9.2 (SAS Institute) was used to estimate the models in Eq. [4–6], and the PDIFF function of LSMEANS was utilized to evaluate means. Significance was determined at $p \leq 0.05$.

RESULTS AND DISCUSSION

Full-Season Grazing

Expected beef yield for full-season grazing by NWSG is presented in Table 5. At AP, there was no difference in expected beef yield across the three NWSGs, but the expected beef yield at HR was 74 kg ha^{-1} higher on SG than BBIG ($P \leq 0.05$). Burns and Fisher (2013) observed no difference in beef yields across SG, BBIG, and EG for the full summer grazing period in North Carolina, which is similar to the results at AP.

Between the locations, the full-season expected beef yield from grazing both BBIG and SG was higher ($P \leq 0.05$) at HR than at AP (Table 5). The expected beef yield was 190 kg ha^{-1} higher for grazing BBIG at HR than at AP and 158 kg ha^{-1} higher for grazing SG at HR than at AP. The differences between locations were probably due to differences in weather and grazing management. The HR location had greater average rainfall and lower average temperatures than the AP location (Table 1), which would promote increased forage production at HR relative to AP, resulting in higher beef yields. The higher temperatures at AP during the study may have also reduced the forage intake of the steers.

At AP and HR, the expected net returns to grazing all NWSGs were greater than zero ($P \leq 0.05$) (Table 5). This means that a profit-maximizing, risk-neutral producer would increase net returns by grazing any of the NWSGs rather than marketing calves at weaning. At AP, there was no difference in net returns across the three NWSGs, but at HR, the expected net returns for grazing BBIG were US\$155 ha^{-1} higher than the net returns to grazing SG (Table 5). Therefore, a profit-maximizing, risk-neutral individual could graze steers on BBIG at HR during the summer months instead of SG, despite the cost of grazing BBIG being higher than the cost of grazing SG. This implies that greater beef yield on BBIG resulted in higher revenue, which was greater than the higher cost of BBIG pasture. Expected net returns from grazing SG and BBIG at HR were greater than at AP, which was due to higher beef yields. Overall, the expected net returns to full-season grazing indicated that the use of any of these NWSGs in a stocker system was profitable at these two locations.

Table 5. Expected beef yield and net returns for full-season grazing with weaned beef steers on three native warm-season grass (NSWG) forages at two locations in Tennessee, 2010–2012.

NWSG†	Beef yield	Net returns
	kg ha^{-1}	US\$ ha^{-1}
Ames Plantation		
SG	256.64 a‡	256.45 a
BBIG	298.73 a	336.59 a
EG	277.59 a	244.75 a
Highland Rim		
SG	488.82 c	852.48 c
BBIG	414.66 b	635.68 b

† BBIG, big bluestem and indiangrass; SG, switchgrass; EG, eastern gamagrass.

‡ In a column, values followed by the same letter across treatments and locations are not significantly different at the 0.05 level.

Early-Season Grazing

Expected beef yields for early-season grazing by NWSG are presented in Table 6. The expected beef yields from early-season grazing were higher ($P \leq 0.05$) for SG than BBIG and EG at AP. There was no difference in expected beef yield ($P \leq 0.05$) for grazing BBIG and EG at AP. There also was no difference in the expected beef yield ($P \leq 0.05$) from early-season grazing between BBIG and SG at HR (Table 6). Between locations, the expected beef yield was highest for SG at AP. Expected beef yields increased on average with the additional days of grazing for BBIG and EG; however, expected beef yields decreased on average with the additional days of grazing for SG at AP. This is probably explained by higher forage quantity for SG at AP during early-season grazing than during full-season grazing (Backus, 2014).

Table 6. Expected beef yield, biomass harvest, and breakeven price of biomass for early-season grazing by native warm-season grass (NWSG) at two locations in Tennessee, 2010 to 2012.

NWSG†	Beef yield	Biomass yield	Breakeven biomass price
	kg ha^{-1}	Mg ha^{-1}	US\$ Mg^{-1}
Ames Plantation			
SG	324.10 b‡	8.65 ab	10.34
BBIG	258.64 a	8.08 ab	43.16
EG	252.92 a	8.80 ab	37.45
Highland Rim			
SG	222.90 a	10.90 b	92.31
BBIG	211.09 a	7.71 a	98.16

† BBIG, big bluestem and indiangrass; SG, switchgrass; EG, eastern gamagrass.

‡ In a column, values followed by the same letter across treatments and locations are not significantly different at the 0.05 level.

At AP, there was no difference ($P \leq 0.05$) in expected biomass yields among BBIG, EG, and SG (Table 6). However, expected biomass yield after early-season grazing was greater ($P \leq 0.05$) for SG than BBIG at HR, producing an additional 3.2 Mg ha^{-1}.

The breakeven price of biomass required by a beef producer to be indifferent between the dual-purpose system and the full-season grazing for each NWSG is presented in Table 6. The expected breakeven price of biomass ranged between US$10 and US$43 Mg^{-1} at AP. This means, for example, that if a beef cattle producer could receive a biomass price of US$44 Mg^{-1}, the producer would be better off using the dual-purpose production system than full-season grazing at AP. The expected breakeven price of biomass for SG and BBIG ranged between US$92 and US$98 Mg^{-1} at HR, which was higher than the breakeven price of biomass at AP. This is explained by the greater net return to full-season grazing at HR relative to AP. That is, the higher net returns to full-season grazing at HR means the price of biomass would have to be much higher for beef producers to forgo grazing for the additional 60 d.

Sensitivity analysis was conducted to show how the breakeven price of biomass would be impacted if the August price of beef increased or decreased (Fig. 1). As the price of beef increased, the breakeven price of biomass also increased for SG at HR, BBIG at HR, BBIG at AP, and EG at AP (Fig. 1). The value of the beef yield from grazing the steer the entire summer would increase; thus, a producer would have to receive a higher biomass price to follow the dual-purpose grazing system. However, the breakeven price of biomass decreased as the price of beef increased for grazing SG at AP (Fig. 1). Steers lost weight grazing SG at AP from Days 30 to 90; thus, a producer would decrease net returns by grazing SG at AP the full season relative to the early-season grazing. The breakeven price of biomass could decrease for a producer to be as profitable as full-season grazing of SG at AP under the dual-purpose system.

Mosali et al. (2013) evaluated animal performance and biomass production of SG in a dual-purpose grazing and biomass production system in Oklahoma. They estimated the breakeven price of biomass required to generate the same net returns for full-season grazing beef production as a dual-purpose early-season grazing and biomass system for three NWSGs. The SG had the lowest expected breakeven price of biomass for all NWSG treatments at both locations, which was similar to what studies have found that compared the breakeven price of biomass for NWSGs under a production system with only biomass harvests (Hallam et al., 2001; Mooney et al., 2009; Griffith et al., 2011; Hong et al., 2013).

CONCLUSIONS

The objectives of this study were to compare net returns for full-season grazing using weaned beef steers in Tennessee on SG, BBIG, and EG at two locations. Moreover, the expected beef yield and biomass production data were also collected for a dual-purpose early-season grazing and biomass system. Therefore, the second objective was to determine the expected biomass price a beef producer would need to break even between using the dual-purpose system and the full-season grazing system for the three NWSG treatments at two locations. The data were collected from two locations from 2010 to 2012. This research provides insight into the profitability of grazing NWSGs in Tennessee and the Southeast. Additionally,

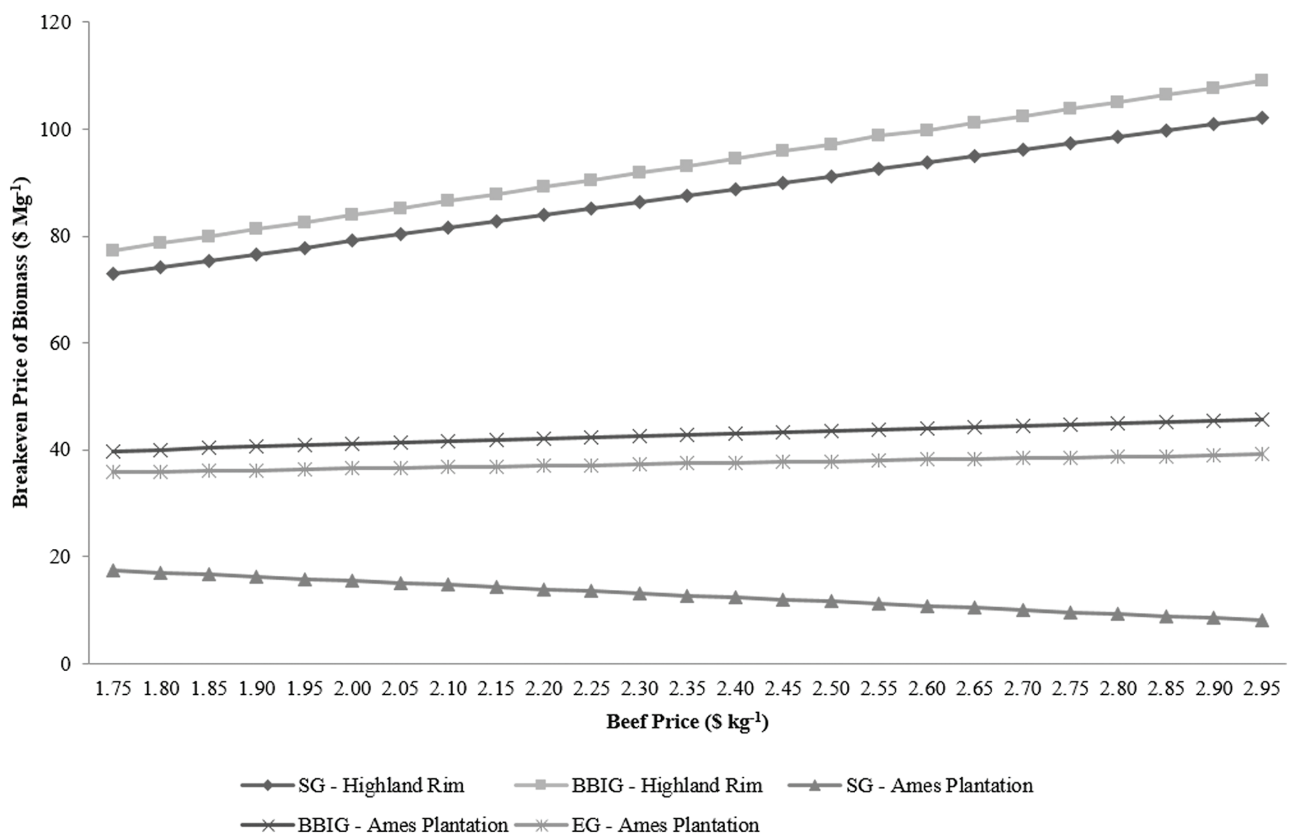

Fig. 1. Changes in the breakeven price of biomass (US$ Mg^{-1}) as the price of beef (US$ kg^{-1}) changes by native warm-season grass—switchgrass (SG), big bluestem–indiangrass mix (BBIG), and eastern gamagrass (EG)—and location.

we provide insight into the biomass prices required for a beef cattle producer to switch from full-season grazing to a dual-purpose grazing and biomass production system.

Expected yield and net returns to full-season grazing were not different among NWSGs at AP. However, expected yield and net returns to full-season grazing were greater for BBIG than SG at HR. The expected net returns to full-season grazing were greater than zero, suggesting that a profit-maximizing, risk-neutral producer would increase net returns by grazing any of the NWSGs rather than marketing calves at weaning. For early-season grazing, the expected beef yield was greatest among NWSGs and locations for SG at AP. The estimated price of biomass required by a beef producer to break even between full-season grazing and using a dual-purpose system ranged between US\$10 and US\$98 Mg^{-1} depending on the NWSG and location.

Further research is needed into how net returns to grazing NWSGs in the Southeast compares with grazing tall fescue during a full-season summer grazing period. A risk analysis of net returns to full-season grazing NWSGs compared with tall fescue would also be of value. Additionally, further research is needed on a dual-purpose grazing and biomass harvest system in the Southeast at different stocking rates and grazing durations to determine how this influences the breakeven price of biomass. Also, there is a need for future research on the breakeven price of biomass from a dual-purpose biomass production system and a strict biomass production system in a side-by-side experiment.

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