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ABSTRACT

We estimate the profitability of developing heifers on one stockpiled cool-season grass and two stockpiled warm-season grasses during the winter months by comparing distributions of net present value (NPV) over an 11-year useful life. Furthermore, distributions of payback period and the break-even price for each calf over the heifer's production life were generated for each forage species. These results are compared across forages as well as to a simulated drylot system for heifer development. Data comes from a grazing experiment in Tennessee, where heifers grazed big bluestem and Indian grass combination (BBIG), switchgrass (SW), or endophyte-infected tall fescue (TF) pastures. Total cost of producing the first calf from a heifer using the three forage-based systems was $1,079/head to $1,149/head, with TF being the most expensive forage-based heifer development system, and the total cost to produce a calf from heifers developed in a drylot system ranged from $574 to $644/head higher than the forage-based systems. The NPV of heifers developed on forage ranged from $264 to $468/head, while heifers developed in a drylot system had an NPV of –$876/head. Payback period was estimated in years of age, and heifers in forage-based systems became profitable at 3–4 years of age, whereas heifers developed in a drylot were 9–10 years of age before they covered their investment cost. The results indicate that SW was the lowest risk and the most profitable forage species relative to TF. These findings suggest that low-input forage-based systems may be more profitable than drylot heifer development systems in the southeastern United States.

KEYWORDS

heifer development, investment costs, breakeven period

INTRODUCTION

Developing a heifer to replace a cull cow is one of the most expensive management decisions for cow-calf producers, which has major implications on the long-term profitability of the herd. Historically, producers have been encouraged to feed weaned heifers to reach 65% of their mature body weight before breeding to maximize pregnancy rates (Patterson et al., 1992). Developing heifers in a drylot system, which is feeding confined animals harvested feedstuffs, is common practice to ensure that they achieve a target body weight to maximize pregnancy rates. However, the marginal cost of feeding a replacement heifer to maximize pregnancy rates may be greater than returns from producing and selling an additional calf or marginal revenue.

Recent studies have shown that developing heifers to a lighter target body weight can reduce development cost without impairing reproductive function (Funston & Deutscher, 2004; Clark et al., 2005; Roberts et al., 2009; Funston & Larson, 2011; Mulliniks et al., 2013). Heifer development cost decreased by $19 to $45/heifer when a producer develops to achieve 50–55% of mature body weight at breeding instead of 65% of mature body weight (Feuz, 2001; Funston & Deutscher, 2004; Clark et al., 2005; Funston & Larson, 2011). These studies have compared traditional drylot systems with alternative approaches whereby heifers graze low-quality forage systems (corn residue and/or winter native range) with additional supplemental protein (Funston & Larson, 2011; Mulliniks et al., 2013; Summers et al., 2014). In addition, these studies determined that reproductive performance was similar across systems, while the cost of development in a drylot was more expensive than grazing heifers (Funston & Larson, 2011; Mulliniks et al., 2013; Summers et al., 2014).

While this research will assist in making profitable heifer development management decisions, these studies were conducted in extensive rangeland systems in the western United States and do not go beyond calculating development cost. Little is known about how these developmental systems affect profitability of heifer development on pasture in the southeastern United States. Beef cattle production in the southeastern United States is centered on forage-based cow-calf production (McBride & Mathews, 2011). Tall fescue (TF) is a cool-season grass that is adaptable, easy to establish, and persistent under adverse conditions (Stuedemann & Hoveland, 1988; Wolf et al., 1979), which is why cattle producers primarily rely on it for pasture and hay in this region (Keyser et al., 2011). Cool-season grasses grow primarily from early March to May, with additional growth from the end of September to November (Keyser et al., 2011).

Endophyte-infected TF has some physiological characteristics that can cause problems for cattle producers (Volenec & Nelson, 2007). During summer, cattle grazing endophyte-infected TF are likely impacted by fescue toxicity, which can elevate body temperature, lower conception rates, and reduce average daily gain (ADG) (Looper et al., 2010; Roberts & Andrae, 2004). These biological effects of fescue toxicity result in losses of over $1 billion a year to U.S. cattle producers (Smith et al., 2012). Thus, some attention has focused on evaluating cattle performance and the net returns to grazing warm-season grasses in the southeastern United States, which primarily grow from May to August (Burns et al. 1984; Burns & Fisher, 2013; Lowe et al., 2015; Lowe et al., 2016). Lowe et al. (2015) reported that grazing steers on warm-season grasses in Tennessee had net returns ranging from $99 to $345/acre, depending on species. Similarly, Lowe et al. (2016) analyzed animal performance and cost of grazing bred dairy heifers on warm-season grasses during the summer months. The cost of grazing dairy heifers on warm-season grasses was between $0.38 and $0.65/head/day, but the cost of developing the heifers in a drylot was greater than $1.89/head/day (Lowe et al., 2016). Overall, grazing warm-season grasses to complement TF grazing systems in the southeastern United States appears to be a profitable alternative to TF.

Since the environment of the southeastern United States allows for multiple forage growing seasons, producers could stockpile cool- and warm-season forages to extend the grazing season in the winter months and reduce the cost of heifer development (Poore et al., 2006; Drewnoski et al., 2009; McFarlane et al., 2017). Poore et al. (2006) and Drewnoski et al. (2009) reported that stockpiling endophyte-infected TF for grazing from December to February was suitable for developing beef heifers. However, little is known about the profitability of developing a heifer in the southeastern United States using stockpiled cool- and warm-season forages during the winter and about how the profits of these heifer development systems compare to a drylot system.

The objective of this research was to determine the profitability of retaining a heifer to develop while grazing stockpiled cool- and warm-season grasses during the winter months. Profitability was measured as net present value (NPV) of the developed heifer over an 11-year production life. We estimated the number of calves that a heifer needs to produce to be profitable (i.e., payback period) and the breakeven price for each calf over the 11-year production life. Data comes from a grazing experiment in Tennessee, where heifers grazed big bluestem and Indian grass combination (BBIG), switchgrass (SW), and endophyte-infected TF pastures. Additionally, we estimated NPV, payback period, and breakeven prices for developing a heifer in a traditional drylot system during the same time period to achieve a target body weight before breeding. Results will help producers improve long-term profitability of their herds by making profitable heifer development decisions.

ECONOMIC MODEL

There are many advantages for producers to develop their own replacement heifers, such as increased control of genetic potential, reduced disease exposure, improved acclimation to the operation environment, and reduced cost when compared with purchased heifers for some operations (Schultz & Gunn, 2014). This might explain why 83% of all cow-calf operations in the United States reported in 2007–2008 that they raised their own replacement heifers (United States Department of Agriculture, 2011). Since this is the common practice among cow-calf producers, we approached this analysis from the perspective of producers raising their own replacement heifers and did not consider the option of purchasing a heifer.

Developing replacement heifers can be viewed as a long-term investment (Ibendahl et al., 2004; Matthews & Short, 2001; Meek et al., 1999). Beef producers have to invest several years of capital before a heifer produces a calf or generates revenue. Cow-calf producers in the southeastern United States typically follow a spring calving season, beginning in January (Campbell et al., 2013; Henry et al., 2016). Therefore, the cost of producing a heifer begins when a cow is bred, which is a year before the heifer is born. In January, a heifer calf is born that will be developed to replace a cull cow and is weaned in September. The heifer calf is bred the following April and calves in the following January at two years of age, and her calf is generally weaned in September. Assuming that producers commonly market their calves after a short weaning period, revenue will include the sale of steer and heifer calves as well as the sale of culled cows. The size of the calves at weaning and the number of cows culled are also components affecting revenue. Therefore, producers incur production costs such as pasture and feed for several years before receiving revenue from heifers. Another important cost to consider in the cow-calf producer's decision to develop a heifer to replace a cull cow is the opportunity cost (Tang et al., 2017). The revenue that the producer could receive from selling the heifer calf at weaning is the opportunity cost.

Given the aforementioned factors to consider, partial budgets were used to estimate net returns for heifer developed on forage-based and drylot systems. The partial budgeting approach only considers the costs that are different across the heifer development systems (Kay et al., 2012). Annual net returns can be generally expressed as

$$E[\pi_{it}] = p^s_{it}y^s_{it}\left(\frac{PR_i}{2}\right) + p^h_{it}y^h_{it}\left(\frac{PR_i}{2} - RR_i\right) + p^c_{it}y^c_{it}(RR_i) - p^h_{it}y^h_{it}\left(\frac{(1-PR_i)}{2} - RR_i\right) - PC_{it} - FC_{it} \tag{1}$$

where π_{it} is the expected annual net returns ($/head) for the ith heifer development system (i = BBIG, SW, TF, and drylot) in time period t ($t = 1, \ldots, 11$); p^s_{it} is the price of steer calves ($/pound); y^s_{it} is the weight of the steer calves (pounds/head); PR_i is the pregnancy rate $0 \le PR_i \le 1$; p^h_{it} is the price of the heifer calves ($/pound); y^h_{it} is the weight of heifer calves (pounds/head); RR_i is the replacement rate of the cow herd $0 \le RR_i \le 1$; p^c_{it} is the price of culled cows ($/pound); y^c_{it} is the weight of cull cows (pounds/head); PC_{it} is the annualized pasture cost for each forage ($/head) in time period t ($t = 1, \ldots, T$); and FC_{it} is the supplemental or harvested feed cost ($/head) for each heifer development system.

Net returns were modeled for a producer who grazes cattle year-round. Therefore, heifers developed on the forages had the cost of pasture and supplemental feed during development. In the drylot system, three months of the year (January through March) heifers will be fed harvested feedstuffs, and the remaining nine months will be spent grazing. Therefore, pasture cost also was included in the drylot system. With the partial budgeting approach, we only consider the annual cost of pasture and feed during the development months of January through March. Therefore, the total cost of developing a heifer would likely be higher than what is reported in this manuscript.

The annual net returns were discounted to find the NPV of each heifer development system, which is generally expressed as

$$E[NPV_i] = \sum_{t=2}^{11}[p^s_{it}y^s_{it}\left(\frac{PR_i}{2}\right) + p^h_{it}y^h_{it}\left(\frac{PR_i}{2} - RR_i\right) + p^c_{it}y^c_{it}(RR_i)]/(1+R)^t - \sum_{t=1}^{11}\left[(PC_{it} + FC_{it})/(1+R)^t - p^h_{it}y^h_{it}\left(\frac{(1-PR_i)}{2} - RR_i\right)/(1+R)\right] \tag{2}$$

where NPV_i is the sum of the discounted annual net returns and R is the risk-adjusted discount rate. The opportunity cost $[p^h_{it}y^h_{it}(\frac{(1-PR_i)}{2} - RR_i)]$ is discounted back one period, because this is a one-time cost that occurs in period one. We selected an 11-year useful life of the raised replacement heifer and assumed that heifers will produce their first calf at age two, which is consistent with assumptions in other studies (Ibendahl et al., 2004; Matthews & Short, 2001; Shane et al., 2017). A positive NPV indicates that cost of the investment was less than the revenue generated from the investment, and a negative NPV indicates that the cost of the investment was greater than the revenue generated from the investment (Kay et al., 2012).

Payback period for the heifer was also estimated. This measurement estimates the age when a heifer that was retained and developed becomes profitable (Kay et al., 2012). This calculation was found by dividing the sum of the annual discounted net returns by the initial investment cost of developing the heifer (Schultz, 2016). The age at which the revenue annual net returns are greater than the investment cost is when heifers become profitable. Therefore, an investment with the shortest payback period is preferred.

Going beyond payback period, we can determine the price that a producer would need to make zero profit for each calf, commonly referred to as a breakeven price (Kay et al., 2012). Equation (1) can be rearranged to show the price (per pound) that producers would need to break even with each calf produced by the heifer over her useful life. The breakeven price is the same for heifers and steers, since the cost of production to raise these calves will be the same. Any price that the producer receives above the breakeven price is profitable, and if the price received is below the breakeven price, profits will be negative. A greater cost of production will result in a higher breakeven price, thus limiting the chances of earning a positive profit. Conversely, a lower cost of production will decrease the breakeven price, and the producer would have a greater opportunity of making a positive profit. Therefore, minimizing cost of production provides the greatest opportunity for profit.

SIMULATION AND RISK ANALYSIS

Retaining and developing heifers can be a risk investment due to variability in production and prices (Matthews & Short, 2001). A Monte Carlo simulation model was developed to estimate distributions of NPV, payback periods, and breakeven prices by forage-based system and drylot. Drylot systems closely monitor for heifer feed intake and growth performance, which reduces the production risk (Funston & Larson, 2011; Mulliniks et al., 2013; Summers et al., 2014). However, price risk is important to consider when using a drylot system. Producers who choose to use a forage-based system for heifer development are potentially taking on greater production risk due to increased variability in growth. Therefore, the forage-based heifer development systems model considered variability of weaning weights and cattle prices, and the drylot system model only considered price variability.

Prices for cull cows, steers, and heifers were randomly drawn from a multivariate empirical distribution derived using historical Tennessee price data from 2002–2017, and calf weights in the forage-based systems were randomly drawn from a Gray, Richardson, Klose, and Schumann (GRKS) distribution, which is similar to Henry et al. (2016). The GRKS distribution is useful when minimal information is available about the distribution, requiring only minimum, midpoint, and maximum values as the bounds for the distribution (Richardson, 2006). The GRKS distribution is a two-piece normal distribution with 50% of the observations below the midpoint and 2.5% below the minimum value, while 50% of the observations are above the midpoint and 2.5% above the maximum value (Richardson, 2006). Simulation and Econometrics to Analyze Risk (SIMETAR©) was used to develop the distributions and perform the simulations (Richardson et al., 2008). A total of 5,000 breakeven price observations were simulated for each of the forage-based heifer development systems.

Stochastic dominance was used to compare the distributions of NPV for each forage-based system and the drylot system. In first-degree stochastic dominance, the scenario with cumulative distribution functions (CDF) F dominates another scenario with CDF G if $F(\pi) \leq G(\pi) \forall \pi$ (Chavas, 2004). First-degree stochastic dominance often does not find one scenario to clearly be preferred over another; therefore, second-degree stochastic dominance adds the restriction that producers are risk averse, which increases the chance of finding a preferable scenario (Chavas, 2004). Second-degree stochastic dominance states that the scenario with CDF F dominates another scenario with CDF G if $G \int F(\pi) d\pi \leq \int G(\pi) d\pi \forall \pi$ (Chavas, 2004). Stochastic dominance is an effective method of conducting a risk analysis of different production practices (Henry et al., 2016). The distributions of the payback period and breakeven prices are presented but are not analyzed using stochastic dominance.

We used NPV distributions for the analysis, since this is the measure of profitability.

DRYLOT FEED COSTS

The primary difference between the forage-based heifer development systems and drylot systems is the cost of feed during the drylot period from January through March (i.e., about 100 days). We assume that producers are grazing heifers from April through December on TF pasture and that from January to March heifers are fed harvested feedstuffs in a drylot. While the fence, fuel, or equipment costs would likely increase in a drylot system, we only accounted for additional feed and labor costs. The cost of the feed rations for the drylot were estimated for January, February, and March, because adequate nutrition was likely available while grazing TF pastures the remaining months of the year.

Rations were generated to meet the predetermined nutritional needs for heifers using the National Academies of Sciences, Engineering, and Medicine Nutrient Requirement of Beef Cattle program (National Academies of Sciences, Engineering, and Medicine, 2016). The program determined the minimal nutritional needs for a heifer based on animal description and feed diet evaluation. The animal description variables were age, body weight, and target ADG. In the diet evaluation section, this program focuses on balancing a cow's required dry matter intake (DMI), net energy for maintenance (NEm), net energy for gain (NEg), total digestible nutrients, and crude protein (CP) using the available feed ration ingredients specified in the program. For example, for a growing heifer that is 500 pounds with a target ADG of 2 pounds/day, the minimum amount of DMI was 18.4 pounds/day, NEm was 3.76 mcal/day, NEg was 2.4 mcal/day, total digestible nutrients was 13.01 pounds/day, and CP was 2.04 pounds/day.

Ingredients for feed rations can be selected by producers based on several criteria. The accessibility and price of the ingredients are likely two of the most important criteria for selecting feed rations. Therefore, the least-cost ration was constructed by selecting from five commonly accessible ingredients in Tennessee, including corn gluten feed, corn silage, dried distillers grains with solubles (DDGS), soybean hulls, and whole cottonseed. Since corn silage is the dominant feedstuff used in Tennessee for large beef producers, we restricted the ration to be at least 90% corn silage. Similar to Henry et al. (2016), a linear programming model was constructed to select across all ingredients to build the least-cost feed rations.

DATA

Animal Production

Data comes from a five-year study of crossbred Angus heifers that were developed on stockpiled BBIG, SW, and endophyte-infected TF at the Middle Tennessee Research & Education Center, Spring Hill, Tennessee. Each forage type was then randomly allocated to receive either a feed supplement of 1.5 pounds/heifer/day of DDGS or 0.48 pound/heifer/day of blood meal and fish meal (BF). Therefore, the treatment combinations were BBIG/BF, BBIG/DDGS, SW/BF, SW/DDGS, TF/BF, and TF/DDGS. Heifer growth, reproductive performance, and first calf performance data were collected for a total of 266 spring-born heifers over the course of the experiment.

The grazing period began in January and was terminated in April at fixed-timed artificial insemination (TAI) every year of the study. Heifers were managed together after termination of the different grazing treatments at the onset of the breeding season. The breeding season began in April every year, and all heifers were synchronized for TAI. Natural service of heifers was provided by cleanup bulls that were turned out 14 days after TAI for a 60-day breeding season. The percentage of heifers that were diagnosed pregnant by forage type were 87% for BBIG/BF, 90% for BBIGDDGS, 92% for SW/BF, 93% for SW/DDGS, 91% for TF/BF, and 94% for TF/DDGS.

Since we were unable to track death loss and stillborn calves because a portion of heifers were sold prior to calving, we used the pregnancy rates for each forage as the calving rate and assumed a replacement rate of 15%, which is typical for Tennessee producers (Henry et al., 2016). Calf body weight was measured at birth and weaning for the first calf of each heifer in the study. Table 1 shows summary statistics of calf weight at weaning from the grazing experiment. In the economic and simulation model, we assumed that calves would have

Table 1. Summary Statistics of Calf Weaning Weight (in Pounds) by Forage and Supplement Type

Pasture	Supp[1]	Mean	Median	SD[2]	Minimum	Maximum
Big bluestem/Indian grass	BF	576	568	60	468	737
	DDGS	531	557	75	345	605
Switchgrass	BF	537	534	73	380	674
	DDGS	548	533	82	405	660
Tall fescue	BF	541	540	67	402	664
	DDGS	557	563	71	380	683

[1] Supplement: Blood and fish meal (BF) and dried distillers grains and solubles (DDGS).
[2] Standard deviation.

Table 2. Annualized Establishment Costs and Annual Operating Expenses ($/acre) for Each Forage Type

Pasture	Annualized Establishment Cost	Annual Operating Expenses	Total Expense
Big bluestem/ Indian grass	$42.88	$185.76	$228.64
Switchgrass	$44.24	$182.78	$227.02
Tall fescue	$31.95	$193.43	$225.38

the same distribution of weaning weights in every year of the heifer's 11-year useful life, which is similar to the useful life assumed by Shane et al. (2017). Further detail on the experimental design and heifer growth data can be found in McFarlane et al. (2017).

Economic Data

Enterprise budgets were used to estimate establishment and operational costs of grazing BBIG, SW, and TF. A 10-year production horizon was assumed (Lowe et al., 2015, 2016), with no grazing occurring in the establishment year. Total establishment and production costs of the forages were calculated following Lowe et al. (2015), Lowe et al. (2016), and Keyser et al. (2016). The establishment costs included seed, herbicide, fertilizer, labor, and machinery and were annualized over the life of the pasture using a discount rate of 5.5% (Lowe et al., 2015, 2016). The annualized establishment cost was added with annual operational cost and annual land rent to calculate total annual cost of production over a 10-year useful life. To account for the risk of failed establishment, a 10% reestablishment cost was assumed in the budget. Estimated total annualized pasture costs are based on 2017 dollars and are shown in Table 2. Detailed enterprise budgets for each forage are provided in the appendix.

Livestock budgets were also constructed following the University of Tennessee Extension Livestock Budgets (University of Tennessee, 2017). Annualized pasture cost were multiplied by the stocking density of one cow-calf pair to one and a half acres to get a pasture cost per herd. The forage-based system fed DDGS or a 50:50 mixture of BF in the months of January, February, and March. The cost per head of each of these supplements from January to March was $10.99 for BF and $11.56 for DDGS.

The opportunity cost was calculated by multiplying the heifer weaning weight by the average heifer calf price. We selected a heifer weaning weight of 530 pounds/head, which was the average weaning weight for heifer calves in the experiment. Prices for Tennessee heifers ranging from 500 to 600 pounds were collected from the U.S. Department of Agriculture Agricultural Marketing Service (USDA AMS) (2017a) for the last 15 years (2002–2017) and adjusted into 2017 dollars using the U.S. Bureau of Labor Statistics Consumer Price Index (United States Department of Labor, 2017). The average heifer price was $1.26/pound (USDA AMS, 2017a), and opportunity cost was calculated by using a randomly drawn price.

To calculate the revenue from cull cows, we also used the randomly drawn price from the Tennessee cull cow price over the last 15 years (USDA AMS, 2017a) and multiplied the price by average cull cow weight of 1,400 pounds. We made these assumptions for both the forage-based system and the drylot system. Production costs were discounted into NPV using the discount rate (*R*) of 5.5%, which is similar to the assumption in Henry et al. (2016).

For the drylot system, monthly prices for the ingredients of the feed rations reported at Memphis, Tennessee, and St. Louis, Missouri (nearest locations to Tennessee), were also collected from USDA AMS (2017b). Seasonal prices were only available from 2002 to 2017 for January, February, and March. All beef and feed ingredient prices were adjusted into 2017 dollar values using the U.S. Bureau of Labor Statistics Consumer Price Index (United States Department of Labor, 2017). Table 3 presents the real monthly average and standard deviation for prices of corn gluten feed, corn silage, DDGS, soybean hulls, and whole cottonseed in the months of January, February, and March (USDA AMS, 2017b). Since we do not have data from a drylot system, we assumed a pregnancy rate of 95%, which is similar to previous reports (Patterson et al., 1992; Funston & Larson, 2011; Mulliniks et al., 2013), and a calf weaning weight of 543 pounds, which is the average of the weaning weight of all the calves in this experiment. The cost of labor for a heifer was assumed to be $80/head higher under a drylot system than a forage-based system. This is because heifers were fed on a daily basis instead of twice weekly in the forage-based treatments.

RESULTS AND DISCUSSION

The cost-minimizing ration formulation was 17.84 pounds/day of corn silage and 0.88 pound/day of corn gluten in January and 16.47 pounds/day of corn silage and 1.93 pounds/day of corn gluten in February and March (Table 4). The total ration cost was $36.24/head in January, $38.18/head in February, and $37.40/head in March, for a total cost of $111.82/head. With the added feed cost for the drylot system, the total cost of producing a calf from a heifer in a drylot system was $1,723/head, which is from $574 to $644/head more expensive

Table 3. Average Monthly Real Prices ($/Dry Ton) for Feed Ration Ingredients from 2000 to 2017, in 2017 Dollars

Month	Corn Gluten Feed ($/ton)	Corn Silage ($/ton)	Dried Distillers Grains ($/ton)	Soybean Hulls ($/ton)	Cottonseed Whole ($/ton)
January	$145.35	$40.03	$173.60	$133.34	$197.74
February	$138.32	$41.32	$156.47	$128.65	$195.81
March	$134.47	$42.13	$156.27	$119.50	$199.72

Source: USDA AMS (2017b) markets in St. Louis, Missouri, and Memphis, Tennessee, as well as the Consumer Price Index (United States Department of Labor, 2017).

Table 4. Amount of Ingredients Fed (Dry Pounds/Day) and Total Cost in Each of the Least-Cost Feed Rations by Month

	Month		
Ingredients (Dry Pounds/Day)	January	February	March
Corn silage	17.84	16.47	16.47
Dried distillers grains	0.88	1.93	1.93
Total	18.72	18.40	18.40
Total cost ($/head)	$36.24	$38.18	$37.40

Source: National Academies of Sciences, Engineering, and Medicine (2016).

Table 5. Summary Statistics of the Simulated Distributions of Total Cost of Developing a Heifer (in $/Head), Net Present Value ($/Head), and Payback Period (Years of Age) by Forage and Supplement Type

Pasture	Supp[1]	Investment Cost	Net Present Value	Payback Period
Big bluestem/ Indian grass	BF	$1,119 (9.07)	$384 (432.65)	3.61 (0.736)
	DDGS	$1,098 (5.58)	$414 (434.65)	3.70 (0.767)
Switchgrass	BF	$1,087 (5.59)	$450 (434.47)	3.58 (0.751)
	DDGS	$1,079 (4.88)	$468 (437.42)	3.45 (0.716)
Tall fescue	BF	$1,149 (6.28)	$264 (433.33)	3.91 (0.803)
	DDGS	$1,135 (4.19)	$289 (435.43)	3.51 (0.742)
Drylot	Harvested feed	$1,723 (3.49)	–$876 (436.15)	9.65 (1.605)

Standard Deviations are noted in parentheses.
[1] Supplement: Blood and fish meal (BF) and dried distillers grains with solubles (DDGS).

than the forage-based heifer development systems (Table 5).

The estimated investment cost of producing a calf using the forage-based systems ranged from $1,079 to $1,149/head (see Table 5). These estimates include costs from breeding until selling the first calf from the heifer. The most expensive forage treatment to develop heifers was TF/BF, and the least expensive forage treatment was SW/DDGS. Overall, TF had the highest cost of production of the three forage treatments. Switching from developing heifers on TF to BBIG or SW was estimated to reduce development costs from $30 to $62/head. Lowe et al. (2015) and Lowe et al. (2016) reported that summer grazing steers and heifers on warm-season grasses was profitable, which further supports the conclusion that warm-seasons grasses might be a profitable complement to TF grazing systems in the southeastern United States.

NPV and payback period for heifers were estimated over an 11-year productive life and are presented in Table 5. NPV ranged from $264 to $468/head for forage-based heifer development. Heifers grazing SW had the greatest average NPV, with $450 and $468/head for SW/BF and SW/DDGS, respectively. The lowest average NPV among forage-based development treatments was determined for heifers grazing TF ($264 and $289/head for TF/BF and TF/DDGS, respectively). In contrast, heifers developed in a drylot system had a negative average NPV (-$876/head). Similarly, Mulliniks et al. (2013) found that net returns for range-based development were greater ($268.56/heifer developed) when compared with drylot-developed heifers ($168.85/heifer developed). This result is similar to several other studies conducted in the western United States (Feuz, 2001; Funston & Deutscher, 2004; Clark et al., 2005; Funston & Larson, 2011).

The distribution of NPV for each forage-based system and drylot were compared, and the treatment combination of SW/DDGS was found to be dominant over all systems by second-degree stochastic dominance (Figure 1). We can conclude

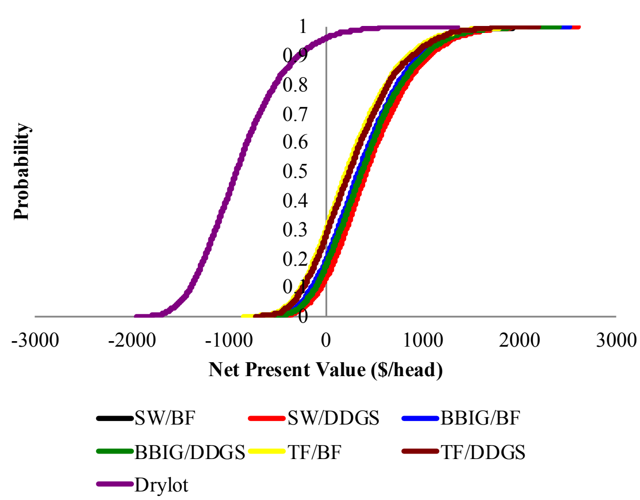

Figure 1. Cumulative Distribution Function of the Breakeven Price of the First Born Calf from a Developed Heifer ($/Pound) by Forage Type and Supplement Type

that both a risk-averse and profit-maximizing producer would select the SW/DDGS heifer development system compared to all other forage-based systems. This results also reinforce the importance of low-cost heifer development on the long-term profitability of the herd.

Heifers developed in forage-based development systems would be approximately 4 years of age before paying back development costs. About 10 years of productivity would be necessary for heifers developed in a drylot system to provide a return on investment. This means that using a forage-based system for heifer development results in the heifer becoming profitable at a younger age than using a drylot system.

Summary statistics of the breakeven prices over an 11-year productive life of heifers are presented in Table 6. The average breakeven price ranged from $2.76/pounds to $3.09/pounds for the first calf of heifers developed in a forage-based system. The average breakeven price for the first calf of drylot heifers was $4.66/pounds. Confidence intervals were calculated for each treatment at the 95% confidence level. The breakeven price from the drylot system was higher at the 95% confidence level than all forage-based treatments. However, there was no difference in the breakeven prices across the forage-based treatments.

Among the forage-based treatments, BBIG/BF had the lowest average breakeven prices, and TF/BF had the greatest average breakeven prices. Within treatments supplementing DDGS, SW had the lowest average breakeven prices, and heifers grazing BBIG had the lowest average breakeven

Table 6. Summary Statistics of the Distribution of Breakeven Price for Calves (in $/Pound) over an 11-Year Production Life by Forage and Supplement Type

	BBIG[1]		SW		TF		
Age[2]	BF[3]	DDGS	BF	DDGS	BF	DDGS	Drylot
2	2.76 (0.31)[a]	3.05 (0.54)[a]	2.96 (0.45)[a]	2.92 (0.37)[a]	3.09 (0.40)[a]	3.00 (0.49)[a]	4.66 (0.02)[b]
3	1.67 (0.14)	1.83 (0.19)	1.79 (0.18)	1.76 (0.15)	1.87 (0.17)	1.81 (0.19)	2.85 (0.01)
4	1.30 (0.09)	1.43 (0.12)	1.40 (0.11)	1.38 (0.10)	1.46 (0.11)	1.42 (0.12)	2.25 (0.01)
5	1.12 (0.07)	1.24 (0.09)	1.21 (0.08)	1.19 (0.07)	1.26 (0.08)	1.22 (0.09)	1.95 (0.01)
6	1.02 (0.05)	1.12 (0.07)	1.09 (0.07)	1.08 (0.06)	1.14 (0.06)	1.11 (0.07)	1.77 (0.01)
7	0.94 (0.05)	1.04 (0.06)	1.01 (0.06)	1.00 (0.05)	1.06 (0.05)	1.03 (0.06)	1.65 (0.01)
8	0.89 (0.04)	0.98 (0.05)	0.96 (0.05)	0.95 (0.04)	1.00 (0.05)	0.97 (0.05)	1.56 (0.01)
9	0.85 (0.04)	0.94 (0.05)	0.92 (0.05)	0.91 (0.04)	0.96 (0.04)	0.93 (0.05)	1.50 (0.01)
10	0.82 (0.03)	0.91 (0.04)	0.89 (0.04)	0.88 (0.04)	0.93 (0.04)	0.90 (0.04)	1.45 (0.01)
11	0.80 (0.03)	0.88 (0.04)	0.86 (0.04)	0.85 (0.03)	0.90 (0.04)	0.87 (0.04)	1.40 (0.01)

Standard deviations are in parentheses.

[a,b] Means with different superscripts differ ($P < 0.05$).

[1] Pasture: Big bluestem and Indian grass (BBIG), switchgrass (SW), and tall fescue (TF)

[2] Age: Cow age is reported in years.

[3] Supplement: Blood and fish meal (BF) and dried distillers grains and solubles (DDGS).

prices when supplemented with BF. With the exception of BBIG/DDGS treatment, the breakeven price for the first calf from a heifer developed on TF was greater on average than for SW and BBIG/BF. First-calf weaning weights were greater on average for heifers grazing TF than SW; thus, the lower cost of production for SW resulted in the breakeven price being lower than for TF. While weaning weights are important in analyzing the profitability of herds, the results demonstrate how the cost of production can impact the likelihood of breakeven.

The price of 500- to 600-pound steer and heifer calves in the last 15 years (2002–2017) has ranged from $0.99 to $2.51/pound, with an average price of $1.37/pound (USDA AMS, 2017a). Thus, 15-year average cattle prices were less than the breakeven prices of the first calf from a heifer in the present study. Therefore, the first calf produced by the heifer will not likely be profitable. However, breakeven prices for calves around 3 and 4 years of age were at or below the average cattle price if a forage-based heifer development system was used. In contrast, heifers developed in a drylot would not break even until approximately 9 to 10 years of age.

The results show that first-calf heifers and three-year-old cows are commonly not profitable for cow-calf producers, assuming they produce a calf in both years. However, if a heifer or three year old cow does not wean a calf or fails to become pregnant, the long-term profitability of the herd will decreased. Therefore, improper management of young two- and three-year-old cows could be costly for producers. However, if heifer development costs are low, selling open heifers in a feeder market could be a profitable option (Clark et al., 2005). Overall, these results illustrate the need for increased selection pressure for heifers that have the ability to remain in the herd longer rather than masking infertility with overfeeding and developing heifers (Roberts et al., 2017).

CONCLUSION

Developing heifers to replace cull cows is a complex decision that can have major implications on herd profitability. Several studies have examined ways to reduce the cost of heifer development in the western United States without impairing reproductive function (Funston & Deutscher, 2004; Clark et al., 2005; Roberts et al., 2009; Funston & Larson, 2011; Mulliniks et al., 2013). However, little is known about the profitability of heifer development in the southeastern United States. Thus, we calculated breakeven prices over an 11-year productive life for heifers that were developed grazing BBIG, SW, and TF. We compared these breakeven prices to estimated breakeven prices from heifers developed in a drylot system. In addition, NPV and payback period were estimated for forage-based and drylot-based heifer development systems. This study builds on previous work by focusing on heifers in the southeastern United States, and the results will be helpful for informing producers about more profitable heifer development systems.

A simulation model was established to estimate a distribution of breakeven prices of calves from heifers developed on forage-based systems. The simulation was constructed to account for the production risk of using a forage-based system. For the drylot system, a least-cost ration was developed to be fed during the months of January, February, and March.

Heifers developed using forage-based systems had an average NPV that ranged from $264 to $468/head. Development in a drylot system resulted in a negative NPV after an 11-year useful life. Heifers developed in a forage-based system would pay back investment at about 3 to 4 years of age. In contrast, drylot-developed heifers would require a 9- to 10-year payback period. The average breakeven price for the first calf from a heifer developed on forage-based systems was found to range from $2.76 to $3.09/pound, whereas the breakeven price under a drylot system was $4.66/pound. For drylot systems, producing a calf from a heifer was $574 to $644/head more expensive than the forage-based heifer development systems. This result also supports recent findings that warm-season grasses are a profitable complement to TF systems in the southeastern United States. In addition, low-cost forage-based heifer development systems improve long-term profitability for beef producers.

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APPENDIX

Table 7. Switchgrass No-Till Establishment Budget for Tennessee in 2017

Item	Unit	Quantity	Price	Amount
Variable Expenses				
Seed	pound	10.00	$13.50	$135.00
No-till drill rental	acre	1.00	$9.80	$9.80
Nitrogen (NO3[a])	pound	0.00	$0.55	$0.00
Phosphorus (P2O5[b])	pound	30.00	$0.69	$20.70
Potassium (K20[c])	pound	30.00	$0.48	$14.40
Fertilizer custom application	acre	1.00	$9.38	$9.38
Lime custom application	ton	0.50	$9.38	$4.69
Gramoxone Max	pt	1.50	$4.33	$6.50
Surfactant	pt	0.50	$0.63	$0.32
Herbicide custom application	acre	1.00	$8.13	$8.13
Fuel[d]	acre	1.00	$7.94	$7.94
Oil and filter[d]	acre	1.00	$1.18	$1.18
Repairs and maintenance[d]	acre	1.00	$4.23	$4.23
Interest on operating capital	acre	1.00	8.00%	$12.18
Land rent	acre	1.00	$20.00	$20.00
Total variable cost	acre	1.00		$254.45
Fixed Costs				
Depreciation[d]	acre	1.00	$2.63	$2.63
Interest[d]	acre	1.00	$3.41	$3.41
Insurance[d]	acre	1.00	$0.23	$0.23
Total fixed costs	acre	1.00		$6.27
Labor cost	hour	0.91	$10.07	$9.16
Total establishment cost	acre	1.00		$269.88
10% risk of reestablishment	acre	10.00%		$26.99
Total cost with 10% risk of reestablishment	acre	1.00		$296.87
Annualized total cost of establishment with 10% risk	acre	1.00		$44.24

[a] NO3=Nitrate
[b] P2O5=Potassium oxide
[c] K2O=Phosphate
[d] Costs are associated with operating a 100-horsepower tractor and a 10-foot rotary mower.

Table 8. Switchgrass, No-Till Establishment, Seeded Expenses per Acre in 2017

Item	Unit	Quantity	Price	Amount
Variable Expenses				
Nitrogen (NO3[a])	pound	60.00	$0.55	$33.00
Phosphorus (P2O5[b])	pound	30.00	$0.69	$20.70
Potassium (K20[c])	pound	30.00	$0.48	$14.40
Fertilizer custom application	acre	2.00	$9.38	$18.77
Lime custom application	ton	0.00	$9.38	$0.00
2, 4-D	pt	1.50	$5.15	$7.73
Surfactant	pt	0.20	$0.63	$0.13
Herbicide custom Application	acre	1.00	$8.13	$8.13
Fuel[d]	acre	1.00	$2.78	$2.78
Oil and filter[d]	acre	1.00	$0.41	$0.41
Repairs and maintenance[d]	acre	1.00	$2.16	$2.16
Interest on operating capital	acre	1.00	8.00%	$4.33
Land rent	acre	1.00	$20.00	$20.00
Total variable cost	acre	1.00		$132.54
Fixed Costs				
Prorated establishment cost	acre	1.00	10 years	$44.24
Depreciation[d]	acre	1.00	$1.13	$1.13
Interest[d]	acre	1.00	$1.53	$1.53
Insurance[d]	acre	1.00	$0.12	$0.12
Total fixed costs	acre	1.00		$47.02
Labor cost	hour	0.32	$10.07	$3.22
Total maintenance expenses	acre	1.00		$182.78

[a] NO3=Nitrate
[b] P2O5=Potassium oxide
[c] K2O=Phosphate
[d] C osts are associated with operating a 100-horsepower tractor and a 10-foot rotary mower.

Table 9. Big Bluestem/Indian Grass No-Till Establishment Budget for Tennessee in 2017

Item	Unit	Quantity	Price	Amount
Variable Expenses				
Big bluestem grass seed	pound	6.00	$15	$90.00
Indian grass seed	pound	3.00	$15	$45.00
No-till drill rental	acre	1.00	$9.80	$9.80
Nitrogen (NO3[a])	pound	0.00	$0.55	$0.00
Phosphorus (P2O5[b])	pound	30.00	$0.69	$20.70
Potassium (K20[c])	pound	30.00	$0.48	$14.40
Fertilizer custom application	acre	1.00	$9.38	$9.38
Lime custom application	ton	0.00	$9.38	$0.00
Gramoxone Max	pt	1.50	$4.33	$6.50
Surfactant	pt	0.50	$0.63	$0.32
Herbicide custom Application	acre	1.00	$8.13	$8.13
Fuel[d]	acre	1.00	$7.94	$7.94
Oil and filter[d]	acre	1.00	$1.18	$1.18
Repairs and maintenance[d]	acre	1.00	$4.23	$4.23
Interest on operating capital	acre	1.00	8.00%	$8.59
Land rent	acre	1.00	$20.00	$20.00
Total variable cost	acre	1.00		$246.17
Fixed Costs				
Depreciation[d]	acre	1.00	$2.63	$2.63
Interest[d]	acre	1.00	$3.41	$3.41
Insurance[d]	acre	1.00	$0.23	$0.23
Total fixed costs	acre	1.00		$6.27
Labor cost	hour	0.91	$10.07	$9.16
Total establishment cost	acre	1.00		$261.60
10% Risk of reestablishment	acre	10.00%		$26.16
Total cost with 10% risk of reestablishment	acre	1.00		$287.76
Annualized total cost of establishment with 10% risk	acre	1.00		$42.88

[a] NO3=Nitrate
[b] P2O5=Potassium oxide
[c] K2O=Phosphate
[d] Costs are associated with operating a 100-horsepower tractor and a 10-foot rotary mower.

Table 10. Big Bluestem/Indian Grass, No-Till Establishment, Seeded Expenses per Acre in 2017

Item	Unit	Quantity	Price	Amount
Variable Expenses				
Nitrogen (NO3[a])	pound	60.00	$0.55	$33.00
Phosphorus (P2O5[b])	pound	30.00	$0.69	$20.70
Potassium (K20[c])	pound	30.00	$0.48	$14.40
Fertilizer custom application	acre	2.00	$9.38	$18.77
Lime custom application	ton	0.00	$9.38	$0.00
Plateau	pt	0.75	$15.93	$11.95
Surfactant	pt	0.125	$0.63	0.08
Herbicide custom application	acre	1.00	$8.13	$8.13
Fuel[d]	acre	1.00	$2.78	$2.78
Oil and filter[d]	acre	1.00	$0.41	$0.41
Repairs and maintenance[d]	acre	1.00	$2.16	$2.16
Interest on operating capital	acre	1.00	8.00%	$4.50
Land rent	acre	1.00	$20.00	$20.00
Total variable cost	acre	1.00		$136.88
Fixed Costs				
Prorated establishment cost	acre	1.00	10 years	$42.88
Depreciation[d]	acre	1.00	$1.13	$1.13
Interest[d]	acre	1.00	$1.53	$1.53
Insurance[d]	acre	1.00	$0.12	$0.12
Total fixed costs	acre	1.00		$45.66
Labor cost	hour	0.32	$10.07	$3.22
Total maintenance expenses	acre	1.00		$185.76

[a] NO3=Nitrate
[b] P2O5=Potassium oxide
[c] K2O=Phosphate
[d] Costs are associated with operating a 100-horsepower tractor and a 10-foot rotary mower.

Table 11. Endophyte-Infected Tall Fescue No-Till Establishment Budget for Tennessee in 2017

Item	Unit	Quantity	Price	Amount
Variable Expenses				
Kentucky 31 tall fescue seed	pound	15.00	$1.32	$19.80
No-till drill rental	acre	1.00	$9.80	$9.80
Nitrogen (NO3[a])	pound	30.00	$0.55	$16.50
Phosphorus (P2O5[b])	pound	60.00	$0.69	$41.40
Potassium (K20[c])	pound	60.00	$0.48	$28.80
Fertilizer custom application	acre	1.00	$9.38	$9.38
Lime custom application	ton	0.50	$9.38	$4.69
Gramoxone Max	pt	1.50	$4.33	$6.50
Surfactant	pt	0.50	$0.63	$0.32
Herbicide custom application	acre	1.00	$8.13	$8.13
Fuel[d]	acre	1.00	$7.94	$7.94
Oil and filter[d]	acre	1.00	$1.18	$1.18
Repairs and maintenance[d]	acre	1.00	$4.23	$4.23
Interest on operating capital	acre	1.00	8.00%	$5.27
Land rent	acre	1.00	$20.00	$20.00
Total variable cost	acre	1.00		$183.93
Fixed Costs				
Depreciation[d]	acre	1.00	$2.63	$2.63
Interest[d]	acre	1.00	$3.41	$3.41
Insurance[d]	acre	1.00	$0.23	$0.23
Total fixed costs	acre	1.00		$6.27
Labor cost	hour	0.91	$10.07	$9.16
Total establishment cost	acre	1.00		$194.92
10% risk of reestablishment	acre	10.00%		$19.49
Total cost with 10% risk of reestablishment	acre	1.00		$214.41
Annualized total cost of establishment with 10% risk	acre	1.00		$31.95

[a] NO3=Nitrate
[b] P2O5=Potassium oxide
[c] K2O=Phosphate
[d] Costs are associated with operating a 100-horsepower tractor and a 10-foot rotary mower.

Table 12. Endophyte-Infected Tall Fescue, No-Till Establishment, Seeded Expenses per Acre in 2017

Item	Unit	Quantity	Price	Amount
Variable Expenses				
Nitrogen (NO3[a])	pound	30.00	$0.55	$16.50
Phosphorus (P2O5[b])	pound	60.00	$0.69	$41.40
Potassium (K20[c])	pound	60.00	$0.48	$28.80
Fertilizer custom application	acre	2.00	$9.38	$18.77
Lime custom application	ton	0.00	$9.38	$0.00
Plateau	pt	0.75	$15.93	$11.95
Surfactant	pt	0.125	$0.63	0.08
Herbicide custom application	acre	1.00	$8.13	$8.13
Fuel[d]	acre	1.00	$2.78	$2.78
Oil and filter[d]	acre	1.00	$0.41	$0.41
Repairs and maintenance[d]	acre	1.00	$2.16	$2.16
Interest on operating capital	acre	1.00	8.00%	$4.50
Land rent	acre	1.00	$20.00	$20.00
Total variable cost	acre	1.00		$155.48
Fixed Costs				
Prorated establishment cost	acre	1.00	10 years	$31.95
Depreciation[d]	acre	1.00	$1.13	$1.13
Interest[d]	acre	1.00	$1.53	$1.53
Insurance[d]	acre	1.00	$0.12	$0.12
Total fixed costs	acre	1.00		$34.73
Labor cost	hour	0.32	$10.07	$3.22
Total maintenance expenses	acre	1.00		$193.43

[a] NO3=Nitrate
[b] P2O5=Potassium oxide
[c] K2O=Phosphate
[d] Costs are associated with operating a 100-horsepower tractor and a 10-foot rotary mower.