Grazing Beef Steers on Native-Warm Season Grasses: Implications for Beef and Biomass Production

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ABSTRACT: Native warm-season grasses (NWSGs) have demonstrated potential to reduce summer forage variability in the region, and there has been growing interest in the use of NWSGs as a lignocellulosic biomass crop. The objectives of this research were to determine if there was a difference in beef yield and net returns for grazing beef steers on three NWSGs during the summer months, and to determine the breakeven price of biomass a beef cattle producer would need to receive to use a dual-purpose grazing and biomass production system. Beef steers grazed switchgrass (*Panicum virgatum* L.) (SG), a big bluestem (*Andropogon gerardii*) and indiangrass (*Sorghastrum nutans*) mixture (BBIG), and eastern gamagrass (*Tripsacum dactyloides*) (EG) at two locations in Tennessee from 2010-2012. The dual-purpose grazing occurred for the first 30-days of summer and the remaining biomass was harvested post-dormancy, and full-season grazing occurred for 90-days of summer. Budgets were developed for each NWSG to calculated net returns, and mixed models were estimated 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 difference across the three NWSGs at AP. However, expected yield and 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 $37-123 Mg^{-1}$ depending on the NWSG and location.

Keywords: Mixed Model, Native Warm Season Grass, Tennessee

Area: Farm Management, Production Economics
INTRODUCTION

Tall fescue (*Festuca arundinacea*) is a cool-season grass that is the primary forage cattle producers rely on for pasture in the Southeast United States (Keyser et al., 2011). Tall fescue has strong growth in the spring and fall months, but physiological characteristics commonly present during the summer grazing months can negatively impact cattle performance and profitability (Smith et al., 2012; Volenec and Nelson, 2007). During the summer months, cattle grazing endophyte-infected tall fescue are confronted with an increased risk of experiencing fescue toxicity. Effects of fescue toxicity on cattle include high body temperature, lower conception rates, reduced average daily gain (ADG), and failure to shed winter coat (Looper et al., 2010; Roberts and Andrae, 2004). Smith et al. (2012) estimated these biological effects of tall fescue toxicity result in annual losses of over one billion dollars to cattle producers.

A possible solution to this problem is to rotate cattle to native warm-season grasses (NWSGs) during the summer months. Several studies have analyzed animal performance on many different NWSGs, but fewer studies have directly compared animal performance on NWSGs. In Nebraska, Krueger and Curtis (1979) found the ADG for yearling steers to be 0.93 kg day$^{-1}$ when grazing switchgrass (SG) (*Panicum virgatum*), 0.70 kg day$^{-1}$ when grazing big bluestem (BB) (*Andropogon gerardii*), and 1.08 kg day$^{-1}$ when grazing indiangrass (IG) (*Sorghastrum nutans*) with total beef gains of 146 kg ha$^{-1}$ on SG, 138 kg ha$^{-1}$ on BB, and 119 kg ha$^{-1}$ on IG. Krueger and Curtis (1979) found total beef gains were higher grazing BB and SG than IG, but the ADG grazing IG was greater than BB and SG. In Iowa, Moore et al. (2004) studied the use of SG and BB as a complement to grazing weaned calves on bromegrass, and found no difference in animal performance between BB and SG.
In the Southeast United States, Burns et al. (1984) found the ADG for steers grazing SG during the summer months was 66% higher than steers grazing a sequence of tall fescue and ‘Coastal’ bermudagrass (*Cynodon dactylon*) 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) (*Tripsacum dactyloides*), SG, and BB in North Carolina over the summer months. Steers grazing EG gained 0.87 kg day\(^{-1}\) with a total beef yield of 752 kg ha\(^{-1}\), steers grazing BB gained 1.08 kg day\(^{-1}\) with a total beef yield of 732 kg ha\(^{-1}\), and steers grazing SG gained 0.91 kg day\(^{-1}\) with a total beef yield of 839 kg ha\(^{-1}\). However, there was not statistical difference in the total beef yield across these three 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 grazing NWSGs could decrease the cost of production by extending grazing days (Anderson et al., 2005; Jordan et al., 1999; Shain et al., 2005). However, if NWSGs are being used to grow cattle prior to marketing then the potential for cattle prices to decrease during the grazing period is an important consideration. The market price of stocker and feeder cattle typically decreases as animals increase in weight. Thus, a producer grazing NWSGs over the summer months has a heavier animal to market and could receive a lower price kg\(^{-1}\) at that time, which makes it difficult to determine if the value of the beef yield from grazing over the summer months was greater than the decrease in price kg\(^{-1}\). Phillips et al. (2004) found calves grazing native range grass in Oklahoma increased net returns for producers by 33% head\(^{-1}\) relative to being placed in a confinement feed-lot after winter wheat grazing. There is little known; however, on the
profitability of grazing NWSGs in the Southeast United States. Knowledge of the net returns to grazing different NWSGs in the southeastern United States would be a unique contribution to the literature as well as benefit Tennessee and southeastern United States cattle producers.

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 (Griffith et al., 2011; Hallam et al., 2001; Heggenstaller et al., 2009; Hong et al., 2013; Mulkey et al., 2008). 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) (Griffith et al., 2011; Hallam et al., 2001; Hong et al., 2013). Currently, there is not a market for biomass in the southeastern United States, but if a market develops, there is a possibility 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 whether SG can be used in a dual-purpose early-season grazing and biomass production system. They found a dual-purpose 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 use of a dual-purpose grazing and biomass system, the research was limited to Oklahoma and 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 determine if there was a difference in expected beef yield and net returns for full-season grazing beef steers in Tennessee on SG, a mixture of big bluestem and indiangrass (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 a beef producer would need to breakeven 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 beef 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 was collected from Ames Plantation in Grand Junction, Tennessee (AP) (35 08N, 89 08W) and Highland Rim Research and Education Center in Springfield, Tennessee (HR) (36 28N, 86 51W) from 2010-2012. Soils at AP were Memphis silt loam, Loring silt loam, and Lexington silt loam, and soils at HR were classified as a Dickson fine-silty loam, siliceous, semiactive, thermic glossic fragiudults (22% clay, 70% silt, 8% sand) with pH of about 6. The NWSG grazing treatments were in a randomized complete block design with three replications of each treatment. The NWSG grazing treatments at AP included SG, BBIG, and EG, and the NWSGs grazed at HR included BBIG and SG. At both locations, 1.214 ha paddocks were established in 2008. Prior to no-till planting, glyphosate was applied to treatment areas for cleanup in the spring of 2008. SG 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 rate of 13.45 kg PLS ha\(^{-1}\). 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 kg K ha\(^{-1}\) 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: 1) early-season grazing and 2) full-season grazing. The early-season grazing period concluded approximately 30-days from the initiation of grazing, and biomass was harvested post-dormancy. The full-season grazing period was terminated approximately 90-days from the initiation of grazing. Table 1 shows rainfall and temperatures by year and location. Grazing duration varied by year, and was often due to rainfall and temperature.

<<< Insert Table 1 Here >>>

**Animal Management**

Tennessee Livestock Producers (Columbia, TN) provided 109 in 2010, 145 in 2011, and 168 in 2012 weaned beef steers for the experiment. Before arriving at AP and HR, the steers were backgrounded for 42 days 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 amount of grazer animals dependent on the forage availability of the NWSG. For full-season grazing, paddocks were stocked to maintain stand height between 38.1 cm and 45.72 cm for BBIG, and grazers were utilized on the SG and EG paddocks to maintain a stand height between 60.96 cm and 76.2 cm. 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 five grazer animals per SG paddock, one per BBIG paddock, and six per EG paddock at HR and AP. In 2012, there were four grazer animals for each SG and EG paddock, and one grazer per BBIG paddock at HR and AP. The total grazing period for all three years ranged from mid-May to early August.

For early-season grazing, grazer animals were used to maintain stand height to between 20.32 cm and 25.4 cm for all NWSG treatments. The initial stocking rate included 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 seven grazer animals per SG paddock, four grazers per BBIG paddock, and eight grazers per EG paddock at each location. In 2012, there were eight grazer animals for each SG and EG paddock, and four grazers per BBIG paddock at both locations.

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 for 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 days pre- and post- grazing. The on pasture
weight was the average of weights from the last two days of the stuffer diet, and the off pasture weight was the average of the last two days of a five-day stuffer diet. For full-season and early-season grazing, the average beginning weight and weight range for beef steers is presented in table 2. ADG was calculated using differences in beginning and ending weights of testers and dividing by the number of days tester steers were grazing. The ADG was multiplied by the total number of grazing days from the tester and grazer animals to find the total beef yield.

<< Insert Table 2 Here >>>

**Budgeting**

Enterprise budgets were used to estimate establishment and operational costs for grazing SG, EG, and BBIG. A 10-year production horizon is 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 (2009). The establishment costs included seed, herbicide, fertilizer, labor, and machinery and was annualized over the life of the pasture using a discount rate of 5.5% (University of Tennessee Switchgrass Budget 2009; U.S. Department of Labor, 2013). The annualized establishment cost was added with annual operational costs and annual land rent to calculate total annual cost of production over a 10-year useful life. To account for the risk of failed establishment, a 10% re-establishment cost was assumed and in the budget.

Based on prices observed in Tennessee, seed costs were assumed to be $36.72 kg for BB, $50.05 kg for IG, $51.26 for EG, and $28.58 kg for SG. Average fertilizer prices were calculated
from 2010-2012 to be $0.59\ kg^{-1} N$, $0.77\ kg^{-1} P$, and $0.83\ kg^{-1} K$ (USDA-NASS, 2013). Fertilizer rates were based on the University of Tennessee Switchgrass recommendations for grazing NWSGs were used for both the full-season and early-season grazing periods. The annual applications $67\ kg\ N\ ha^{-1}$, $34\ kg\ P\ ha^{-1}$, and $34\ kg\ K\ ha^{-1}$. Estimated total annualized pasture costs in 2012 dollars for the NWSGs are shown in Table 3.

Some operational costs were different between the early- and full-season grazing treatments. 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 $24.98\ ha^{-1}$ and $9.59\ ha^{-1}$, respectively. Baling and staging costs were $14.64\ bale^{-1}$ and $4.50\ bale^{-1}$, respectively. Harvest costs are included in Table 3 for the dual-purpose grazing and biomass production system.

The average historic prices for 272.1-317.45 kg steers in Tennessee in the month of May from 2002-2011 (McKinley and Griffith, 2012) were used to reflect the purchase price of steers to graze on a NWSG, or the opportunity cost of grazing steers on a NWSG instead of marketing them at the beginning of the grazing period. The average price for 272.1-317.45 kg steers in Tennessee for the month of August were 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 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 and the average price of beef was $2.56\ kg^{-1}$ in May and $2.58\ kg^{-1}$ in
August. For early-season grazing, the average price for 272.1- 317.45 kg steers in Tennessee for the month of June from 2002-2011 (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 $2.56 kg$^{-1}$ in June. It is assumed steers are marketed immediately after being removed from pastures for both early and full-season grazing.

**Economic Framework**

For producers that traditionally market their calves after a short weaning period, the decision to graze a 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 NWSGs instead of marketing them at the beginning of the grazing period. The producer’s expected net returns to grazing NWSG is expressed as

$$E[NR_i^f] = E[((p_m^f \times w_i^f) - (p_p \times w_p)) - AEC_i - OC_i - LR]$$  \[1\]

where $E[NR_i^f]$ is expected annual net returns ($\text{\$ ha}^{-1}$) for full-season grazing ($f$) the $i$th ($i=1, \ldots, 3$) NWSG treatment; $p_m^f$ is the marketing price of beef ($\text{\$ kg}^{-1}$) 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 $i$th NWSG treatment; $p_p$ is the purchase price of beef steers ($\text{\$ kg}^{-1}$) 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 $i$th NWSG treatment; $AEC_i$ is annualized pasture establishment cost ($\text{\$ ha}^{-1}$) for NWSG treatment $i$; $OC_i$ is the annual operational pasture cost ($\text{\$ ha}^{-1}$), including
pasture maintenance, mowing, and fertilizer; and \( LR \) is the annual land rent ($ ha\(^{-1}\)). The opportunity cost of grazing the steers over the summer months instead of marketing them at the beginning of the grazing period is represented by \((p_p \times w_p)\). The establishment cost of the pasture includes the cost of seed, fertilizer, herbicide, and land rent in year zero. Establishment cost is annualized to determine the annual expected net returns over the useful life of the pasture.

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 estimate the price of biomass a beef producer would need to receive to remove cattle from the pasture and harvest the NWSGs for biomass. This price of biomass indicates the price were a producer would receive greater expected net returns using a dual-purpose system instead of 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 of the NWSGs can be calculated using the following equation:

\[
E[NR^e_i] = E\left[ \left( (p_m^e \times w_m^e) - (p_p \times w_p) \right) + (p_{bm}^i \times z_i) - AEC_i - OC_i - LR - h(z_i) \right]
\]

where \( E[NR^e_i] \) is the annual expected net return ($ ha\(^{-1}\)) for early-season grazing, \( e \), the \( i \)th NWSG treatment; \( p_m^e \) is the marketing price of beef ($ kg\(^{-1}\)) at the end of the early-season grazing period; \( w_m^e \) is the final weight (kg ha\(^{-1}\)) of the steers when sold at the end of the early-season grazing period for the \( i \)th NWSG treatment; \( p_{bm}^i \) is the price of biomass ($ Mg\(^{-1}\)); \( z_i \) is the
biomass yield (Mg ha\(^{-1}\)) for NWSG treatment \(i\); and \(h(z_i)\) is the harvest cost ($ ha\(^{-1}\)) for the \(i\)th NWSG treatment, where the harvest cost is a function of yield.

Since \(p_{i,m}^{hm}\) 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 \(p_{i,m}^{hm}\) 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

\[
E[p_{i,m}^{hm}] = E\left[ \frac{(p_{m}^{f} \times w_{f}^{e}) - (p_{m}^{e} \times w_{i}^{e}) + h(z_i)}{z_i} \right].
\]  

[3]

The NWSG that results in the lowest breakeven price of biomass will likely 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 on the expected beef yield, net returns to grazing, biomass yield, and breakeven price of biomass at the two locations. 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

\[
BY_{itl} = \gamma_0 + D_l + \sum_{i=1}^{3} \gamma_i I_i + \sum_{i=1}^{3} \beta_{il} I_{il} D_l + v_t + \epsilon_{itl}
\]  

[4]

where \(BY_{itl}\) is the beef yield (kg ha\(^{-1}\)) at time \(t\) for grazing the \(i\)th NWSG treatment and \(l\)th location; \(\gamma_0\) is the intercept coefficient for NWSG treatment \(i\); \(D_l\) is an indicator variable for
location \( l \); \( \gamma_i \) is the coefficient for NWSG treatment \( i \); \( I_i \) is an indicator variable for NWSG treatment \( i \); \( \beta_{il} \) is the coefficient for the interaction term for NWSG treatment \( i \) and location \( l \); \( \nu_t \sim N(0, \sigma_{\nu}^2) \) is the year random effect; and \( \epsilon_{til} \sim N(0, \sigma_{\epsilon}^2) \) 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 NWSG and location. 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 treatment and location, which is expressed as

\[
NR_{til} = \gamma_0 + D_i + \sum_{i=1}^{3-1} \gamma_i I_i + \sum_{i=1}^{3-1} \beta_{ii} I_i D_i + \nu_t + \epsilon_{til} \quad [5]
\]

where \( NR_{til} \) is the net returns (\$ ha\(^{-1}\)) at time \( t \) for full-season grazing the \( i \)th NWSG treatment and \( l \)th location. The null hypothesis was that expected net returns were not different across NWSG treatments and between locations. These results will provide insight into the profitability of a full-season grazing NWSGs in the Southeast United States.

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

\[
y_{il} = \gamma_0 + D_i + \sum_{i=1}^{3-1} \gamma_i I_i + \sum_{i=1}^{3-1} \beta_{ii} I_i D_i + \nu_t + \epsilon_{il} \quad [6]
\]

where \( y_{il} \) is the yield (Mg ha\(^{-1}\)) at time \( t \) for the \( i \)th NWSG treatment and \( l \)th location. The null hypothesis was that biomass yields were not different across NWSG treatments and between locations. The MIXED procedure in SAS 9.2 was used to estimate the models in Eq. [4]-[6] and
PDIFF function of LSMEANS was utilized to evaluate means. (SAS Institute Inc., 2004)
Significance was determined at $p \leq 0.05$.

**RESULTS**

**Full-Season Grazing**

Expected beef yield for full-season grazing by NWSG is presented in Table 4. At AP, the there was no difference in expected beef yield across the three NWSGs. The expected beef yield at HR was 74 kg ha$^{-1}$ higher on BBIG than SG ($p \leq 0.05$). Burns and Fisher (2013) also observed no difference in beef yields across SG, BBIG, and EG for the full summer grazing period in North Carolina.

<< Insert Table 4 Here >>>

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. The expected beef yield was 190 kg ha$^{-1}$ higher for grazing BBIG at HR than AP, and 158 kg ha$^{-1}$ higher for grazing SG at HR than at AP. The differences between locations were largely explained by weather during the study. 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 forage intake of steers at AP.

Expected net returns for full-season grazing by NWSG are presented in Table 4. At AP and HR, the expected net returns to grazing all the NWSGs were greater than zero ($p \leq 0.05$). This means a profit-maximizing, risk neutral individual would increase net returns by grazing
any of the NWSGs over 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 $155 ha$^{-1}$ higher return than net returns to grazing SG. Therefore, a profit-maximizing, risk-neutral individual could graze steers on BBIG at HR over the summer months instead of SG, despite the cost of the grazing BBIG was higher than the cost of grazing SG. This implies that higher in beef yield on BBIG resulted in higher revenue which was greater than the higher cost of BBIG pasture. Expected net returns were more profitable grazing SG and BBIG at HR than at AP, which is due to higher beef yields. Overall, the expected net returns to full-season grazing found in this study indicated the use of any of these NWSGs in a stocker system was profitable at these two locations.

**Early-Season Grazing**

Expected beef yields for early-season grazing by NWSG are presented in Table 5. The expected beef yield from early-season grazing were higher ($p \leq 0.05$) for SG than BBIG and EG at AP. The expected beef yield was 324 kg ha$^{-1}$ for grazing SG, 258 kg ha$^{-1}$ for grazing BBIG, and 253 kg ha$^{-1}$ for grazing EG. There was no difference in expected beef yield ($p \leq 0.05$) for grazing BBIG and EG at AP. There was no difference in the expected beef yield ($p \leq 0.05$) from early-season grazing of BBIG and SG at HR. 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 likely explained by higher forage quantity for SG at AP during early-season grazing than during full-season grazing (Backus, 2014).
Results for the expected biomass yield by NWSG are also presented in Table 5. At AP, there was no difference \((p \leq 0.05)\) across the expected biomass yields for BBIG, EG, and SG. The expected biomass was 8.8 Mg ha\(^{-1}\) for EG, 8.6 Mg ha\(^{-1}\) for SG, and 8.1 Mg ha\(^{-1}\) for BBIG. However, expected biomass yield after early-season grazing was higher \((p \leq 0.05)\) for SG than BBIG at HR, producing an additional 3.2 Mg ha\(^{-1}\) more biomass than BBIG. Between the locations, the expected biomass was not different across the NWSGs.

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 5. The expected breakeven price of biomass ranged between $37-56 Mg\(^{-1}\) at AP. This means, for example, if a beef cattle producer could receive a price of biomass of $57 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 $118-123 Mg\(^{-1}\) at HR, which was higher than the breakeven price of biomass at AP. This is most likely 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 days.

Mosali et al. (2013) evaluated animal performance and biomass production of SG in a dual-purpose grazing and biomass production system in Oklahoma. This study extends Mosali et al. (2013) by estimating 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. SG had the lowest expected breakeven price of biomass for all NWSG
treatments at both locations, which is similar to what studies find that compare the breakeven price of biomass for NWSGs under a production system with only biomass harvests (Griffith et al., 2011; Hallam et al., 2001; Hong et al., 2013; Mooney et al., 2009).

CONCLUSIONS

The objectives of this study were to determine if there was a difference in expected beef yield and net returns for full-season grazing beef steers in Tennessee on SG, BBIG, and EG at two locations. Moreover, 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 breakeven 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 2010-2012. This research provides insight into the profitability of grazing NWSGs in Tennessee and the Southeast. Additionally, we provide insight into biomass prices required for a beef cattle producer to switch to a dual-purpose grazing and biomass production system.

Expected yield and net returns to full-season grazing were not difference across the three NWSGs at AP. However, expected yield and net returns to full-season grazing were higher 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 individual would increase net returns by grazing any of the NWSGs over marketing calves at weaning. For early-season grazing, the expected beef yield was highest across all NWSGs and location for SG at AP. The estimated price of
biomass required by a beef producer to breakeven between full-season grazing and using a dual-purpose system ranged between $37-$123 Mg$^{-1}$ depending on the NWSG and location.

Further research is needed into how net returns to grazing NWSGs in the Southeast compares to grazing fescue during a full-season summer grazing period. A risk analysis of net returns to full-season grazing NWSGs compared to 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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Table 1. Average daily temperature (C°) and total rainfall (cm) during grazing months by location and year

<table>
<thead>
<tr>
<th></th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
<th>Average</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Temp.†</td>
<td>Rainfall</td>
<td>Temp.</td>
<td>Rainfall</td>
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<tr>
<td><strong>Ames Plantation</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>May</td>
<td>21.91</td>
<td>34.29</td>
<td>19.93</td>
<td>13.41</td>
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<tr>
<td>June</td>
<td>27.62</td>
<td>1.45</td>
<td>26.54</td>
<td>8.74</td>
</tr>
<tr>
<td>July</td>
<td>28.05</td>
<td>22.71</td>
<td>28.20</td>
<td>7.54</td>
</tr>
<tr>
<td>August</td>
<td>28.32</td>
<td>6.05</td>
<td>25.00</td>
<td>5.31</td>
</tr>
<tr>
<td>May-August</td>
<td>26.48</td>
<td>64.5</td>
<td>25.41</td>
<td>35.00</td>
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<tr>
<td></td>
<td><strong>Highland Rim</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>June</td>
<td>26.23</td>
<td>9.58</td>
<td>25.71</td>
<td>12.88</td>
</tr>
<tr>
<td>July</td>
<td>27.40</td>
<td>3.33</td>
<td>27.23</td>
<td>7.14</td>
</tr>
<tr>
<td>August</td>
<td>27.10</td>
<td>7.39</td>
<td>25.72</td>
<td>5.08</td>
</tr>
<tr>
<td>May-August</td>
<td>25.30</td>
<td>46.56</td>
<td>24.32</td>
<td>38.31</td>
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</tbody>
</table>

† Source: NOAA, Milan, TN weather station.
Table 2. Beginning weight (in kg) of beef steers for full-season and early-season grazing periods

<table>
<thead>
<tr>
<th>Location</th>
<th>Grazing Period</th>
<th>Year</th>
<th>Minimum Weight</th>
<th>Maximum Weight</th>
<th>Average Weight</th>
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<tr>
<td>Ames Plantation</td>
<td>Full-Season</td>
<td>2010</td>
<td>247.61</td>
<td>291.15</td>
<td>267.57</td>
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<td>2011</td>
<td>219.94</td>
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<td></td>
<td></td>
<td>2012</td>
<td>233.55</td>
<td>273.00</td>
<td>250.89</td>
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<tr>
<td></td>
<td>Early-Season</td>
<td>2010</td>
<td>245.39</td>
<td>293.93</td>
<td>268.47</td>
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<td>2011</td>
<td>232.46</td>
<td>278.50</td>
<td>258.79</td>
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<td></td>
<td></td>
<td>2012</td>
<td>215.00</td>
<td>274.42</td>
<td>253.30</td>
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<tr>
<td>Highland Rim</td>
<td>Full-Season</td>
<td>2010</td>
<td>244.03</td>
<td>295.28</td>
<td>269.08</td>
</tr>
<tr>
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<td>2011</td>
<td>251.28</td>
<td>278.95</td>
<td>265.08</td>
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<td>2012</td>
<td>255.37</td>
<td>291.20</td>
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<tr>
<td></td>
<td>Early-Season</td>
<td>2010</td>
<td>250.84</td>
<td>298.46</td>
<td>267.92</td>
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<tr>
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<td></td>
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<td>249.02</td>
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<td></td>
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<td>2012</td>
<td>263.54</td>
<td>294.38</td>
<td>277.71</td>
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### Table 3. Total annualized pasture costs ($ ha$^{−1}$) for establishing and maintaining the native warm-season grasses pastures over a ten year useful life.

<table>
<thead>
<tr>
<th>Total Pasture Costs</th>
<th>BBIG†</th>
<th>EG†</th>
<th>SG†</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Establishment Costs</strong></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>NWSG Seed‡</td>
<td>$487.08</td>
<td>$575.51</td>
<td>$192.51</td>
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<tr>
<td>Establishment§</td>
<td>$517.51</td>
<td>$517.51</td>
<td>$574.00</td>
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<tr>
<td>Risk of Re-establishment¶</td>
<td>$100.46</td>
<td>$109.30</td>
<td>$76.65</td>
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<tr>
<td><strong>Total</strong></td>
<td>$1,105.06</td>
<td>$1,202.32</td>
<td>$843.16</td>
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<tr>
<td>Annualize Establishment</td>
<td>$146.61</td>
<td>$159.51</td>
<td>$111.86</td>
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<tr>
<td><strong>Operational Costs</strong></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Fertilizer</td>
<td>$195.95</td>
<td>$195.95</td>
<td>$195.95</td>
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<tr>
<td>Land Rent</td>
<td>$51.87</td>
<td>$51.87</td>
<td>$51.87</td>
</tr>
<tr>
<td><strong>Total Annual Pasture Cost</strong></td>
<td>$415.46</td>
<td>$428.36</td>
<td>$380.72</td>
</tr>
</tbody>
</table>

† BBIG=Big Bluestem and Indiangrass; EG= Eastern Gamagrass; SG= Switchgrass.
‡ Seed cost was $36.72 kg$^{−1}$ for big bluestem, $50.05$ kg$^{−1}$ for indiangrass, $51.26$ kg$^{−1}$ for eastern gamagrass, and $28.58$ 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 Switchgrass, Budget 2009).
¶ Total NWSG establishment costs include 10% risk of failed establishment that results in replanting.
Table 4. Expected beef yield (kg ha\(^{-1}\)) and net returns ($ ha\(^{-1}\)) for full-season grazing by native warm-season grass and location

<table>
<thead>
<tr>
<th>NWSG</th>
<th>Beef Yield</th>
<th>Net Returns</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Ames Plantation</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SG†</td>
<td>256.64a‡</td>
<td>$281.40a</td>
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<td>BBIG†</td>
<td>298.73a</td>
<td>$355.27a</td>
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<td>EG†</td>
<td>277.59a</td>
<td>$287.82a</td>
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<tr>
<td><strong>Highland Rim</strong></td>
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<tr>
<td>SG†</td>
<td>414.66b</td>
<td>$680.81b</td>
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<td>BBIG†</td>
<td>488.82c</td>
<td>$835.91c</td>
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</tbody>
</table>

† BBIG=Big Bluestem and Indian Grass; SG=Switchgrass; EG=Eastern Gamagrass.
‡ 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.
Table 5. Expected beef yield (kg ha\(^{-1}\)), biomass harvest (Mg ha\(^{-1}\)), breakeven price of biomass ($ Mg\(^{-1}\)) for early-season grazing by native warm-season grass and location

<table>
<thead>
<tr>
<th>NWSG</th>
<th>Beef Yield</th>
<th>Biomass Yield</th>
<th>Breakeven Biomass Price</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Ames Plantation</strong></td>
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<td></td>
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<tr>
<td>SG†</td>
<td>324.10b‡</td>
<td>8.65a,b</td>
<td>$44.18a</td>
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<tr>
<td>BBIG†</td>
<td>258.64a</td>
<td>8.08a,b</td>
<td>$37.29a</td>
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<td>EG†</td>
<td>252.92a</td>
<td>8.80a,b</td>
<td>$56.42a</td>
</tr>
</tbody>
</table>

| **Highland Rim** |            |               |                         |
| SG†      | 222.90a   | 10.90b        | $123.43b                 |
| BBIG†    | 211.09a   | 7.71a         | $118.55b                 |

†BBIG=Big Bluestem and Indian Grass; SG=Switchgrass; EG=Eastern Gamagrass.
‡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.