Switchgrass as an Income Stabilizing Crop for Cow-calf Producers Impacted by Drought

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ABSTRACT

Cow-calf producers in Arkansas experience annual fluctuations in their farm returns and are increasingly scrutinized for their role in climate change. Increasing farm efficiency can increase farm returns and either increase or decrease net greenhouse gas emissions, but often these practices also increase income risk. Diversifying enterprise choices, the addition of switchgrass production grown on converted pasture land, in this case, is thought to lower income risk by providing a drought hardy crop while at the same time a supply of lignocellulosic biomass for potential bio-refineries. Adopting rotational grazing, compared to a baseline of continuous grazing, frees pasture acreage to either increase beef output or to the production of a dedicated energy crop. The objectives are to determine what switchgrass price is needed to be income neutral and whether adoption of switchgrass does in fact impact income risk without affecting feed or food supply. Decision support software, the Forage and Cattle Planner (FORCAP), is used to compare financial returns, along with GHG emissions, across multiple farm management strategies. The study reveals that the addition of switchgrass production, when compared to increased beef production, offers lower income risk but the needed switchgrass price to break even is higher than the price needed to compete with the least intensive continuous grazing option and lowest stocking rate. Net GHG emissions implications of changes are quite small.

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INTRODUCTION

Cow-calf producers in Arkansas experience annual fluctuations in their farm returns and are increasingly scrutinized for their role in climate change. Their annual returns are often a reflection of their reliance on weather, for forage production, and the national cattle supply and demand, for cattle prices. Many different management practices exist for the purpose of increasing producer efficiency which may or may not increase returns and or curtail cow-calf production impacts on the environment. Risk implications of modified management practices on producer returns and greenhouse gas (GHG) emissions are also an important consideration for producer adoption of alternative management practices. Diversification of enterprise choices is often a method suggested to decrease overall risk. As such, a potential diversification approach for cow-calf producers is the addition of growing a lignocellulosic energy crop for bio-fuel production.

Switchgrass, as a dedicated energy crop, is proposed within as it has a perennial growth habit, an extensive root system and single fall harvest that make its yield fluctuation due to climatic conditions from year to year less variable than pasture or hay production, for example. A potential added benefit is soil carbon sequestration and relative ease of adoption as producers already have the necessary equipment for harvest. While biofuel, sourced from plant material, is a potentially growing industry in the United States, this analysis attempts to determine under what conditions beef producers might set aside some of their pasture acreage to switchgrass production as a dedicated energy crop. At the same time, enhanced pasture productivity by switching from continuous to rotational grazing is expected to allow beef output to remain the same. A second risk/return comparison entails an operation that has changed to rotational grazing and switchgrass production holding beef output constant vs. an operation that also changes to rotational grazing but uses the added efficiency to increase beef production rather than diversifying to switchgrass.

The objectives of this paper are thus to determine if switchgrass, grown on pastures, would serve the following purposes: i) to increase supply for alternative energy production without affecting feed or food supply and at what switchgrass price; ii) provide motive for cattle producers to enhance pasture use efficiency; and iii) quantify, and potentially reduce, income variability with switchgrass as an income stabilizing enterprise under droughty conditions.

LITERATURE REVIEW

Beef Cattle Production

Beef cattle production methods tend to vary across climatic regions given differences in forage type and seasonal availability. This study focuses on a production region in northwest Arkansas given access to both warm season and cool season grasses with significant annual rainfall but also high likelihood of summertime drought. Management of forage resources is thus key to limiting the amount of costly hay feeding during the production season. This topic has received significant attention with extension efforts targeting an extended grazing season (Jennings and Jones, n.d.). To enhance pasture use efficiency, recommendations range from rotational grazing, to stockpiling fescue or bermudagrass, to fertilizing based on soil testing, to over seeding legumes, to planting winter forages, to harvesting excess forage for hay, and to reducing hay waste during storage and feeding. The focus of these recommendations is to increase producer returns by increasing farm efficiency and such strategy recommendations are common throughout the southeastern U.S.

Different stocking rate strategies have also been offered as a means to mitigate drought risk to cow-calf producers. One of the main problems cow-calf producers face is an uneven, seasonal growing pattern of forages. Many farms face dormant forage in the winter, excessive forage in late spring and early summer, and barely sufficient forage to meet cattle nutrient needs in late summer and fall. Producers often harvest the excess forage in spring for late summer and winter feeding. Varying stocking rates to match available forage is thus a method to reduce excess forage. Torell, Murugan and Ramirez (2010) studied the economics of flexible versus conservative stocking rates as a way to mitigate drought risk. They determined that a conservative cow-calf stocking rate along with a flexible feeder calf stocking rate would assist producers with managing the whole farm under both drought and non-drought conditions. However, this also exposes the producer to additional risk due to the fluctuations in cattle prices associated with buying and selling of feeder cattle. Stocking rate also has implications on GHG emissions. A study in Texas found more efficient farms produce less GHG emission per unit of beef produced and per hectare than less efficient farms (Wang et al., 2013). Zilverberg et al. (2011) studied energy use per cow and per hectare and recommended use of locally adapted forages with high N efficiency, and replacement of feeding hay with grazing unfertilized dormant forage to reduce cow-calf energy use. The literature demonstrates that the use of intensive pasture management requires less land and promotes positive environmental and economic changes on cow-calf farms.

Switchgrass Production

Switchgrass was introduced as a potential, cultivated herbaceous bioenergy crop in the early 1990's "due to the close compatibility of crop management strategies with existing farming practices" along with its perennial nature and ability to produce a large amount of cellulosic material (McLaughlin and Kszos, 2005). Much of the early research, as directed by the US Department of Energy (DOE), focused on the use of marginal land for switchgrass production (McLaughlin and Kszos, 2005). The DOE recommended the use of marginal land so that dedicated energy crops did not compete with land used for food production. Recent research has compared the profitability and positive environmental aspects of switchgrass production to other dedicated energy crops, namely willow and poplar (Kells and Swinton, 2014), wheat production (Debnath, Stoecker, and Epplin, 2014), land in corn (Bonner et al., 2014; Kells and Swinton, 2014; Raneses, Kenneth, and Shapouri, 1998; Sharp and Miller, 2014; Vadas, Barnett, and Undersander, 2008; Walsh et al., 2003), along with land in pasture and hay production (Kells & Swinton, 2014; Raneses et al., 1998; Walsh et al., 2003). Within these studies, Bonner et al. (2014) focuses on subfield plantings of switchgrass, on sections of the field where corn is modeled to return a net loss. Raneses et al. (1998) found that at a price of $24 per ton and yield of 7.9 tons per acre, switchgrass would compete for pasture and hay land but not with crop production. In contrast, using an agriculture policy simulation model (POLYSYS) Walsh et al. (2003) conclude that more crop land will be converted to dedicated energy crops than pasture land at both $33 and $44 per dry metric ton. Spatial adoption on the basis of switchgrass' profitability relative to other crops has also been analyzed by Popp & Nalley (2011) in the context of analyzing tradeoffs with respect to declining irrigation water resources, potential access to a carbon offset market and to estimate dedicated energy crop supply. Monti et al. (2012) studied switchgrass and its ability to reduce GHG emissions in different land environments. Ma et al. (2000a) studied switchgrass and its ability to positively affect the environment by sequestering carbon to the soil. Hence, not only cost of production but GHG impact, water use and the opportunity cost of alternative land use choices need to be considered. Harvest method (Popp and Hogan, 2007), moisture content at time of harvest (Popp et al., 2015), and nutrient removal at time of harvest (Gouzaye et al., 2014) have also been studied. Vadas et al. (2008) focus on a net benefit approach between corn, an alfalfa-corn rotation, and switchgrass for ethanol production and found that switchgrass had the greatest net energy production (outputs-inputs) and was the most energy efficient (outputs/inputs). Cost of production, profit, soil erosion, and N leaching are all factors of their net benefit approach. Thus, switchgrass is a crop alternative to traditional crops and pasture but subject to the farm-gate price bio-refineries are willing and able to pay, along with the farm proximity to a cellulosic biofuels processing plant (Qualls et al., 2012).

Drought Impacts

Switchgrass is also described as being drought tolerant given its extensive root system's ability to source water from greater depth than conventional hay and pasture forage species. Multiple studies have focused on yield effects of drought and found, that while yield is decreased during drought, the roots survive (Barney et al., 2009; Stroup et al., 2003). This is an important trait for switchgrass grown in Arkansas. In the period of 2004-2013, Arkansas experienced two major droughts, in 2006 and again in 2011-2012. The United States Drought Monitor (USDM), "produced jointly by the National Drought Mitigation Center at the University of Nebraska-Lincoln, the United States Department of Agriculture, and the National Oceanic and Atmospheric Administration," tracks and classifies drought weekly in the United States as a percent of area that is abnormally dry (D0), or experiencing: moderate drought (D1), severe drought (D2), extreme drought (D3), or exceptional drought (D4) (NDMC, n.d.). Figure 1 depicts the percent of Arkansas that experienced drought from 2004-2013 and Figure 2 depicts the number of weeks spent in drought categories D1-D4 in each calendar year.

The drought of 2012, in particular, was widespread throughout the southern U.S. and has led to a significant reduction in the U.S. cow herd as cow calf operations with inadequate water resources had to sell cows given a lack of both pasture forage production, having to transport drinking water, and buying expensive hay. Restocking the herd at cyclically increasing cattle prices in the following year along with reestablishing pastures proved a major capital barrier. Hence, it is anticipated that producers are keen to entertain strategies that might lessen drought risk.

MATERIALS AND METHODS

Cost, returns and net GHG emissions of cow-calf production

In part as a response to these weather events, but also in an effort to model economic and environmental tradeoffs associated with forage and cattle management strategies, decision support software for cow calf producers and researchers was developed at the University of Arkansas. The Forage and Cattle Planner (FORCAP), a spreadsheet based tool available via internet, allows the user to estimate their farm's net returns (NR) and GHG emissions and compare across a range of decision parameters that relate to: i) pasture management (rotational vs. continuous grazing as well as matching forage species and their production potential to calving season dependent cattle feed needs); ii) pasture and hay fertility management to allow varying stocking rates and hay harvest by modifying fertilizer application; iii) differences in herd size and equipment complement; iv) cattle genetics; v) weaning age; and vi) a host of default and user-specifiable cost and price choices. GHG emissions are estimated from cattle (respiration, enteric fermentation, urine and manure), forage production (soil carbon sequestration as a result of hay and pasture production), and agricultural input use (direct emissions: fuel, fertilizers and twine; indirect emissions: fertilizers) as outlined in Smith, Popp, and Keeton (2013).

The model was designed to operate in a steady state environment assuming no change in cow herd size over time. Forage production and nutrient needs are calculated on a monthly time step with the ability to modify monthly forage production to model drought impact. Model modifications for this analysis were thus needed to estimate returns and GHG emissions under user-specified conditions of herd growth or decline over time. A 100 calving cow herd size was chosen as producers of this size often have equipment necessary for hay production, and to allow replenishment of the breeding herd from replacement heifers raised on the farm rather than having to purchase cattle for herd size replenishment.

Drought Impacts

To assess whether drought impacts affected Arkansas state-level annual hay yields, as available from the National Agricultural Statistics Service (NASS) (USDA, n.d.), hay yield was regressed against the annual percent of land area under different levels of drought (shown in Figure 1) as follows:

$$(1)\quad Y_i = 2.25 - 0.0046\, x_{i0} + 0.0248\, x_{i1} - 0.0716\, x_{i2} + 0.0499\, x_{i3} - 0.1548\, x_{i4} \qquad \text{Adj. } R^2 = 0.82$$
$$(0.10)^{***}\ (0.0085)\quad (0.0215)\quad (0.0259)^{**}\quad (0.0304)\quad (0.072)^{*}$$

where Y_i is the annual hay yield in year *i*, x_i is percent area in drought in year *i* and the second subscript on *x* is zero through four as per drought levels from Figure 1. Numbers in parentheses on the second line are standard errors with *, ** and *** indicating level of significance at the 10, 5 and 1% levels, respectively. Figure 3 depicts actual and estimated hay yield for 2000-2014 and suggested that drought stress explained a large proportion of the variation in yield in the absence of available data on fertilizer and hay production practices that might otherwise explain variation in yield.

Therefore, the ratio of estimated yields in Figure 3 to the steady state annual hay yield assumption in FORCAP of 2.1 ton/acre, to adjust monthly forage production in the model over time, was deemed a reasonable method to account for drought impact on the yield performance of pastures and hay land used for cow-calf production. As an example, in a severe drought year, 2011, forage production in each month as shown in Figure 4 was adjusted downward by 43% to account for risk associated with droughty conditions. As shown in the bottom two panels of Figure 4, the red bars indicate hay feeding. While nutrition needs remained constant, pasture forage production to be grazed by animals, needed to be supplemented to a much larger extent with supplemental hay in a droughty vs. normal year.

To arrive at similar yield implications of drought for Alamo switchgrass, Dr. Rocateli (Rocateli, 2014), a recent Ph.D. graduate at Texas Tech University, was approached to simulate switchgrass yields from 2004 to 2013 using recent model modifications to ALMANAC, a biophysical crop growth model for switchgrass initially developed by Kiniry et al. (1996). He used a common soil profile (Captina silt loam) for pasture conditions in northwest Arkansas along with daily Fayetteville, AR weather data to arrive at switchgrass yield estimates of a stand that was modeled to be established in 2003.

Using switchgrass cost of production information and methods as shown in Table 1 with a conservative expectation of a prorated, average yield of 5.01 tons per acre, annual variation in harvesting cost and yields was calculated by adjusting annual yields by the ratio of the annually estimated ALMANAC yield to the average ALMANAC yield from 2004 to 2013. Table 2 shows annual net returns to 90 acres of switchgrass as a function of yield and attendant harvest cost fluctuations including fertilizer price risk, that are summarized as the net future value (NFV_S) of earnings due to switchgrass production as of 2014 as follows:

$$(2)\quad NFV_S = \sum_{t=2004}^{2013}\left\{(p_S \cdot Y_{S,t} - C_{S,t}) \cdot (1+k)^{-(t-2014)}\right\}$$

where p_S is the price of switchgrass that would be contractually set with the bio-refinery over the life of the stand or 10 years, $Y_{S,t}$ is the time-varying yield of switchgrass as described above, $C_{S,t}$ are yield- and fertilizer price-dependent cost of production in constant 2014 dollars as shown in Table 4 and k is the compounding rate set at 6% p.a.

Modifying the switchgrass price used to arrive at NFV_S in Eq. 2, allows estimation of a breakeven price where the sum of NFV_S and the net future value of net returns from cattle and forage production as calculated annually in FORCAP and summed over time in a similar fashion as shown in Eq. 2 across different combinations of cattle and switchgrass management practices are the same, or:

$$(3)\quad NFV_s + NFV_{C_{alt}} = NFV_{C_{base}}$$

where $NFV_{C_{alt}}$ is the net future value associated with a cattle management strategy that includes switchgrass production and $NFV_{C_{base}}$ is the net future value of production strategies that do not include switchgrass production (one option with continuous grazing and a low stocking rate and one option with rotational grazing and a higher stocking rate).

Cow-calf Baseline Scenario and Alternatives to Compare

<u>Baseline</u>

To determine the economic and GHG effects of adding switchgrass production or additional cattle, to a baseline cattle operation, the following parameters were chosen in FORCAP:

- 525 acres are divided into 125 hay acres and 400 pasture acres;
- Pastures are perimeter fenced with barbed wire with fence corners constructed of steel pipe;
- Forage species on pasture land consist of 65 percent fescue, 25 percent bermudagrass and 10 percent clover by area;
- Forage species on hay land consist of 40 percent fescue, 50 percent bermudagrass and 10 percent clover by area;
- Hay land is fertilized annually with poultry litter applied at two tons per acre and 1 ton per acre of lime is applied every four years;
- Pasture land receives no fertilizer but lime is applied at the same rate as on hay land;
- No stockpiling, planting of winter forages, or strip grazing takes place on the farm;
- The pastures are continuously grazed;
- The cow herd consists of 83 commercial white cows with an average weight of 1,200 pounds and 17 young cows at a weight of 900 pounds at first calf; 17 replacements are retained and 16 cows are culled each year with a death loss of one cow per year;
- The farm maintains four breeding bulls with an average weight of 1,850 pounds – bulls are kept on farm for four years. One bull is sold and replaced each year;
- The farm has calves year round with an average birth weight of 90 pounds and a seven month average weaning weight for heifers and steers of 520 and 555 pounds respectively;
- Replacement heifers are bred at 15 months of age to calve at two years of age;
- Fourteen percent breeding failures are expected along with one percent in cow death losses and three percent in calf death losses each year;

- The farm feeds hay, forage, and minerals with no supplemental feeding of grains;
- Transportation of animals to market consists of one custom hauling trip and five personal hauling trips each year;
- All animals are dewormed once per year. Cows, bulls and replacements are vaccinated with 7-way Blackleg, 4-way Viral and Vibro-Lepto 5 while calves are vaccinated with 7-way Blackleg and 4-way Viral. Additionally, heifer calves are tested for Brucellosis and bull calves are castrated and given growth implants. No horns are removed prior to marketing. Pinkeye, scours and Pasturella are treated on farm on an as needed basis and conditions requiring veterinary visits include: 2 prolapse, 1 cesarean, 11 sick treatments and 4 bull soundness checks annually;
- The buildings on the farm include a 1,000 sqft. Hay barn and an 800sqft. Storage shed;
- The farm owns the equipment necessary to bale hay which includes one: 75 hp tractor, disk mower, hay rake, and round baler;
- The farm also owns a stock trailer, hay wagon, brush mower and a corral and chute system;
- Default cattle and input prices reflect 2014 conditions with a cattle price option of the past ten-year deflated average price using overall U.S. beef cattle prices for all cattle and calves.

To establish a baseline scenario, the farm, as described above, required several changes to model annual variation and included: i) changing hay yield in Figure 3 and hay prices as shown in Table 3; ii) changing cattle prices as shown in Table 3; iii) model runs with a static cow herd, where the farm balances the sale of cull cows and replacement heifers each year to maintain 100 cows; and iv) model runs with a fluctuating cow herd where the herd increases, by retaining more heifer calves, and decreases, by selling more cull cows, in a similar pattern as that recorded for the Arkansas state cow herd numbers for the period of 2004 – 2013 as shown in Table 4. The move from a static to a varying cow herd size over time is expected to capture the effect of drought on herd size as well as producer responses to changing cattle and input costs. The results of these model runs are thus expected to show net returns and GHG emissions that result as a function of varying hay yields and prices, mainly due to climatic conditions and either constant or changing beef output at varying cattle prices. The baseline scenario thus utilizes 400 pasture acres using continuous grazing with attendant performance statistics using either a static or fluctuating herd size.

Rotational Grazing Impact and Management Alternatives to Baseline

When changing from a continuous grazing strategy to a rotational grazing strategy, the baseline model farm increases grazing efficiency, the ratio of grazed forage intake as a fraction of total animal feed needs, from 46% to 56% as rotational grazing allows the operator to rest pastures and minimize forage losses as a result of selective grazing (Teague, Dowhower, and Waggoner, 2004). The main effect is that holding stocking rate, or beef output, constant, the operation is now able to free 90 acres of pasture for alternative use. Investment in extra fencing is required, but now on fewer acres with a net investment increase of less than $1,000 and modeled using default parameters in FORCAP. Importantly, hay feeding needs change only marginally, with the need for purchased hay increasing from 198 bales under continuous grazing to 207 bales under rotational grazing under normal forage production conditions. It is these 90 pasture acres that are now available for switchgrass production as the first alternative to the baseline with the alternative now grazing 100 cows on 310 acres of pasture.

A second alternative holds the 400 acres of pasture constant, also changes to rotational grazing requiring an additional approximate $6,000 in fencing investment and increasing the herd size to 113 calving cows thereby increasing beef output while not significantly modifying hay imports to the farm (now at 195 bales vs. 198 bales with continuous grazing).

These alternatives thus represent a more intensive use of pasture land by either diversifying to switchgrass production and a greater cattle stocking rate or more cattle at the same greater stocking rate. Implications of climatic variation are captured in net returns to cattle and switchgrass production (if any) under either constant beef output over time or fluctuating beef output. Price risk in constant

2014 dollars includes fertilizer, hay and cattle price risk as these represent the main cost categories for the enterprises analyzed. Production risk is captured by variations in hay and pasture yields as described above as well as simulated switchgrass yield risk.

RESULTS

Cow-calf Return Comparisons

Table 5 shows the farms' cash returns, returns to management and land, total CO_2 equivalent emissions (GHG emissions – GHG sequestration), hay bought or sold and days on feed for the baseline and alternative production strategies for the static and fluctuating herd sizes, respectively. The switchgrass enterprise was not added to the middle column, the scenario where the pasture area was reduced to free up acreage for switchgrass (Rotational 310), to highlight impacts of cattle enterprise changes without the influence of switchgrass. Table 5 suggests that varying the cow herd size over time increased average annual returns and decreased average days on feed, hay purchased, and CO_2 equivalent emissions compared to a static herd size. Varying the herd numbers also decreased the standard deviation of returns such that cash flows from herd liquidation and rebuilding tended to lessen financial risk when compared to maintaining a static herd size by buying needed hay or selling excess hay. The farm, prior to any management changes, has average cash returns of $16,934 and $19,247 when their herd number is static and varying, respectively. Varying the herd is especially beneficial in drought years as a means to mitigate cash return losses by reducing hay requirements for the herd. This is reflected in the minimum cash return of -$13,568 for varying the herd compared to -$24,954 for a static herd in 2012 (not shown in Table 5) in the only year in which cash returns for all cattle scenarios, prior to the switchgrass addition, was negative.

Both rotational grazing strategies, under both static and varying cow herd numbers, prior to assessing switchgrass production returns, increase farm returns, however, the risk associated with the increased returns is also greater as illustrated by the standard deviation. Varying the cow herd size, as opposed to maintaining a constant herd size, again shows lesser risk and for the same reason -- buying hay is costly in drought years. These findings are consistent with Torell, Murugan and Ramirez (2010).

Switchgrass Returns

To be considered a feasible addition to the farm, switchgrass production would need to provide at least similar levels of return as the baseline, or alternatively, the potential returns of the rotational grazing scenario with the higher stocking rate and more cattle. Table 6 shows the switchgrass price needed, which varies significantly whether the switchgrass alternative is compared to added cattle production or the baseline farm with beef output constant. Table 6 also highlights risk implications of adding switchgrass for each of the management scenarios. A comparison with the baseline without added cattle requires a switchgrass price near $31 per ton to provide similar returns. Competing with added cattle returns as a result of rotational grazing, however, raises the switchgrass price needed to approximately $48 per ton. Adding switchgrass at an intermediate farm gate price level of $40 per ton shows that switchgrass can increase returns to management and land with a minimal increase to farm income risk when compared to the low-stocking rate option of the baseline or a more sizable decline in farm income risk when compared to the high-stocking rate option.

Returns to management and land presented in Figure 5, shows more annual detail with the impact of added switchgrass modeled at $40 per ton. For five of the ten years analyzed, the farm, regardless of management choices, experienced negative returns to management and land. Switchgrass production had a loss in three of the ten years, 2007, 2009, and 2011. The only year switchgrass loss coincides with loss from cattle production is 2011. In the other four years with cattle losses, switchgrass provided positive returns to management lessening the overall farm loss in those years. Switchgrass production, at a price of $40 per ton, does not provide returns greater than the alternative of rotationally grazing the whole farm with additional cows. However, switchgrass does provide greater returns, or lower losses, than the baseline farm in all years except 2011. Overall, switchgrass production is risk mitigating but the size of returns at $40 per ton of switchgrass are simply not large enough to make a substantial difference.

The last column in Table 6 reveals the ratio of NFV to the standard deviation of annual returns to management and land to compare the level of return per unit of risk. To achieve the same ratio of returns to risk, switchgrass price would need to rise to nearly $47 per ton (bottom row in Table 6).

Switchgrass GHG and Energy Impacts

Net GHG emission impacts of switchgrass production, reported in Table 2, show soil carbon sequestration with the exception of 2011. Nonetheless, while net GHG reducing, the addition of switchgrass as a pasture alternative has a smaller impact than modifying grazing practices from continuous to rotational grazing as shown in the changes in GHG emissions in Table 5. It is thus unlikely that producers would grow switchgrass for changes in GHG impact.

Without a doubt, however, the addition of switchgrass does provide biomass for conversion to fuel. Four hundred pasture acres, originally devoted to continuously grazed livestock production, was shown to allow ninety acres of switchgrass production without materially affecting beef or hay supply. With a conservative switchgrass yield of 5 tons per acre, one initially continuously grazed pasture acre would thus yield roughly one ton of biomass for conversion to biofuel in addition to the same beef output.

DISCUSSION

The objectives of this paper were to determine if switchgrass, grown on pastures, would serve to: i) increase supply of biomass for alternative energy production without affecting feed or food supply and at what switchgrass price; ii) provide motive for cattle producers to enhance pasture use efficiency;

and iii) quantify, and potentially reduce, income variability with switchgrass as an income stabilizing enterprise under droughty conditions.

Biofuel refineries seeking land devoted to bioenergy crops in a proximal radius of the plant, to limit transportation costs, will need to secure this land through long term contracts or leases (Mohua et al. 2014). Given this need to source cellulosic material close to the plant, pasture land will come under scrutiny as a source for biomass. This study offers an analysis of economic and environmental tradeoffs associated with the practice of rotational grazing and higher cattle stocking rate. It shows under what switchgrass price conditions, pasture land may be converted to dedicated energy crop production. Switchgrass is shown to have income risk mitigating effects under droughty conditions. However, to compete with an alternative of added cattle production, switchgrass prices approach nearly $50 per ton to compete given the cattle producer conditions evaluated in this analysis. At the same time, positive environmental impacts associated with adding switchgrass production were found to be minor at a conservative yield estimate of 5 tons per acre (ALMANAC yields were 7.85 tons per acre per year, for example).

Limitations to this study are that only one farm size and operation type was studied. It may well be that operation size could have larger implications than provided here. Baling an annual average of 450 tons of switchgrass using an 800lb bale size, for example, may soon have the operator looking to larger haying equipment given the number of bales produced. By the same token, other pasture alternatives may include other forms of grazing livestock. Drought years may also lead to the release of Conservation Reserve Program (CRP) acreage for grazing or haying and hence hay yield risk may not be as severe as modeled within. Finally, cow herd size changes for the average of a state is likely an underestimate of the types of changes that would occur from farm to farm and hence the income risk of cattle production may be low in the varying herd size scenarios. The breakeven prices for switchgrass in Table 6 are thus offered as a way to show a possible range of price levels that are a function of a number of factors that will drive beef producer willingness to accept offers to produce switchgrass. It is clear that GHG implications will likely play a minor role although higher switchgrass yields are certainly in the realm of possibilities and would heighten the potential for soil carbon sequestration as modeled here.

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Figure 1. The annual average percent area of the state of Arkansas in each drought category (D0-D4) as reported by USDM.

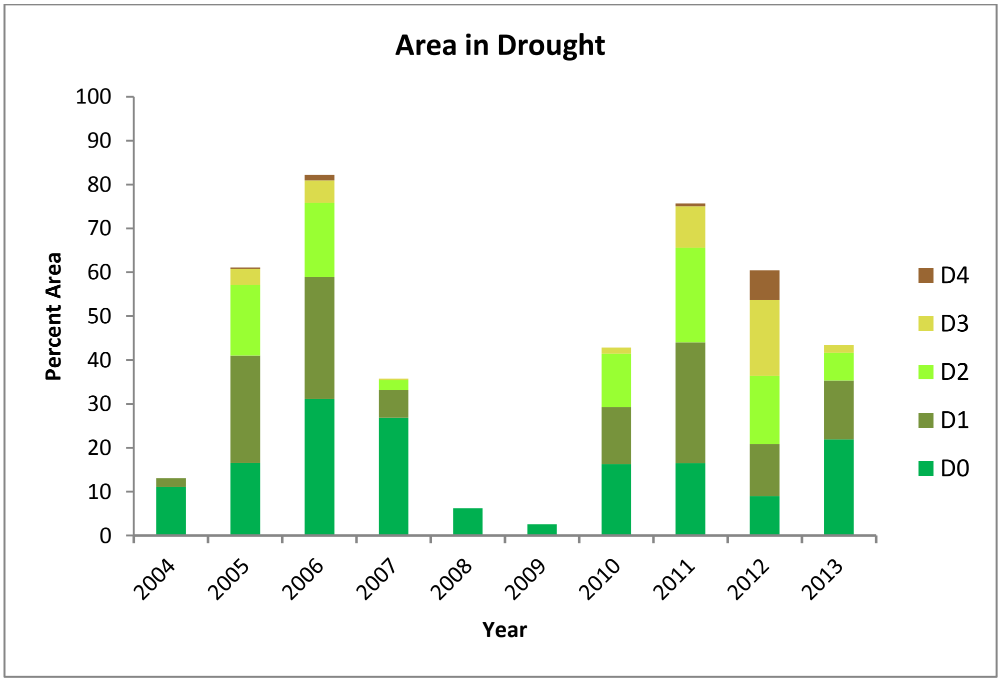


Figure 2. The annual number of weeks in each drought category (D1-D4) per year in the state of Arkansas as reported by USDM.

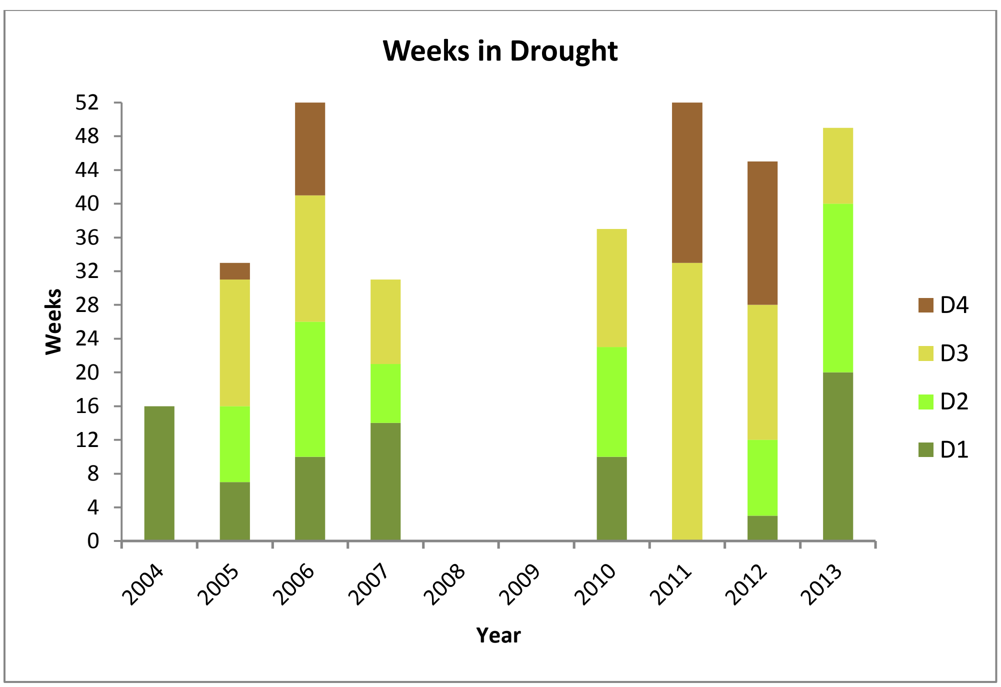


Figure 2. Comparison of observed Arkansas state average hay yield, as reported by NASS, and regression estimated average hay yield, from Equation 1, for fifteen years (2000-2014) .

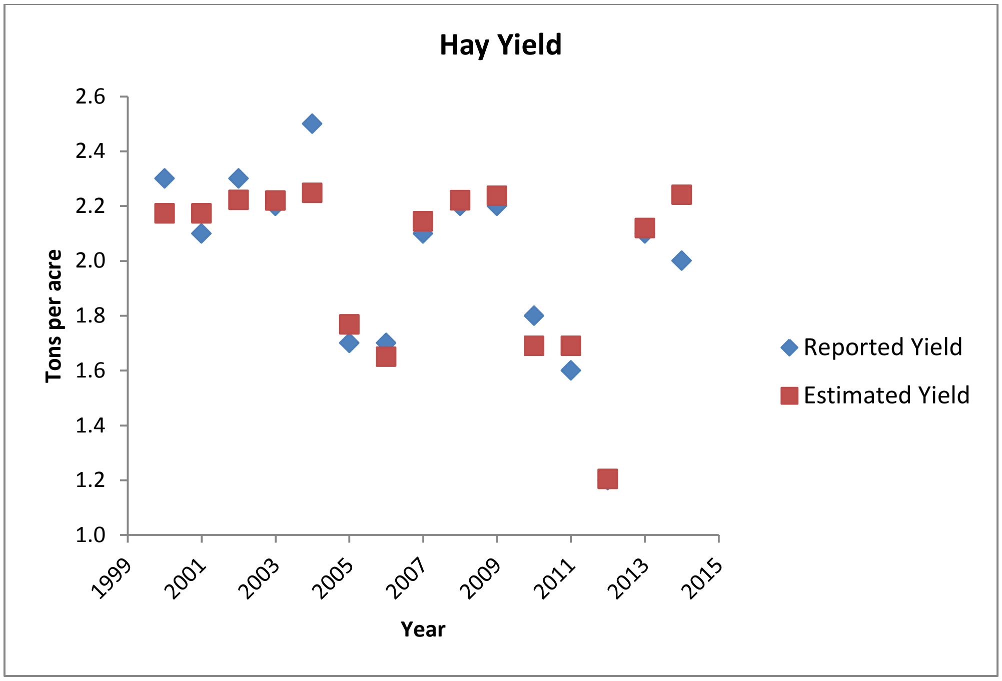


Figure 4. Example of Forage Production adjustment and resultant change in hay needs as a result of drought. Top panel is the base year seasonal distribution of forage production. The middle panel reflects a 43% reduction in forage production. The bottom left panel shows the forage balance corresponding with a normal production year and the bottom right panel shows increasing reliance on hay (the red portion of the bar) under severe drought. While Orchardgrass growth is listed in the figure below it was not planted on any acres and thus has no effect on forage balance.

Normal

Available Forage vs. Grazing Intake (incl. Extra Cattle if any)

Bench / Your Farm — Monthly Forage Available By Species (Your Farm)

Hay Land Grazing

Species -- Default	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Bermuda	*0%*	*0%*	*0%*	*0%*	10%	25%	35%	20%	10%	0%	0%	0%	100%
Fescue	*0%*	3%	7%	20%	27%	15%	0%	0%	2%	13%	11%	2%	100%
Orchardgrass			15%	25%	25%	10%	3%	2%	5%	10%	5%		100%
Clovers	*0%*	*0%*	5%	20%	25%	20%	5%	0%	5%	15%	5%	*0%*	100%

Drought

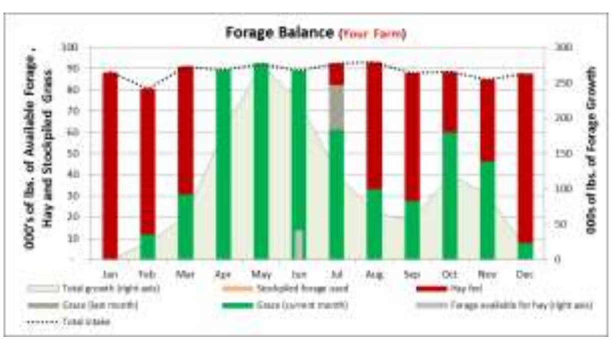
Available Forage vs. Grazing Intake (incl. Extra Cattle if any)

Bench / Your Farm — Monthly Forage Available By Species (Your Farm)

Hay Land Grazing

Species -- Default	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Bermuda					*6%*	*14%*	*20%*	*11%*	*6%*				*57%*
Fescue		*2%*	*4%*	*11%*	*15%*	*9%*	0%	0%	*1%*	*7%*	*6%*	*1%*	*57%*
Orchardgrass			*9%*	*14%*	*14%*	*6%*	*2%*	*1%*	*3%*	*6%*	*3%*		*57%*
Clovers			*3%*	*11%*	*14%*	*11%*	*3%*	0%	*3%*	*9%*	*3%*		*57%*

Normal



Drought

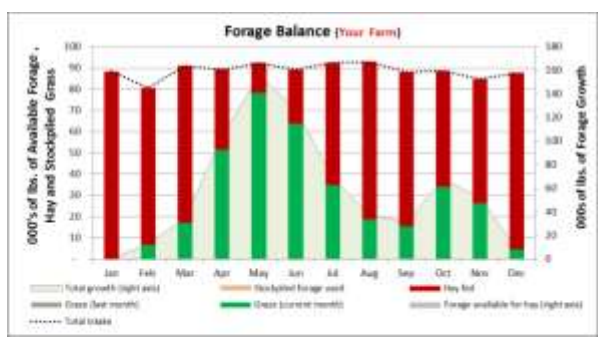
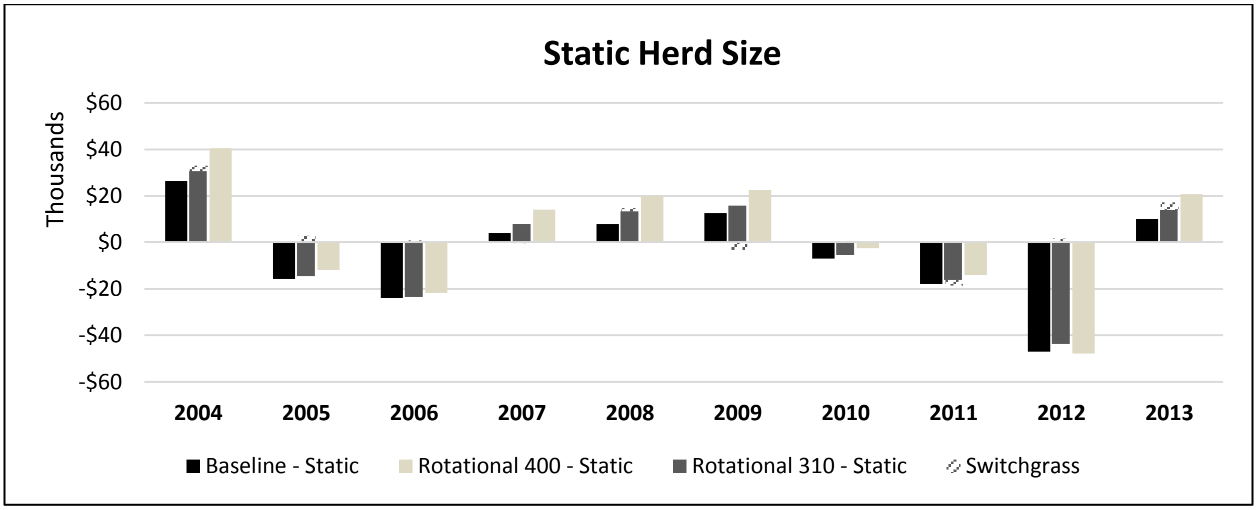


Figure 5. Comparison of Annual Net Returns to Management and Labor with a Static or Varying Cow Herd Size, Modified Stocking rate with Rotational Grazing and Diversification with Switchgrass at $40 per ton.



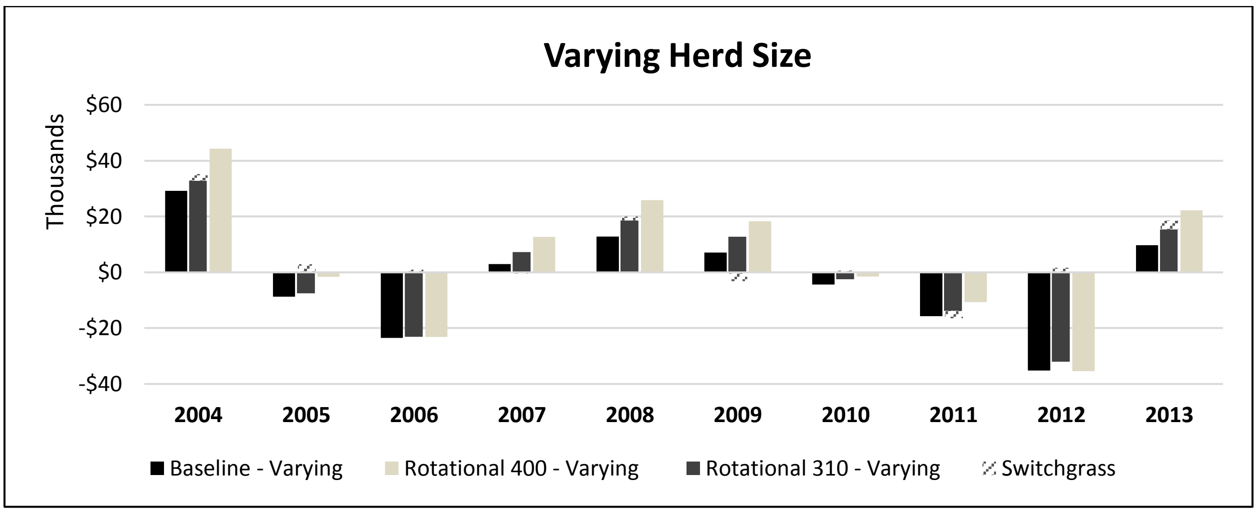


Table 1. Baled Switchgrass Stored at Field Side including Storage and Grinding Losses. Estimated Cost of Production on Pasture Land, Arkansas, 2014.[a]

Description	Total Cost ($)	Prorated Present Value of Total Cost Over Useful Life of Stand at 6% ($)
Establishment Year		
Pre-Plant Weed Control [b]	25.00	2.50
Field Preparation [c]	137.34	13.73
Planting [d]	96.67	9.67
Post-Plant Weed Control [e]	38.90	3.89
Operating Interest [f]	22.58	2.26
Total Specified Expenses	320.48	
Replant Charge [g]	80.12	8.01
Year 2		
Fertilizer [h]	111.51	10.51
Harvest [i]	53.56	5.05
Operating Interest [j]	5.76	0.54
Total Specified Expenses	167.60	
Years 3+		
Fertilizer [h]	111.51	65.33
Harvest [i]	74.13	43.43
Operating Interest [j]	6.32	3.70
Total Specified Expenses	191.96	
Total Specified Expenses - PV over useful Life [k]		$168.63
Useful Life of Stand		10 yrs
Dry Matter Yield - Year 2		4.5 tons
Dry Matter Yield - Year 3+		6.25 tons
Prorated Dry Matter Yield - Net of Losses		5.01 tons/acre
Breakeven Price per dry ton [l]		$44.86
Prorated Annual GHG emissions in lbs of CO_2 per acre [m]		896
Annual Soil Carbon Sequestration in lbs of CO_2 per acre [n]		1,034

Notes:

[a] Please contact authors for further cost of production details not included below. All fertilizer and herbicide are custom applications at $6/acre. Cost information is the deflated ten year average for fertilizers. Switchgrass seed is $10/lb of pure live seed and diesel fuel is $3.17/gal. Operating interest and the capital recovery rate are charged at 7.75% and 6%, respectively. Operator and hired labor are charged at $9.25 and $8.00/hr, respectively.

[b] This includes 2 lb a.i. or 4 pt of glyphosate (Roundup) at $4.75 per pt in late March to kill existing vegetation.

[c] Field preparation occurs in April and includes two passes with a disk to break sod and incorporate 1 ton of lime, 55 lbs of phosphate (0-45-0) and 120 lbs of potash (0-0-60) fertilizers. One pass with a cultipacker smoothes the field. Fertilizers are custom applied.

[d] A no-till grass seed planter is rented at $150 per day in early May. Seeding rate is 8 lbs of pure live seed at $10 per pound.

[e] Herbicide application of 0.33 lb a.i. quinclorac (Paramount) at $55 per lb a.i. and 0.5 oz a.i. imazapyr (Ally or Cimaron) at $29.50 per oz a.i.

[f] Operating interest is charged on all expenses except capital recovery on owned equipment for 1 year given the lack of harvest in the establishment year.

[g] Replanting charges include the fraction of total specified expenses for the establishment year that did not establish (25%).

[h] The fertilizer program is the same as the establishment year with the addition of 200 lbs of ammonium nitrate (34-0-0) for year 2 and onward and no more lime. Nutrient replacement is not scaled for yield differences between years 2 and 3+.

[i] Harvest is performed using a mower conditioner, hay rake (25% of acreage), small round baler (#680 dry matter or #800 as is 15% moisture) using twine and an automatic bale mover for staging without tarp or storage pad preparation. Costs increase with yield beyond year 2.

[j] Operating interest is again applied to operating expense except for only half year given sale of product.

[k] This represents the average, discounted per acre annual cost adjusted for yield and cost differences across the life of the stand at establishment.

[l] This is the breakeven price at establishment adjusted for timing of yield which is adjusted for baling, storage and transport losses of 8%.

[m] Greenhouse gas emissions include diesel fuel use emissions, direct and indirect fertilizer emissions as well as emissions from use of chemicals and twine using values of Lal, et al. (2004).

[n] Carbon sequestration is a function of the shoot:root ratio of 2.05 (Ma et al., 2000b; Lee et al., 2007), 42% carbon content in above and below ground biomass (Lemus et al., 2002; Girouard et el., 1999; Frank et al., 2004) and a 10% of above ground harvested biomass remaining as stubble and crown. Carbon sequestered is thus a function of yield as 50% of the carbon in decomposing root biomass is expected to remain in the soil. Given the perennial growth habit, however, only 1/3[rd] of the root system dies off each year (West, 2015). Finally, it is expected that 5% of the non-harvested above ground biomass comes in soil contact via equipment traffic and thereby available for soil carbon sequestration with soil carbon fluxes affected by soil texture as in Popp et al. (2011). The switchgrass growth model ALMANAC (Kiniry et al., 1996) recently updated by Rocateli (2014) uses a Captina silt loam which to a depth of 55 cm is classified as 31% sandy, 32% loamy and 37% clayey. This leads to approx. 72% of captured carbon remaining in the soil long term.

Table 2. Fertilizer price, yield, harvest cost, operating interest, GHG impacts and Returns to Alamo Switchgrass production on 90 acres, Captina Silt Loam soils, Fayetteville, AR, 2004 to 2013 using yield estimates generated by ALMANAC and adjusted to 5.01 tons/acre at a switchgrass price of $40 per dry ton as stored at the side of the field in 800 lb round bales.

Production Year	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**
Fertilizer in 2014 dollars										
Phosphate $/ton	594	574	587	608	645	730	632	607	693	694
Potash $/ton	404	470	495	407	452	975	637	577	632	589
Ammonium Nitrate $/ton	587	560	663	555	410	501	496	460	546	539
Lime $/ton	47.10	40.50	37.50	32.41	18.55	31.31	34.29	44.53	54.66	54.36
Fertilizer Cost $/acre	$104.71	$105.09	$115.84	$100.94	$90.29	$133.36	$110.31	$103.74	$118.16	$114.94
Yield dry ton/acre	5.39	5.62	5.28	4.37	4.63	4.48	5.02	3.75	5.59	5.97
Harvest cost $/acre	$52.69	$54.46	$52.39	$46.85	$48.41	$47.55	$50.83	$43.05	$54.29	$56.60
Operating interest $/acre	$5.34	$5.40	$5.74	$4.95	$4.60	$6.23	$5.46	$4.91	$5.90	$5.87
Annual Net Returns to Management and Land in 2014 dollars (excluding labor)[a] $/farm	$2,378	$2,997	$960	($399)	$1,371	($3,086)	$703	($2,553)	$1,689	$3,142
GHG emissions (CO_2 eq. lb/acre)	910	918	905	873	882	877	896	850	917	931
GHG sequestration (CO_2 eq. lb/acre)	1112	1159	1089	901	954	925	1036	773	1153	1231
net GHG sequestration (CO_2 eq. lb/acre)	203	241	183	29	72	48	140	(77)	236	301
NFV_S [b]	$11,141		Standard Deviation [c]		$2,152		Average and Standard Deviation of tons of GHG Sequestered [d]		6.2	(5.3)

Notes:

[a] Net returns to management and land include all costs shown in Table 1 with the exception of varying fertilizer and yield-dependent harvest costs and exclude labor charges on the 90 acres of pasture modeled.

[b] Net future value is the sum of annual net returns compounded to 2014 as shown in Eq. 2 at 6%.

[c] Standard deviation of annual net returns.

[d] Based on the 90 acres of switchgrass with fuel use, fertilizer direct and indirect emissions as well as emissions for twine and chemicals. Emissions include farm activities to the point of staging bales at the side of the field and do not include transport emissions to the bio-refinery.

Table 3. Annual hay and cattle price in 2014 dollars.

Production Year		2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Hay Price[a] $/bale		39.19	56.62	70.25	62.73	46.53	41.51	46.00	46.46	52.80	49.90
Cattle Type		Prices $/cwt									
Steers[b, c]	4-500 lb.	214.70	220.04	228.19	208.47	197.41	206.81	205.50	202.95	221.56	217.55
	5-600 lb.	196.75	199.78	206.61	192.75	182.91	191.09	191.57	189.39	201.54	196.10
	6-700 lb.	182.17	188.29	189.52	179.82	170.90	177.99	179.44	177.24	184.69	180.32
	7-800 lb.	171.01	178.25	176.37	169.51	161.81	168.64	169.41	168.45	173.74	169.92
Heifers[b, c]	4-500 lb.	195.15	203.56	202.78	182.28	170.67	175.89	178.40	177.69	192.97	191.07
	5-600 lb.	181.70	189.02	187.23	171.23	162.28	167.44	169.13	168.24	179.30	175.89
	6-700 lb.	170.63	176.20	175.23	163.42	155.45	161.52	162.27	160.46	168.14	165.04
	7-800 lb.	160.74	166.64	165.25	156.61	149.88	155.28	156.60	153.79	158.01	156.19
Cows[b, d]	75-80% Lean	86.44	86.50	80.67	80.37	83.73	82.90	88.10	90.69	95.42	93.45
Bulls[b, e]	1-2,000 lb.	110.01	108.80	99.52	100.26	105.39	104.84	106.83	107.11	112.86	114.67

Notes:

[a] Reported by USDA, NASS as $/ton, converted to $/800lb bale and adjusted for inflation to constant 2014 dollars.

[b] State average market prices as reported by the USDA, Agricultural Marketing Service. Yearly average prices of all monthly prices are weighted by 15,18,14,9,5,5,3,3,8,8,8,4 percent for January through December, respectively as in Doye et al. (2008). All prices are reported in $/cwt and are deflated to 2014 using the beef cattle price deflator option in FORCAP.

[c] Medium and large frame No. 1

[d] Breaking Utility and Commercial

[e] Yield grade 1-2

Table 4. Annual change in the number of calving cows, consistent with recorded changes in the Jan. 1, Arkansas state cow herd inventory numbers, for both rotationally grazing 310 acres with 100 cows and 400 acres with 113 cows.

Rotationally Grazing 310 acres with 100 cows										
Production Year	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**
Total Cows [ab]	104	102	95	97	99	95	98	97	96	89
Old Cows	84	85	78	78	81	79	79	81	80	73
Young Cows	20	17	17	19	18	16	19	16	16	16
Replacements [c]	17	17	19	18	16	19	16	16	16	16
Cull Cows [d]	18	23	16	15	19	15	16	16	22	14
Death Loss	1	1	1	1	1	1	1	1	1	1
Rotationally Grazing 400 acres with 113 cows										
Total Cows [ab]	118	115	107	110	112	107	111	110	108	100
Old Cows	95	96	88	89	92	88	89	92	90	82
Young Cows	23	19	19	21	20	19	22	18	18	18
Replacements [c]	19	19	21	20	19	22	18	18	18	18
Cull Cows [d]	21	26	17	17	23	17	18	19	25	16
Death Loss	1	1	1	1	1	1	1	1	1	1

Notes:

[a] Adjusted annual herd numbers based on the annual change in Arkansas state cow herd numbers as reported by NASS.

[b] Began accounting for herd change in 2000 with 100 and 113 cows for Rotational 310 and Rotational 400 respectively. Replacement heifers from the previous year are the young cows of the current year. Old cows are culled, death losses are assumed to occur in the old cow category and young cows from the previous year are added to the inventory of old cows defined as those that have had 2 or more calves.

[c] Increased in years with herd growth.

[d] Increased in years with herd decline.

Table 5. Cattle Performance Statistic Summary for Static and Varying Herdsizes from 2004 to 2013 in Arkansas. Economic Data is expressed in 2014 dollars.

Static Cow Numbers	**Baseline** [a]		**Rotational 310** [b]		**Rotational 400** [c]	
	Average	St. Dev.	Average	St. Dev.	Average	St. Dev.
No. of Cows	100	-	100	-	113	-
Pasture Forage Growth [d]	2,635	1,089	2,635	1,089	2,635	1,089
Estimated Days on Feed	203	56	211	55	197	57
Hay Sold/(Bought) [e]	(390)	420	(402)	441	(433)	521
Gross Income [f]	$84,351	$4,214	$84,382	$4,286	$97,307	$5,515
Cash Returns [g]	$16,934	$21,555	$20,185	$22,488	$25,678	$26,295
Returns to Management and Land [h]	($5,035)	$21,555	($2,099)	$22,488	$2,009	$26,295
Total CO_2 Equivalent [i]	491	27	488	26	542	31
NFV [i]	($55,331)		($14,666)		$46,269	
Varying Cow Numbers [k]						
No. of Cows	97.2	4	97.2	4	109.8	5
Pasture Forage Growth [d]	2,635	1,089	2,635	1,089	2,635	1,089
Estimated Days on Feed	200	56	207	56	194	56
Hay Sold/(Bought) [e]	(345)	393	(353)	418	(359)	505
Gross Income [f]	$84,005	$8,263	$83,977	$8,214	$96,501	$9,557
Cash Returns [g]	$19,247	$19,073	$22,949	$20,321	$28,549	$24,305
Returns to Management and Land [h]	($2,569)	$18,973	$818	$20,237	$5,087	$24,213
Total CO_2 Equivalent [i]	477	27	474	26	524	31
NFV [j]	($21,195)		$24,778		$88,909	

Notes:

[a] Continuous grazing on 400 pasture acres with 100 cows.

[b] Rotational grazing on 310 pasture acres with 100 cows to set aside 90 acres for switchgrass. Switchgrass returns are not included.

[c] Rotational grazing on 400 acres with 113 cows.

[d] in pounds of available forage/acre per year.

[e] 800lbs per bale as is weight.

[f] Income from sale of caves, cull cows and bulls as well as excess bales of hay if any.

[g] Gross income less direct costs of feed, fertilizer, veterinary and drug, minerals, marketing and hauling, fuel, repair and maintenance and operating interest (charged at ½ total direct costs).

[h] Cash returns less ownership charges (capital recovery, opportunity cost on breeding stock, property tax and insurance). Fixed costs are constant across years in the static herd but vary with cow numbers as the opportunity cost of breeding stock changes.

[i] Net carbon emissions from cattle (respiration, enteric fermentation, and nitrous oxide), soil carbon sequestration by forages and hay, and agricultural inputs (fertilizer – $CO_2$and NO_2, fuel and other) as reported by FORCAP and expressed in tons per farm.

[j] Net Future Value of net returns to management and land calculated using Eq. 2.

[k] Adjusted annual herd numbers based on the annual change in Arkansas state cow herd numbers as reported by NASS and shown in Table 6.

Table 6. Breakeven switchgrass price and income risk ramifications of adding switchgrass as an alternative to beef production on pasture land by modifying grazing practices, Northwestern Arkansas, 2004 – 2013.

Farm Description[a]	NFV[b]	Income Risk[c]	Switchgrass Price[d]	Rotational 310 Income Risk with Switchgrass[a]	$ Returns / $ Risk[e]
Baseline (Continuous 400 – 100 cows)					
Static	($55,331)	$21,555	$31.79	$22,582	($2.57)
Varying	($21,195)	$18,973	$30.95	$20,533	($1.12)
Rotational 400 – 113 cows					
Static	$46,269	$26,295	$47.89	$22,566	$1.76
Varying	$88,909	$24,213	$48.40	$20,605	$3.67
Rotational 310 – 100 cows (with Switchgrass at $40 per ton)					
Static	($3,525)	$22,568	$40.00		($0.16)
Varying	$35,919	$20,563			$1.75
Rotational 310 – 100 cows (with Switchgrass – Risk neutral with Rotational 400)					
Static	$39,715	$22,565	$46.85		$1.76
Varying	$75,558	$20,593	$46.28		$3.67

Notes:

[a] "Baseline" refers to the farm operation using 400 pasture acres with 100 calving cows using continuous grazing. "Static" refers to the situation where cow herd size is not allowed to fluctuate. "Varying" refers to the situation where the cow herd changes in a similar fashion as the Arkansas State cattle inventory. "Rotational 400" is the farm situation using 400 pasture acres with 113 calving cows given greater grazing efficiency with rotational grazing and "Rotational 310" now refers to a farm operation that has 100 calving cows grazing on 310 acres of pasture using rotational grazing together with managing 90 pasture acres growing switchgrass.

[b] Calculated by compounding annual returns to management and land and summing across 2004 to 2013 to reflect the returns over the period analyzed as of 2014 with all prices and cost deflated to 2014 dollars. See also Eq. 2.

[c] This is the standard deviation of non-compounded annual returns to management and land for years 2004 to 2013.

[d] This is the switchgrass price where the NFV to cattle production is the same as the NFV of cattle and switchgrass production as shown in Eq. 3. It is the contract price the producer would have signed in 2004.

[e] Ratio of NFV of returns to management and income risk in the second and third columns, respectively.