ANALYSIS OF LABOR USE AND PROFITABILITY IN THREE PASTURE SYSTEMS FOR THE GRASS-FED BEEF PRODUCTION IN THE U.S.

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Abstract

An experiment to compare three pasture systems was conducted at the Iberia Research Station in Jeanerette, Louisiana, for five consecutive years from 2009/10 to 2013/14. System 1 included of bermudagrass and ryegrass pasture; System 2 included bermudagrass, ryegrass, clover mix (berseem, red and white clovers), rye, and dallisgrass; and System 3 included bermudagrass, ryegrass, sorghum sudan, soybeans, clover mix (berseem, red and white clovers), rye, and dallisgrass. Fifty-four May-weaned steers were divided into nine groups of six based on their body weight and randomly placed into one of the replications of the three pasture systems. Detailed records of daily activities along with various inputs, machinery and labor use, and outputs was collected. Analysis was done using the Kenward-Roger Degrees of Freedom method with and without including labor expenses. Systems 1 and 2 yielded higher profit than System 3 in both cases. System 1 consumed the highest labor inputs among the systems. Simulation and dominance analysis showed that System 1 dominated Systems 2 and 3, and System 2 dominated to System 3 without including labor. With labor, the decision between Systems 1 and 2 was based on the risk preference of the decision maker. Again, Systems 1 and 2 dominated System 3. Sensitivity analysis showed that System 2 would be numerically dominant than System 1 when the labor charge per hour was >\$32.

Key words: Grass-fed beef, bermudagrass, ryegrass, dallisgrass, stochastic dominance, sensitivity analysis

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Introduction

Labor is a major input in agricultural and livestock production. Grass-fed beef (GFB) operations are particularly labor-intensive, with labor requirements differing with production system. The major work performed by labor in a grass-fed beef operation includes moving, checking, and working animals, and operating machinery and equipment. According to USDA-NASS (2007), most beef operations in the U.S. are comparatively small; 50% of beef farms have fewer than 20 cows and operate on a fixed land area. The labor requirements of such farms are fulfilled mostly by land owners and their family members. A wide range of pasture management systems are used for grass-fed beef production throughout the U.S. with considerable differences in management complexities. Grass-fed beef production accounts for a very small share, i.e. less than 1% of the U.S. beef industry as a whole (Pelletier, Pirog, and Rasmuseen, 2010), but it has gained interest over the last two decades due to human health, environment, and animal welfare concerns (Wright, 2005, Mills, 2003; McCluskey et al., 2005). Grass-fed beef producers are interested in pasture systems that utilize less labor but yield higher profitability.

Several studies have examined farm labor differences by agricultural production system. Reed et al. (2010) conducted an economic analysis of farm labor and profitability in three villages in Nepal and reported that the use of conservation systems such as strip tillage and cowpea intercropping improved the livelihoods of subsistence farmers. Gillespie et al. (2008) analyzed the roles of labor and profitability in choosing a grazing strategy for cow-calf production in the U.S. Gulf Coast Region. They found that labor requirements were higher with

rotational grazing systems than with continuous grazing systems, reducing the profitability associated with rotational grazing. Wyatt et al. (2013) evaluated the effects of year-round stocking rate and stocking method on cow-calf production systems considering costs, returns and labor considerations. None of these studies have focused on grass-fed beef production. In this paper, we estimate the relative profitability of three pasture systems for grass-fed beef production with and without considering the costs associated with labor.

The specific objectives of this paper are to: 1) determine the direct costs, fixed costs, gross returns, and net returns of three pasture systems under grass-fed beef production; 2) determine the involvement of labor in specific activities in the three pasture systems; and 3) determine the most profitable pasture system for forage-fed beef production in the Gulf Coast Region considering labor and profitability.

The Theoretical Model

The theoretical model is represented by the following profit maximizing problem for the grass-fed beef producer:

$$max \ \pi(x) = \sum_{t=1}^{T} \pi_t(X_{it})$$

$$= \sum_{t=1}^{T} \{P_{slaugh,t} * f(X_{it}) + P_{hay,t} * g[f(X_{it})] - \sum_{i=1}^{n} W_{it} * X_{it}\}, \qquad (1)$$

where: $\pi_t(.)$ is profit at year t, T is the number of years in planning, X_{it} is the amount of input i used at time t, $P_{slaugh,t}$ is the price of a slaughter animal in year t, $f(X_{it})$ is the production function for a grass-fed slaughter animal, $P_{hay,t}$ is the price of hay in year t, $g[f(X_{it})]$ is the production function for hay which is a function of the production of slaughter animals, and W_{it} is

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the price of input i in year t. Here, the production function for hay is a function of slaughter animal production; the primary purpose of growing and maintaining pasture for forage-fed beef production is to produce beef, not hay. Since the primary purpose of growing forages is for grazing animals, only the left-over or excess forage is generally used to produce hay, which is in turn generally fed during periods of low grazing potential. Left-over hay after feeding animals is sold.

By taking the first order conditions, the optimum quantity of input j for profit maximization can be estimated as follows:

$$\sum_{t=1}^{T} \{P_{slaugh,t} * \partial f(X_{it})/\partial X_j + P_{hay,t} * \frac{\partial g[f(X_{it})]}{\partial X_j}\} = \sum_{t=1}^{T} W_{it}, \quad (2)$$

where the left hand side value represents the marginal value product and the right hand side represents the marginal factor cost, showing that the profit-maximizing producer determines optimal input usage by considering the marginal physical productivity, output prices, and input prices. In the case of using multiple forage species for pastures and/or hay, additional costs of inputs including labor will be incurred if the additional value of the product (finished animals and hay) is greater than the additional costs associated with the labor input.

If extensive data were available, solving the profit-maximizing problem using the production function could provide the optimum level of input usage. It is difficult, however, to find such extensive data from experimental research, making it impossible to estimate the optimum input-output combination based on the above theoretical model. However, optimal solutions can be approximated at discrete points in the production function. In this study, comparisons were made between three different pasture combinations evaluating direct expenses including labor

involvement for different activities, fixed expenses, steer income, hay income, and net return associated with each system.

Data and Empirical Methods

Three treatments used in a field experiment at the Iberia Research Station (IRS) in Jeanerette, LA, from 2009-2010 to 2013-2014 represented pasture systems with different degrees of management complexity. The three forage systems were: (1) Bermudagrass as summer pasture, ryegrass as winter pasture; (2) Bermudagrass as summer pasture, dallisgrass and clover mix as fall and winter pastures,and annual ryegrass, rye, and clover mix (berseem, red, and white clovers) as winter pastures; and (3) Bermudagrass, sorghum-sudan hybrid, forage soybean as summer pastures, dallisgrass and clover mix as fall and winter pastures, and annual ryegrass, rye, and clover mix (berseem, red, and white clovers) as winter pastures. These systems were chosen as representative of the types of systems currently being used for GFB production in the U.S. Gulf Coast Region (Scaglia et al., 2014). The pasture systems differ from each other in terms of management complexity. System 1 consists of only two forages and is the simplest system while System 3 consists of nine forage types and is the most complex among these systems.

Annually, 54 seven to eight month old Fall-born steers were assigned to one of the three pasture systems immediately after weaning and remained until time of harvest at age 17-19 months. The same pastures were used for each treatment each year. The experimental year began in May and ended by the end of April the following year. The three forage systems were managed in different sub-paddocks at the IRS, and animals were rotated among the sub-paddocks based on forage availability. The steers were blocked at weaning by weight into nine groups (six steers/group). Each group was randomly assigned to one of the three treatments, each

of which was replicated three times. During the transition period when forage availability was low (mid-November to December), animals were fed hay produced in the paddocks allocated to the system/ replication group. Constructed portable shades were made available for the animals in each group. They were moved along with the animals when rotated. Water and mineral mix were available at all times. The stocking rate was one hectare per animal for each entire system.

Detailed cost and input records were kept for each pasture by year. These records were used to develop detailed cost and return estimates for each treatment/replication. Budgets included returns, direct expenses, fixed expenses, and land rent. Expenses for seed, fertilizer, pesticide, minerals, medication, twine, fuel, purchased weaned steers, repair and maintenance of machinery, and interest on operating capital were included in the direct expenses. Depreciation and interest on machinery (trucks, tractors, and other implements), permanent fencing, and temporary fencing were included in the fixed expenses. The fixed costs of machinery and equipment were allocated according to use, assuming their useful life and performance rates as shown in Boucher and Gillespie (2009-2013). The opportunity cost of land rental was included. Similarly, labor used for each activity was kept by pasture system. A total of 45 cost and returns estimates were made for the project: (3 treatments ˣ 3 replications ˣ 5 years).

For the analysis of labor, labor usage was categorized into the following four subgroups. **Moving animals and shades** involved all activities including measuring the availability of forage and movement of animals as per the availability of forages in the different paddocks within the same pasture system. It also included the movement of shades and water troughs. The second category was **checking animals and routine tasks,** which included checking animals twice per day Monday-Friday and once per day during the weekend. On days the animals were moved, the checking task was conducted at the same time. Therefore, no separate labor was required for this

task on the animal moving day. Another category of labor was for **vaccinating animals**. This was done as per vaccination requirements. The labor required for moving and vaccinating animals was included in this category. The final category of labor was **operator labor,** which included the operator labor for all machinery as well as labor involved in the repair and maintenance activities. Previous work examining labor use by stocking strategy includes Gillespie et al. (2008) and Wyatt et al. (2013).

Annual input and output prices are presented in Table 1. These are based mostly on those used by Boucher and Gillespie (2009, 2010, 2011, 2012, and 2013) in cost and return estimates for cattle and forage production. The prices of weaned calves were taken from 2011 Louisiana Agricultural Statistics (LSU Agricultural Center, USDA-NASS, 2012). We used the Weekly Texas Hay Report for hay prices (USDA-TX, 2010, 2011, 2012, 2013, and 2014). The price of hay was at its peak, i.e. $82.50 per large round bale, in 2012 due to the unfavorable climate and low hay production in that particular year. The price of hay was approximately double that of the preceding and succeeding years. We used the USDA-ERS (2014) published prices for fed steers as a base, adjusted for the grass-fed steer price by adding $0.44/kg as suggested by the manager of one of the larger grass-fed beef production firms in the Gulf Coast Region.

Net returns, fixed costs, direct costs, labor use, steer returns, and hay returns were estimated. Similarly, differences in the labor involved in each category were also estimated. Differences in each were determined using the **Kenward-Roger Degrees of Freedom** method (Kenward and Roger 1997).

Table 1. Prices of Inputs and Outputs for the Experimental Years.

Inputs/Outputs	Unit	Price in $				
		2009	2010	2011	2012	2013
Urea	ls	0.18	0.16	0.19	0.19	0.28
Gramoxone Max	pt	4.97	5.46	5.46	5.46	5.46
Grazon P+D	pt	4.01	4.94	3.87	4.16	4.23
Outrider	onz	20.00	N/A	N/A	N/A	N/A
Roundup Original Max	pt	6.56	7.25	7.20	6.08	6.00
Malathion	pt	N/A	4.25	4.23	4.23	N/A
Sevin 80% WP	lb	6.13	6.81	7.35	7.35	7.35
Bovishield	dose	2.50	2.50	2.50	2.50	2.50
One Shot	shut	2.50	2.50	2.50	2.50	2.50
Sweetlix	block	18.00	18.00	18.00	18	18
Ultrabac 8	dose	0.40	0.40	0.40	0.40	0.40
Vigortone 3V2	bag	26.20	26.20	26.20	26.20	26.20
Vigortone 3V5	bag	17.13	17.13	17.13	17.13	17.13
Weaning Calf	cwt	98.30	114.00	114.00	125.00	150.00
Twine	ton	0.75	0.75	0.75	0.75	0.75
Berseem Clover Seed	lb	2.14	2.15	3.50	3.50	N/A
Red Clover Seed	lb	2.50	3.00	1.20	1.20	1.80
White Clover Seed	lb	2.50	3.20	3.10	3.00	3.00
Rye Seed	lb	0.22	0.44	0.44	0.45	0.50
Ryegrass Seed	lb	0.61	0.70	0.50	0.48	0.50
Cowpea Seed	lb	N/A	N/A	N/A	1.00	1.00
Soybeans Seed	lb	0.56	0.53	0.60	0.60	0.60
Sorghum Sudan Seed	lb	0.47	0.80	0.80	0.84	1.00
Hay*	bale	45.00	40.00	82.50	37.50	40.00
Steers at Harvest*	cwt	116.00	133.00	141.00	147.00	168.00
Diesel Fuel	gallon	2.20	2.30	2.75	3.50	3.31

* Although the prices of hay and steer at harvest were tabulated as 2009, 2010, 2011, 2012, and 2013, those were based on USDA prices in the following years (2010, 2011, 2012, 2013, and 2014) since the harvesting and selling of hay and steers was in the second calendar year of the experiment.

Note: N/A indicates data not available.

Since this research analysis is based on only 5 years of data, i.e. 45 observations, simulation and dominance techniques were used to strengthen the analysis. Simetar, a commercial mathematical simulation software developed by Richardson et al. (2008) was used to simulate 1,000 randomly simulated input (fertilizer, fuel, and calves) and output (steers and hay) prices developed based on historical data (13 years, 2001-2013). Hay yield was estimated based on 13 years of historical rainfall data at the IRS and 1,000 randomly simulated values were developed from the same software. We did not observe significant variation in the other input variables and other prices and quantities of steers, so these were taken as constant for this analysis. Based on these simulated values and constant values, 1,000 net returns for each of the systems were developed.

Certainty equivalents (CE) were estimated assuming different risk aversion coefficients using the 1,000 simulated net returns for each system as per the relationship outlined by Hardakar et al. (2004). The CE is defined as the net return value held with certainty at which the decision maker is indifferent to a risky distribution of net return values. The utility function of the decision maker is used to estimate the CE. The relationship between the utility function *U(w)* and the absolute risk aversion coefficient, $r_a(w)$ is shown in equation (1):

(1)   *U(w) = -exp(−r_a(w)),*

where *w* is the wealth or income associated with the choice. Equation (2) defines the absolute risk aversion coefficient as the negative ratio of the second and first derivatives of the utility function:

(2) $r_a(w) = -\dfrac{u''(w)}{u'(w)}$.

The relationship between the absolute risk aversion coefficient and the relative risk aversion coefficient, $r_r(w)$, is expressed as:

(3) $r_a(w) = r_r(w)/w.$

The CE for a random sample of size n from risky alternatives w is estimated as follows, as shown by Hardaker et al. (2004):

(4) $CE(w, r_a(w)) = ln\left\{\left(\frac{1}{n}\sum_i^n exp(-r_a(w)w_i)\right)^{-1/r_a(w)}\right\}.$

A general classification of relative risk aversion coefficients falling in the range of 0 for risk neutral to 4 for highly risk averse was proposed by Anderson and Dillon (1992). Absolute risk aversion coefficients were obtained by dividing a range of relative risk aversion coefficients (0 to 4) by the estimated mean net return. This gives the maximum absolute risk aversion coefficient of 0.0024, which is used in a stochastic efficiency with respect to function (SERF) analysis. SERF provides a means to evaluate the risky alternatives in terms of certainty equivalents for a specified range of absolute risk aversion coefficients. The result is graphed to analyze the dominance by system.

Results and Discussion

Revenue and expenses excluding labor are presented in Table 2. Mean steer incomes were $1,434.42, $1,445.68, and $1,440.78 for Systems 1, 2, and 3, respectively, which did not differ significantly at $p \leq 0.10$ among the systems. Hay incomes were $667.51, $527.24, and $350.91 for Systems 1, 2, and 3, respectively, which differed among these systems. System 1 had the highest hay income while System 3 had the lowest, as more hay was harvested in System1 than System 2 and in System 2 than in System 3. Total incomes were $2,109.94, $1,972.93 and $1,791.70 for

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Systems 1, 2, and 3, respectively. Systems 1 and 2 had higher total income than System 3. The major income determinant by system was hay production.

Direct expenses included seed, fertilizer, pesticides, weanling animals, minerals, vaccinations, diesel, repair and maintenance, and interest on operating capital. Overall, direct costs excluding labor were $1,275.68, $1,264.27, and $1,279.27 for Systems 1, 2, and 3, respectively, which did not differ statistically at $p \leq 0.10$ among the systems. Although fertilizer cost was greater in System 1 than in Systems 2 and 3 and seed cost was greater in System 3 than in Systems 1 and 2, the total direct cost did not differ statistically among the systems.

Table 2. Revenue, Expenses, and Return over Expenses (Without Labor Included) per Animal Basis.

	System 1	System 2	System 3
Total Revenue	2,109.94[c]	1,972.93[c]	1,791.70[ab]
Steer Income	1,434.42	1,445.68	1,440.78
Hay Income	667.51[bc]	527.24[ca]	350.91[ab]
Direct Expenses	1,275.68	1,264.27	1,279.27
Return over Direct Expenses	826.19[c]	708.60[c]	512.34[ab]
Fixed Expenses	198.03[bc]	158.82[ac]	135.03[ab]
Total Specified Expenses	1,473.73[c]	1,423.20	1,414.42[a]
Return over Specified Expenses	628.08[c]	549.68[c]	377.18[ab]
Residual Income	545.70[c]	457.58[c]	305.09[ab]

Note: Superscript a means differ significantly from System 1, superscript b means differ significantly from System 2, and superscript c means differ significantly from System 3 within rows at *p<0.1*

Residual Return = Total Income - Direct Expense - Fixed Expense - Land Rent

Labor involvement in the 3 systems is presented in Table 3. In total, 16.89, 14.55, and 13.15 hours of labor per animal were involved annually in the different activities in Systems 1, 2, and 3, respectively. Higher labor involvement in System 1 was due to the higher use of machinery for harvesting and making hay. Similarly, the movement of animals was greatest in System 1 and least in System 3, which was due to more movement among the sub-paddocks than the movement of animals between paddocks. The labor involved in vaccinating animals did not differ as all systems were treated the same in this regard. Although labor involved in checking animals and routine tasks should generally be the same across the different systems, it differed among the systems because checking animals was conducted at the same time as moving animals on the days animals were moved. More than 50% of the total labor involved was operator labor. Movement of animals was the second-largest labor-consuming activity, while vaccinating was the least labor-consuming activity.

Table 3. Annual Labor Usage Hours in the Different Systems, per Animal.

	System 1	System 2	System 3
Total labor	16.89^{bc}	14.55^{ac}	13.15^{ab}
Moving Animals and Shades	4.26^{bc}	3.87^{ca}	3.42^{ab}
Checking and Routine Tasks	2.93^{c}	2.97^{c}	3.02^{ab}
Vaccinating Animals	0.37	0.37	0.37
Operator Labor	9.33^{bc}	7.35^{ac}	6.34^{ab}

Note: Superscript a means differ significantly from System 1, superscript b means differ significantly from System 2, and superscript c means differ significantly from System 3 within rows at $p<0.1$

When labor costs were included, direct costs increased from $127 to $165 among the systems. Results including labor are presented in Table 4.

Table 4. Revenue, Expenses, and Return over Expenses (Labor $9.60/hour Included), per Animal Basis.

	System 1	System 2	System 3
Direct Expenses	1,442.06	1,408.67	1,406.52
Return over Direct Expenses	660.51^c	564.19^c	385.08^{ab}
Fixed Expenses	197.37^{bc}	158.84^{ac}	135.20^{ab}
Total Specified Expenses	1,639.17^{bc}	1,567.59^a	1,541.79^a
Return over Specified Expenses	463.04^c	405.27^c	249.87^{ab}
Residual Income	380.72^c	331.02^c	177.72^{ab}

Note: Superscript a means differ significantly from System 1, superscript b means differ significantly from System 2, and superscript c means differ significantly from System 3 within rows at $p<0.1$

Residual Return = Total Income - Direct Expense - Fixed Expense - Land Rent

Returns over direct expenses were $826.19, $708.60, and $512.34 for Systems 1, 2, and 3, respectively, without accounting for the labor costs. System 3 had a lower return over direct cost than Systems 1 and 2. The returns over direct expenses when including labor costs were reduced to $660.51, $564.19, and $385.08 for Systems 1, 2, and 3, respectively. Again, System 3 had a lower return over direct cost than the other systems, as shown in Table 4. Though labor used in System 1 was greater that for the other systems, System 1 remained the most profitable of the systems. The residual return was estimated by subtracting direct cost, fixed cost, and land rent from total income.

The residual returns were $545.7, $475.58, and $305.09 for Systems 1, 2, and 3, respectively, excluding labor, while these were $380.72, $331.02, and $177.72 for these systems

when accounting for labor. Without accounting for labor involvement, the residual returns for Systems 1 and 2 were different from System 3, while there was no significant difference between Systems 1 and 2. After accounting for labor involvement, again the residual returns of Systems 1 and 2 were greater than with System 3. There was no statistical difference in the residual return between Systems 1 and 2.

Sensitivity analysis showed that if the wage rate for the labor were greater than $32 per hour, System 2 would be numerically more profitable than System 1. In all cases, Systems 1 and 2 dominated System 3.

Results of the simulations and stochastic efficiency analysis are presented in Figures 1 and 2. Figure 1 shows the stochastic efficiency with respect to a function without including labor. It clearly shows that System 1 dominates Systems 2 and 3 at all levels of risk aversion, though the margin of dominance narrows when the risk aversion coefficient becomes larger, as shown in the figure. These results confirm the findings from the cost and returns analysis.

Figure 1 Stochastic Efficiency without Labor.
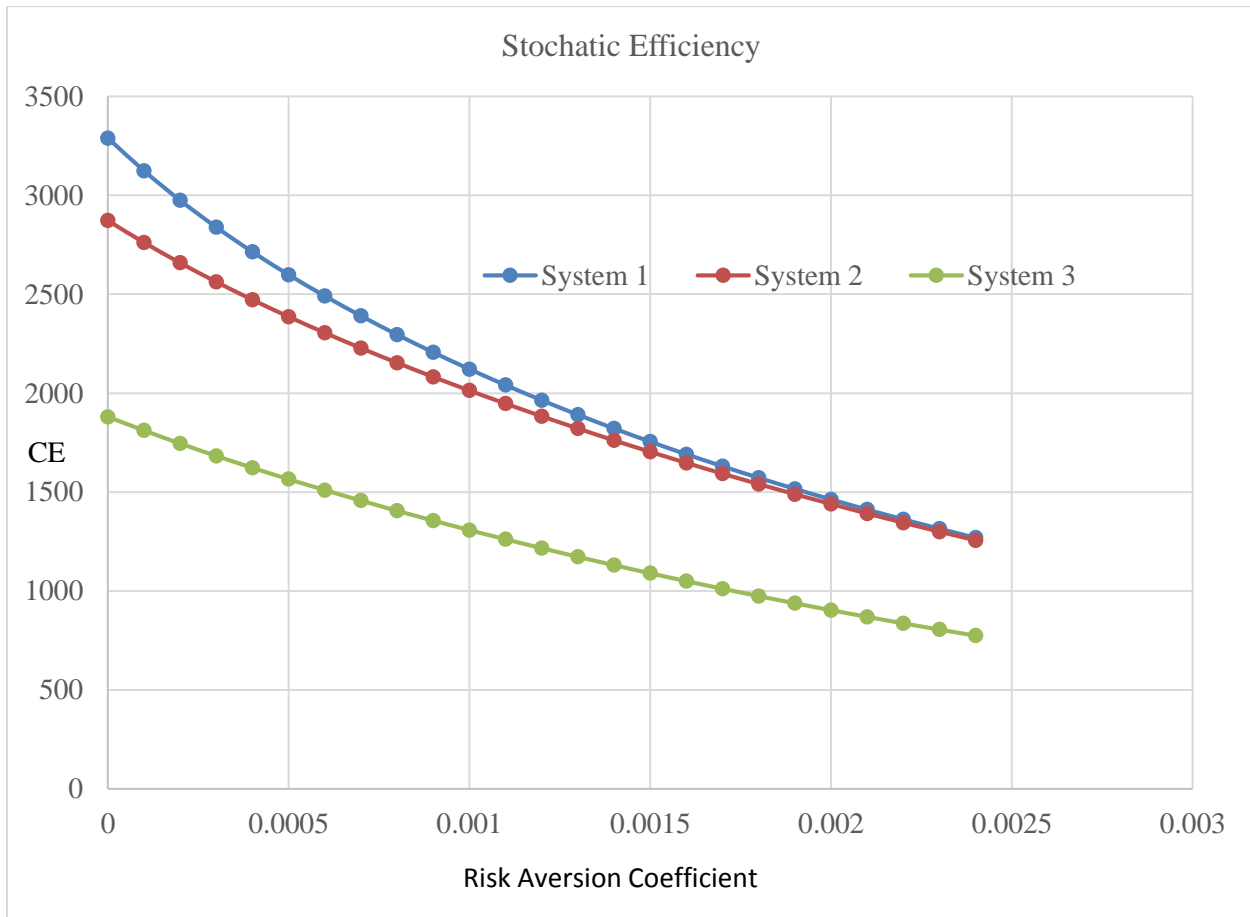
The situation changes when labor is included in profitability estimates (Figure 2). In all cases, Systems 1 and 2 dominate System 3. With risk aversion coefficients of <0.0008, System 1 dominates System 2, but when the risk aversion coefficient is >0.0008, System 2 dominates System 1. Thus, the producer would make his or her decision among Systems 1 or System 2 based on his/ her risk preference.

Figure 2 Stochastic Efficiency with Labor
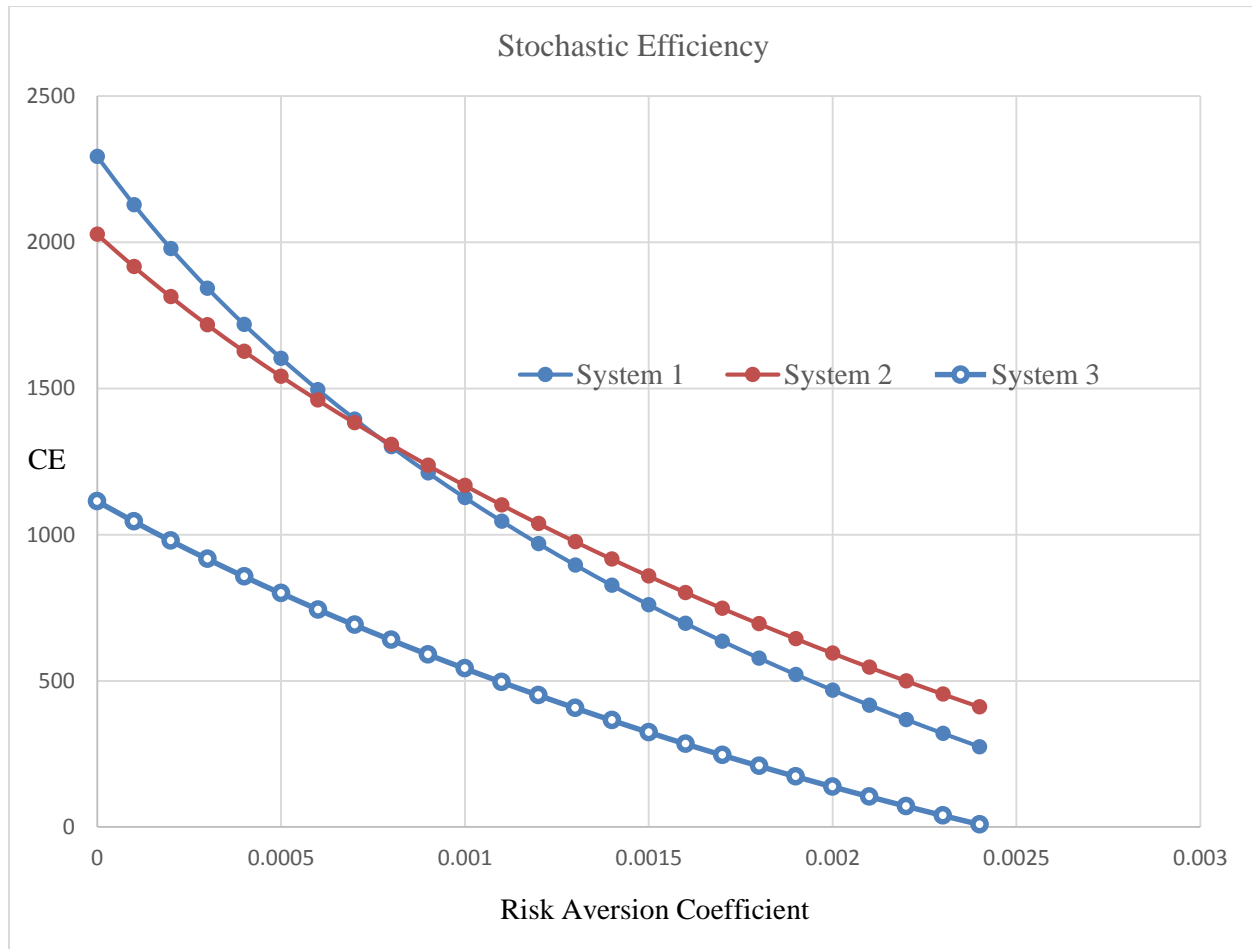
3.5. Conclusions

Without accounting for labor, Systems 1 and 2 were more profitable than System 3. Under this condition, there is no conclusive evidence that the bermudagrass and ryegrass combination system differs in profitability from the bermudagrass, ryegrass, rye, dallisgrass and clover mix (berseem, red, and white clover) system. When accounting for labor, Systems 1 and 2 were again more profitable than System 3, with no significant difference between Systems 1 and 2. Though

many farm operations are run by household members, accounting for the value of labor has a significant impact on the net farm return.

System 1 was more profitable and more labor-consuming because of the higher use of machinery for hay making and harvesting. Therefore, there was less difference in the residual return among the various systems after accounting for labor. Since System 1 consists of bermudagrass and ryegrass, it is the simplest system in the context of management complexity.

Results of simulation and stochastic efficiency analysis further confirm the results of the cost and returns analysis. In both cases, with or without including labor inputs, Systems 1 and 2 dominate System 3. But the choice between Systems 1 and 2 changed after accounting for labor based on the risk aversion of the decision maker. The price of labor would have to be $32 or more before System 2 would become numerically more profitable holding all else equal.

The findings of this study are useful in the context of developing a grass-fed beef production program in the Southern U.S. Since the results are based on experimental data from the research station where conditions are relatively controlled, there might be some variation in their wider application.

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