12-2013

The Economics of Grazing Beef and Dairy Cattle on Native Warm-Season Grasses in Tennessee

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I am submitting herewith a thesis written by Joe Kenneth Lowe entitled "The Economics of Grazing Beef and Dairy Cattle on Native Warm-Season Grasses in Tennessee." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Agricultural Economics.

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The Economics of Grazing Beef and Dairy Cattle on Native Warm-Season Grasses in Tennessee

A Thesis Presented for the
Master of Science Degree
The University of Tennessee, Knoxville

Joe Kenneth Lowe
December 2013

Abstract

Two separate studies focusing on the economics and animal performance of grazing native warm-season grasses (NWSGs) are presented in this thesis. In the first study, the first objective was to determine if there was a difference in net returns to full-season grazing of beef steers on switchgrass (SG), big bluestem and indiangrass (BBIG), and eastern gamagrass (EG). The second objective was to determine the price of biomass a producer would need to receive to breakeven between full-season grazing beef steers and early-season grazing with a biomass harvest (i.e., a dual purpose grazing and biomass production system) for SG, BBIG, and EG. Mixed models were used to evaluate differences in expected beef yield and net returns from full-season grazing across the NWSGs for the first objective. Mixed models were also used to evaluate differences in expected beef yield, net returns, biomass yield, and the breakeven price of biomass from early-season grazing across the NWSGs for the second objective. Results from the first study indicate the profitability of grazing the NSWGs depends on the location, but on average steers grazing SG had the highest expected net returns to full-season grazing. Additionally, SG had the lowest expected breakeven price of biomass.

In the second study, the objective was to determine the cost of grazing SG and BBIG, with and without legumes, in bred dairy heifer development and compare the cost of grazing to the cost of using traditional feedstuffs. Mixed models were used to evaluate differences in expected cost per animal unit day (AUD) and expected average daily gain (ADG) across the NWSG treatments. The ADG for the Holstein heifers grazing NWSGs was used to design feed rations to obtain the same ADG over the same number of days. The cost day^-1 [cost per day] of using these rations was calculated with different daily yardage fees and compared the cost

AUD^-1 [cost per animal unit day] of grazing bred dairy heifers on NWSGs. Results from the second study indicate SG to have the lowest expected cost AUD^-1 of developing bred dairy heifers of all the NWSGs and feed rations.

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Chapter 1: Introduction

Tall fescue is a cool-season grass that is adaptable, easy to establish, and persistent under adverse conditions (Stuedemann and Hoveland 1988; Wolf et al. 1979). For these reasons, tall fescue is the primary forage cattle producers rely on for pasture and hay in the Southeast United States (Keyser et al. 2011a) and covers over 3.5 million acres in Tennessee (Bates 1994). While fescue has strong growth in April and May as well as in the fall season, physiological characteristics of tall fescue can cause problems for cattle producers during the summer months (Volenec and Nelson 2007).

Most tall fescue planted prior to 1980 is infected with a microscopic fungus (*Neotyphodium coenophialum*), often referred to as an endophyte (Roberts and Andrae 2004). The same endophyte that causes the plant to be persistent in a southeastern environment has a negative impact on cattle (Bates 1994). During the summer months, cattle grazing endophyte-infected fescue are confronted with an increased risk of experiencing fescue toxicity. Effects of fescue toxicity on cattle include high body temperature, reduced average daily gain (ADG), and failure to shed winter coat (Roberts and Andrae 2004). In addition to these symptoms, Looper et al. (2010) found that females grazing endophyte-infected fescue experienced lower conception rates than those consuming a novel endophyte variety. There is also decreased milk production by lactating cows grazing endophyte-infected fescue (Bates 1994). These biological effects of fescue toxicity result in losses of over $1 billion a year to cattle producers (Smith et al. 2012). Along with the negative impact of fescue toxicity, decreased forage yield during the summer months presents another obstacle to cattle producers. In a continuous grazing system, options producers have to deal with diminished summer fescue growth are to provide cattle with relatively expensive supplement feedstuffs or to reduce stocking rate.

A possible solution to the problems with grazing fescue during the summer months is to use complementary grazing. Complementary grazing is the rotation of cattle between cool- and warm-season grasses during the spring, summer, and fall months. This practice can increase grazing days and help improve pastures by allowing a rest period for cool-season grasses during the summer months (Moore et. al 2004). A low-input option for a complementary grazing system would be to use native warm-season grasses (NWSGs) along with a cool-season forage program (Moore et al. 2004; Mousel et al. 2006; Smith et al. 2009).

NWSGs 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. 2011a). The ideal conditions for growing NWSGs are when temperatures are between 29.4 and 35 degrees C (Harper et al. 2007). NWSGs have a different photosynthetic system than cool-season grasses, allowing them to be both more drought and heat tolerant than cool-season grasses (Brown 1999). Studies have shown that warm-season range grasses yield between 65% and 75% of their annual production during mid-summer (Jung et al. 1978), and that NWSGs averaged 205% greater forage yield in July and August compared to cool-season grasses in central Illinois (Tracy et al. 2010). NWSGs ability to tolerate heat and drought along with being responsive to nitrogen (N) fertilizer make them a potential candidate for complementary grazing in the southeastern United States (Doxon et al. 2011; Harper et al. 2007).

In the southeastern United States, there are four NWSGs commonly used to graze livestock: 1) switchgrass (SG) (*Pancium virgatum*); 2) big bluestem (BB) (*Andropogon gerardii*); 3) eastern gamagrass (EG) (*Tripsacum dactyloides*); and 4) indiangrass (IG) (*Sorghastrum nutans*) (Keyser et al. 2011b). SG begins growth in April and May and is suitable

for livestock grazing and hay production in the majority of the continental United States (Stubbendiek et al. 1997). SG is drought tolerant and can be adapted to poorly drained soils (Ball et. al 2007). BB is palatable (Tomanek et al. 1958) and can contain crude protein levels of 16-18% from May through August (Owsley 2011) when the protein level of tall fescue is at its lowest (Volenec and Nelson 2007; Wolf et al. 1979). EG is adaptable to moist, fertile soil in the southeastern United States and suitable for grazing and hay throughout the growing season beginning in late spring (Stubbendiek et al. 1997). IG is commonly used in a mixture with other NWSGs and is known to be highly adaptable to the southeastern United States, and highly palatable to cattle before the forage reaches maturity (Stubbendiek et al. 1997).

Annual warm-season grasses (AWSGs) are another low-input summer forage alternative to complement grazing cool-season grasses. Tracy et al. (2010) found that NWSGs were more difficult to establish than AWSGs, but NWSGs yielded 65% greater herbage mass over a three-year period in Illinois. Although there was a higher initial cost associated with the NWSG establishment compared to AWSGs, the initial savings of an AWSGs system were offset by management costs of machinery and fertilizer associated with repeated establishment over time (Tracy et al. 2010). Tracy et al. (2010) found no difference in animal performance from grazing AWSGs and NWSGs despite higher nutrient levels in the AWSGs. The study found ADG did not vary when grazing a mixture of EG, BB, and IG with kura clover (*Trifolium ambiguum*) compared to grazing AWSGs. For these reasons, NWSGs appeared to be a better long-term solution for summer forage needs than AWSGs.

However, there can be some disadvantages associated with grazing NWSGs. NWSGs can be expensive to establish, and no grazing or hay production should be expected during the

establishment year while the root system is developing (Harper et al. 2007; Keyser et al. 2011a). In the second year, most NWSG have not reached full yield potential and should be utilized lightly in grazing and hay production (Harper et al. 2007). Once established, grazing NWSGs requires careful management by producers. If pastures are overgrazed, areas will be killed out, and if it is under-utilized, pastures will go to seed, decreasing nutritional value and palatability of the forage (Harper et al. 2007).

The use of NWSGs is not limited to grazing beef cattle, but there has been a substantial amount of research that has studied the use of NWSGs as a lignocellulosic biomass crop (Griffith et al. 2011; Hallam et al. 2001; Haggenstaller et al. 2009; Hong et al. 2013; Mulkey et al. 2008). There is not a market for biomass in the southeastern United States, but if a market develops, there is a possibility that high biomass prices could result in beef producers using a dual-purpose biomass and grazing system to maximize profits. In this system, NWSG would be grazed for a short period of time, and animals would be removed mid-summer. The biomass growth from the last grazing day to dormancy would then be available to harvest for biomass production (Mosali et al. 2013). The current literature has primarily focused on producing NWSGs for biomass in a strict biomass production system, but beef producers might be able to increase profits using a dual-purpose early-season grazing and biomass harvest production system if the biomass price is high enough.

Two separate studies are presented on the economics and animal performance of grazing NWSGs in the Southeast United States. For the first study, the first objective was to determine if there was a difference in net returns to full-season grazing of beef steers across three NWSG treatments, and the second objective was to determine the price of biomass a beef producer

would need to breakeven between full-season grazing beef steers and using a dual-purpose early-season grazing and biomass harvest system for the three NWSGs. In the second study, the objective was to determine the cost of grazing four NWSG treatments in bred dairy heifer development and compare the cost of grazing to the cost of development using traditional feedstuffs.

Estimating the profitability of grazing beef and dairy cattle on monocultures and polycultures of NWSGs in the southeastern United States would be a unique contribution to the literature. Studies of stocker cattle grazing NWSGs have mainly been outside of the southeastern United States, and these studies provide limited information on the net returns to grazing monocultures and polycultures of NWSGs. Additionally, this research provides insight on how a dual-purpose grazing and biomass production system in the southeastern United States could affect the breakeven price of biomass. The research would also benefit beef producers in the Southeast United States by determining if grazing NWSGs is profitable. Finally, determining the cost of using NWSGs in a bred dairy heifer grazing program, and how it compares to traditional feed costs in the southeastern United States would benefit dairy heifer developers and expand the current literature.

Chapter 2: The Economics of Grazing Beef Steers on Native Warm-Season Grasses

Abstract

There is limited research on the economics of grazing beef steers on native warm-season grasses (NWSGs). The objectives of this research were 1) to determine if there is a difference in expected net returns to full-season grazing beef steers on three NWSGs, and 2) determine the price of biomass a beef producer would require to breakeven between full-season grazing beef steer and using a dual-purpose early-season grazing and biomass harvest system for the three NWSGs. From 2010-2012, beef steers grazed switchgrass (SG), a big bluestem and indiangrass mixture (BBIG), and eastern gamagrass (EG) at Ames Plantation (AP) and beef steers grazed SG and BBIG at the Highland Rim Research and Education Center (HR). At both locations and for all the NWSG treatments, steers were grazed for a full-season and for an early-season period. The early-season grazing treatments concluded approximately 30-days from the initiation of grazing while the full-season grazing treatments were grazed for approximately 90-days before termination. After early-season grazing was completed, the forage was allowed to grow biomass until post dormancy when forage samples were taken to estimate a biomass yield. Expected beef yield (kg ha^{-1}) and expected net returns ($ ha^{-1}) to grazing were calculated for the full-season treatments and the expected beef yield, biomass yield (Mg ha^{-1}), and the breakeven price of biomass ($ Mg^{-1}) were calculated for the early-season treatments.

There was no difference in the expected beef yield from full-season grazing across the NWSG treatments within the location. However, the beef yield from full-season grazing SG and BBIG were statistically higher at HR than at AP, which might be explained by weather differences. Expected net returns to grazing at AP for BBIG, EG, and SG were $311.63 ha^{-1}, $235.02 ha^{-1}, and $331.16 ha^{-1}, respectively. At AP, expected net returns to grazing NWSGs

were not statistically different across treatments. While net returns to grazing BBIG and SG at AP were statistically greater than zero, net returns to EG were not different from zero. The expected net returns to grazing BBIG and SG at HR were significantly different from zero, but there was no statistical difference in the expected net returns to grazing of \$738.83 ha^{-1} for BBIG and \$836.45 ha^{-1} for SG.

Expected beef yield from early-season grazing did not vary among NWSG treatments within a location, and there was no difference in expected beef yield across locations for the NWSG treatments. At AP, the expected breakeven price of biomass for a beef producer using a dual-purpose grazing and biomass system was not different across all NWSG treatments. At AP, the expected breakeven price for biomass for BBIG, EG, and SG in a dual-purpose grazing and biomass system was \$41.51 Mg^{-1}, \$37.19 Mg^{-1}, and \$20.43 Mg^{-1}, respectively. At HR, the expected breakeven price of biomass in a dual-purpose grazing and biomass system was \$81.57 Mg^{-1} for SG, which was statistically lower than the expected breakeven price of biomass of \$110 Mg^{-1} for BBIG. However, the expected breakeven price of biomass for both SG and BBIG was statistically higher at HR than at AP.

Furthermore, there was no statistical difference in expected beef yield or net return between full- and early-season grazing for each NWSG treatment at AP. This indicates the additional 60 days of grazing did not increase beef yield or net returns at AP. Both beef yield and net return at HR were statistically higher for full-season grazing than early-season grazing within the same NWSG treatment.

Introduction

There has been a substantial amount of research conducted on stocker beef cattle grazing native warm season grasses (NWSGs) across the western United States. However, native range grasses were often grazed within a complementary grazing system prior to feed-lot entry and animal performance from grazing monocultures of NWSGs was not the focus of the research (Jordan et al, 1999; Shain et al. 2005; Hudson et al. 2010). While most of the research on grazing NWSGs has been in a range pasture within a cattle finishing system, there have been multiple studies determining the differences animal performance from grazing monocultures of NWSGs. In Nebraska, Krueger and Curtis (1979) found the average daily gain (ADG) for yearling steers was 0.93 kg day^{-1} when grazing switchgrass (SG), 0.70 kg day^{-1} for grazing big bluestem (BB), and 1.08 kg day^{-1} for grazing indiangrass (IG), and the total beef gains were 146 kg ha^{-1} on SG, 138 kg ha^{-1} on BB, and 119 kg ha^{-1} on IG. The results from Krueger and Curtis (1979) found that the total gains were statistically higher for BB and SG than IG, but the ADG for IG was statistically higher 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, with and without legumes. They found no difference in animal performance between BB and SG.

In the southeastern United States, research on animal performance of beef cattle grazing NWSGs is more limited. 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 in North Carolina. In addition, steers grazing SG yielded 322 kg ha^{-1} of gain before the Coastal bermudagrass was first available to graze. Burns and Fisher (2013) compared ADG and total beef yield of steers grazing monocultures of eastern gamagrass (EG), SG, and BB in

North Carolina over the summer months. The 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}. The total beef yield was highest for SG because it could support a higher stocking rate than other NWSGs.

Along with the animal performance benefits, grazing NWSGs could potentially provide economic benefits to producers (Lewis et al. 1990). With a fall calving herd, producers could market calves at weaning in April or May or could graze the stockers throughout the summer. During the traditional weaning period for the fall herd, tall fescue is still at the peak of its spring growth curve, allowing for relatively cheap cost of gain. Grazing NWSGs could potentially extend the grazing period for fall born calves, providing a relatively cheap cost of gain compared to mechanically harvested feeds in the feedlot (Peel 2006; Phillips et al. 2004; Shain et al. 1998; Shain et al. 2005). According to Peel (2006), there was an inverse relationship between grazing days and the breakeven price of production.

Jordan et al. (1999) found that steers in Nebraska that grazed warm-season range grasses had a lower breakeven price of production than cattle sequentially removed from bromegrass or Sandhill prairie. The study found additional grazing days reduced the breakeven price of producing beef because steers gained weight on forage with a fixed cost instead of the variable cost of harvested feeds. Anderson et al. (2005) found the use of NWSGs post weaning for fall born steers in Nebraska reduced days in the feedlot, lowering the breakeven price of production from calving to slaughter by \$0.15 kg^{-1}. A five-year study in Nebraska found that the use of native range grasses in a complementary grazing system of cool- and warm-season grass reduced the breakeven price at slaughter by 3% relative to continuous bromegrass grazing because

producers were able to maximize the gains on forage before entry to the feedlot (Shain et al. 2005). Along with greater gains on forage, cattle in a complementary grazing system also had greater feed-efficiency once placed in the feedlot, fewer days on feed, and a \$0.04 kg^{-1} lower breakeven price (Shain et al. 2005). Moreover, Hudson et al. (2010) found that producers were able to use a late summer grazing period with fall born calves without conceding carcass quality. Steers that were late weaned and placed on native tall grass prairie in Oklahoma had a greater hot carcass weight at time of slaughter than those sent to feedlot earlier (Hudson et al. 2010). The ability to extend grazing without conceding carcass quality is especially important if producers retain ownership of their calves in the feedlot.

Much of the research on the economics of grazing NWSGs has been focused in the western and mid-western United States, and much of it is with respect to complementary grazing native rangelands with crested wheatgrass (Hart et al. 1988; Lodge 1963), bromegrass (Moore et al. 2004; Shain et al. 2005), and native tall-grass prairie (Anderson et al. 2008; Faulkner et al. 2010; Jordan et al. 1999; Owensby et al. 2008; Peel 2006; Shain et al. 2005). Additionally, these studies have focused on the impact of grazing NWSGs on the cost of production and have not directly addressed the profitability of grazing NWSGs. While research suggests that grazing NWSGs could decrease the cost of production, the market price of beef could decrease from May to August, and the market price of beef typically decreases as the animals increase in weight. Thus, a producer that grazes NWSGs over the summer months has a heavier animal to market in August but 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 that calves grazing native range grass in Oklahoma

instead of being placed in a confinement feed-lot after winter wheat grazing increased net returns for producers by 33% head^{-1}, but what is lacking in the literature is the knowledge of the net returns to grazing across different monocultures and polycultures of NWSGs in a stocker system in the southeastern 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. Beef is a major commodity produced in Tennessee. Cash receipts from the beef cattle industry in Tennessee were $586.3 million in 2011, which accounted for 16.7% of Tennessee's total agricultural output (Menard et al. 2013). East of the Mississippi River, only Kentucky has more cattle than Tennessee and nationwide only Texas, Missouri, and Oklahoma have more cow-calf operations than Tennessee (Neel 2009). Therefore, analyzing the net returns to grazing NWSGs would be beneficial to beef producers seeking to implement or expand a summer forage program in the Southeast.

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). Results from these studies commonly found that the lowest costing biomass was produced from monoculture SG (Hallam et al. 2001; Hong et al. 2013; Griffith et al. 2011). In the southeastern United States, lignocellulosic biomass crops are more likely to be produced for biofuels than corn since corn yields are lower in this region compared to the Corn Belt and growing seasons are longer (English et al. 2006).

Currently, there is not a market for biomass in the southeastern United States; however, the use of a dual-purpose biomass and early-season grazing system could potentially be a production system for beef cattle producers if a market for biomass is developed. In this dual-purpose system, producers could graze a NWSG for a short period early in the seasonal growth stage of the NWSGs and remove the animals sometime mid-summer. The biomass growth from the last grazing day to dormancy would then be available to harvest for biomass production.

Research in Oklahoma studied whether SG can be used in a dual-purpose early-season grazing and biomass production system (Mosali et al. 2013). Across different stocking rates, the biomass yield for SG was between 50-67% of the biomass yield from the SG grown strictly for biomass. This study indicated a dual-purpose system of early-season grazing and biomass production was possible in Oklahoma. A dual-purpose system could allow stocker cattle to remain on forage for a longer period of time before entering the feedlot, result in greater gains, and produce a biomass harvest annually on the same pastures (Mosali et al. 2013). 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 still 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: 1) determine if there was a difference in expected 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 and 2) determine the expected price for biomass a beef producer would need to breakeven between using a dual-purpose early-season grazing and biomass system and a full-season grazing for these three NWSG treatments at two locations.

Conceptual Framework

Full-Season Beef Steer Grazing

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 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. In this study, the producer will choose to graze or not graze a NWSG by their expected net returns, which are calculated using the following equation

$$(1) \quad \max_{i} \mathrm{E}[NR_i^f] = \mathrm{E}\left[\left((p_m^f \times w_m^f) - (p_p \times w_p)\right) - AEC_i - OC_i - LR\right],$$

where $\mathrm{E}[NR_i^f]$ is expected annual net returns (\$ ha^{-1}) for full-season grazing *f* the *i*th (*i*=1, …, 3) NWSG treatment; p_m^f is the live weight marketing price of beef (\$ kg^{-1}) at the end of the full-season grazing period; w_m^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 live weight purchase price of beef steers (\$ kg^{-1}) at the beginning of the grazing period; w_p is the initial 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 (\$ ha^{-1}) for NWSG treatment *i*; and OC_i is the annual operational pasture cost (\$ 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. Annualized establishment cost can be calculated using the following equation,

$$(2) \quad AEC_i = \frac{r(EC_i)}{1-(1+r)^{-N}},$$

where AEC_i is the annualized pasture establishment cost ($ ha^{-1}) for the ith NWSG treatment; EC_i is the establishment cost ($ ha^{-1}) for treatment i; N is the useful life of the NWSG treatment; and r is the discount rate.

Dual Purpose Early-Season Grazing and Biomass Harvest

Similarly, the decision to implement a dual-purpose early-season grazing and biomass harvest system can also be analyzed under a profit maximization framework. Expected net returns are 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:

$$(3) \quad \mathrm{E}[NR_i^e] = \mathrm{E}\left[\left((p_m^e \times w_m^e) - (p_p \times w_p)\right) + (p_i^{bm} \times (Z_i) - AEC_i - OC_i - LR - h(Z_i))\right],$$

where $\mathrm{E}[NR_i^e]$ is the annual expected net return ($ ha^{-1}) for early-season grazing e the ith NWSG treatment; p_m^e is the live weight 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 ith NWSG treatment; p_p is the live weight purchase price of beef ($ kg^{-1}) at the beginning of the grazing period; w_p is the initial purchase weight (kg ha^{-1}) at the

beginning of the grazing period for the ith NWSG treatment; p_i^{bm} is the price of biomass (\$ Mg^{-1}); Z_i is the biomass yield (Mg ha^{-1}) for NWSG treatment i; AEC_i is annualized pasture establishment cost (\$ ha^{-1}) for NWSG treatment i; and OC_i is the annual operational pasture cost (\$ ha^{-1}), including pasture maintenance, mowing, and fertilizer; and LR is the annual land rent (\$ ha^{-1}); and $h(Z_i)$ is the harvest cost (\$ ha^{-1}) for the ith NWSG treatment, where the harvest cost is a function of yield.

Currently there is not a biomass market in the southeastern United States; therefore, the price of biomass as an energy feedstock has not been established. Since p_i^{bm} is unknown, equation 3 was set equal to the expected net returns to full-season grazing (equation 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

$$(4) \quad \mathrm{E}\left[p_i^{bm}\right] = \mathrm{E}\left[\frac{\left(p_m^f \times w_m^f\right) - \left(p_m^e \times w_m^e\right) + h(Z_i)}{Z_i}\right].$$

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.

Data

Full-Season Beef Steer Grazing

Data was collected from Ames Plantation (AP) in Grand Junction, Tennessee and Highland Rim Research and Education Center (HR) in Springfield, Tennessee from 2010-2012. At AP, 1.214 hectare paddocks were established in three different treatments including 1) SG, 2) EG, and 3)

BBIG. At HR, 1.214 hectare paddocks were established for SG and BBIG. The NWSG treatments were in a randomized complete block design with three replications of each treatment

Forage

At AP, pastures were established in 2008. In June 2007, 7.94 kg a.i. ha^{-1} of glyphosate was used to target the elimination of warm-season grasses, and in September 2007, 7.94 kg a.i. ha^{-1} of glyphosate was applied to target cool-season grasses. Prior to planting, 3.97 a.i. kg ha^{-1} of 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}. In 2008, a portion of the EG paddocks required replanting, and in 2009, parts of BBIG paddocks also required reseeding. In April 2009, 0.722 liters ha^{-1} of imazapic was applied along with 2.92 kg a.i. ha^{-1} of paraquat dichloride to the reseeded portions of BBIG. Some paddocks of BBIG were treated with 0.170 liters a.i. ha^{-1} of imazapic along with 7.94 kg a.i. ha^{-1} of glyphosate. Other BBIG paddocks were treated with 2,4-d at a rate of 4.676 liters ha^{-1}. In May 2009, all the SG paddocks were treated with 0.219 liters a.i. ha^{-1} of quinclorac, and in June of 2010, all the SG pastures received 0.485 liters ha^{-1} a.i of monosodium acid methanearsonate. All the treatments were fertilized in April of each year, and rates were determined from soil samples. In 2010, all the paddocks received 67 kg N ha^{-1} and 90 kg P ha^{-1}, and only a few paddocks received 45 kg K ha^{-1}. In both 2011 and 2012, all the 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 the HR, pastures were seeded in June of 2008. In June 2007, 7.94 kg a.i. ha^{-1} of glyphosate was used to target the elimination of warm-season grasses, and in September 2007, 7.94 kg a.i. ha^{-1} of glyphosate was applied to target cool-season grasses. In April 2008, glyphosate was applied to all treatments and replications at a rate of 3.97 kg a.i. ha^{-1}. After the glyphosate application in April 2008, SG was seeded at a rate of 6.72 kg PLS ha^{-1}, and BBIG was seeded at rate of 6.72 kg PLS ha^{-1} for BB and 3.36 kg PLS ha^{-1} for IG. After planting, 0.193 liters a.i. ha^{-1} of quinclorac was applied to all the SG treatments. Some of the SG paddocks had to be replanted in 2009 and 2010, and because of these replants, 0.291 liters ha^{-1} a.i of monosodium acid methanearsonate was applied in July 2009 and 2,4-D was applied at a rate of 1.75 liters ha^{-1} in April of 2010. In both 2011 and 2012, 1.75 liters ha^{-1} of 2,4-D was applied to all paddocks. All the paddocks were burned at the end of each season after forage samples were taken. Soil tests were conducted in the fall of 2008 and 2009 and spring of 2010 and 2011 and fertilizer was applied accordingly. In 2010 and 2011, 67 kg N ha^{-1} was applied to all paddocks. In 2012, paddocks received a combination of 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}.

Animal

At AP and HR, steers were placed on a stuffer diet before and after being tested on pasture to account for irregular gut fill. With this diet, steers were fed at 2.0% body weight 5 days pre- and post- grazing. On a dry matter (DM) basis, the ration was 12.9% crude protein (CP) and 27.2% crude fiber. Ingredients of the ration include: cottonseed hulls, soy hulls, citrus pulp, dried distillers grain and molasses. 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. Weights were taken daily during the five days prior to grazing, and the on pasture weight was the average of weights from the last two days of the stuffer diet. The off pasture weight was the average of the last two days of a five-day stuffer diet. This was done for all three years of the study.

A continuous grazing system with variable stocking rate was utilized to manage forage at the desired height at each location. Each paddock contained four tester steers with a variable amount of grazer animals dependent on the forage availability of the NWSG. Initial stocking rates varied by NWSG and year (Table 2.1). In 2010, the initial stocking rate included four tester steers with one additional grazer per BBIG paddock and two additional grazers for each SG and EG paddock. In 2011, the initial stocking rate included five additional grazer animals per SG paddock, one additional per BBIG paddock, and six additional per EG paddock. In 2012, there were four additional grazer animals for each SG and EG paddock, and one additional grazer per BBIG paddock. Grazing animals were stocked with the goal of maintaining stand height at between 38.1 cm and 45.72 cm for BBIG. The grazers were utilized on the SG and EG paddocks to maintain a stand height between 60.96 cm and 76.2 cm. The total grazing period for all three years ranged from mid-May to early August and was approximately 90-days. At AP, there were three NWSG treatments with three replications of each, resulting in 108 total tester animals and 27 paddock observations over the three-year period. At HR, there were two NWSG treatments with three replications, with each replication containing four tester steers, giving a total of 72 tester animals and 18 paddock observations over the three-year period.

At AP, beginning weight for beef steers ranged from 247.61-291.15 kg with an average of 267.57 kg in 2010, 219.94-287.07 kg with an average of 256 kg in 2011, and 233.55-273 kg with an average of 250.89 kg in 2012. At HR, beginning weight for beef steers ranged from 244.03-295.28 kg with an average of 269.08 kg in 2010, 251.28-278.95 kg with an average of 265.08 kg in 2011, and 276.23-291.2 kg with an average of 255.37 kg in 2012. ADG was calculated using differences in beginning and ending weights of testers and dividing by the number of days tester steers were grazing and is shown by NWSG, year, and location in Table 2.2.

On dates steers were weighed, NWSG samples were taken to determine forage availability. Samples were processed using a near-infrared reflectance spectrophotometer to determine nutrient content. Decisions on the termination of grazing were based on animal performance and/or pasture conditions. Table 2.3 shows rainfall and temperatures by year and location. Grazing duration varied by year, and was often due to rainfall and temperature.

Budgeting

Enterprise budgets were used to estimate establishment and operational costs for grazing SG, EG, and BBIG. A 10-year production horizon is assumed, with no grazing occurring in the establishment year. A 10-year production life is often used in the literature (Duffy 2007; Khanna et al. 2008; Haque et al. 2009; Mooney et al. 2009; Griffith et al. 2011). In the establishment year, a seedbed was prepared for no-till planting by spraying the paddocks with herbicide and seed was planted. As stated before, NWSGs can be difficult to establish and sometimes require re-establishment. To account for this risk of failed establishment, a 10% chance of failed

establishment for each NWSG was assumed and accounted for in the budget. A discount rate of 5.5% was calculated using a 10-year average inflation rate of 2.5% from 2003-2012 (U.S. Department of Labor 2013) and subtracting it from the nominal interest rate used in the University of Tennessee Switchgrass Budget (2009).

Total establishment and production costs of NWSGs were calculated following the University of Tennessee Switchgrass Budget (2009) and Doxon et al. (2011). The establishment costs included seed, herbicide, fertilizer, labor, and machinery. The total establishment cost was annualized, and the annualized cost was added with annual operational costs and annual land rent to calculate total annual cost of production over a 10-year useful life. An average of local seed prices were used and seed cost was \$36.72 kg for BB, \$50.05 kg for IG, \$51.26 for EG, and \$28.58 kg for SG. Annual operational costs included mowing, and fertilizer cost. An annual fertilizer application of 67 kg N ha^{-1}, 34 kg P ha^{-1}, and 34 kg K ha^{-1} was the assumed for full-season grazing. It is assumed that a combination of ammonium nitrate, diammonium phosphate, and muriate of potash were used to fertilizer pasture. The prices of ammonium nitrate, diammonium phosphate, and muriate of potash were \$591.69 Mg^{-1}, \$766.92 Mg^{-1}, and \$828.15 Mg^{-1}, respectively (USDA-NASS 2013). These applications were based upon the University of Tennessee Switchgrass Budget (2009) and Doxon et al. (2011). Estimated total annualized pasture costs in 2012 dollars for full-season grazing are shown in Table 2.4.

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 (Table 2.5). 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) (Table 2.5). 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. It is assumed that producers would market steers immediately once removed from pastures.

Dual Purpose Early-Season Grazing and Biomass Harvest

Animal performance and forage data was collected from AP and HR from 2010-2012 from early-season grazing treatments, which was approximately 30-days. At AP, 1.214 hectare paddocks were established in three different treatments including 1) SG, 2) EG, and 3) BBIG. At HR, 1.214 hectare paddocks were established for SG and BBIG. Each of the NWSG treatments was grazed for approximately 30-days and forage data was collected post-dormancy to estimate a biomass harvest yield. The NWSG treatments were in a randomized complete block design with three replications of each treatment.

Forage

The paddocks at AP and HR were established and maintained at the same time and with the same inputs as the full-season beef steer grazing paddocks. At the end of the grazing season, after forage samples were taken to simulate a biomass harvest, fields were burned instead of mowed at AP.

Animal

As with full-season grazing, steers were placed on a stuffer diet to account for irregular gut fill. The rations and time frame of the diet were identical to those used in the full season grazing experiment. Grazing began in the spring when NWSG height reached approximately 38.1 cm. A continuous grazing system with a variable stocking rate was utilized to manage NWSG at the desired height at each location. Each paddock contained four tester steers with a variable amount of grazer animals dependent upon NWSG availability. Initial stocking rates varied by NWSG and year (Table 2.6). In 2010, the initial stocking rate included three additional grazers per BBIG paddock and four additional grazers for each SG and EG paddock. In 2011, the initial stocking rate included seven additional grazer animals per SG paddock, four additional grazers per BBIG paddock, and eight additional grazers per EG paddock. In 2012, there were eight additional grazer animals for each SG and EG paddock, and four additional grazers per BBIG paddock. The early-season treatments of NWSGs were stocked with the goal of reducing stand height to between 20.32 cm and 25.4 cm after 28 days. The same number NWSG treatments and replications were used for the early-season grazing treatment as the full-season grazing treatment at AP and HR.

At AP, the beginning weight for beef steers ranged from 245.39-293.93 kg with an average of 268.47 kg in 2010, 232.46-278.50 kg with an average of 258.79 kg in 2011, and 215.0-274.42 kg with an average of 253.30 kg in 2012. At HR, beef steers' beginning weight ranged from 250.84-298.46 kg with an average of 267.92 kg in 2010, 249.02-283.04 kg with an average of 264.99 kg in 2011, and 263.54-294.38 kg with an average of 277.71 kg in 2012. ADG was calculated using the difference between the ending weight and the beginning of testers

divided by the number of days the tester steers were grazing, and is shown by year and location in Table 2.7.

After early-season intensive grazing, pastures were grown for biomass until dormancy. Post-dormancy NWSG was tested using a near-infrared reflectance spectrophotometer to find forage nutrient content. The results of the samples were used to estimate a biomass harvest.

Budgeting

Establishment costs for early-season grazing were calculated the same as for full-season grazing pastures with the same useful life and discount rate. However, some operational costs are different between the early- and full-season grazing treatments. The cost of harvesting biomass was based on budgets from Griffith et al. (2011) and Boyer et al. (2013). Mowing and raking costs are both on a per hectare basis, baling and staging costs are per bale costs. Additionally, different fertilizer rates were used in the early-season grazing due to need to replace nutrients removed by harvesting biomass. It is assumed an annual application of 67 kg N ha^{-1}, 45 kg P ha^{-1}, and 90 kg K ha^{-1} was applied for the dual-purpose system compared to 67 kg N ha^{-1}, 34 kg P ha^{-1}, and 34 kg K ha^{-1} for full-season grazing. Like with full-season grazing treatments, it is assumed that a combination of ammonium nitrate, diammonium phosphate, and muriate of potash were used to fertilizer pasture. These applications were based upon the University of Tennessee Switchgrass Budget (2009) and Doxon et al. (2011). The total annualized pasture costs for early-season grazing at AP and HR are shown in Table 2.8.

Similar to the full-season grazing, the average price for 272.1-317.45 kg steers in Tennessee for the month of May from 2002-2011 (McKinley and Griffith 2012) were used to

reflect the purchase price of steers to graze the NWSG, or the opportunity cost of grazing steers on NWSG instead of marketing them at the beginning of the grazing period (Table 2.5). The average price for 272.1- 317.45 kg steers in Tennessee for the month of June from 2002-2011 (McKinley and Griffith 2012) were used to reflect the marketing price of beef steers for early-season grazing (Table 2.5). The prices were adjusted for inflation, and the average price of beef was \$2.56 kg^{-1} in June. It is assumed that producers would market steers immediately once removed from pastures.

Methods

Full-Season Beef Steer Grazing

The data is substituted into equation 1 to calculate the expected net returns and a mixed model was used to perform an ANOVA on the effects of each NWSG treatment and location on the expected net returns. A random effect was included for year variability to account for things such as stochastic weather events. The following model was estimated for differences in expected net returns across NWSG treatments and between locations for the full-season grazing period

$$(5) \qquad NR_{til}^{f} = \gamma_0 + D_l + \sum_{i=1}^{3-1} \gamma_i I_i + \sum_{i=1}^{3-1} \beta_{il} I_{il} D_{il} + v_t + \varepsilon_{til},$$

where NR_{til}^{f} is the net returns (\$ ha^{-1}) at time *t* for full-season grazing the *i*th NWSG treatment and *l*th location; γ_0 is the intercept coefficient for NWSG treatment *i*; D_l is an indicator variable for location *l*; γ_i is the coefficient for NWSG treatment *i*; I_i is an indicator variable for NWSG treatment *i*; β_{il} is the coefficient for the interaction term for NWSG treatment *i* and location *l*; $v_t \sim N(0, \sigma_v^2)$ is the year random effect; and $\varepsilon_{til} \sim N(0, \sigma_\varepsilon^2)$ is a random error term. The null

hypothesis was that net returns were not different across NWSG treatments and between locations.

While the difference in expected net returns was the primary focus of this analysis, difference in the expected beef yield are presented to the animal performance of each NWSG in the southeast United States. A mixed model was estimated to test for differences in the beef yield across NWSG treatments and between locations. Similarly, a random effect was included for year variability to account for things such as stochastic weather events. The equation to estimate the full-season beef yield by NWSG and location was formulated as

$$(6) \qquad BY_{til}^{f} = \gamma_0 + D_l + \sum_{i=1}^{3-1} \gamma_i I_i + \sum_{i=1}^{3-1} \beta_{il} I_{il} D_{il} + v_t + \varepsilon_{til},$$

where BY_{til}^{f} is the beef yield (ha^{-1}) at time *t* for full-season grazing the *i*th NWSG treatment and *l*th location; γ_0 is the intercept coefficient for NWSG treatment *i*; D_l is an indicator variable for location *l*; γ_i is the coefficient for NWSG treatment *i*; I_i is an indicator variable for NWSG treatment *i*; β_{il} is the coefficient for the interaction term for NWSG treatment *i* and location *l*; $v_t \sim N(0, \sigma_v^2)$ 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 full-season NWSG treatments and between locations.

Dual Purpose Early-Season Grazing and Biomass Harvest

Mixed models were used to perform an ANOVA on the effects of each early-season NWSG treatment and location on the expected beef yield, net returns, biomass yield, and breakeven price of biomass. A random effect was included for year variability to account for things such as

stochastic weather events. Estimating the expected beef yield for each NWSG shows the animals performance over the early-season grazing period and can be compared to the expected beef yield for the full-season grazing to determine if beef yields increase with the full-season grazing period. The following model was estimated for differences in beef yield across NWSG treatments and between locations for the early-season grazing period

$$(7)\qquad BY_{til}^{e} = \gamma_0 + D_l + \sum_{i=1}^{3-1} \gamma_i \, I_i + \sum_{i=1}^{3-1} \beta_{il} \, I_{il} D_{il} + v_t + \varepsilon_{til},$$

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

Then, Equation (3) is modified to find the expected net returns for the early-season grazing of each NWSG by location. This does not include the revenue and cost associated with the biomass production. The early-season net returns strictly is for the value of beef produced in the early-season grazing period. This was estimated to compare the expected net returns to early-season grazing to the expected net returns to full-season grazing. This will provide insight into how the additional days of grazing changes the expected net returns to grazing. A mixed model with a random effect for year was estimated for differences in expected net returns for early-season grazing by NWSG treatment and location. The equation is shown below as

(8) $$NR_{til}^{e} = \gamma_0 + D_l + \sum_{i=1}^{3-1} \gamma_i I_i + \sum_{i=1}^{3-1} \beta_{il} I_{il} D_{il} + v_t + \varepsilon_{til},$$

where NR_{til}^{e} is the net returns ($ ha^{-1}) at time *t* for early-season grazing the *i*th NWSG treatment and *l*th location; γ_0 is the intercept coefficient for NWSG treatment *i*; D_l is an indicator variable for location *l*; γi is the coefficient for NWSG treatment *i*; I_i is an indicator variable for NWSG treatment *i*; β_{il} is the coefficient for the interaction term for NWSG treatment *i* and location *l*; $v_t \sim N(0, \sigma_v^2)$ is the year random effect; and $\varepsilon_{til} \sim N(0, \sigma_\varepsilon^2)$ is a random error term. The null hypothesis was that net returns were not different across NWSG treatment, location, and grazing system.

A mixed model was estimated for differences in the expected biomass yield across NWSG treatments and between locations. Presenting the results for biomass yield by NWSG provide insight into how much biomass a producer would have to sell to a biofuel processor. A random effect was included for year variability to account for things such as stochastic weather events. The following model was estimated for biomass yield

(9) $$\mathrm{y}_{til} = \gamma_0 + D_l + \sum_{i=1}^{3-1} \gamma_i I_i + \sum_{i=1}^{3-1} \beta_{il} I_{il} D_{il} + v_t + \varepsilon_{til},$$

where y_{til} is the yield (Mg ha^{-1}) at time *t* for the *i*th NWSG treatment and *l*th location; γ_0 is the intercept coefficient for NWSG treatment *i*; D_l is an indicator variable for location *l*; γ_i is the coefficient for NWSG treatment *i*; I_i is an indicator variable for NWSG treatment *i*; β_l is the coefficient for the interaction term for NWSG treatment *i* and location *l*; $v_t \sim N(0, \sigma_v^2)$ is the year random effect; and $\varepsilon_{til} \sim N(0, \sigma_\varepsilon^2)$ is a random error term. The null hypothesis was that biomass yields are not different across NWSG treatments and between locations.

The data was substituted into equation (4) to determine the expected breakeven price of biomass required for beef producers to generate the same net returns to early-season grazing and biomass harvest as full-season grazing for each NWSG by locations. A mixed model was estimated for differences in the expected breakeven price of biomass across NWSG treatments and between locations. A random effect was included for year variability to account for things such as stochastic weather events. The equation was formulated as

$$(10) \quad p_{til}^{bm} = \gamma_0 + D_l + \sum_{i=1}^{3-1} \gamma_i I_i + \sum_{i=1}^{3-1} \beta_{il} I_{il} D_{il} + v_t + \varepsilon_{til},$$

where p_{til}^{bm} is the breakeven price of biomass ($ Mg^{-1}) at time *t* for the *i*th NWSG treatment and *l*th location; γ_0 is the intercept coefficient for NWSG treatment *i*; D_l is an indicator variable for location *l*; γ_i is the coefficient for NWSG treatment *i*; I_i is an indicator variable for NWSG treatment *i*; β_{il} is the coefficient for the interaction term for NWSG treatment *i* and location *l*; $v_t \sim N(0, \sigma_v^2)$ is the year random effect; and $\varepsilon_{til} \sim N(0, \sigma_\varepsilon^2)$ is a random error term. The null hypothesis was that the breakeven price of biomass was not different across NWSG treatments and between locations.

The MIXED procedure in SAS 9.2 was used to estimate the models in equations 5 through 10 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

A likelihood ratio test was performed to determine if the restricted model, the model with a year random effect, performs as well as the unrestricted model, the model without the year random effect. The null hypothesis was that the random effect equals zero. The null hypothesis was rejected ($p \leq 0.05$) and results from the restricted model were presented.

Results for the expected beef yield for full-season grazing by NWSG and year are presented in Table 2.9. The expected beef yield at AP was 475.46 hg ha^{-1} for SG and 450.89 kg ha^{-1} for BBIG, and there was no difference in the expected beef yield ($p \leq 0.05$) between the SG and BBIG full-season grazing treatments at HR. Burns and Fisher (2013) observed similar findings for grazing these NWSGs in North Carolina. At AP, the null hypothesis was not rejected ($p \leq 0.05$) that there was no statistical difference in the expected beef yield of 275.92 kg ha^{-1} for SG, 281.82 kg ha^{-1} for BBIG, and 257.12 kg ha^{-1} for EG. Burns and Fisher (2013) found grazing EG resulted in a higher beef yield than grazing SG and BB, which is different from what was observed 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. The expected beef yield was 169.07 kg ha^{-1} higher for grazing BBIG at HR than at AP, and 199.53 kg ha^{-1} higher for grazing SG at HR than at AP. The statistical differences between locations can most likely be explained by weather during the study. The HR location had greater average rainfall and lower average temperatures than the AP location (Table 2.3), which might have reduced the drought and heat stress on the NWSGs at HR relative to AP, resulting in higher beef yields. The higher temperatures at AP during the study may have also reduced intake of steers relative to HR. Also, another possibility

that might explain differences in beef yield at the two locations could be differences in management. If the stands of NWSG were grazed too intensively in the early part of the growing season it is possible it had a negative affect on animal performance later in the season.

The expected net returns to full-season grazing of SG and BBIG were statistically different from zero ($p \leq 0.05$), but there was no difference ($p \leq 0.05$) between the expected net returns to full-season grazing of BBIG and SG at HR (Table 2.10). The net returns to grazing were \$836.45 ha^{-1} for grazing steers on SG and \$738.83 ha^{-1} for grazing steers on BBIG at HR (Table 2.10). Similarly, the expected net returns to full-season grazing at AP were not different ($p \leq 0.05$) across NWSG treatments (Table 2.10). The expected net returns to grazing EG was not statistically different from zero at AP, meaning the expected benefit of grazing EG was not greater than the cost of grazing at AP. Therefore, a profit-maximizing, risk neutral individual would choose to market their calves in May instead of grazing EG over the summer months at AP. However, expected net returns to grazing both BBIG and SG were statistically greater than zero at \$311.63 ha^{-1} and \$331.16 ha^{-1}, respectively. The expected net returns to full-season grazing at HR were higher ($p \leq 0.05$) than at AP. On average, net returns to full-season grazing BBIG were \$427.20 ha^{-1} higher at HR than at AP and \$505.29 ha^{-1} higher for SG at HR than at AP. Annual pasture cost of grazing BBIG was \$34.74 ha^{-1} greater than the pasture costs for grazing SG. The higher pasture cost for grazing BBIG was more than the value of the additional 5.9 kg ha^{-1} of beef gained from grazing BBIG relative to grazing SG at AP, resulting in a lower expected net return on average than grazing SG at AP.

Early-Season Grazing

There was no difference in the expected beef yield ($p \leq 0.05$) from early-season grazing of BBIG and SG at HR. The expected beef yield was 307.62 kg ha^{-1} for grazing SG and 245.57 kg ha^{-1} for grazing BBIG (Table 2.11). The expected beef yield from early-season grazing was not different ($p \leq 0.05$) across NWSGs at AP. The expected beef yield was 349.45 kg ha^{-1} for grazing SG, 280.3 kg ha^{-1} for grazing BBIG, and 274.10 kg ha^{-1} for grazing EG (Table 2.11).

Results for the expected biomass yield by NWSG and year are presented in Table 2.12. 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. However, at AP, there was no statistical 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 Expected biomass yield from SG at HR was statistically higher than the expected biomass yield for SG at AP, but there was no difference ($p \leq 0.05$) between the locations for the expected biomass yield for BBIG. Compared to the Mosali et al. (2013), the expected biomass yields were higher at both locations in this study.

The results from equations 7 and 9 are substituted into equation 4 to find 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. The expected breakeven price of biomass was estimated using equation 10 and the results are presented in Table 2.13. The expected breakeven price of biomass for SG was statistically lower ($p \leq 0.05$) than the expected price of biomass for BBIG at HR by \$28.42 Mg^{-1}. At AP, the expected breakeven price of biomass was not statistically different ($p \leq 0.05$) across NWSG treatments. The expected breakeven price of

biomass was \$41.51 Mg^{-1} for BBIG, \$37.19 Mg^{-1} for EG and \$20.43 Mg^{-1} for SG at AP. The results indicate that SG would be the most economically feasible biomass at both locations. The breakeven price of both SG and BBIG was statistically lower at AP than HR. This is most likely explained by the statistically 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 much higher for beef producers to give up the net returns to grazing for the additional 60 days.

Early-Season versus Full-Season Grazing

Pair-wise comparisons were made to determine if there were differences between the full-season and early-season expected beef yields and expected net returns to grazing for each NWSG treatment. There was no statistical difference ($p \leq 0.05$) between early- and full-season grazing beef yield at AP within NWSG treatments (Table 2.14). This result implies that grazing days 30-90 did not statistically increase the beef yield from the first 30 days of grazing at AP. Conversely, the expected beef yield from full-season grazing of SG and BBIG was higher ($p \leq 0.05$) than the expected beef yield from early-season grazing of BBIG and SG at HR (Table 2.14). Therefore, the additional 60 days of grazing increased beef yield at HR. Similarly, the expected net returns to full-season grazing were not statistically different ($p \leq 0.05$) than the expected net returns to early-season grazing at AP for each NWSG treatment (Table 2.15). Conversely, the expected net returns to full-season grazing at HR were higher ($p \leq 0.05$) than the expected net returns from early-season grazing for all NWSGs (Table 2.15).

Given that there was no statistical difference between expected beef yield from grazing early- and full-season treatments of NWSGs at AP, it is possible that temperatures became too

warm and/or rainfall levels too low for full-season grazing to have a significantly greater beef yield than early-season at AP. This is counter to what was found at HR, where full-season beef yields were statistically higher for both SG and BBIG than the early-season treatments as expected. At HR, the average temperatures were lower and more average rainfall was received, which could explain the statistically higher gains from grazing days 30-90.

Discussion

Annual pasture cost for grazing EG was the highest across the NWSG treatments, and the steers that grazed EG had the lowest beef yield on average, resulting in the lowest net returns to grazing EG on average in this study. Although steers grazing BBIG achieved a greater beef yield on average than those grazing SG at AP, the annual pasture cost of BBIG was greater than the annual pasture cost of SG, resulting in higher expected net returns for grazing SG on average. The higher annual pasture cost for BBIG was mostly due to the relatively high seed cost of BBIG compared to SG. Seed cost accounted for 22% of total establishment cost for SG and 44% of total BBIG establishment. These factors most likely explain why full-season grazing of SG generated greater expected net returns than BBIG, on average, across location.

The expected net returns to full-season grazing found in this study indicated that the use of NWSG in a stocker system was profitable. At HR and AP, the expected net returns for grazing BBIG and SG over the full-season were positive and significantly greater from zero; therefore, a profit-maximizing, risk-neutral individual would choose to graze steers on BBIG and SG at HR and AP over the summer months. However, results of the study also found the expected net returns to full-season grazing EG at AP were not statistically different from zero. Thus, a profit-

maximizing, risk neutral individual would not graze steers on the EG over the summer months. The net returns to full-season grazing BBIG and SG generated net returns greater at HR than at AP, which means location was an important component in determining to use a summer grazing program with NWSGs. While there was no difference between net returns to full-season grazing BBIG and SG, the results of this study suggest that on average grazing SG was the best option for full-season grazing of beef steers in Tennessee.

It is still unclear to what degree grazing NWSGs extend the summer grazing period for fall born calves post-weaning in the Southeast. While the average full-season ADG for BBIG and SG in this study was higher than what was generally reported as the ADG for grazing Kentucky-31 tall fescue (Ball et al. 2007; Beck et al. 2008), there is a difference, on average, between early-season ADG for beef steers compared to full-season grazing. The average full-season ADG was 54-80% of the ADG from early-season grazing of the same NWSGs at the same locations. This implies that there was a lower average ADG associated with grazing in June, July, and August compared to May. Additionally, the expected beef yield was not statistically different between full-season and early-season grazing at AP in this study. However, the expected beef yield was statistically higher for full-season grazing relative to early-season grazing at HR. The physiological process of fescue allows for strong growth from March through June, and sometimes July, in the Southeast (Ball et al. 2007). Given the overlap in forage availability and results from this study, it cannot be definitively said that NWSGs substantially prolong the post-weaning grazing period for fall born calves relative to fescue despite difference in physiological characteristics of NWSGs.

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. From the standpoint of a biomass producer instead of a beef producer, if the net returns to the dual-purpose system had been set equal to zero instead of the net returns to full-season grazing the breakeven price of biomass would have potentially been even lower than found in this study. This suggests that biomass is likely more efficiently produced under a strict biomass production system than a dual-purpose early-season grazing and biomass production system. Nevertheless, 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 (Hallam et al. 2001; Hong et al. 2013; Griffith et al. 2011; Mooney et al. 2009).

Conclusions

The objectives of this research were 1) to determine if there is a difference in net returns to grazing beef steers on different pure stands of NWSGs, and 2) determine the price of biomass a beef producer would need to breakeven between full-season grazing and a dual-purpose grazing and biomass harvest system for three NWSGs. Data was collected from an experiment AP, Tennessee and HR from 2010 to 2012 for beef steers grazing mature stands of NWSGs over a full-season and early-season. This research provides insight into the economics of NWSG grazing and biomass production in the Southeast.

Net returns to full-season grazing BBIG and SG were statistically greater than zero at both AP and HR, while net returns to grazing EG were not different from zero. There were no differences in the net returns for full-season grazing of BBIG and SG at HR and no difference in net returns across NWSGs at AP. However, the expected net return to full-season grazing at HR was greater than AP. The estimated price of biomass required by a beef producer to breakeven between full-season grazing and using a dual-purpose system ranged from \$81.57-\$110 Mg^{-1} at HR and \$20.42-\$41.51 Mg^{-1} at AP. The net returns to full-season grazing and early-season grazing were not statistically different within NWSG treatments at AP, but they were different at HR. This implies the additional 60 days of grazing does not provide any additional value at AP while these days do provide additional value at HR.

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 and 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.

Appendix

Table 2.1. Initial Steer Stocking Rate for Full-Season Grazing (paddock^{-1})† by Native Warm-Season Grass, Location, and Year

NWSG‡	2010	2011	2012
Ames Plantation			
SG	6	9	8
BBIG	5	5	5
EG	6	10	8
Highland Rim			
SG	6	9	8
BBIG	5	5	5

† One paddock is approximately 1.124 ha.
‡BBIG=Big Bluestem and Indian Grass; SG=Switchgrass; EG= Eastern Gamagrass.

Table 2.2. ADG (kg) for Full-Season Grazing by Native Warm-Season Grass, Location, and Year

NWSG†	2010	2011	2012	Average
Ames Plantation				
SG	0.60	0.58	0.67	0.62
BBIG	0.95	0.41	0.93	0.76
EG	0.51	0.29	0.64	0.48
Highland Rim				
SG	0.90	0.80	0.88	0.86
BBIG	1.10	0.70	1.02	0.94

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

Table 2.3. Average Daily Temperature (C°) and Total Rainfall (cm) During Early- and Full-Season Grazing Months by Location and Year†

	2010		2011		2012		Average	
Month	Temp.	Rainfall	Temp.	Rainfall	Temp.	Rainfall	Temp.	Rainfall
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
August	28.32	6.05	27.00	5.31	25.86	6.07	27.06	5.81
May-August	26.48	64.5	25.41	35	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
August	27.10	7.39	25.72	5.08	24.13	7.21	25.65	6.56
May-August	25.3	46.56	24.32	38.31	24.13	49.4	24.58	44.76

† Source: NOAA, Milan, TN weather station.

Table 2.4. Total Annualized Pasture Costs (\$ ha^{-1}) for Full-Season Grazing Native Warm-Season Grasses

Total Pasture Costs†	BBIG	EG	SG
Establishment Costs			
NWSG Seed‡	$487.08	$575.51	$192.51
Establishment§	$517.51	$517.51	$574.00
Risk of Re-establishment¶	$100.46	$109.30	$76.65
Total	$1,105.06	$1,202.32	$843.16
Annualize Establishment	$146.61	$159.51	$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	$415.46	$428.36	$380.72

† BBIG=Big Bluestem and Indiangrass; EG= Eastern Gamagrass; SG= Switchgrass.
‡ Seed cost was $36.72 kg for big bluestem, $50.05 kg for indiangrass, $51.26 for eastern gamagrass, and $28.58 kg 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 2.5. Historical Tennessee Steer Prices (\$ kg^{-1}) for 272.1-317.45 kg Steers by Year and Month†

Year	May	June	August
2002	$2.15	$2.11	$2.13
2003	$2.26	$2.32	$2.45
2004	$2.78	$2.92	$2.99
2005	$3.03	$2.92	$2.86
2006	$2.66	$2.79	$2.78
2007	$2.60	$2.54	$2.65
2008	$2.40	$2.40	$2.43
2009	$2.32	$2.24	$2.23
2010	$2.52	$2.52	$2.54
2011	$2.81	$2.79	$2.78
Average	$2.56	$2.56	$2.58

† Prices Adjusted for Inflation (2012).

Table 2.6. Initial Steer Stocking Rate for Early-Season Grazing (paddock^{-1})† by Native Warm-Season Grass, Location, and Year

NWSG‡	2010	2011	2012
Ames Plantation			
SG	8	11	12
BBIG	7	8	8
EG	8	12	12
Highland Rim			
SG	8	11	12
BBIG	7	8	8

† One paddock is approximately 1.124 ha.
‡ BBIG=Big Bluestem and Indian Grass; SG=Switchgrass; EG= Eastern Gamagrass.

Table 2.7. ADG (kg) for Early-Season Grazing by Native Warm-Season Grass, Location, and Year

NWSG†	2010	2011	2012	Average
Ames Plantation				
SG	0.96	1.28	1.17	1.14
BBIG	1.07	1.28	1.31	1.22
EG	0.76	0.78	0.98	0.84
Highland Rim				
SG	1.04	0.68	1.56	1.30
BBIG	1.27	0.90	1.33	1.17

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

Table 2.8. Total Annualized Pasture Costs ($ ha^{-1}) and Biomass Harvest Costs for Early-Season Grazing Native Warm-Season Grasses

Total Pasture Costs†	BBIG	EG	SG
Establishment Costs			
NWSG Seed‡	$487.08	$575.51	$192.51
Establishment§	$517.51	$517.51	$574.00
Risk of Re-establishment¶	$100.46	$109.30	$76.65
Total	$1,105.06	$1,202.32	$843.16
Annualize Establishment	$146.61	$159.51	$111.86
Operational Costs			
Fertilizer	$282.96	$282.96	$282.96
Land Rent	$51.87	$51.87	$51.87
Total Annual Pasture Cost	$481.44	$494.34	$446.69
Hectare^{-1} Harvest Costs•			
Mowing	$24.98	$24.98	$24.98
Raking	$9.59	$9.59	$9.59
Bale^{-1} Harvest Costs			
Baling	$14.64	14.64	14.64
Staging	$4.50	$4.50	$4.50

† BBIG=Big Bluestem and Indiangrass; EG= Eastern Gamagrass; SG= Switchgrass.

‡ Seed cost was $36.72 kg for big bluestem, $50.05 kg for indiangrass, $51.26 for eastern gamagrass, and $28.58 kg 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 SG establishment costs include 10% risk of failed establishment that results in replanting.

•Mowing and raking are per hectare costs and baling and staging costs are a function of yield and on a per bale basis. Each bale is assumed to be 0.681 Mg (Griffith et al. 2011).

Table 2.9. Expected Beef Yield (kg ha^{-1}) for Full-Season Grazing by Native Warm-Season Grass, Location, and Year

NWSG†	2010	2011	2012	Average‡
Ames Plantation				
SG	158.05	250.79	418.93	275.92[a]
BBIG	203.27	332.12	310.07	281.82[a]
EG	172.09	228.43	370.86	257.12[a]
Highland Rim				
SG	304.16	455.18	667.04	475.46[b]
BBIG	374.14	449.62	528.93	450.89[b]

† BBIG=Big Bluestem and Indian Grass; SG=Switchgrass; EG=Eastern Gamagrass
‡ Least Squared Means Beef Yield (kg ha^{-1}).
[a,b] If letter is the same across treatment and location then beef yields are not different at the 0.05 level.

Table 2.10. Expected Net Returns to Full-Season Grazing ($ ha^{-1}) by Native Warm-Season Grass, Location, and Year

NWSG†	2010	2011	2012	Average‡
Ames Plantation				
SG	$27.05	$266.31	$700.11	$331.16[a]
BBIG	$108.96	$441.39	$384.53	$311.63[a]
EG	$15.62	$160.99	$528.44	$235.02[a]
Highland Rim				
SG	$397.92	$784.53	$1,326.89	$836.45[b]
BBIG	$542.33	$735.56	$938.59	$738.83[b]

† BBIG=Big Bluestem and Indian Grass; SG=Switchgrass; EG=Eastern Gamagrass
‡ Least Squared Means Beef Yield (kg ha^{-1}).
[a,b] If letter is the same across treatments and locations then net returns are not different at the 0.05 level.

Table 2.11. Expected Beef Yield (kg ha^{-1}) for Early-Season Grazing by Native Warm-Season Grass, Location, and Year

NWSG†	2010	2011	2012	Average‡
Ames Plantation				
SG[a]	212.04	416.55	419.77	349.45[b]
BBIG	227.46	293.56	319.88	280.30[a,b]
EG	196.32	267.44	358.55	274.10[a,b]
Highland Rim				
SG	246.18	194.96	481.71	307.62[a,b]
BBIG	251.18	191.92	293.58	245.57[a]

† BBIG=Big Bluestem and Indian Grass; SG=Switchgrass; EG=Eastern Gamagrass
‡ Least Squared Means Beef Yield (kg ha^{-1}).
[a,b,c] If letter is the same across treatment and location then beef yields are not different at the 0.05 level.

Table 2.12. Expected Biomass Harvest (Mg ha^{-1}) by Native Warm-Season Grass, Location, and Year

NWSG†	2010	2011	2012	Average‡
Ames Plantation				
SG	8.24	9.69	8.00	8.65[a,b]
BBIG	8.12	9.90	6.24	8.08[a,b]
EG	8.88	11.00	6.51	8.80[a,b]
Highland Rim				
SG	11.48	9.51	11.17	10.90[b]
BBIG	7.58	7.38	8.17	7.71[a]

† BBIG=Big Bluestem and Indian Grass; SG=Switchgrass; EG=Eastern Gamagrass
‡ Least Squared Means Beef Yield (kg ha^{-1}).
[a,b]If letter is the same across treatment and location then biomass yields are not different at the 0.05 level.

Table 2.13. Expected Breakeven Price ($ Mg^{-1}) of Biomass for Dual-Purpose Early-Season Grazing and Biomass Harvest by Native Warm-Season Grass, Location, and Year

NWSG†	2010	2011	2012	Average‡
Ames Plantation				
SG	$24.26	-$4.40	$41.42	$20.42[a]
BBIG	$35.08	$48.91	$40.54	$41.51[a]
EG	$33.21	$28.34	$50.13	$37.19[a]
Highland Rim				
SG	$53.22	$112.09	$79.40	$81.57[b]
BBIG	$81.96	$131.78	$116.25	$110.00[c]

† BBIG=Big Bluestem and Indian Grass; SG=Switchgrass; EG=Eastern Gamagrass
‡ Least Squared Means Beef Yield (kg ha^{-1}).
[a,b] If letter is the same across treatments and locations then breakeven prices of biomass are not different at the 0.05 level.

Table 2.14. Expected Early- and Full-Season Beef Yield (kg ha^{-1}) by Native Warm-Season Grass, Location, and Year

NWSG†	Early-Season‡	Full-Season‡
Ames Plantation		
SG	349.45^{e}	275.92^{e}
BBIG	280.30^{c}	281.82^{c}
EG	274.10^{b}	257.12^{b}
Highland Rim		
SG	307.62^{d}	475.46^{g}
BBIG	245.57^{a}	450.89^{f}

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

‡ Least Squared Means Beef Yield (kg ha^{-1}).

^{a,b,c,d,e,f,g} If letter is the same within treatments and locations across grazing treatments then beef yields are not different at the 0.05 level.

Table 2.15. Expected Early- and Full-Season Net Returns to Full-Season Grazing (\$ ha^{-1}) by Native Warm-Season Grass, Location, and Year

NWSG†	Early-Season‡	Full-Season‡
Ames Plantation		
SG	$447.91^{e}	$331.16^{e}
BBIG	$236.13^{c}	$311.63^{c}
EG	$207.37^{b}	$235.02^{b}
Highland Rim		
SG	$340.82^{d}	$836.45^{g}
BBIG	$147.21^{a}	$738.83^{f}

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

‡ Least Squared Means Beef Yield (kg ha^{-1}).

^{a,b,c,d,e,f,g} If letter is the same within treatments and locations across grazing treatments then net returns are not different at the 0.05 level.

Chapter 3: The Economics of Grazing Native Warm-Season Grass in Bred Dairy Heifer Development

Abstract

There is limited research on the economics of grazing bred dairy heifers on native warm-season grasses (NWSGs). The objective of this chapter is to determine the cost of grazing NWSGs, with and without legumes, in bred dairy heifer development, and compare the cost of grazing to the cost of developing the heifer using traditional feedstuffs. From May to August, Holstein heifers continuously grazed switchgrass (SG), SG with legumes (SG+L), a big bluestem and indiangrass mixture (BBIG), and BBIG with legumes (BBIG+L). Total animal unit days (AUDs) were calculated for each NWSG treatment to determine the expected cost AUD^{-1} of grazing, and the expected average daily gain (ADG) was calculated for each NWSG treatment to determine the expected cost of feeding traditional feed rations.

The expected cost AUD^{-1} was statistically the lowest for SG at \$0.38 AUD^{-1}, and the expected cost AUD^{-1} was statistically the highest for BBIG+L at \$1.13 AUD^{-1}. For both BBIG and SG, legumes increased the expected cost AUD^{-1} because there was not enough of an increase in AUDs to account for the additional cost of the legumes. Three feed rations were developed for each NWSG treatment that would result in the same weight gain over the same number of grazing days as the NWSG treatment. There was no statistical difference in expected ADG between SG and SG+L, and BBIG and BBIG+L; however, the expected ADG was statistically higher for BBIG and BBIG+L than SG and SG+L. The expected cost $head^{-1}$ day^{-1} of feeding these three rations was calculated using the ADG estimates and compared to the expected cost AUD^{-1} of grazing for each of the NWSGs. The expected cost AUD^{-1} was lower for all NWSG treatments than the expected cost $head^{-1}$ day^{-1} for all comparable feed rations at a low, average, and high yardage fee. Results of this study suggest that SG was the best NWSG alternative to

harvested feeds for bred dairy heifer development. SG had the lowest expected cost AUD^{-1} for all NWSG treatments, and the cost AUD^{-1} was lower than the expected cost $head^{-1}$ day^{-1} of feeding a ration that produces equivalent animal performance.

Introduction

For a dairy operation, heifer development is one of the largest production expenses (Heinrichs 1993; Harsh et al. 2001). A common alternative to developing heifers within the milking operation is to outsource heifer development to a custom developer that grows calves from as young as one week old to until they are springers (Olynk and Wolf 2010). For a custom heifer developer, feed costs are a major expense and can account for as much as 64% of the total cost of production (Gabler et al. 2000). Traditionally, corn silage has been the primary forage ingredient used in dairy heifer development rations. The price of corn silage is closely tied to the market price for corn (Lauer and Undersander 2004), which has increased by 184% since 2002 (USDA-NASS 2013). This has likely increased the cost of production for custom heifer developers in recent years.

Unlike in beef production, increased animal growth is not necessarily the primary objective in dairy heifer development. While weight gain is important for the heifers to reach puberty and calving weight, research has found that there is a negative relationship between average daily gain (ADG) during development and first lactation milk yield (Hoffman et al. 1996). First lactation performance can be limited due to restricted mammary development and excessive body condition caused by additional animal growth (Hoffman et al. 1996). Research has also found that high ADG during heifer development results in decreased milk fat percentage during first lactation performance (Albeni et al. 2000).

In contract heifer development, 51% of contract producers are paid on head^{-1} day^{-1} basis at an average rate of \$1.59 head^{-1} day^{-1} for a bred heifer (Wolf 2003). Therefore, a profit-maximizing dairy heifer producer's objective is to reduce production costs while holding output,

a bred dairy heifer meeting all contractual obligations, constant. In the Southeast United States, developing dairy heifers will likely graze tall fescue pastures in the spring and fall to reduce feeding costs relative to feeding harvested feedstuffs, and will likely have to be fed some degree of harvested feedstuffs in the summer months. However, grazing the dairy heifers on native warm-season grasses (NWSGs) in the summer months could potentially increase producers' net returns by lowering feed costs relative to the cost of feeding harvested feedstuffs.

Research on NWSGs in dairy heifer development has been limited. A study in Wisconsin used eastern gamagrass (*Tripsacum dactyloides*) as an additive to corn silage and alfalfa haylage (Coblentz et al. 2012). Coblentz et al. (2012) found eastern gamagrass to be suitable for diluting energy content and limiting dry matter intake in dairy heifers. However, there were no studies on animal performance or the cost of grazing NWSGs in the development of bred dairy heifers in the southeastern United States found in the review of literature.

There is also limited research on grazing NWSGs with legumes in the Southeast United States. A potential shortcoming of using NWSGs in a summer grazing program can be the cost of nitrogen (N) fertilizer applied (Biermacher et al. 2012; OCES 2012; University of Tennessee Switchgrass Budget 2009). One possible substitute for N fertilizer in NWSG production is the use of legumes to fixate atmospheric N (Howieson et al. 2000). Research has shown that legumes can successfully be grown with switchgrass (SG) (Blantchet et al. 1995), but legumes have also been found to potentially hinder SG stands (Bow et al. 2008). Biermacher et al. (2012) studied the economics of using legumes as a substitute for N fertilizer while grazing bermudagrass pastures in the Great Plains. Biermacher et al. (2012) found the net returns to grazing to be higher for the pastures where N fertilizer was applied than the pastures where

legumes were used. However, the results were highly dependent on the duration of grazing period, soil quality, and successful establishment. Biermacher et al. (2012) provided some useful insight into the economics of grazing a warm-season grass with legumes, but more research is needed on the use of grazing NWSGs with legumes in the Southeast United States.

The objective of this research was to determine the cost of grazing bred dairy replacement heifers on SG and a big bluestem and indiangrass mixture (BBIG), with and without legumes. Animal performance data was used to develop three feed rations that will result in the equivalent weight gain over the same time period as each NWSG treatment. The cost of using these feed rations was calculated and compared to the cost of grazing NWSGs to determine the lowest cost feed for bred dairy heifers during the summer months. Data used in this analysis was collected from an experiment conducted in Tennessee from 2010-2012. The results from this research could benefit contract dairy heifer producers in the Southeast by reducing feed costs in the summer months.

Conceptual Framework

Grazing Cost

For the framework of this research, the assumption was made that dairy heifer developers are paid on a per head per day basis to develop a heifer to lactation since this is how the majority of dairy heifer developers are paid (Wolf et al. 2003). It is assumed that producers operate in a perfectly competitive market for inputs and outputs, where the end product is a dairy heifer bred to seven months meeting all contractual agreements. Once the heifer is bred and showing signs of lactation, every heifer is worth the same dollar value, meaning the producer is a price taker

and has no influence on the price they receive. Therefore, a risk neutral, profit-maximizing custom heifer developer would need to minimize their cost of producing a heifer from the time of breeding until the heifer is a springer to achieve the largest expected economic profit (Nicholson 1998). In this study, a profit-maximizing, risk neutral producer would select the NWSG treatment that maximizes profits by minimizing the expected cost head^{-1} day^{-1}. In this study, the equation for profit can be defined as

$$(1) \quad \mathrm{E}[\pi_i] = \mathrm{E}[TR - TC_i],$$

where $E[\pi_i]$ is the expected profit head^{-1} day^{-1} on the ith (i=1,…,4) NWSG treatment; TR is the expected revenue head^{-1} day^{-1}; and TC_i is the expected total cost head^{-1} day^{-1} for NWSG treatment i. The total revenue head^{-1} day^{-1} is defined as the contract payment received on a head^{-1} day^{-1} multiplied by the number of animals grazed. The total cost is the annual pasture cost ha^{-1} divided by the number of dairy heifers day^{-1} that can be grazed on each NWSG treatment.

To find the annual pasture cost, the first step is to annualize the establishment cost of each NWSG pasture. Pasture establishment cost is annualized using the following formula,

$$(2) \quad AEC_i = \frac{r(EC_i)}{1-(1+r)^{-N}},$$

where AEC_i is the annualized pasture cost ha^{-1} for the ith NWSG treatment; EC_i is the establishment cost ha^{-1} for NWSG treatment i; N is the useful grazing life of the NWSGs; and r is the discount rate. The annualized establishment cost is added to the annual operational costs to find the total annual pasture cost, which is expressed as

$$(3) \quad PC_i = AEC_i + OC_i + LR + LC_i,$$

where PC_i is the total annual pasture cost ha^{-1} for the ith NWSG treatment; AEC_i is the annualized pasture establishment cost ha^{-1} for the ith NWSG; OC_i is the annual operational cost

ha^{-1} for mowing, labor for the ith NWSG; LR is the annual land rent; and LC_i is the cost of annual legume seeding ha^{-1} for the ith NWSG treatment.

To calculate the expected cost head^{-1} day^{-1}, the annual pasture cost has to be divided by the number of head day^{-1} grazed on the given NWSG treatment. Animal unit days (AUDs) are a measurement for the number of days that a 453.9 kg animal that can graze 2.6% body weight on a dry matter basis. Therefore, the cost with respect to AUDs provides the best measure relative to the payment structure of dollars head^{-1} day^{-1} that most custom heifer developers receive. The cost AUD^{-1} can be interpreted as the cost head^{-1} day^{-1} to graze a 453.59 kg animal at 2.6% body weight on a dry matter basis (Meyer et al. 2009; Ruyle and Ogden 1993). Therefore, the producer's objective is to maximize profits with respect to the expected cost AUD^{-1}, subject to the production of a bred heifer meeting all contractual obligations. To calculate the expected cost AUD^{-1}, AUD ha^{-1} is first calculated using the equation

$$(5) \quad AUD_i = \sum_{l=1}^{2} \frac{X_{il} \times \theta_l \times D_{il}}{z}$$

where AUD_i is the number of animal unit days ha^{-1} for the ith NWSG treatment; X_{il} is the number of animals grazing the ith NWSG and lth breed (l=1,2); θ_l is the animal unit assigned to the animal grazing for the lth breed; D_{il} is the number of grazing days for the ith NWSG treatment and lth breed; and z is the number of hectares grazed. In this study, both Jersey and Holstein heifers were used to graze NWSG treatments. To account for the size differences between the Holsteins and Jersey heifers, a metabolic body size conversion factor was calculated (Ruyle and Ogden 1993) and used to determine an animal unit equivalent between Holstein and Jersey heifers. Given the weight of Holstein heifers in the study, the Holsteins were assigned the

base animal unit of 1.0. Using the conversion factor, the animal unit equivalent for Jersey heifers was 0.77.

Once the expected AUD by NWSG treatment is determined, the expected AUD ha^{-1} is divided by the total pasture cost ha^{-1} to find the expected annual cost AUD^{-1}. This calculation is expressed as

$$(6) \quad \mathrm{E}[C_i] = \frac{AUD_i}{PC_i},$$

where $\mathrm{E}[C_i]$ is the producers expected annual cost AUD^{-1} for the *i*th NWSG treatment; AUD_i is the number of animal unit days ha^{-1} for treatment *i*; and PC_i is the annual pasture cost ha^{-1} for NWSG treatment *i*.

The cost AUD^{-1} would be the daily cost of grazing a bred dairy heifer during the summer months on a NWSG treatment, and the producer would choose the NWSG treatment with the lowest cost AUD^{-1}. Thus, the producer will choose to maximize profit by minimizing cost, which is expressed as

$$(7) \quad \max_i = \mathrm{E}(\pi_i) = (p^{hd} - \mathrm{E}[C_i]) \times q^d \,,$$

where $\mathrm{E}(\pi_i)$ is expected profit $head^{-1}$ day^{-1} for the *i*th NWSG treatment; p^{hd} is the price $head^{-1}$ day^{-1} received according to the contract; $E[C_i]$, is total expected cost AUD^{-1} for the *i*th NWSG treatment; and q^d is the number of days grazed annually.

Ration Feed Cost

The expected cost AUD^{-1} of grazing the NWSGs is then compared to the expected cost $head^{-1}$ day^{-1} using harvested feedstuffs. Three rations were developed to achieve equivalent animal performance as each of the NWSG treatments over the same time period, giving a total of 12

rations. The three types of feed rations included: a wet distillers grain based ration, a corn silage with soybean meal ration, and a corn silage with dried distillers grain ration. To accurately compare the expected cost AUD^{-1} to the expected cost $head^{-1}$ day^{-1} of using harvested feed rations with the equivalent animal performance as the NWSGs, a composition of ingredients had to be determined for each ration to achieve the same average ADG over the same number of grazing days for the same size Holstein heifer as the NWSG treatment. Then, the expected cost of the feed ration can be calculated by multiplying the cost of the ingredients by the quantity needed of each ingredient to achieve an equivalent ADG over the same time period as each NWSG treatment. First, the expected cost kg^{-1} of the feed ration can be calculated as

$$(8)\quad E\left[FC_j\right] = \sum_{k=1}^{K} \phi_{jk} I_{jk},$$

where $E[FC_j]$ is the expected feed cost kg^{-1} of the ration j (j=1,…,12); ϕ_{jk} is the percentage of the kth (k=1,…,K) ingredient for the jth feed ration; I_{jk} is the ingredient cost for the kth (k=1,…,K) ingredient in the jth (j=1,…,12) feed ration. Then, the expected cost kg^{-1} of gain on the harvested feed has to be calculated, which is expressed as

$$(9)\quad E[C_j] = E[FC_j] \times E[FG_j]\ ,$$

where $E[C_j]$ is the producers expected cost kg^{-1} of gain for the jth (j = 1,…,12) feed ration; $E[FC_j]$ is the expected cost kg^{-1} of feed ration j; and $E[FG_j]$ is the expected feed to gain ratio on an as-fed basis for the jth feed ration, which is the amount of feed required to achieve one kg of gain.

The following equation was then used to determine expected cost head^{-1} day^{-1} using harvested feed by multiplying expected ADG by the expected cost for one kg of gain, which is expressed as

(10) $E[CF_j] = E[ADG_i] \times E[C_j]$,

where $E[CF_j]$ is the producers expected cost head^{-1} day^{-1} for the jth (j = 1,…,12) feed ration; ADG_i is the average daily gain for the ith NWSG treatment (i=1,…,4) that the feed ration was designed to achieve; E[C_j] is the producers expected cost of gain (\$ kg^{-1}) for the jth (j = 1,…,12) feed ration.

Data

Data was collected from an experiment at the Middle Tennessee Research and Education Center (MTREC) in Spring Hill, Tennessee from 2010 to 2012. Animal performance data was collected for bred Holstein and Jersey heifers grazing mature stands of four NWSG treatments: 1) SG, 2) BBIG, 3) SG with legumes (SG+L), and 4) BBIG with legumes (BBIG+L). Treatments were assigned in a randomized complete block design with four replications.

Forages

Each NWSG treatment was established in 2008 on 1.214 ha paddocks; therefore, the animals were grazing a mature stand of NWSG from 2010-2012. In the establishment year, a seedbed was prepared for no-till planting by spraying the paddocks with herbicide and seed was planted. Seeding was done with a 90-horsepower tractor and 4.57 meter no-till drill. Alamo SG was planted at a rate of 11.2 kg PLS ha^{-1}, and a 1:1 mixture BBIG was seeded at 5.6 kg PLS ha^{-1}

each. 'Cinnamon Plus' clover was drilled in February of each year in the legume treatments at a rate of 6.74 kg PLS ha^{-1}. In the fall of each year, all paddocks were clipped for excess forage. Equipment utilized was a 90-horsepower tractor and 4.57 meter mower. There was no lime, fertilizer, or herbicide application to the treatments in any year.

Animal

Animals were managed in a continuous grazing system with a variable stocking rate. Grazing began on May 14th in 2010, May 13th in 2011, and May 11th in 2012. In 2010 and 2012, four Holstein heifers between 30 and 160 days bred were designated as testers animals and were turned into each 1.214-hectare paddock. In 2011, three Holstein heifers and one Jersey heifer were assigned as tester animals and were turned into each 1.214-hectare paddock. Each paddock contained four continuously grazing tester heifers with a variable amount of Jersey heifer grazer animals. Grazer animals were used in each year of the experiment to keep the NWSG treatments from becoming too mature, which varied based on NWSG availability. The initial stocking rate was four tester heifers per paddock in 2010 and 2012 for all NWSG treatments, but in 2011 the initial stocking rate was four testers and one grazer for BBIG pastures, and four testers and three grazers for SG pastures.

In 2010, the initial weight of bred Holstein heifers ranged from 340-575 kg with an average on weight of 452 kg. In 2011, a combination of Holstein and Jersey heifers were turned onto the paddocks. The initial weight of the Jersey heifers ranged from 281.81-365.45 kg with an average on weight of 339.65 kg, while the beginning weight for the Holstein heifers ranged from 381.81-629.54 kg with an average on grass weight of 453.84 kg. In 2012, bred Holstein heifers

were used with an on weight ranging between 393.63-690.9 kg and an average on weight of 508.29 kg. The total grazing days for each paddock included the grazing days for the grazer animals summed with the grazing days for the tester heifers. AUD for each paddock was calculated by multiplying grazing days for each breed by the animal unit equivalent, which is 1.0 for Holsteins and for Jerseys the AU was 0.77. Table 3.1 displays the average AUD by NWSG and year.

To account for irregular gut fill, heifers were placed on a stuffer diet for 5-days before and after being tested, where heifers were fed at 2.0% body weight 5-days pre- and post- grazing. On a dry matter (DM) basis, the stuffer ration was 12.9% crude protein (CP) and 27.2% crude fiber. Ingredients of the ration include: cottonseed hulls, soy hull pellets, citrus pulp, dried distillers grain, and molasses. This diet was used as a way to regulate gut fill without adding weight to the animals. This allowed for more accurate measurements of gain than traditional weighing methods such as averaging weights from multiple days. The last two days of the 5-day stuffer diet prior to grazing were averaged to calculate an average on-weight, and the last two days of the 5-day stuffer diet post grazing were to calculate the off-weight.

On dates that heifers were weighed, forage samples for yield and quality data were taken from each NWSG treatment. Samples were scanned using near-infrared reflectance spectrophotometer to determine nutrient levels. Average CP levels by NWSG and year are shown in Table 3.2. Along with CP levels, the NWSG cover, clover levels, bare ground, other forages, and weed levels were calculated. Decisions on termination of grazing were based upon animal performance and/or pasture conditions. For example, in 2012, Holstein heifers grazing BBIG paddocks were removed from grass two weeks earlier than the heifers on the SG

paddocks. This removal was based on the NWSG availability, which was dependent on rainfall and temperature. Table 3.3 shows rainfall and temperature at MTREC from 2010-2012.

Feed Rations

The ingredients for each feed ration were determined using the Cattle Grower Ration Balancing Spreadsheet (University of Arkansas 2006) for a Holstein heifer that has the same beginning weight as the average beginning weight of the Holsteins in the experiment. For a Holstein heifer, three feed rations were developed to achieve the same ADG over the same number of days as one of the NWSG treatments, giving a total of 12 rations. The three ration types selected were corn silage with soybean meal, corn silage with dry distillers grain, and a wet distillers grain based ration. Table 3.4 shows the portions of ingredients in the as-fed diet composition of the wet distillers grain, corn silage with soybean meal, and corn silage with dry distillers grain based rations that achieve the same ADG over the same number of grazing days as each of the NWSG treatments. Table 3.5 shows moisture level of the rations, nutritional value on a dry matter basis, and the as-fed feed-to-gain ratio associated with each ration developed for each NWSG treatment.

A four-year monthly average in 2012 dollars of feedstuff inputs for the months grazing occurred is shown in Table 3.6. The prices of wet distillers grain (65-70% moisture) and dry distillers grain (10% moisture) were found using the USDA Livestock and Grain Market News Portal (USDA 2013b). The price of corn silage was estimated using historical corn yields and prices for Tennessee (USDA-NASS 2013) along with the Corn Silage Crop Calculator (Purdue University 2013). The Corn Silage Crop Calculator takes into account the price of a bushel of

corn and uses that to calculate the cost for one Mg of corn silage. The price of hay used comes from a non-alfalfa hay market in Kentucky (USDA-NASS 2013). Kentucky hay prices were used because Kentucky is the nearest hay market to Tennessee that has price data available by year and month. Historical marketing year prices of soybean meal were used (USDA-NASS 2013) because monthly prices were unavailable (Table 3.6). Due to a lack of historical prices of calcium carbonate, current local price was used in calculating the cost of each ration, which was \$88 Mg^{-1}.

Budgeting

Enterprise budgets were used to estimate establishment, operational, and legume costs for grazing BBIG, BBIG+L, SG, and SG+L. A 10-year production horizon was assumed, with no grazing occurring in the establishment year. A 10-year production life was often used in the literature (Duffy 2007; Khanna et al. 2008; Haque et al. 2009; Mooney et al. 2009; Griffith et al. 2011) and was also consistent with the agronomics of NWSGs. In the establishment year, a seedbed was prepared for no-till planting by spraying the paddocks and seed was planted. As stated before, NWSGs can be difficult to establish and sometimes requires reestablishment. To account for this risk, a 10% chance of failed establishment was assumed in the establishment cost, which would require reestablishment in the following year. A discount rate of 5.5% was calculated using a 10-year average inflation rate of 2.5% for the years 2003-2012 (U.S. Department of Labor 2013) and subtracting it from the nominal interest rate of 8.0% used in the University of Tennessee Switchgrass Budget (2009).

Total establishment and production costs of NWSGs were calculated following the University of Tennessee Switchgrass Budget (2009) and Doxon et al. (2011) and are presented in Table 3.7. The establishment costs included seed, herbicide, machinery, and labor. An average of local prices were used to determine seed costs of \$36.72 kg for big bluestem (BB), \$50.05 kg for indiangrass (IG), and \$28.58 kg for SG. The total establishment cost was annualized and added to the annual operational costs of land rent and legume costs to calculate total annual cost of production over a 10-year useful pasture life. Legume establishment cost was estimated using University of Tennessee Clover Budget (2007), which included seed, machinery, and labor. Clover was seeded each year in the study so this cost was included on an annual basis.

Methods

A mixed model was used to perform an ANOVA on the effects of each NWSG treatment on the expected cost AUD^{-1} and ADG. A random effect was included for year variability such as stochastic weather events. The following model was estimated for differences in cost AUD^{-1} across NWSG treatments

$$(11) \quad CAUD_{ti} = \gamma_0 + \sum_{i=1}^{4} \gamma_i I_i + v_t + \varepsilon_{ti},$$

where $CAUD_{ti}$ is the cost AUD^{-1} at time *t* for the *i*th NWSG treatment; γ_0 is the intercept coefficient for NWSG treatment *i*; γ_i is the coefficient for the NWSG treatment *i*; I_i is an indicator variable for the *i*th treatment; $v_t \sim N(0, \sigma_v^2)$ is the year random effect; and $\varepsilon_{ti} \sim N(0, \sigma_\varepsilon^2)$ is a random error term. The null hypothesis is that the expected cost AUD^{-1} was not different across NWSG treatments.

A mixed model with a year random effect was estimated to test for differences in the expected ADG across NWSG treatments. The equation was formulated as

$$(12)\quad ADG_{ti} = \gamma_0 + \sum_{i=1}^{4} \gamma_i I_i + v_t + \varepsilon_{ti},$$

where ADG_{ti} is the ADG at time *t* for the *i*th NWSG treatment; γ_0 is the intercept coefficient for NWSG treatment *i*; γ_i is the coefficient for the NWSG treatment *i*; I_i is an indicator variable for the *i*th treatment; $v_t \sim N(0, \sigma_v^2)$ is the year random effect; and $\varepsilon_{ti} \sim N(0, \sigma_\varepsilon^2)$ is a random error term. The null hypothesis was that ADG is not different across NWSG treatments.

The MIXED procedure in SAS 9.2 was used to estimate the models in equations 11 and 12 and PDIFF function of LSMEANS was utilized to evaluate means. (SAS Institute Inc., 2004) Significance was determined at $p \leq 0.05$.

Results

A likelihood ratio test was performed to determine if the restricted model, the model with a year random effect, performs as well as the unrestricted model, the model without the year random effect. The null hypothesis was that the random effect equals zero. The null hypothesis was rejected ($p \leq 0.05$) and results from the restricted model were presented.

Results for the expected cost AUD^{-1} are shown in Table 3.8. The expected cost AUD^{-1} ($p \leq 0.05$) was not statistically different across all NWSG treatments. Results from pair-wise comparisons indicated that the expected cost AUD^{-1} was lowest ($p \leq 0.05$) for SG at \$0.38 AUD^{-1}. Assuming the producer was a risk neutral, profit maximizing individual they would choose to graze SG over the other NWSGs because it provides the lowest expected cost AUD^{-1}. Including

the legumes with SG resulted in the cost AUD^{-1} being \$0.29 greater ($p \leq 0.05$) than the SG treatment. There was no statistical difference between SG+L and BBIG, but the expected cost AUD^{-1} was lower ($p \leq 0.05$) for BBIG than BBIG+L. Combining legumes with BBIG resulted in a \$0.38 AUD^{-1} greater ($p \leq 0.05$) expected cost than the expected cost for BBIG. The BBIG+L treatment was found to have the highest ($p \leq 0.05$) expected cost at \$1.13 AUD^{-1} for all the NWSG treatments. However, the expected cost AUD^{-1} of grazing all NWSGs in this study was lower than the average contract price reported by Wolf (2003) of \$1.59 $head^{-1}$ day^{-1}.

The expected cost AUD^{-1} was then compared to the expected cost $head^{-1}$ day^{-1} using harvested feed rations in dairy heifer development. As noted before, to develop rations with an equivalent animal performance to NWSG grazing, the expected ADG by NWSG treatment has to be estimated to determine the ingredients in the ration that will produce the equivalent expected ADG over the same time period. Table 3.9 shows the expected ADG for the heifers associated with each NWSG treatment. The expected ADG for the heifers was found to be not statistically different ($p \leq 0.05$) across all NWSG treatments, but pair-wise comparisons of the ADG were made between the NWSG treatments. The results indicated that the expected ADG of 0.94 kg day^{-1} for heifers on BBIG+L was not statistically different from the ADG of 0.85 kg day^{-1} for heifers on BBIG. Moreover, no statistical difference was found in the heifers' expected ADG between SG and SG+L. However, the expected ADG for heifers on SG and SG+L was lower ($p \leq 0.05$) than the expected ADG for heifers on BBIG and BBIG+L. The heifers gained on average 0.14 kg day^{-1} more ($p \leq 0.05$) on BBIG than the heifers on SG and 0.15 kg day^{-1} higher ($p \leq 0.05$) than the heifers on SG+L. The expected ADG for heifers on BBIG+L was 0.23 kg day^{-}

^{1} higher ($p \leq 0.05$) than the heifers grazing SG and 0.24 kg day^{-1} higher ($p \leq 0.05$) than the heifers grazing SG+L.

Table 3.10 depicts the expected cost kg^{-1} of gain for each of the rations that achieve the same expected ADG as grazing each of the NWSG treatments. For each of the NWSG treatments, the expected cost of gain kg^{-1} for heifers on corn silage with soybean meal was the highest of all the rations. Corn silage with dry distillers grain had the lowest expected cost of gain kg^{-1} for the heifers when compared to the heifers grazing BBIG, SG, and SG+L, and wet distillers grain was the lowest expected cost of gain kg^{-1} for heifers when compared to the heifers grazing BBIG+L.

The expected cost head^{-1} day^{-1} on harvested feed was calculated by multiplying the expected cost of gain kg^{-1} by the expected ADG to give an expected feed cost head^{-1} day^{-1}. Three separate prices of yardage and transportation fee were included in the expected feed cost head^{-1} day^{-1}. The yardage fees used were \$0.35, \$0.40, and \$0.45 head^{-1} day^{-1}, which were intended to represent a low, medium, and high daily yardage fee within the range generally charged by custom feeders (Lardy 2013). The daily feed costs with the daily yardage fee and transportation included are shown in Table 3.11. On average, the cost of feeding the three rations equivalent to grazing SG ranged from \$1.91 head^{-1} day^{-1} for corn silage with dry distillers grains to \$2.82 head^{-1} day^{-1} for corn silage with soybean meal. The cost of the feed rations equivalent to grazing SG+L was slightly lower on average than for SG, and ranged from \$1.89 head^{-1} day^{-1} for corn silage with wet dry distillers grain to \$2.79 head^{-1} day^{-1} with corn silage and soybean meal. On average, the cost of rations equivalent to grazing BBIG ranged from \$2.02 head^{-1} day^{-1} for corn silage with dry distillers grain to \$2.99 head^{-1} day^{-1} for corn silage with soybean meal, which was

higher than the feed rations for SG and SG+L. For BBIG+L, the expected cost head^{-1} day^{-1} was higher than any other NWSG treatment, and ranged from \$2.05 head^{-1} day^{-1} for corn silage with wet distillers grain to \$3.16 head^{-1} day^{-1} for corn silage with soybean meal. All NWSG treatments had a lower expected cost of grazing than all equivalent rations at all yardage fees.

Discussion

Results of the study indicate that grazing SG has the best potential to be an alternative to feeding corn silage and wet distillers grain based rations in bred dairy heifer development. The SG treatment was found to have a lower establishment cost than BBIG and BBIG+L, resulting in SG being the most economically feasible NWSG treatment to graze bred dairy heifers. This can likely be explained by SG having a relatively high stocking rate compared to BBIG and BBIG+L, and the cost of seed was 63.4% of the establishment cost for the BBIG and BBIG+L treatments, compared to only 43.7% of the establishment for the SG and SG+L treatments. Due to high seed cost, BBIG and BBIG+L were not as economically feasible for dairy heifer development as the other NWSG treatments.

A potential reason for the differences in the expected cost AUD^{-1} between legume and non-legume treatments was the inconsistency in legume establishment from year to year. The additional cost of legume establishment without any increased performance resulted in a higher expected cost AUD^{-1} for SG+L than SG, and for BBIG+L than BBIG. Although research has found that legumes can be successfully established in SG (Blantchet et al. 1995), in this study legumes were difficult to establish in stands of SG and BBIG. Further research is needed on the

establishment of legumes in NWSG in the southeastern United States before robust conclusions can be made on the economics of grazing NWSG with legumes.

The expected cost of gain kg^{-1} from the feed rations with equivalent animal performance to heifers grazing SG and SG+L was higher than the expected cost of gain kg^{-1} from the feed rations with equivalent animal performance to heifers grazing BBIG and BBIG+L (Table 3.10). However, the expected ADG for heifers grazing the BBIG and BBIG+L treatments were higher than the expected ADG for heifers grazing SG and SG+L treatments. Therefore, the marginal cost of gain from feed rations equivalent to SG and SG+L was higher than the marginal cost of gain for feed rations equivalent to BBIG and BBIG+L (Table 3.11). This is likely explained by the amount of hay required in the rations equivalent to grazing SG treatment and the cost of hay. Rations that have the same animal performance as grazing SG and SG+L had higher percentages of hay than for the rations that have the same animal performance as grazing BBIG and BBIG+L. Feeding at a lower rate of gain resulted in higher percentages of hay in rations, leading to a higher expected cost of gain kg^{-1} for the rations comparable to grazing SG and SG+L. Aside from soybean meal and dry distillers grain, which were fed in limited quantities for protein supplementation, hay was the most expensive input on an as-fed basis in the rations. Although corn silage was the lowest cost input, prices of corn silage were tied to market price of corn. Given increasing corn costs (USDA-NASS 2013) and relatively low nutritional quality of corn silage (University of Arkansas 2006), Grazing NWSGs may be a lower cost and less price volatile alternative to corn silage in bred dairy heifer development. Future research should look into the impacts of price risk between grazing NWSGs and feeding harvested feeds.

Replacement Holstein heifers have an energy requirement that might be met from grazing NWSGs (National Research Council 2001), but the literature indicates that developing a heifer at a lower ADG may actually improve future milking performance. Excess body condition has been found to reduce first lactation yield (Hoffman et al. 1996), which could reduce revenue for the dairyman once the animal is in the milking herd. A study in Wisconsin found that feeding postpubertal heifers to gain 0.93 kg day^{-1} resulted in lower first lactation performance than for heifers gaining 0.78 kg day^{-1} (Hoffman et al. 1996). The results from this study indicate that the expected ADG from grazing SG and SG+L might be better for long-term milk yield than the expected ADG from grazing BBIG and BBIG+L.

Furthermore, the CP levels for the NWSGs were lower than the CP levels in the rations. However, the literature suggests that due to selectivity of grazing, quality of forage consumed by animals is consistently higher than that found using forage sampling techniques (Coleman and Barth 1973; Dubbs et al. 2003; Hughes et al. 2010). Dubbs et al. (2003) found that samples obtained from ruminally cannulated steers had 4.5 percentage units greater CP than hand clipped samples in the same fescue pastures. Animal performance found in this study combined with the finding in the literature, suggest that NWSGs appear to be suitable for dairy heifer development despite the relatively low CP levels in the forage samples compared to National Research Council (2001) recommendations.

Conclusions

The objective of this research was to determine how the cost of grazing bred dairy heifers on SG, SG+L, BBIG, and BBIG+L compares to the cost of using traditional harvested feedstuff rations.

Data used in this research was collected from an experiment at the Middle Tennessee Research and Education Center in Spring Hill, Tennessee from 2010 to 2012 for Holstein and Jersey heifers grazing mature stands of four NWSG treatments. This research provides insights into the economics of NWSG grazing in dairy heifer development in the Southeast United States, and could help dairy heifer developers reduce feeding cost in the summer months.

Results from the analysis showed that the expected cost AUD^{-1} for grazing SG was statistically lower than the expected cost AUD^{-1} for grazing all other NWSG treatments. Grazing SG was also found to have a lower expected cost AUD^{-1} than the expected cost $head^{-1}$ day^{-1} of feeding three feed rations used in bred dairy heifer development that had the equivalent animal performance to grazing the NWSG treatments. For these reasons, grazing bred dairy heifers on SG during the summer months appears to be the most economically feasible feed for contract dairy heifer developers to maximize their expected profits.

Further research is needed into the establishment of legumes with NWSGs before the economic feasibility of legume use can be determined. Additionally, research is also needed to determine how the use of NWSGs in dairy heifer development compares economically to a fescue based systems. Furthermore, research is needed into how first lactation performance is affected by heifer development on a NWSG grazing program compared to traditional heifer rearing methods before a definitive conclusion can be made.

Appendix

Table 3.1. Average Animal Unit Days (AUD) ha^{-1} for Bred Dairy Heifers by Year and Native Warm-Season Grass

NWSG†	2010	2011	2012	Average
BBIG	289.95	238.57	151.56	226.69
BBIG+L	289.95	239.84	151.56	227.11
SG	320.07	315.96	222.29	286.18
SG+L	350.21	316.59	228.00	298.26

† BBIG=Big Bluestem and Indian Grass; BBIG+L= Big bluestem and indiangrass with legumes; SG=Switchgrass; SG+L= Switchgrass with legumes.

Table 3.2. Mean Protein Level (%DM) for the Native Warm-Season Grasses by Year

NWSG†	2010	2011	2012	Average
BBIG	7.94	7.65	8.61	8.07
BBIG+L	7.74	8.68	11.41	9.28
SG	6.00	6.59	8.45	7.01
SG+L	5.60	7.39	8.71	7.23

† BBIG=Big Bluestem and Indian Grass; BBIG+L= Big bluestem and indiangrass with legumes; SG=Switchgrass; SG+L= Switchgrass with legumes.

Table 3.3. Average Daily Temperature (C°) and Total Rainfall (cm) During Grazing Months by Year and Month†

	2010		2011		2012		Average	
Month	Temp.	Rainfall	Temp.	Rainfall	Temp.	Rainfall	Temp.	Rainfall
May	20.22	34.98	18.14	9.35	20.93	9.78	19.76	18.04
June	26.29	6.15	24.69	10.62	22.87	3.63	24.62	6.80
July	27.21	11.86	26.76	3.20	26.71	22.76	26.89	12.61
August	27.12	6.25	25.54	4.01	23.52	10.95	25.39	7.07
May-August	25.21	59.24	23.78	27.18	23.51	47.12	24.17	44.81

† Source: NOAA, Milan, TN weather station.

Table 3.4. As-Fed Diet Composition for Bred Holstein Heifers for Gains Equivalent to Native Warm-Season Grass

	NWSG†			
Ration	BBIG	BBIG+L	SG	SG+L
Wet Distillers Grain				
Wet Distillers Grain	60.75%	65.50%	49.50%	49.50%
Mixed Grass Hay	38.25%	33.50%	49.50%	49.50%
Calcium Carbonate	1.00%	1.00%	1.00%	1.00%
Corn Silage- Soybean Meal				
Corn Silage	71.00%	78.50%	50.00%	50.00%
Mixed Grass Hay	22.00%	14.50%	42.00%	42.00%
Soybean Meal	7.00%	7.00%	8.00%	8.00%
Corn Silage- Dry Distillers Grain				
Corn Silage	44.50%	54.50%	21.00%	21.00%
Mixed Grass Hay	40.50%	30.50%	64.00%	64.00%
Dry Distillers Grain	15.00%	15.00%	15.00%	15.00%

† BBIG=Big Bluestem and Indian Grass; BBIG+L= Big bluestem and indiangrass with legumes; SG=Switchgrass; SG+L= Switchgrass with legumes.

Table 3.5. Ration Nutrients for Bred Holstein Heifers for Gains Equivalent to Native Warm-Season Grass Grazing

Ration†	Feed:Gain‡	DM %§	TDN%¶	CP%•
Wet Distillers Grain				
BBIG	27.36	49.7%	63.2%	15.4%
BBIG+L	24.75	46.7%	65.1%	16.1%
SG	29.10	56.7%	60.1%	14.2%
SG+L	29.28	56.7%	60.1%	14.2%
Corn Silage- Soybean Meal				
BBIG	27.81	48.9%	63.1%	15.1%
BBIG+L	27.46	44.8%	64.8%	15.4%
SG	27.48	60.4%	60.1%	15.2%
SG+L	27.48	60.4%	60.1%	15.2%
Corn Silage- Dry Distillers				
BBIG	21.32	63.8%	63.4%	14.8%
BBIG+L	20.89	58.4%	65.1%	15.0%
SG	21.67	76.6%	60.3%	14.4%
SG+L	21.67	76.6%	60.3%	14.4%

† BBIG=Big Bluestem and Indian Grass; BBIG+L= Big bluestem and indiangrass with legumes; SG=Switchgrass; SG+L= Switchgrass with legumes.
‡ Ratio of Ration Fed to Gain Achieved (kg) on an As-Fed Basis.
§ Percent Dry Matter (DM) of Ration.
¶ Percentage Total Digestible Nutrients (TDN) on a DM Basis.
• Percentage Crude Protein (CP) on a DM Basis.

Table 3.6. As-Fed Average Price ($ Mg^{-1})† for Bred Dairy Heifer Ration Inputs by Year and Month in 2012 dollars

Ration Input	2009	2010	2011	2012	Average
Wet Distillers Grain‡					
May	$49.04	$37.04	$80.76	$81.41	$62.06
June	$49.69	$35.15	$80.88	$82.01	$61.93
July	$39.01	$34.95	$77.36	$98.94	$62.57
August	$35.18	$36.58	$77.77	$117.00	$66.63
Corn Silage§					
May	$48.64	$43.08	$60.71	$61.06	$53.37
June	$50.65	$38.62	$69.80	$58.33	$54.35
July	$49.45	$42.99	$73.52	$72.52	$59.62
August	$43.22	$44.24	$66.55	$62.67	$54.17
Grass Hay¶					
May	$111.78	$98.44	$84.41	$88.18	$95.70
June	$117.66	$98.44	$84.41	$88.18	$97.17
July	$111.78	$89.75	$90.03	$88.18	$94.94
August	$94.12	$81.06	$90.03	$99.21	$91.11
Dry Distillers Grain•					
May	$161.09	$135.41	$231.72	$242.74	$192.74
June	$167.25	$123.90	$230.87	$242.82	$191.21
July	$117.24	$120.48	$223.43	$298.99	$190.03
August	$104.60	$126.75	$225.54	$336.85	$198.43
Soybean Meal❖					
Marketing Year	$629.24	$693.07	$677.80	$655.90	$679.75

†Prices are adjusted for Inflation into 2012 dollars.
‡ 65-70% Moisture Distillers Grain.
§35% Dry Matter Corn Silage.
¶ Prices Received for Hay (Excluding Alfalfa) in Kentucky.
• 10% Moisture Distillers Grain.
❖ Soybean Meal-44.

Table 3.7. Total and Annualized Pasture Costs ($ ha^{-1}) for each Native Warm-Season Grass in 2012 Dollars

Total Pasture Costs†	BBIG	BBIG+L	SG	SG+L
Establishment Costs				
NWSG Seed‡	$487.08	$487.08	$192.51	$192.51
Establishment§	$208.17	$208.17	$208.17	$208.17
Risk of Re-establishment¶	$69.53	$69.53	$40.07	$40.07
Total	$764.78	$764.78	$440.75	$440.75
Annualized Establishment	$101.46	$101.46	$58.47	$58.47
Legume Costs				
Seed	-	$81.51	-	$81.51
Machinery and Labor	-	$31.41	-	$31.41
Total	-	$112.92	-	$112.92
Operational Costs				
Mowing	$21.04	$21.04	$21.04	$21.04
Land Rent	$51.87	$51.87	$51.87	$51.87
Total Annual Pasture Cost	$174.37	$287.29	$131.38	$244.31

† BBIG=Big Bluestem and Indian Grass; BBIG+L= Big bluestem and indiangrass with legumes; SG=Switchgrass; SG+L= Switchgrass with legumes.
‡ Seed cost was $36.72 kg for big bluestem, $50.05 kg for indiangrass, and $28.58 kg for switchgrass.
§ Other Establishment costs include herbicide, machinery, land rent for the establishment year, labor, and fixed costs such as depreciation on equipment and interest.
¶ A 10% chance of failed establishment is assumed and accounted for in the budget.

Table 3.8. Expected Cost per Animal Unit Day ($ day^{-1}) for Heifers Grazing Native Warm-Season Grasses by Year

NWSG†	2010	2011	2012	Average‡
BBIG	$0.46	$0.60	$0.88	$0.65[b]
BBIG+L	$0.76	$1.18	$1.46	$1.13[c]
SG	$0.30	$0.35	$0.48	$0.38[a]
SG+L	$0.48	$0.65	$0.89	$0.67[b]

† BBIG=Big Bluestem and Indian Grass; BBIG+L= Big bluestem and indiangrass with legumes; SG=Switchgrass; SG+L= Switchgrass with legumes.
‡ Least Squared Means Average Cost AUD^{-1} ($ AUD^{-1}).
[a,b,c] If letter is the same across NWSG treatments then Cost AUD^{-1} is not different at the 0.05 level.

Table 3.9. Expected Average Daily Gain (kg day^{-1}) by Native Warm-Season Grass and Year

NWSG†	2010	2011	2012	Average ADG‡
BBIG	0.77	1.01	0.89	0.85[b]
BBIG+L	0.76	0.99	1.16	0.94[b]
SG	0.64	0.93	0.61	0.71[a]
SG+L	0.64	0.80	0.69	0.70[a]

† BBIG=Big Bluestem and Indian Grass; BBIG+L= Big bluestem and indiangrass with legumes; SG=Switchgrass; SG+L= Switchgrass with legumes.
‡ Least Squared Means ADG (kg day^{-1}).
[a,b] If letter is the same across NWSG treatments then ADG is not different at the 0.05 level.

Table 3.10. Expected Cost of Gain ($ kg^{-1}) for Gains Equivalent to Grazing Native Warm-Season Grass

Ration†	Cost of Gain
Wet Distillers Grain	
BBIG	$2.03
BBIG+L	$1.81
SG	$2.28
SG+L	$2.29
Corn Silage- Soybean Meal	
BBIG	$2.99
BBIG+L	$2.88
SG	$3.34
SG+L	$3.34
Corn Silage- Dry Distillers	
BBIG	$1.96
BBIG+L	$1.83
SG	$2.19
SG+L	$2.19

† BBIG=Big Bluestem and Indian Grass; BBIG+L= Big bluestem and indiangrass with legumes; SG=Switchgrass; SG+L= Switchgrass with legumes.

Table 3.11. Expected Cost Head^{-1} Day^{-1} for Heifers Consuming Distillers Grain and Corn Silage Based Rations to Achieve the Same Animal Performance as Grazing the Native Warm-Season Grass Treatments

Ration†	Yardage Low	Yardage Average	Yardage High
Wet Distillers Grain			
BBIG	$2.08	$2.13	$2.18
BBIG+L	$2.05	$2.10	$2.15
SG	$1.97	$2.02	$2.07
SG+L	$1.95	$2.00	$2.05
Corn Silage-Soybean Meal			
BBIG	$2.89	$2.94	$2.99
BBIG+L	$3.06	$3.11	$3.16
SG	$2.72	$2.77	$2.82
SG+L	$2.69	$2.74	$2.79
Corn Silage- Dry Distillers			
BBIG	$2.02	$2.07	$2.12
BBIG+L	$2.07	$2.12	$2.17
SG	$1.91	$1.96	$2.01
SG+L	$1.89	$1.94	$1.99

† BBIG=Big Bluestem and Indian Grass; BBIG+L= Big bluestem and indiangrass with legumes; SG=Switchgrass; SG+L= Switchgrass with legumes.

Chapter 4: Conclusions

This thesis evaluated the economics of grazing native warm-season grasses (NWSGs) in the southeastern United States. Findings of this thesis are both a contribution to the literature and useful to producers grazing stocker cattle and developing replacement dairy heifers alike.

The first study had two objectives. The first objective was to determine if there was a difference in net returns to full-season grazing beef steers on different stands of switchgrass (SG), a mixture of big blue and indiangrass (BBIG), and eastern gamagrass (EG). The second objective of the study was to determine the breakeven price of biomass a producer would need to be indifferent between a dual-purpose grazing and biomass harvest system for SG, BBIG, and EG. The first study found that, on average, steers grazing SG generated the greatest net returns at both locations. This study also found that the breakeven price of biomass for SG was lowest across the NWSGs.

Though grazing SG and BBIG generated positive net returns at both locations, it is unclear to what extent the use of NWSGs was able to extend the grazing season relative to traditional cool-season forages such as tall fescue. The ADG associated with full-season grazing was 54-80% of the ADG from early-season grazing the same NWSGs at the same locations. At Ames Plantation (AP), there was no statistical difference in expected net returns or expected beef yield within NWSG treatments. These results indicate that animal performance decreased from the end of early-season grazing and the end of full-season grazing. Also, it is unclear how advantageous the dual-purpose grazing and biomass system would be for beef producers. Given that early-season grazing occurred from mid-May through mid-June, this does not necessarily imply that early-season grazing NWSGs extends the grazing season relative to grazing fescue.

However, this may be advantageous for lignocellulosic biomass producers seeking to lower the breakeven price of biomass relative to a system in which only biomass is harvested.

The second study evaluated how grazing NWSGs, with and without legumes, in bred dairy heifer development affects the cost of development compared to traditional feedstuffs. Results from the study found that the expected cost AUD^{-1} for SG was statistically lower than the expected cost AUD^{-1} for all other NWSG treatments. Grazing SG was also found to have a lower cost AUD^{-1} than the cost $head^{-1}$ day^{-1} of feeding three common feed rations used in bred dairy heifer development. For these reasons, grazing bred dairy heifers on SG appears to be the most economically feasible feed for contract dairy heifer developers to maximize their expected net returns during the summer months.

Robust conclusions were unable to be made about the economics of legume use in stands of NWSGs given the inconsistent levels of legume cover across years in this study. The use of legumes increased annual pasture cost without generating a statistically higher level of animal performance relative to treatments without legumes. Additionally, the expected ADG found by animals grazing NWSGs in this study is consistent in the literature as to what an ideal growth rate for postpubertal heifers would be to optimize first lactation performance.

The results of this study provide a conduit for future research on the economics of grazing NWSGs for both dairy heifer development and beef steer grazing in the Southeast. Future research is needed into how net returns to full-season grazing NWSGs in the Southeast compare to full-season grazing of fescue during the summer months. Additionally, future research on how the breakeven price of biomass is affected by early-season grazing and a biomass harvest at differing stocking rates and grazing durations. The breakeven price at

differing stocking rates and grazing durations also needs compared to the breakeven price of biomass from a biomass harvest only system. Furthermore, further research is needed on successful legume establishment in stands of NWSGs in the Southeast before a robust conclusion can be made about their use as a substitute for N fertilizer. Also, research is needed to determine how first lactation performance of heifers developed on NWSGs compares to that of traditional feedstuffs.

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Vita

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