12-2015

Modifying a Cow-Calf Biophysical Simulation Model for Analyses of Alternative Enterprises

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Modifying a Cow-Calf Biophysical Simulation Model for Analyses of Alternative Enterprises

A thesis submitted in partial fulfillment
of the requirements for the degree of
Master of Science in Agricultural Economics

by

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University of Arkansas
Bachelor of Science in Poultry Science, 2013

December 2015
University of Arkansas

This thesis is approved for recommendation to the Graduate Council.

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Abstract

Cow-calf producers in the United States, tasked with providing beef calves for the beef industry, have had a multitude of difficulties to overcome in recent years. Producers in northwest Arkansas were negatively impacted by high hay prices coupled with low beef cattle market prices due to severe drought experienced in portions of 2010, 2011, and 2012. During this time they also faced high grain prices, due to a record low harvest, combined with portions of the corn harvest diverted from human and animal feed to ethanol production. Tight lending policies of this time, reminiscent of the housing market crash in 2008, along with the negative public attention associated with high levels of greenhouse gas emissions associated with beef production, lead to a tough situation for cattle producers faced with increasing input costs, decreased revenue, and lack of access to loans. With these issues in mind, this research aimed to determine if incorporating switchgrass (*Panicum virgatum*) production on a cow-calf farm could serve to increase net returns, decrease income volatility, lower net greenhouse gas (GHG) emissions without decreasing beef output, and provide a viable source of feedstock for a potential bio-refinery. The study determined that switchgrass is a potential solution to these problems and thus aimed to discover differences in switchgrass supply under different government policies in four northwestern counties in Arkansas to an as-yet, non-existent bio-refinery.

It was determined that growing switchgrass on pastureland, once devoted to cow-calf production, is a viable enterprise diversification tool that under the right conditions could be used to improve producer financial and environmental outcomes. However, bioenergy production is slow to gain traction in the US due to adverse market conditions from low fossil fuel prices. Thus, in the US, there are only a few bio-refineries currently online and accepting lignocellulosic

biomass, however none of them are close enough to northwest Arkansas to incentivize biomass production in this region. With this in mind, the results from an individual farm with switchgrass were extrapolated to a four county region to determine potential biomass supply for a hypothetical biorefinery. In conjunction with this analysis, two potential policies aimed at increasing biomass supply and lowering carbon emissions, were analyzed for their implications on the financial and environmental wellbeing of farms. It turns out, each of the two policies, the Biomass Crop Assistance Program (BCAP) and a Carbon Offset Program (CO), encourage the production of switchgrass and policy outcomes are most favorable when land of adequate quality is chosen to support higher switchgrass yield. At lower yield levels, the inclusion of switchgrass on pastures leads to less positive environmental outcomes and increased producer income variance.

Acknowledgments

There are many people to which I owe gratitude to for the completion of this Master's Thesis. Some are directly responsible for the content within by pushing me to edit, reedit, and then edit again; all the while reassuring that it can be completed in time. Dr. M. Popp, this was your role and I could not imagine a better candidate for this position. The insight you provided is immeasurably high and I am grateful. Dr. Nalley, you always push me to look at the world around me differently, taking the lid off Pandora's Box; without your input this research undoubtedly would not have all of the insights. Dr. Dixon, I aspire to one day obtain the incredible knowledge you possess and am quite grateful to have had the opportunity to learn from you. You utilize every opportunity to facilitate learning as only great teachers do.

There are also the people that helped me maintain a sense of sanity while enduring this process. I'm quite sure I wouldn't have made it through without the friends I've made in graduate school. Their reassuring words, endless encouragement and relentless patience while listening to my struggles will forever remind me of the powerful influence great people can have on us.

Finally, the acknowledgments would be incomplete without a mention of my amazing family. I know none of this would have been possible without their infinite support. This thesis is so much more than the four chapters contained within. It is a culmination of years of experiences gained from all of the people mentioned above along with many others to whom I am immensely grateful. Thank you for all the support you have given over the years.

Dedication

I dedicate this thesis to my family, specifically, to my parents, husband, and children. Without their love and support, I would have never attempted to pursue this endeavor. I cannot express the gratitude I have for their endless patience, devotion, and encouragement throughout the vicissitudes of this process. To my husband, you have been my rock, my cheerleader, and my coach and this success ours to share, I love you.

Table of Contents

List of Figures and Tables

Chapter II

Chapter III

Chapter I

I. Introduction

Cow-calf producers in Arkansas were impacted by a set of independent forces that, over the period of 2004 to 2013, led to significant stress on producer income. During the latter part of that period, producers experienced a major drought while corn prices were at a record high, due to both the drought and US department of Energy ethanol mandates. Further, financial lending was still tight due to the backlash from the US housing market crash in 2008. Thus, cow-calf producers were impacted by the lack of forage growth, increased supplemental feeding with high priced hay and grains, low market prices due to cattle flooding the market, and lack of access to loans to see them through these adversities. Producers had limited options if they intended to maintain their farm through the drought. If they had the financial means, they could purchase hay to maintain their cattle herd size, and if not, they had the option to sell their cattle at the lower market prices. Many producers, with the desire to remain in business, opted to lower their farm stocking rate to lower their hay requirements and provide cashflow for added feed purchases to alleviate financial distress.

While not all attributable to the drought, Arkansas lost more than 1,900 farms with beef cows and over 134,500 head of beef cows between 2007 and 2012 (NASS, 2014). Even with these losses, beef cattle production remained a major economic asset to Arkansas agriculture, accounting for 7.66 million dollars of products sold in 2012, or 7.9% of all agricultural products sold (NASS, 2014). NASS (2014) also reported that 90.4% of Arkansas cattle farms rear beef cows- of these farms with beef cows, only 6.7% have more than 100 cows, but make up 37.3% of the state’s beef cow inventory.

While cow-calf farms are important to the state as a whole, they are also important to the northwest region of Arkansas, where this study is conducted. Of the 602,000 acres in Washington County, Arkansas, 311,000 acres (51.7%) are in farms. Of these farmed acres, 164,000 acres consist of pastureland. In 2012, 60.2% of all the farms in Washington County had beef cows and a market value of cattle and calves sold (48,787 hd) of 39.9 million dollars (NASS, 2014). This ranked Washington County third in the state for value of sales of cattle and calves, and accounted for 9% of total market value of agricultural products sold in the county (NASS, 2014). As such, cow-calf production is a major economic asset to both Washington County and the state of Arkansas.

In 2010, the National Academy of Sciences Division on Earth and Life Studies released the report Toward Sustainable Agricultural Systems in the 21st Century. In this report the committee details current challenges to US agriculture that include: increased demand, scarcity of natural resources (land and water availability and climate change), environmental degradation (water, air and soil quality), economic concerns (profitability, increasing input costs and consolidation of mid-size farms), and social concerns (labor, food quality, safety and security, animal welfare, community well-being and quality of life). The report goes on to say "that agriculture has the potential to meet the demand of food, feed, and fiber: reduce its environmental footprint; and address other social concerns such as animal welfare and labor justice" (p. 74) and that sustainability practices should incorporate all four sustainability goals (productivity, efficiency, environmental impact, and quality of life) rather than only one or two. While it is challenging for research efforts to focus on all four goals collectively, this research attempts to incorporate three of the four in the context of cow-calf farmers in northwest Arkansas. Quality of life proves the most difficult to incorporate but arguably, if productivity, efficiency, and environmental impacts are all improved, it would reasonably follow that quality of life could also improve.

Cow-calf producers in Arkansas, recently affected by drought, increased input costs, and pressure to decrease GHG emissions, are simultaneously facing multiple management challenges. Climate change, increasing fossil fuel and grain prices along with increased financial risk are major drives of these challenges. Weather volatility, due to climate change (Retchless et al., 2014), increases the risk for crop damaging droughts and 100-year floods, which alter the landscape and force producers to alter their management practices to preserve their farms. Other environmental challenges to cow-calf farms include the push to reduce GHG emissions, as a means to mitigate climate change, on both a national and global scale (Fan and Ramirez, 2012). Fan and Ramirez (2012) indicate that farm producers can reduce their risk exposure to climate change by choosing more integrated farming systems that are diversified and optimize crop productivity while limiting GHG emissions.

US cattle producers have been identified as one of the largest agricultural GHG emitters due to the large amounts of carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) released from respiration, enteric fermentation, manure breakdown, and fertilizer usage, respectively (FAO, 2013). However, there are currently little or no agricultural or environmental policy tools that encourage US cattle producers to specifically reduce their GHG emissions. This study proposes to assess whether added returns to management and land (accounting for both operating and ownership charges as well as potential monetary policy incentives) and/or decreased return risk, associated with incorporating switchgrass production as a lignocellulosic energy crop on pastures, are viable stimuli to decrease cow-calf farm GHG emissions.

The Forage & Cattle Planner (FORCAP), released by the University of Arkansas in 2013, was designed to enable cow-calf producers in Arkansas to analyze the economic and environmental outcomes of altering their farm management practices. FORCAP allows the user to model their current management practices by offering user-specified options regarding: i) input pricing; ii) cattle breed and management; iii) pasture and hay forage species composition and management; iv) equipment, building and fencing options; v) along with transportation, supplemental feed, and veterinary costs (Popp et al., 2014). With this information, FORCAP generates a budget summary, with associated income, expenses, and net returns, and also, estimates net GHG emissions. All of which can be saved and used to compare current management practices with the outcome of new management practices to determine if the new practices are feasible for both the environment and the financial stability of the producer. In this research, FORCAP was utilized extensively to model a cow-calf farm in Washington County, Arkansas, to determine the financial and environmental consequences associated with drought conditions and offer insight to alternative management practices that could potentially alleviate environmental consequences, reduce net return risk, and perhaps be net return neutral.

Objectives

Using grazing efficiency gains associated with switching from continuous to rotational grazing on a cow-calf farm, along with diversification of farming practices to include the lignocellulosic energy crop, switchgrass, financial and environmental consequences of multiple beef farm management practices over ten years (before, during and after the major 2012 drought) are evaluated. Thus, the objectives of this research are to determine the financial implications and net GHG emissions effects as they are affected by: i) continuously grazing cattle; ii) rotationally grazing more cattle on the same amount of land; iii) rotationally grazing cattle and incorporating energy crop production on the same land without decreasing beef output. The study further iv) estimates supply of lignocellulosic feedstock for alternative energy production without affecting feed or food supply which is conditional to the success of adding an energy crop on pastures; v) evaluates whether a potential switchgrass market provides motive for cattle producers to enhance pasture use efficiency; and vi) quantifies net return variability changes associated with adding drought-tolerant switchgrass. Net returns, net return risk, and associated switchgrass yield is further evaluated with the addition of two different agricultural policy instruments intended to increase available biomass for bio-refineries as a way to reduce dependence on fossil fuel use and to decrease GHG emissions.

Components of Thesis

This thesis is divided into four components or chapters. Chapter one introduces the thesis and provides the rationale for the research. Chapter two determines if incorporating switchgrass production on a cow-calf farm can act to stabilize producer net returns during drought. Chapter three demonstrates the potential implications of two agricultural policy instruments (the Biomass Crop Assistance Program and a Carbon Offset program) on potential biomass availability for a bio-refinery in the four county region in Arkansas encompassing Washington, Benton, Carroll and Madison counties. The cow-calf producer's decision to adopt switchgrass production on their farm is evaluated in terms of net returns, net return risk, and environmental net GHG emissions repercussions associated with this decision. Finally, Chapter four concludes this thesis and provides suggestions for future research.

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Chapter II

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

by

Jennifer Lutes and Michael Popp

Selected Paper prepared for presentation at the 2015 Agricultural & Applied Economics Association and Western Agricultural Economics Association Annual Meeting, San Francisco, CA, July 26-28

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

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 net return risk. Establishing switchgrass on pasture acres, freed by enhancing grazing efficiency, is thought to lower overall farm net return risk by growing a drought-tolerant crop as a means to diversify among farming enterprises and, simultaneously, to supply lignocellulosic biomass for a potential bio-refinery. Adopting rotational grazing, compared to a baseline of continuous grazing, to enhance grazing efficiency can either be devoted to increasing beef output or to the production of a dedicated energy crop. The objectives of this study are to determine what switchgrass price is needed to be net return neutral and whether adoption of switchgrass does in fact lower net return risk without affecting feed or food supply. Decision support software, the Forage and Cattle Planner (FORCAP), is used to compare financial returns, along with greenhouse gas (GHG) emissions, across multiple farm management strategies. The analysis reveals that the addition of switchgrass production, when compared to increased beef production, offers lower net return risk but the needed switchgrass price to break even is higher than the price needed when comparing added switchgrass to the least intensive continuous grazing option and lowest stocking rate. Net GHG emissions changes are quite small.

Introduction

Cow-calf producers experience annual fluctuations in their farm returns and are increasingly scrutinized for their role in climate change. Producer annual returns to management and land change with i) climate, impacting both forage and animal performance; and ii) national cattle supply and demand conditions. Many different management practices exist for the purpose of increasing cow-calf producer efficiencies, which may or may not increase net returns and/or environmental ramifications. Assessing modified management practices with respect to their impact on producer net returns, net return risk, and net GHG emissions is therefore an important consideration for determining the likelihood of producer adoption of alternative management practices. Diversification of enterprise choices is often a method suggested to decrease overall net return 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 in this study because it is a perennial crop, has an extensive root system and a single fall harvest that makes its yield fluctuation, due to climatic conditions from year to year, less variable than pasture or hay production. A potential added benefit is soil carbon sequestration and relative ease of adoption as producers already have the necessary equipment for its production. While biofuel, sourced from plant material, is only a potential industry in the United States at this time, this analysis attempts to determine under what conditions cow-calf producers might set aside some of their pasture acreage to switchgrass production as a dedicated energy crop. Converting part of pasture to another use suggests less beef production. However, enhancing grazing efficiency by changing from continuous to rotational grazing allows the volume of beef output to remain the same. Further, a risk/return comparison entails an operation that has changed to rotational grazing and switchgrass production holding beef output constant versus an operation that has also changed to rotational grazing but uses the added efficiency to increase beef production rather than diversifying to switchgrass.

The objectives of this paper are to determine i) at what switchgrass price, switchgrass could compete for pasture acreage and thereby become a source of biomass for alternative energy production without affecting feed or food supply; ii) if switchgrass production would provide incentives for cattle producers to enhance pasture use efficiency at a specific price; and iii) whether switchgrass could potentially reduce farm net return variability 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 characterized by both warm season and cool season grasses and substantial annual rainfall but also a high likelihood of summertime drought. Management of forage resources becomes key to limiting costly hay feeding during the production season. This topic has received substantial 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 (Jennings and Jones, n.d.). The focus of these recommendations is to increase producer net returns to management and land by increasing farm efficiency. Such strategy recommendations are common throughout the southeastern US (Jennings and Jones, n.d.).

Modifying stocking rate affects how much supplemental feed is required during the course of seasonal variation in pasture forage available. Lowering the stocking rate leads to greater unused forage, translating to waste in a normal weather year, but offers a buffer as cattle, in the absence of receiving supplemental feed, can graze lesser quality forage when such forage is protected from trampling, an opportunity that exists when practicing rotational grazing as opposed to allow access to all pasture all the time in a continuous grazing strategy. As such, modifying grazing management and stocking rate can affect supplemental feed required where supplemental feed needs are a function of seasonal climate. Hence, one of the main problems cow-calf producers face is an uneven, seasonal growing pattern of forages. Many farms experience 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. Adjusting stocking rates to match available forage is 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 feeder cattle. Stocking rate also affects GHG emissions. A Texas study found that 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. These studies imply 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 & 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 & 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 & Swinton, 2014), wheat production (Debnath, Stoecker, & Epplin, 2014), land in corn (Bonner et al., 2014; Kells & Swinton, 2014; Raneses, Kenneth, & Shapouri, 1998; Sharp & Miller, 2014; Vadas, Barnett, & 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 switchgrass 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 in Arkansas on the basis of switchgrass' profitability relative to other crops has also been analyzed by Popp and 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. They found switchgrass competitive on crop land and more so when irrigation resources were restricted as switchgrass performs well under non-irrigated conditions. Monti et al. (2012) studied switchgrass and its ability to reduce GHG emissions in different land environments. They found both positive and negative CO2 abatement results when switchgrass was grown on pastureland. Ma et al. (2000a) studied switchgrass and reported positive environmental effects via increased soil carbon, microbial biomass carbon, and carbon turnover. Hence, not only cost of production but GHG impact, irrigation water needs, 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 and suggest that different production practices can affect production cost and thereby the switchgrass price biorefineries need to pay to secure feedstock resources for their plant. 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 to pay along with the farm proximity to a cellulosic biofuels processing plant (Qualls et al., 2012).

Drought Impacts

Switchgrass is 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 during 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), available via efforts 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 2011-2012, in particular, was widespread throughout the southern U.S. and led to a large reduction in the U.S. cow herd as cow calf operations with inadequate water resources had to sell cows given a lack of 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 to be a major capital barrier (Bryant et al., 2014). Hence, it is anticipated that producers are willing to ascertain strategies that might lessen drought risk.

Climate Change Implications

While planning for potential drought is important, it is equally important for a producer to understand that GHG mitigation alone is not enough to alter the increasing global temperature estimates for the next 25 years and that adaptation is also required (McCarl, 2015). Rose (2015) identifies farmers' ability to adapt as critical to their survival. Rose (2015) provides three types of on farm adaptation responses to address climate change: i) adjusting management practices, ii) changing production systems, iii) adopting new technology. Altering the proposed cow-calf farm's management practices to include rotational grazing and new switchgrass production allows the producer to utilize all three adaptation responses simultaneously while also enabling GHG mitigation with plant based biofuels. Rose (2015) acknowledges that producers will "only adapt if it is valuable to do so, changing practices to avoid loss or pursue opportunities" (p. 3), and finds that farmers are already adapting to climate change.

Material and Methods

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

In part as a response to 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 the internet, allows the user to estimate their farm's net returns (NR) and net GHG emissions to compare across a range of decision parameters that relate to: i) pasture management (rotational versus 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. Net 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 FORCAP 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 monthly with the ability to modify forage production to model drought impact. Model modifications for this analysis were 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:

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

Adj. $R^2 = 0.82$.

where Y_i is the annual hay yield in tons per acre per 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. County level observations on annual hay yields were not available.

Therefore, the ratio of estimated yields in Figure 3 to the steady state annual hay yield assumption of 1.9 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, 2012, forage production in each month as shown in Figure 4 was adjusted downward by 37% 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 larger extent with supplemental hay in a droughty versus normal year.

To arrive at similar yield implications of drought for Alamo switchgrass, the recently modified biophysical crop growth model ALMANAC was used to simulate annual switchgrass yields from 2004 to 2013 (Kiniry et al., 1996, Rocateli, 2015). The model run used a common soil profile (Captina silt loam) for pasture conditions in northwest Arkansas along with daily Fayetteville, Arkansas weather data to arrive at switchgrass yield estimates of a stand that was 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, that are summarized as the net future value (NFV_S) of earnings due to switchgrass production as of 2014 as follows:

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

where p_S is the price of switchgrass in dollars per ton 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 in tons per acre of switchgrass as described above, $C_{S,t}$ are yield- and fertilizer price-dependent cost of production in constant 2014 dollars per acre as shown in Table 4 and *k* is the annual real, risk-adjusted compounding rate set at 6% and reflective of typical risk-adjusted discount rates ranging from 3 to 10% in agricultural production analyses (Hardie, 1984).

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) $NFV_s + NFV_{C_{alt}} = NFV_{C_{base}}$

where $NFV_{C_{alt}}$ is the net future value associated with a cattle management strategy that includes 90 acres of 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 one 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 eleven trips per year using a cattle trailer with a capacity to haul 8 cows at a time and a distance to market of 25 miles;
- 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 sq ft. hay barn and an 800 sq ft. 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, 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 a constant breeding stock of 100 cows; and iv) model runs with a fluctuating cow herd where the herd size 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 expected to show net returns and net GHG emissions that occur 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 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 to 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, & Waggoner, 2004). The main effect is that holding stocking rate, or beef output, constant, the operation is able to free 90 acres of pasture for alternative use. Investment in extra fencing is required, but on fewer total pasture 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. The 90 pasture acres become 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, one time $6,000 investment in fencing 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 versus 198 bales with continuous grazing).

These alternatives represent a more intensive use of pasture land by either diversifying to switchgrass production and a greater cattle stocking rate or more cattle without switchgrass. 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 US 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 variability.

Results

Cow-calf Return Comparisons

Table 5 shows the farms' cash net returns (revenue less cash operating expenses), net returns to management and land (revenue less specified operating and ownership charges), total net 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 net returns and decreased average days on feed, hay purchased, and net CO_2 equivalent emissions compared to a static herd size. Varying the herd numbers also decreased the standard deviation of net returns to management and land 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 net returns to management and land of $4,607 and $7,321 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 return to management and land of -$8,012 for varying the herd compared to -$19,738 for a static herd in

2012 (not shown in Table 5), the only year in which cash returns for all cattle scenarios, prior to the switchgrass addition, were negative.

Rotational grazing strategies, using either the static or varying cow herd numbers, prior to assessing switchgrass production returns, increases farm net returns to management and land; however, the risk associated with the increased net 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 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 net return as the baseline, or alternatively, the potential net returns of the rotational grazing scenario with the higher stocking rate and more cattle. Table 6 shows the switchgrass price needed, which varies substantially 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 $26 per ton to provide similar net returns. Competing with added cattle net returns as a result of rotational grazing, however, raises the switchgrass price needed to approximately $50 per ton. Adding switchgrass at an intermediate farm gate price level of $40 per ton shows that switchgrass can increase net returns to management and land with a minimal increase to farm net return risk when compared to the low-stocking rate option of the baseline or a more sizable decline in farm net return risk when compared to the high-stocking rate option.

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

The last column in Table 6 reveals the ratio of NFV to the standard deviation of annual net returns to management and land to compare the level of net return per unit of net return risk. To achieve the same ratio of net returns to net return risk as rotationally grazing additional cattle, switchgrass price would need to rise to nearly $47 per ton (Table 6). While the net return/net return risk ratio is the same at this price level, actual net returns and net return risk are both higher for additional cattle.

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 emissions are reduced, 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 and consistent with the findings of Wang et al. (2013). It is thus unlikely that producers would grow switchgrass to mitigate GHG impact.

Adding switchgrass provides biomass for conversion to fuel. Four hundred pasture acres, originally devoted to continuously grazed livestock production, were shown to allow ninety acres of switchgrass production without materially affecting beef or hay supply. With a conservative switchgrass yield of five tons per acre, one initially, continuously grazed pasture acre yields approximately one ton of biomass for conversion to biofuel (while maintaining beef output) as approximately $1/5^{th}$ of a continuously grazed pasture acre can be used for switchgrass production when grazing efficiency increases with rotational grazing implemented.

Discussion

The objectives of this paper were to determine if switchgrass, grown on pasture, 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 incentive 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 25 to 30 mile 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 for a cow calf farm with 100 cows in NWA. 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 near $51 per ton are needed to achieve similar net returns as attainable with intensive cattle production under 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 five tons per acre.

Limitations to this study are that only one farm size and operation type was modeled. 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 quickly motivate the operator to purchase larger haying equipment given the number of bales produced. By the same token, other pasture alternatives may include other methods of grazing livestock. Drought years may also lead to the release of Conservation Reserve Program (CRP) acreage for grazing or haying and hence overall hay supply variability may not be as severe as modeled within. Finally, cow herd size changes based on the state average are likely an underestimate of the types of changes that would occur from farm to farm on an annual basis 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 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. Average annual percent area of the state of Arkansas in each drought category (D0-D4) as reported by USDM.

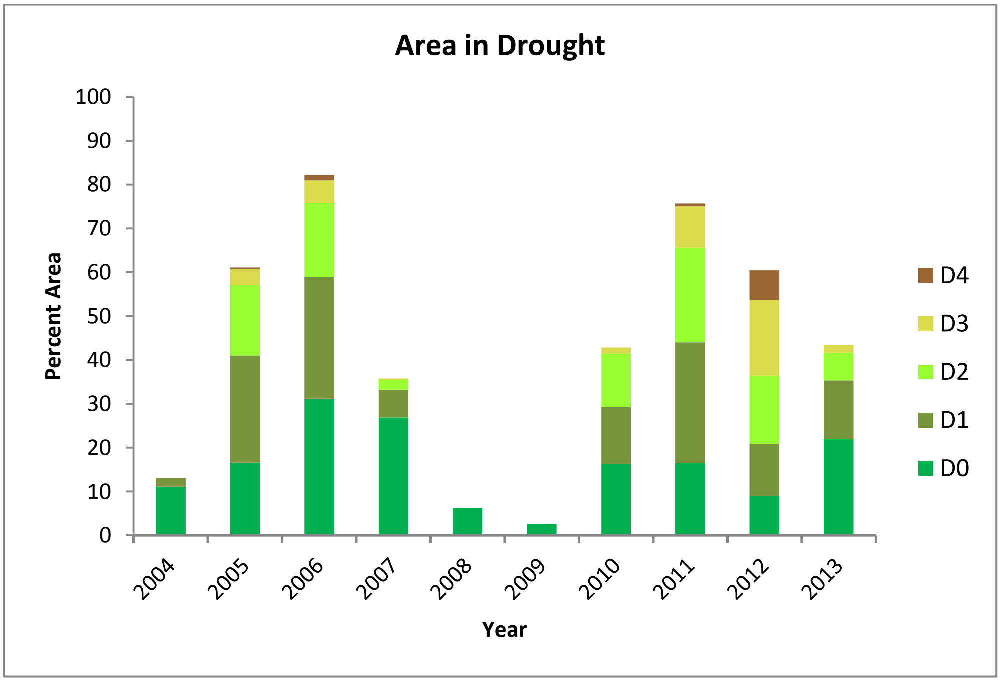


Figure 2. The annual number of weeks in each drought category (D1-D4) per year in the state of Arkansas as reported by USDM.

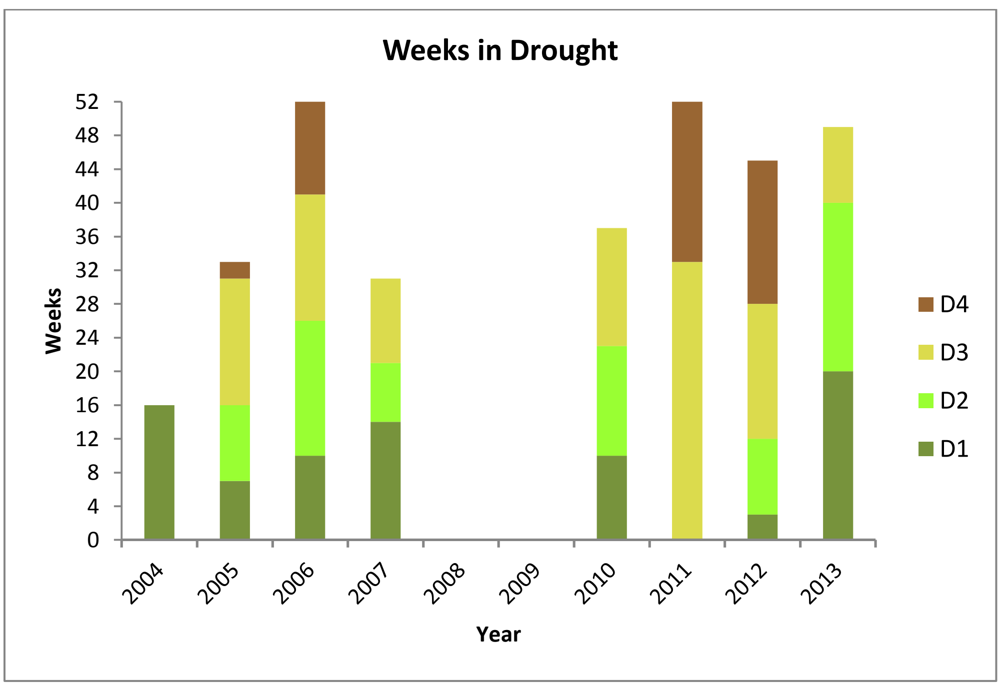


Figure 3. Comparison of observed Arkansas state average hay yield, as reported by NASS, and regression estimated average hay yield, from Equation 1, for fifteen years (2000-2014).

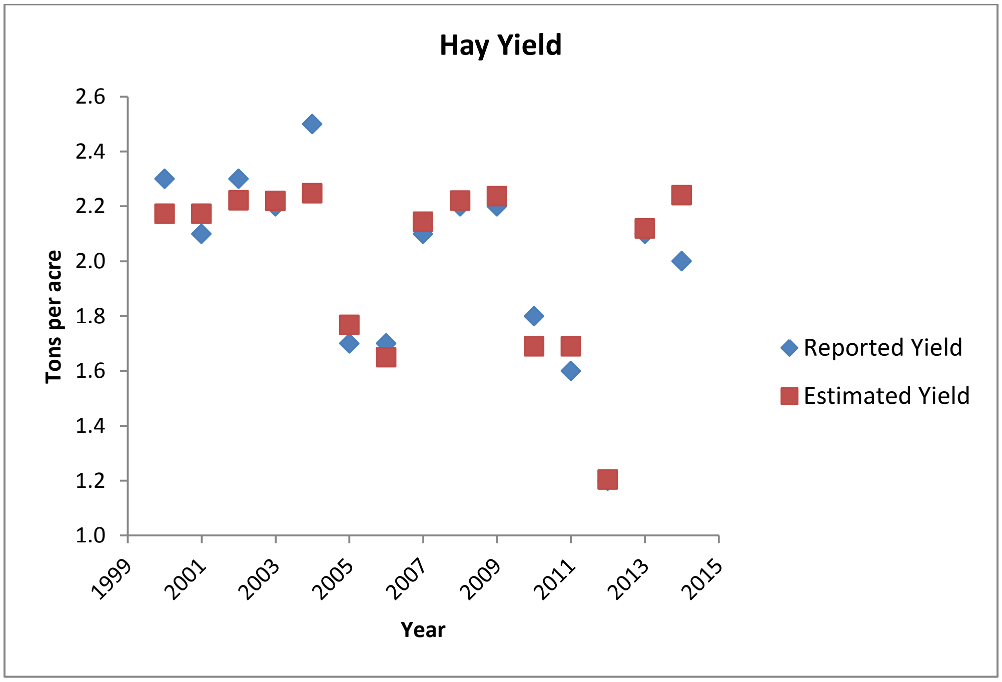


Figure 4. Example of Forage Production adjustment and resultant change in hay needs as a result of drought. Top panel is the base year seasonal distribution of forage production. The middle panel reflects a 37% reduction in forage production. The bottom left panel shows the forage balance corresponding 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)

Monthly Forage Available By Species (Your Farm)

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

Drought

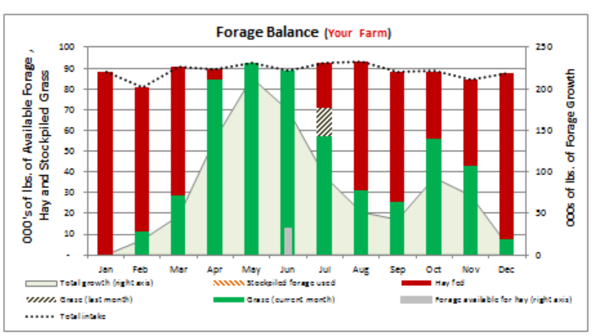
Available Forage vs. Grazing Intake (incl. Extra Cattle if any)

Monthly Forage Available By Species (Your Farm)

Species -- Default	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Bermuda	0%	0%	0%	0%	6%	16%	22%	13%	6%	0%	0%	0%	63%
Fescue	0%	2%	4%	13%	17%	9%	0%	0%	1%	8%	7%	1%	63%
Orchardgrass			9%	16%	16%	6%	2%	1%	3%	6%	3%		63%
Clovers	0%	0%	3%	13%	16%	13%	3%	0%	3%	9%	3%	0%	63%

Normal

Drought



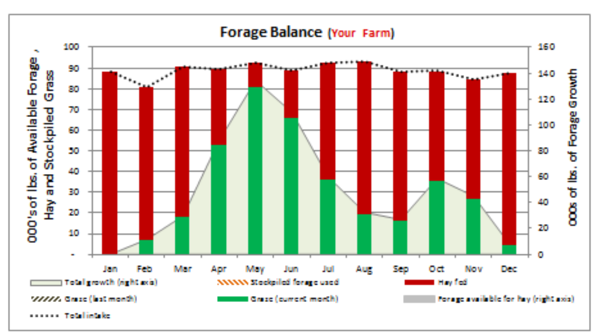
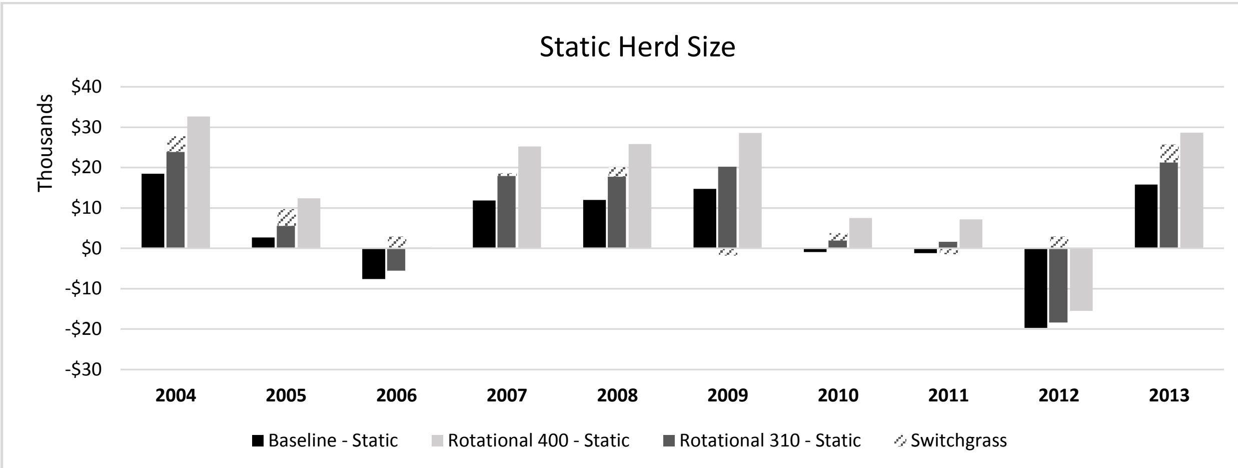


Figure 5. Comparison of Annual Net Returns to Management and Labor with a Static or Varying Cow Herd Size, Modified Stocking rate with Rotational Grazing and Diversification with Switchgrass at $40 per ton.



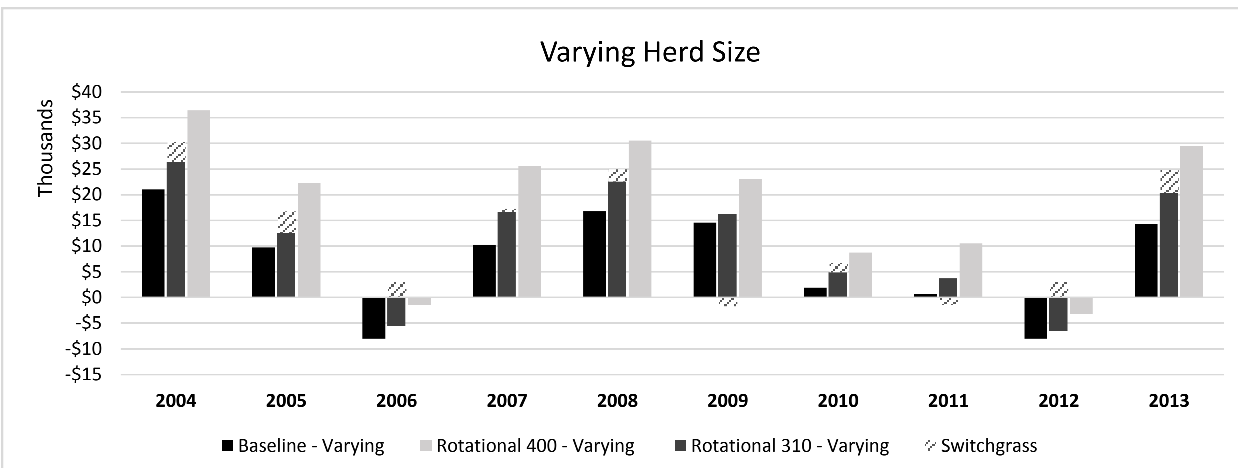


Table 1. Baled Switchgrass Stored at Field Side including Storage and Grinding Losses. Estimated Cost of Production on Pasture Land, Arkansas, 2014.[a]

Description	Total	Prorated Present Value of
Establishment Year		
Pre-Plant Weed Control [b]	59.50	5.95
Field Preparation [c]	131.23	13.12
Planting [d]	92.75	9.28
Post-Plant Weed Control [e]	20.75	2.08
Operating Interest [f]	17.34	1.73
Total Specified Expenses	321.58	
Replant Charge [g]	80.39	8.03
Year 2		
Fertilizer [h]	100.71	9.59
Harvest [i]	44.91	4.28
Operating Interest [j]	3.89	0.37
Total Specified Expenses	149.51	
Years 3+		
Fertilizer [h]	100.71	61.99
Harvest [i]	60.29	37.11
Operating Interest [j]	4.19	2.58
Total Specified Expenses	165.19	

Total Specified Expenses - PV over useful Life	\$156.12
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]	\$39.69
Prorated Annual GHG emissions in lbs of CO_2	807
Annual Soil Carbon Sequestration in lbs of	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 8 pt of glyphosate (Roundup) at \$4.75 per pt in late March to kill existing vegetation and another 2 pt application of glyphosate prior to planting.

[c] Field preparation occurs in April and includes two passes with a disk to break sod and incorporate 1 ton of lime, 67 lbs of phosphate (0-45-0) and 67 lbs of potash (0-0-60) fertilizers. One pass with a cultipacker smoothes the field. Fertilizers are custom applied.

[d] A no-till grain drill (12' width) is used in early May. Seeding rate is 8 lbs of pure live seed at \$10 per pound.

[e] Herbicide application of 0.5 oz a.i. imazapyr (Ally or Cimaron) at $29.50 per oz a.i. for broadleaf weed control.

[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 at a rate of 6% p.a.

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

[h] The fertilizer program is 130 lbs of urea (46-0-0), 50 lbs of phosphate (0-45-0) and 140 lbs of potash (0-0-60) fertilizers 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 (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 1/3rd of the root system dies off each year (West, 2015). Finally, it is expected that 10% 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
Urea $/ton	616	637	656	658	445	555	559	505	612	586
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	$85.87	$89.73	$92.25	$87.40	$77.12	$117.01	$95.59	$89.37	$102.04	$98.05
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	$55.18	$56.57	$54.49	$48.94	$50.50	$49.63	$52.93	$45.12	$56.40	$58.73
Operating interest $/acre	$3.67	$3.83	$3.84	$3.53	$3.27	$4.44	$3.89	$3.47	$4.19	$4.14
Annual Net Returns to Management and Land in 2014 dollars (excluding labor)[a] $/farm	$6,923	$7,090	$4,670	$940	$3,338	-$2,376	$2,330	-$1,727	$3,336	$4,762

Table 2.Cont.

Production Year	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**
GHG emissions (CO_2 eq. lb/acre)	813	817	811	797	801	799	807	787	816	822
GHG sequestration (CO_2 eq. lb/acre)	1112	1159	1089	901	954	925	1036	773	1153	1231
Net GHG emissions (CO_2 eq. lb/acre)	299	342	278	105	153	126	229	-14	337	409

NFV_S [b]	$29,287	Standard Deviation [c]	$2,224	Average and Standard Deviation of tons of GHG Sequestered [d]	10.2	(5.9)

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
Hay Index[f]		1.18	0.93	0.87	1.13	1.17	1.18	0.89	0.89	0.63	1.12
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 deflated to 2014, 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 Jan through Dec, respectively as in Doye et al. (2008).

[c] Medium and large frame No. 1 [d] Breaking Utility and Commercial [e] Yield grade 1-2

[f] Ratio of estimated hay yield and ten year average hay yield, applied in FORCAP to simulate weather on forage growth

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	**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	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	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	3,091	572	3,091	572	3,091	572
Est. Days on Feed	176	25	185	27	170	24
Hay Sold/(Bought) [e]	(225)	245	(219)	280	(200)	324
Gross Income [f]	$83,538	$2,919	$83,995	$2,640	$97,443	$2,852
Cash Returns [g]	$26,576	$12,188	$30,899	$13,853	$38,938	$15,545
Returns to Mgmt&Land [h]	$4,607	$12,188	$8,615	$13,853	$15,269	$15,545
Total CO_2 Equivalent		18		17	529	20
NFV [j]	$72,024		$128,65		$223,482	
Varying Cow Numbers [k]						
No. of Cows	97	4	97	4	110	5
Pasture Forage	3,091	572	3,091	572	3,091	572
Est. Days on Feed	173	24	181	25	166	22
Hay Sold/(Bought) [e]	(171)	242	(173)	263	(128)	317
Gross Income [f]	$84,313	$6,358	$84,584	$6,278	$97,784	$6,684
Cash Returns [g]	$29,137	$10,309	$33,223	$11,612	$41,648	$13,844
Returns to Mgmt&Land [h]	$7,321	$10,207	$11,093	$11,522	$18,187	$13,758
Total CO_2 Equivalent	465	22	463	21	511	25
NFV [j]	$109,405		$162,78		$264,291	

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, 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	$72,024	$12,188	$26.38	$13,922	$5.91
Varying	$109,405	$10,207	$26.90	$11,872	$10.72
Rotational 400 – 113 cows					
Static	$223,482	$15,545	$50.39	$13,949	$14.38
Varying	$264,291	$13,758	$51.45	$12,106	$19.21
Rotational 310 – 100 cows (with Switchgrass at $40 per ton)					
Static	$157,939	$13,918	$40.00		$11.35
Varying	$192,070	$11,973			$16.04
Rotational 310 – 100 cows (with Switchgrass – Risk neutral with Rotational 400)					
Static	$200,385	$13,935	$46.73		$14.38
Varying	$231,299	$12,041	$46.22		$19.21

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 net returns to management and land and summing across 2004 to 2013 to reflect the net 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 net 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 net returns to management and income risk in the second and third columns, respectively.

Chapter III

Estimating Effects of an Energy Crop on Cattle Farms under Subsidy and Carbon Offset Policies

by

Jennifer Lutes and Michael Popp

III. Estimating Effects of an Energy Crop on Cattle Farms under Subsidy and Carbon Offset Policies

Abstract

The United States and other countries are evaluating methods to mitigate greenhouse gas (GHG) emissions to lessen their impact on climate change. The Environmental Protection Agency (EPA) listed the US Agriculture sector as fourth on their list of the largest sectors for anthropogenic GHG emissions with beef cattle responsible for a significant share of that total. Cow-calf producers, faced with many competing resource constraints face potential added pressure to reduce GHG emissions. This study evaluates the effects of adding switchgrass as an alternative energy crop on pasture freed by increasing intensive grazing practices on a model farm in northwest Arkansas. Three different agricultural policies aimed at either subsidizing alternative energy production, paying for lesser net GHG emissions, or both, are analyzed to estimate effects on producer net returns, income risk, switchgrass supply, and farm-gate net GHG emissions. Results show that switchgrass production has the potential to increase net farm returns, lower income risk and GHG emissions. The magnitudes of such changes rely largely on switchgrass yields. The higher the switchgrass yield, the greater the program payments, energy feedstock supply, GHG mitigation and competitiveness with the cattle enterprise.

Introduction

With mounting evidence in support of anthropogenic climate change, the United States Environmental Protection Agency (EPA) is evaluating methods to mitigate greenhouse gas (GHG) emissions to lessen their impact on climate change. Lifecycle assessments of net GHG emissions of carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O), collectively labeled as "carbon" emissions, are used to measure the impact of varying production practices on global warming in CO_2 equivalents. The EPA, in their annual inventory of anthropogenic GHG emissions and sinks, lists agriculture as the fourth largest emitter among six economic sectors after electric power, transportation and industry in the United States (US EPA, 2015). Accounting for roughly 8.8% of total US carbon emissions in 2015, the agriculture sector's CH_4 emissions from enteric fermentation is the second highest CO_2 equivalent emitter, comprising approximately 2.5% of total US carbon emissions (US EPA, 2015). Beef cattle, accounted for 71% of enteric fermentation emissions and also released CO_2 and N_2O, respectively, from respiration and manure decomposition (FAO, 2013). These findings suggest a need for research to develop and evaluate GHG mitigating strategies on cattle farms that decrease whole farm emissions without decreasing beef output, producer income, or increase producer income risk. A recent study (Lutes and Popp, 2015) evaluated incorporating switchgrass production on pastures as a means to combat income risk in light of drought. As a lignocellulosic energy crop, switchgrass serves the dual purpose of providing feedstock for renewable energy production and works to combat income variability on cow-calf farms often faced with summer-time drought (Parrish & Fike, 2005; Richner et al., 2014). Lutes and Popp (2015) proposed that cow-calf producers could lower their income risk and maintain income by implementing rotational compared to continuous grazing and adding switchgrass production on the land freed by increased cattle grazing efficiency with improved pasture management while maintaining beef output. The impact of this strategy on net GHG emissions, however, in conjunction with various agricultural or EPA policies to speed producer adoption, has not been carefully evaluated.

This paper aims to i) evaluate the effects of switchgrass production when included on pastures of cattle farms; ii) conduct a farm-gate life cycle assessment of net GHG emissions; and iii) estimate economic and environmental changes both in terms of level and variability under two different agricultural policy instruments intended to increase available cellulosic feedstock for alternative energy production. Results from this study provide insight as to whether an agricultural subsidy, a carbon offset program, or both improve cow-calf income, risk exposure, quantity of switchgrass produced, and net GHG emissions. The analysis is framed within the context of attempting to supply a bio-refinery interested in converting switchgrass to alternative energy from a three-county region in Northwest Arkansas to test the hypothesis that more efficient pasture management, as a result of policy incentives in conjunction with an as yet non-existent switchgrass market, could lead to a steady supply of switchgrass (Figure 1). This agricultural region relies heavily on poultry and beef for agricultural income with little acreage suited for crop production. Thereby, it is ideal for establishment of switchgrass on marginally productive farm land.

Background Information

Lutes and Popp (2015), Keeton et al. (2013), and Smith et al. (2016) utilized the Forage and Cattle Planner (FORCAP), a spreadsheet based tool that allows cow-calf producers and researchers to estimate cow-calf farms' net returns and net GHG emissions, to examine net GHG versus net return tradeoffs under a variety of different management practices and parameters (Popp et al., 2014). Specifically, Lutes and Popp (2015) determined the feasibility of using switchgrass as an income stabilizing crop. They modeled farm output of a 400 pasture acre cow-calf farm, in Washington County, AR, from 2004 to 2013, under continuous and rotational grazing management with increased rotational grazing efficiency either leading to greater beef output or to the substitution of pasture with 90 acres of switchgrass production without a change in beef output when compared to the continuous grazing baseline alternative. Results of that study, analyzing risk-return tradeoffs between additional cows and a new switchgrass enterprise, demonstrated that a switchgrass price of approximately $51 per dry ton was required to compete with returns generated by increasing the stocking rate. At that price, switchgrass also provided lower associated income risk than the scenario with added livestock. Lutes and Popp (2015) concluded that drought-resistant switchgrass, even at a price of $40 per dry ton, was risk mitigating when compared to an operation using continuous grazing since the switchgrass enterprise had positive returns in drought years when the cattle enterprise showed negative returns. However, the returns were deemed insufficient to encourage producer adoption of switchgrass in comparison to added cattle.

This is not an isolated finding. Agricultural producers in the United States have been slow to adopt switchgrass as a bioenergy crop. Ongoing research points to barriers to adoption not only due to a lack of producer profitability and logistical problems (Parrish & Fike, 2005; Vadas et al., 2008; Boyer et al., 2013; Bonner et al., 2014; Cahill et al., 2014; and Popp et al., 2015) but also bio-refinery demand closely tied to petroleum prices (Mallory, Hayes and Babcock, 2011). To encourage producer adoption of dedicated energy crops, the Energy Act of 2008, a portion of the US Farm Bill, authorized the Biomass Crop Assistance Program (BCAP) to provide establishment and harvest cost financial assistance to producers in approved project areas. Figure 1 depicts the BCAP approved project areas for native perennial grasses and switchgrass along with miscanthus in the four-state region of Kansas, Missouri, Oklahoma and Arkansas as reported on FSA website (FSA, 2015). These project areas are centered around approved, existing lignocellulosic biomass facilities which may expand in number in the future. For example, switchgrass production may gain traction in northwest Arkansas if similar programs become politically and economically viable for producers such that goals of mitigating GHG emissions, stabilizing producer income, and creating additional jobs from alternative energy production, as a form of rural development, can be achieved.

McCarl (2015) describes two forms of climate change adaptation necessary to mitigate climate change - private and planned. He further explains that "private adaptations are those that individuals undertake in their own best interest, while planned are implemented by governments" (p. 2). While governments can regulate change, there is often an associated social welfare loss. Hence, it is much preferred for farmers to adapt and avoid the net social welfare loss (Gonzalez-Ramirez, Kling, & Valcu, 2012). Currently, the U.S. government does not participate in a carbon cap and trade program. However, Canada and the European Union do participate in a cap and trade program to reduce carbon equivalent emissions. Recent research has analyzed the potential for a cap and trade type initiative in the U.S. (Murray et al., 2012; Nalley, Popp and Fortin, 2011; National Academy of Science, 2010). For a cap and trade or carbon offset program to work, income from carbon credits may only be generated for changes in producer practices that lead to carbon equivalent emission or sequestration changes that are less in net amount to carbon equivalent emissions associated with current production practices. Gonzalez-Ramirez, Kling, and Valcu (2012) describe this concept of additionality as a major issue in carbon offset programs due to the need to establish baseline emissions. They argue that, prior to an offset program, baselines cannot be directly observed and are thus subject to uncertainty. The Kyoto protocol also addresses this concern and requires carbon projects to meet additionality standards (Mooney et al., 2002). In the absence of a cap and trade program, Jones, Nickerson and Heisey (2013) propose investing in research and development, to increase agricultural productivity – specifically, developing new technologies with little or no GHG emissions that can serve a dual purpose of increasing productivity and promoting GHG mitigation. The latter goal coincides with the objectives of this study in the sense that increased grazing efficiency would free acreage for growing switchgrass to aid with income stabilization and promoting supply of alternative energy feedstock without affecting food supply.

Another critical aspect is how environmental outcomes are measured. Research can sometimes be difficult to evaluate as researchers report GHG emission changes in multiple metrics: whole farm, per land unit, and per unit of output. While these calculations all report carbon emissions from the farm, they can potentially be misleading. Total emissions are often not disclosed in research findings and thus the reader is left to assume total environmental impact. John Rolfe (2010) found that while improving beef production can lead to lower levels of emissions per unit of beef produced, it is also expected to increase the number of cattle on farm and thus increase total emissions. White et al. (2014) and Wang et al. (2013) both demonstrate that improving farm technical efficiency decreased GHG emissions per unit of output, but neither report whole farm emissions. As such, the reader is unaware if whole farm emissions increase or decrease as output is likely to increase given the greater efficiency. The Food and Agriculture Organization of the United Nations (FAO, 2013) recommends expressing GHG emissions from cattle on a digestible energy intake basis or per unit of animal product as this reflects the accuracy of a given mitigation practice. To show more complete, farm-gate environmental implications, GHG emissions in this study are reported using multiple methods: whole farm, per acre, and per unit of output for both beef and switchgrass using a three-county region with existing cattle farms and pasture acreage as a baseline.

The 2012 Census for Agriculture reveals that four counties, Benton, Carroll, Madison and Washington, in northwest Arkansas rely more heavily on poultry and livestock production than row crops (Table 1). Within this four county area over half of the land is farmland, and, with the exception of Madison County (36.6%), over half of the farmland is devoted to pasture. While poultry production is the major economic revenue generator, cattle sales also play a large role in each of the four counties. A host of different production practices and size of cattle farms exists in cattle production as production environments tend to vary from farm to farm. This paper models the impact on operations with 400 acres of pasture at a moderate stocking rate of 4 acres per cow using continuous grazing and increasing stocking density by providing only 3.1 acres per cow under rotational grazing to free acreage for switchgrass production. This strategy, in concept, is deemed appropriate for larger cow calf operations where sufficient cow and herd sire numbers as well as pasture acreage would allow rotational grazing on pasture acres, subdivided into paddocks, to be implemented (paddock size is not too small and the herd can be split into sufficient subsets to maintain a 25 cow to herd sire ratio). Computations for available pasture resources for supplying a bio-refinery are thus limited to pasture acreage grazed by larger beef cattle operations that, based on stocking density, would have 400 acres of pasture land available in the range of pasture acreage needed to support the number of cows on their operation (bottom rows of Table 1 provide the size distribution of cattle farms as well as their expected pasture acres). Further potential acreage is limited to those areas where current stocking density is less or cows are provided with greater than 3.1 acres per cow.

Materials and Methods

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

Lutes and Popp (2015) utilized FORCAP to model the economic risks, returns, and GHG emissions of a cow-calf farm in Washington County, AR that increased grazing efficiency and either added additional cows or converted 90 acres to switchgrass production as a means to mitigate drought risk over the course of 2004 to 2013. This farm consisted of 400 pasture acres on which 100 beef cows were initially, continuously grazed. The hypothesis of that research was to determine whether a producer could decrease their risk of negative net returns as a result of additional hay feeding requirements in drought affected years, by changing from continuous grazing to rotational grazing and converting 90 pasture acres to switchgrass production (Table 2). The risk and returns in constant 2014 dollars from this model were compared to the alternative of utilizing the increase in grazing efficiency to add 13 cows to the herd (Table 3). The number of acres converted to switchgrass, or the number of cows added for either of the scenarios was chosen on the basis of similar amount of hay feeding in a normal weather year. Producer income variability resulted from annual weather effects on hay yield and thereby pasture productivity as well as the need to purchase needed hay or sell excess hay as produced on farm on 125 acres of hay land. Pasture forage growth was modeled to deviate annually from average, long-term yields in a similar fashion as predicted state hay yields that were regressed against the percent area of drought to capture variation in forage growth due to extreme weather. Along with varying cattle, hay, fuel and fertilizer prices in constant 2014 dollars, Tables 2 and 3 show selected key performance statistics for the cattle and hay operations as modeled. More detailed cost and price information as well as details regarding the modeling of pasture performance is available in Lutes and Popp (2015).

Switchgrass yields, costs, returns, and net GHG emissions

Using ALMANAC (Kiniry et al., 1996), a biophysical crop model for switchgrass and other grass species, a ten-year yield history of switchgrass was developed using latest model modifications as reported by Rocateli (2014). The simulation included stand establishment in 2003, and reflected soil parameters from a research plot in Fayetteville, AR, that consisted of

Captina silt loam, which to a depth of 55 cm, is classified as 31% sandy, 32% loamy and 37% clayey. Daily weather data for the agricultural research experiment station were used from 2003 to 2013. Annual ALMANAC switchgrass yields averaged 7.85 tons per acre and were adjusted to an average yield of 5.01 tons/acre as reported by Cahill et al. (2014) to reflect experimentally observed average performance that was not linked to a particular stand establishment year and also included an experimental site on a more rocky soil considered reflective of marginal land in the study region. Hence the ratio of annual yields to the 2004 – 2013 average, as modeled by ALMANAC, was used to create a time series of yields with an average of 5.01 tons per acre as reported by Cahill et al. (2014). Along with this yield history, annual fertilizer applications and an equipment complement, similar to what a cattle operation would have for hay production, were used as inputs to model producer returns using the Energy Crop Analysis and Planning (ENCAP) decision support software (Lindsay et al., 2015). A summary of key performance statistics and annual net returns for 2004 to 2013 is reported in Table 4.

Annual GHG emissions were based on use of fuel, fertilizer, chemicals and twine. Both direct and indirect fertilizer emissions from fertilizer applications are included using GHG parameters for inputs as reported by Lal (2004). Carbon sequestration in the soil was estimated as a function of yield and soil texture effects using a procedure as reported in Popp et al. (2011). In essence, switchgrass yield is converted to carbon content of biomass in contact with soil that remains after carbon fluxes between the soil and the atmosphere are accounted for. Hence i) an average shoot to root ratio of 2.05 (*SR*) (Ma et al., 2000; Lee et al., 2007) is used to calculated the amount of root biomass as a function of above ground harvestable yield and ii) 42% carbon content (*CC*) in above and below ground biomass (Lemus et al., 2002; Girouard et el., 1999; Frank et al., 2004) is used to arrive at the amount of carbon in the biomass on a dry weight basis.

This amount of carbon is adjusted for potential soil sequestration by assuming that 1% (α) of above ground harvestable biomass comes in contact with soil due to equipment traffic and that only 1/3 of root biomass decomposes each year given switchgrass' perennial growth habit (West, 2015) with the remainder of the root system performing nutrient exchange functions throughout the year. Finally, this adjusted amount of carbon provides the base estimate of potential carbon sequestration for clayey soils that are undisturbed. With greater soil porosity, air flow and faster wetting and drying cycles in sandy and loamy soils compared to clayey soils, greater gas exchange requires that the base line of 50% (β) of carbon exchanged with the atmosphere in undisturbed clayey soils is further adjusted downward 30% (γ) for loamy soils and 60% (δ) for sandy soils or an average of 28% (ε) given the Captina silt loam soil described above (Popp et al., 2011). On average, 1,033.3 lbs/acre CO_2 equivalent are estimated to be sequestered in the soil using the following equation:

$$(1) \qquad SSCO_2 = Y_s \cdot 2{,}160 \cdot CC \cdot \beta(\alpha + {}^{\frac{1}{SR}}\!/_{3})(1-\varepsilon) \cdot 44/12$$

where $SSCO_2$ is the annual soil CO_2 equivalent sequestered in lbs/acre, Y_s is the harvested yield in dry ton/acre, 2,160 converts the harvested yield to pounds of standing biomass adjusting for 8% extra weight due to harvest processing losses, and 44/12 stoichiometrically converts carbon to CO_2.

GHG emissions fluctuate as a result of more or less fuel needed to harvest higher or lower yielding switchgrass stands, respectively. Subtracting emissions from sequestration led to net CO_2 equivalent annual average sequestration of 226.4 lbs/acre over the study period and ranged from a low of 14 lbs of CO_2 equivalent emitted in a low yielding year to 409 lbs of CO_2 sequestered in the highest yielding year (Table 4).

Agriculture Policy – BCAP and Carbon Offset

BCAP, a Farm Service Agency program designed to support and enhance producer biomass production in approved areas around planned or existing biomass conversion facilities, subsidizes establishment costs and provides two years of matching payments for eligible biomass delivered to a qualified biomass conversion facility (QBCF) for approved herbaceous perennial biomass producers. Establishment subsidies pay producers half of their actual establishment costs not to exceed $500 per acre, or $750 per acre for socially disadvantaged farmers (USDA, 2015). The matching payment portion of BCAP matches QBCF payments dollar for dollar for eligible, delivered material. Matching payments are limited to two years and are up to $20 per dry ton of biomass delivered to and purchased by a QBCF. Thus, the following equations account for total BCAP payments made to the producer in the first two years:

(2) $$BCAP_1 = .5EC + Y_{S,1} \cdot HS_1$$

(3) $$BCAP_2 = Y_{S,2} \cdot HS_2$$

where $BCAP_1$ is the payment received in year one and is comprised of 50% of establishment costs (*EC*) or $401.97/acre as modeled in ENCAP in this study, plus the annual harvest subsidy (*HS*) of $20 per ton times the switchgrass yield for first and second year deliveries as presented in Table 4.

Carbon offset payments (*CO*) occur annually and are a function of carbon price (*CP*), reported in dollars per ton, and the annual reduction of CO_2 equivalent emission (RC_t), in tons relative to a baseline level of emissions (BC_t) for any of the t years between 2003 and 2014. The baseline is chosen on the basis of maximum overall producer net returns over the course of those ten years without policy intervention. Net GHG emission reductions compared to the baseline are thus rewarded with added income from *CO* payments for reductions in net GHG emissions whereas production alternatives with higher net GHG emissions are charged a *CO* penalty to allow greater net GHG emissions than the baseline.

Comparing Outcomes

To compare outcomes of competing production practices and agricultural policies over the course of ten years, producer farm level net returns to management and land from cow-calf and potential switchgrass production activities were summarized using net future values (*NFV*) of annual farm net returns in constant 2014 dollars using a real, risk-adjusted 6% compounding rate as is within the range of 3 to 10% reported conventional for agricultural enterprises (Hardie, 1984). The discount rate accounts for differences in the timing of net returns that could vary substantially depending on the following available choice set of production practices:

- CONTINOUS 100 – using continuous grazing on 400 pasture acres with 100 cows and no switchgrass
- ROTATE 113 – using rotational grazing on 400 pasture acres with 113 cows and no switchgrass
- SWITCHGRASS 100 – using rotational grazing on 310 pasture acres with 100 cows and 90 acres of switchgrass
- BCAP 100 – same as switchgrass 100 but with the BCAP subsidy
- CO 100 – same as switchgrass 100 but with the CO program
- BCAP & CO 100 – same as switchgrass 100 but with BCAP subsidy and the CO program

Using the production alternative with the greater *NFV* among the CONTINOUS 100 and the ROTATE 113 options as the baseline, CO program payments could be calculated. Further, a contractually set switchgrass price of $40 per dry ton and a CO_2 equivalent price of $40 per ton was assumed. The switchgrass price level was chosen to provide low-cost feedstock to bio-refineries struggling to potentially compete with fossil fuel prices. The carbon price reflects a mid-range estimate of policy prices hypothesized in other studies (Nalley et al., 2011). Policy comparisons between the BCAP 100, CO 100 and BCAP & CO 100 and the baseline over the simulated ten year production horizon were then performed in terms of i) farm income as measured by *NFV*; ii) environmental impact as measured by net GHG footprint; iii) income risk as measured by the coefficient of variation in annual net returns as calculated in inflation adjusted 2014 dollars; and iv) supply of switchgrass feedstock over the four county production region.

Aggregating farm level outcomes to the production region

To determine the potential biomass supply for a hypothetical bio-refinery, situated in the center of the proposed four-county study region (Figure 1), data was extrapolated from the single model farm in Washington County (for details see: Lutes & Popp, 2015) to the aggregate available pastureland in each of the four counties. Available pasture, as reported in the 2012 Census, was calculated for farm sizes reporting use of 400 acres of pasture in their herd size category (Table 1). Multiplying cow numbers from eligible farm size categories by the 2012 reported stocking density, expressed in acres per cow, allowed estimation of freed acreage for switchgrass production by using the higher stocking density (or fewer acres per cow) as modeled in FORCAP. For example, the farms in the 100 – 199 cow herd size category in Washington county at 3.5 acres per cow would use 39,375 acres of pasture when applying the average of the range of cow numbers and # of farms (3.5 acre per cow * 150 average cows per farm * 75 farms = 39,375 acres of pasture). At the proposed higher stocking density using only 3.1 acres per cow, 0.4 acres per cow are freed for switchgrass production resulting in 4,500 acres for switchgrass production for that farm size category in Washington County. Using this method, total estimated available pasture acres exceeded the Census reported numbers as the farm sizes for individual farms in a size category were not known. Hence the estimates were adjusted downward, by the same amount in each size category, until estimated pasture acreage at reported stocking densities, equaled reported pastureland for the county. Using this procedure, only grazing efficiency gains on pasture land currently stocking at a lower than the proposed intensive grazing rate are included as only three of the four counties could improve their grazing efficiency to free land. Madison County is the exception. Their stocking density, at 3 acres per cow, is already higher than the pasture use of 3.1 acres per cow modeled in the FORCAP scenarios; thus, that county would likely benefit from an individual analysis as their current production practices are likely different than those modeled and described in Lutes and Popp (2015).

Available biomass from switchgrass production was ultimately determined by multiplying the total freed acres in each county by switchgrass yields. County level switchgrass production was tallied to determine both annual and daily bio-refinery supply along with total annual carbon sequestration from the switchgrass production across the four counties. Since beef production was held constant across policy alternatives, its emission levels only affected the baseline scenario.

Results

The first three scenario columns in Table 5 for CONTINUOUS 100, ROTATE 113 and ROTATE 100, report the cow-calf and haying farm level income, income risk and GHG emissions related to the cattle enterprise only. The ROTATE 113 option, having the highest *NFV* was chosen as the baseline to calculate CO payments and for comparison to a farm operation with switchgrass or the ROTATE 100 operation with 90 acres of added switchgrass. The remaining four columns show the impact under varying levels of government support: i) no policy or a free market environment (SWITCHGRASS 100); ii) with the BCAP program (BCAP 100); iii) with CO payments (CO 100); and iv) with BCAP & CO and 100 cows. All operations are supplied by 125 acres of hay intended to feed the cattle with excess sold to the market in high hay yield years and extra feed purchased from the market place to meet feed requirements when droughty conditions lead to yield shortfalls and added demand for supplemental feed.

Table 5 shows total farm net GHG emissions to be highest with the baseline operation as more cattle are on the operation when compared to the Cont. 100 or Rot. 100 alternatives. A comparison of the Cont. 100 to the Rot. 100 scenarios in Table 5 reveals a marginal improvement in 10 year net GHG emissions as a result of changes in grazing efficiency associated with switching from continuous to rotational grazing. Adding switchgrass to the operation further reduces net GHG emissions. However, these net GHG emission changes are small in comparison to the net GHG emission changes associated with changes in the number of cows on the operation.

A comparison of income effects proved switchgrass to only marginally add to *NFV* when switchgrass yields were modeled at low yields. The low yield scenario is a situation where switchgrass yields were high enough such that BCAP and CO payments were large enough to make the *NFV* of the BCAP & CO 100 scenario equal to the baseline with the higher cattle stocking rate. At the opposite end of the switchgrass yield spectrum is a situation where switchgrass yields are sufficiently high to yield *NFV* without BCAP or CO payments that were similar to the baseline. At that higher level of switchgrass yield, environmental benefits associated with the adoption of switchgrass were also greatest as net GHG sequestration was largest. This range of yield levels are likely attainable with producers selecting either marginal or more productive pasture land as the area where they would plan to grow switchgrass. If producers, interested in maximizing profitability, be that from cattle and switchgrass production, or from BCAP and CO payments, or both, selected better quality pasture land for switchgrass production. Using high quality land for switchgrass with attendant yield benefits also led to maximum environmental benefits. Significantly more feedstock for alternative energy production would become available and income risk would be reduced as the lowest coefficient of variation observations occurred when yield expectations were highest. Nonetheless, producers may also choose to grow switchgrass on their poorest quality land in hopes of maintaining upward production potential for their cattle operation and thereby lower switchgrass yields would lower environmental benefits. Risk, as measured by CV, is only reduced compared to the baseline if higher quality pasture ground is chosen and would lead to the higher end of yield expectations.

Table 6 summarizes this latter effect of choosing low to high yielding pasture land for switchgrass production. Total switchgrass production across the three county study region could vary significantly depending on the type of land chosen for switchgrass production. Table 7 reveals the level of daily switchgrass supply once split over a 360 day processing period for a hypothetical plant located in the three county region. Annual net GHG sequestration benefits range from 1,724 tons of net GHG emissions reductions as modeled to the farm gate for cow-calf operations to 8,971 tons depending on the switchgrass yields attained. The total daily supply is less than the 2,000 ton per day plant size often espoused as the economically viable bio-refinery size (Epplin & Haque, 2012).

Discussion

Cow-calf producers currently supply feeder calves to the beef market. While these producers have management options that can lower their GHG emissions, the change from continuous to rotational grazing with the same number of cows does not generate a substantial change in whole farm emissions (Table 5). As such, cow-calf producers who seek to lower their GHG emissions, beyond the potential reductions from altering cattle management practices, may consider incorporating a farm practice that sequesters carbon. Switchgrass, grown as a lignocellulosic energy crop, is a potential, environmentally-friendly alternative for cow-calf producers to consider in addition to their cattle. This study shows the potential of increasing cow-calf producer returns and decreasing income risk without decreasing beef output by altering current management practices and incorporating switchgrass production on the farm. However, switchgrass yield and farm-gate price as affected by BCAP subsidies and CO payments would all influence producer adoption decisions. These results suggest that cow-calf producers in northwest Arkansas would benefit from some type of planned adaptation (McCarl, 2015) to mitigate their role in climate change. This planned adaptation could be in the form of subsidies, CO payments, or research that discovers higher yielding switchgrass varieties that do well in a range of soil and climate types. Gonzalez-Ramirez, Kling and Valcu (2012) indicate that research and private adoption is preferred to avoid a net social welfare loss. However, it seems unlikely, given the results within, that cow-calf producers will participate in private adaptations (McCarl, 2015) without an external catalyst that either rewards lower carbon emissions, or punishes current high carbon emissions unless they operated on pastures where switchgrass yield potential was high.

The potential benefits of incorporating switchgrass production include decreasing whole farm and per acre net GHG emissions. Cattle emissions from beef were lowest with the option where stocking density was increased, leading to added grazing efficiency and thereby reduced GHG emissions per pound of beef sold. Without a BCAP and CO program, producers would only pursue switchgrass if planted on highest yielding pasture ground with attendant consequences of minor income risk reduction. With BCAP and CO programs, environmental benefits and income risk reduction were attainable while also creating significant three county switchgrass supply totals without affecting food production.

This research has potential limitations. A single operation type of a particular size was used to aggregate to a larger production region where significant variation in farm conditions might lead to significantly different operating methods and thereby aggregation results. Also, the modeling of pasture yield variation due to weather suffered from a lack of available information about spatially varying stocking rates, land quality and operation size information. Nonetheless, the sensitivity analysis on potential switchgrass yield showed a range of possible results that may result if a QBCF decided to locate in Northwest Arkansas with the sole purpose of converting switchgrass sourced from cow-calf operations that decided to convert pasture to an alternative use to reduce their income risk and capture potentially available BCAP subsidies or CO payments in lieu of increasing their cattle stocking rate. Additional sources of feedstock for bio-refineries may be excess hay production or other lignocellulosic feedstock sources like municipal yard waste and/or forestry residue. It is also possible, that smaller or even large scale cattle operations may abandon cattle production to adopt switchgrass production should beef demand deteriorate and cattle prices decline. By the same token fuel prices could increase or remain at currently low levels either promoting or continuing to slow biofuel investment. This would undoubtedly alter the results of this study. Recommendations for further research would include a more detailed analysis of the four county's biomass potential that would attempt to address in more detail the previously mentioned limitations.

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Figure 1. BCAP approved project areas in Arkansas, Kansas, Missouri and Oklahoma and Proposed Study Region.

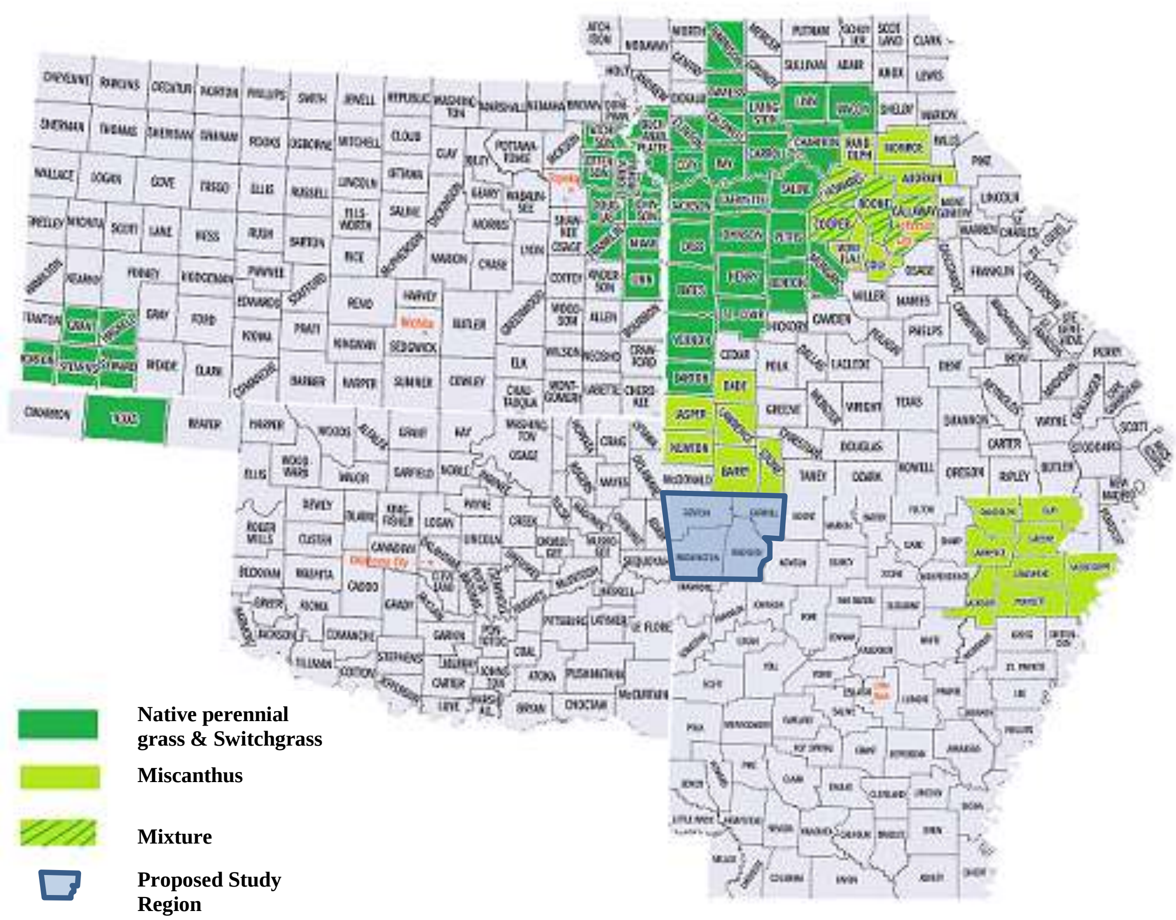

Table 1. Selected demographics and farm size distribution of agricultural producers in four northwest Arkansas counties, 2012.

	units	**Benton**	**Carroll**	**Madison**	**Washington**
Total Agriculture Sales	$1,000's	$ 529,128	$ 307,006	$ 208,163	$ 443,025
Poultry Sales	% of total Ag sales	86.5%	85.9%	86.8%	88.4%
Cattle Sales		10.8%	13.0%	10.6%	9.0%
Harvested Crop Sales		1.0%	0.6%	0.3%	1.6%
Farm Land	% of total land	56.2%	63.6%	50.5%	51.7%
Pasture Land	% of farm land	57.4%	66.7%	36.6%	52.7%
Farms w/ Beef Cows	total	1,409	751	848	1,506
Cattle & Calves Sold	$1,000's	$ 57,152	$ 40,021	$ 21,995	$ 39,888
Revenue / Cow	average	$ 819	$ 791	$ 703	$ 818
Use of Intensive Grazing Practices	% of farms	30%	29%	36%	31%
Cow Stocking Density	acres/ cow	3.2	4.5	3.0	3.5
		# of farms (min. – max. acres based on stocking density and range of cows)			
Farm Size Distribution by herd size in cows (2012)	1-9	410 (3 – 29)	131 (4 – 40)	191 (3 – 27)	454 (4 – 32)
	10-19	302 (32 – 61)	136 (45 – 85)	155 (30 – 57)	331 (35 – 67)
	20-49	424 (64 – 157)	238 (90 – 220)	303 (60 – 146)	459 (71 – 173)
	50-99	150 (160 – 317)	165 (225 – 445)	130 (149 – 296)	163 (176 – 349)
	100-199	85 (320 – 636)	56 (450 – 895)	52 (299 – 594)	75 (353 – 702)
	200-499	23 (640 – 1,596)	21 (899 – 2,243)	17 (597 – 1,491)	24 (706 – 1,761)
	500-1000	15 (1,599 – 3,198)	4 (2,248 – 4,495)	-	-

Source: (USDA Census, 2014).

Table 2. Selected annual FORCAP performance statistics for rotationally grazing 100 cows on 310 pasture acres with 54,477 lbs of beef sold annually at prevailing cattle, hay, fertilizer and fuel prices, 2004 – 2013.

	Units	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Pasture Forage Growth	lbs/ acre	3,652	2,878	2,692	3,497	3,621	3,652	2,754	2,754	1,950	3,466
Hay Forage Growth	lbs/ acre	7,148	5,633	5,270	6,845	7,087	7,148	5,391	5,391	3,816	6,784
Grazing Efficiency[a]	%	53%	57%	58%	54%	53%	53%	57%	57%	60%	55%
Days on Feed		161	192	201	165	161	161	198	198	242	166
Hay Sold/(Bought)	# 800 bales	46	(315)	(409)	(15)	35	46	(378)	(378)	(791)	(29)
Gross Income	$/farm	$86,387	$86,420	$86,589	$81,297	$79,990	$82,555	$82,187	$82,046	$87,204	$85,272
Cash Returns	$/farm	$46,151	$27,815	$16,764	$40,242	$39,986	$42,461	$24,202	$23,887	$3,928	$43,555
Net Returns[b]	$/farm	$23,867	$5,531	($5,521)	$17,958	$17,701	$20,177	$1,917	$1,603	($18,356)	$21,271
	$/cow	$239	$55	($55)	$180	$177	$202	$19	$16	($184)	$213
	$/acre	$55	$13	($13)	$41	$41	$46	$4	$4	($42)	$49
Total GHG	tons	460	484	489	465	461	460	487	487	512	466
GHG / acre	lbs	2,134	2,224	2,249	2,134	2,121	2,117	2,134	2,241	2,352	2,134
GHG / lb[c]	lbs	16.94	17.76	17.96	16.94	16.94	16.90	16.94	17.89	18.78	16.94

Notes:

[a] Grazing efficiency is the percent of pasture forage growth consumed by grazing animals as opposed to being trampled or otherwise not eaten.

[b] Net returns are returns to management and labor and are defined in FORCAP as cattle and excess hay revenues less operating costs of purchased feed, salt, minerals, fuel, twine, operating interest, veterinary and medicine, marketing charges, repair & maintenance, and ownership charges on buildings, equipment and breeding stock. Cash Returns exclude ownership charges. Gross Income is the revenue associated with cull animal, weaned calf and excess hay sales. $/cow and $/acre are returns to management and labor per farm divided by the number of cows in the herd and the number of pasture and hay acres, respectively.

[c] GHG, measured in CO_2 eq., per pound of beef sold is on a live weight basis and includes weaned calves and cull animals sold.

Table 3. Selected annual FORCAP performance statistics for rotationally grazing 113 cows on 400 pasture acres with 62,524 lbs of beef sold annually at prevailing cattle, hay, fertilizer and fuel prices, 2004 – 2013.

	Unit	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Pasture Forage Growth	lbs/ acre	3,652	2,878	2,692	3,497	3,621	3,652	2,754	2,754	1,950	3,466
Hay Forage Growth	lbs/ acre	7,148	5,633	5,270	6,845	7,087	7,148	5,391	5,391	3,816	6,784
Grazing Efficiency[a]	%	49%	56%	56%	51%	50%	49%	56%	56%	60%	51%
Days on Feed		149	174	184	153	150	149	181	181	225	154
Hay Sold/(Bought)	# 800 bales	123	(310)	(420)	10	104	123	(384)	(384)	(859)	(7)
Gross Income	$/farm	$101,793	$99,444	$99,639	$94,108	$94,657	$97,526	$94,528	$94,356	$100,293	$98,082
Cash Returns	$/farm	$56,340	$36,024	$23,900	$48,875	$49,477	$52,238	$31,169	$30,822	$8,197	$52,333
Net Returns[b]	$/farm	$32,672	$12,355	$231	$25,207	$25,809	$28,569	$7,501	$7,153	($15,472)	$28,664
	$/cow	$289	$109	$2	$223	$228	$253	$66	$63	($137)	$254
	$/acre	$62	$24	$0	$48	$49	$54	$14	$14	($29)	$55
Total GHG	tons	510	537	543	515	511	510	541	541	569	516
GHG / Acre	lbs	2,134	2,045	2,070	2,134	1,947	1,943	2,134	2,062	2,169	2,134
GHG / lb[c]	lbs	16.94	17.17	17.38	16.94	16.35	16.32	16.94	17.31	18.21	16.94

Notes:

[a] Grazing efficiency is the percent of pasture forage growth consumed by grazing animals as opposed to being trampled or otherwise not eaten.

[b] Net returns are returns to management and labor and are defined in FORCAP as cattle and excess hay revenues less operating costs of purchased feed, salt, minerals, fuel, twine, operating interest, veterinary & medicine, marketing charges, repair & maintenance, and ownership charges on buildings, equipment and breeding stock. Cash Returns exclude ownership charges. Gross Income is the revenue associated with cull animal, weaned calf and excess hay sales. $/cow and $/acre are returns to management and labor per farm divided by the number of cows in the herd and the number of pasture and hay acres, respectively.

[c] GHG, measured in CO_2 eq., per pound of beef sold is on a live weight basis and includes weaned calves and cull animals sold.

Table 4. Yield, harvest cost, Net Returns and GHG Impact of 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**
Yield in 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	$55.18	$56.57	$54.49	$48.94	$50.50	$49.63	$52.93	$45.12	$56.40	$58.73
Net Returns[a] in $/farm	$6,923	$7,090	$4,670	$940	$3,338	-$2,376	$2,330	-$1,727	$3,336	$4,762
GHG emissions (CO_2 eq. lb/acre)	813	817	811	797	801	799	807	787	816	822
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)	299	342	278	105	153	126	229	-14	337	409
NFV_S [b]	$29,287		Standard Deviation [c]		$2,224		Average and Standard Deviation of tons of GHG Sequestered [d]		10.2	(5.9)

Notes:

[a] Net returns to management and land include fertilizer and chemical, application and yield dependent harvest costs at time-varying prices excluding labor charges on the 90 acres of pasture modeled.

[b] Net future value is the sum of annual net returns compounded to 2014 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 5. Summary of 2003 to 2014 GHG and income results of a 400 pasture and 125 hay acre model farm potentially substituting 90 acres of pasture with switchgrass at low (4.34 ton/acre), medium (5.01 ton/acre) and high (6.55 ton/acre) yields in Northwest Arkansas.

	Cattle Only[a]				**100 Cows & Switchgrass**[b]			
	Cont. 100	**Rot. 113**	**Rot. 100**	**Switch-grass Yield**	**Switch-grass 100**	**BCAP 100**	**CO 100**	**BCAP & CO 100**
Total 10 Year Farm GHG Emissions in tons	4,797	5,295	4,773	Low Med. High	4,728 4,671 4,539			
Switchgrass 10 Year Farm Net GHG Sequestration in tons	-	-	-	Low Med. High	45 102 234			
NFV[c] (thousands of 2014 $/farm)	72	223	129	Low Med. High	130 158 223	192 225 301	161 193 266	223 260 343
% change in NFV compared to Baseline	-68	Base-line	-29	Low Med. High	-42 -29 same	-14 1 35	-28 -14 19	same 16 54
Total BCAP Dollars (thousands of 2014 $/farm)	-	-	-	Low Med. High	-	35 38 44	-	35 38 44
Total CO Credits (thousands of 2014 $/farm)	na	Base-line	na	Low Med. High	-	-	23 25 30	
CV[d]	2.65	1.02	1.61	Low Med. High	1.62 1.31 .91	1.57 1.35 1.04	1.27 1.05 0.76	1.32 1.15 0.90
Avg. annual GHG Emissions (lbs/acre)[e]	1,827	2,017	1,818	Low Med. High	1,801 1,779 1,729			
Avg. Switchgrass Net GHG Seq. (lbs/ton)[f]	-	-	-	Low Med. High	23 45 79			
Avg. GHG Emissions per lb of beef produced[g]	17.6	16.9	17.5					

Notes:

[a] Cattle production occurred on 400 acres of pasture either continuously grazed with 100 cows (Cont. 100) or rotationally grazed at a higher stocking rate (Rot. 113). The last option, Rot. 100 occurs on 310 acres of pasture with 90 acres diverted to switchgrass. The Cattle Only column reflects cattle emissions and income only and includes hay production on 125 acres. Rot. 113 with highest overall income serves as the baseline for determination of carbon offset credits using the concept of additionality.

[b] This column reflects GHG emissions and income when switchgrass is added to 100 cows rotationally grazing on 310 acres of pasture with continued hay production on 125 acres. The policy scenarios are i) Switchgrass 100 without government program intervention; ii) BCAP 100 with BCAP subsidies; iii) CO 100 with carbon offset credits paid to producers for reductions of GHG emissions compared to the Rot. 113 baseline; and iv) BCAP & CO 100 with subsidies and carbon offset credits. The farms growing switchgrass are evaluated at three yield levels: i) low, where BCAP & CO 100 subsidies and credits allow for that scenario to return the same NFV as the baseline using a carbon offset price of $40 per ton of CO_2 equivalent net emissions avoided and $40 per dry ton of switchgrass staged at the side of the farmer's field; ii) medium, representing current estimates of switchgrass yields as based on local experimental trials on marginal soils; and iii) high, where NFV with no government intervention is the same as the baseline NFV.

[c] Net future value of annual returns to management and land, compounded to 2014 at 6%.

[d] The coefficient of variation is the ratio of the standard deviation of annual returns to management and land to the average annual returns to management and land from 2003 to 2014. Returns were reported in inflation adjusted 2014 dollars as in Tables 2 to 4.

[e] Average annual net emissions divided by the total of 525 acres of land used for cattle, hay and switchgrass production depending on scenario.

[f] Average, annual net GHG sequestration per ton of switchgrass. While harvest emissions and sequestration are relatively constant per ton, the emissions per acre for chemical and fertilizer applications are spread over different yield levels.

[g] Average cattle GHG emissions per pound of beef produced in terms of live weight of cull animals and weaned calves sold each year. Changes in emission levels mainly reflect modifications in grazing efficiency due to stocking rate differences.

Table 6. Potential annual switchgrass biomass supply in dry tons by farm size category and county from pastureland freed on cow-calf farms in three northwest Arkansas counties at three switchgrass yield levels.

# of cows on farm	# of Farms[a] per Size Category	SG Acres / Avg. Size Farm[b]	Annual Supply of Switchgrass (SG) at different yield levels		
			Low[c]	Med.	High
	Benton County (orig.				
50-99	-	-	-	-	-
100-199	59	15	3,197	3,691	4,826
200-499	16	34	2,023	2,335	3,053
>500	10	73	2,831	3,268	4,272
Benton County Total in tons			8,051	9,293	12,150
50-99	116	104	47,764	55,138	72,087
100-199	40	209	32,531	37,553	49,096
200-499	15	488	28,519	32,921	43,041
>500	3	1,047	11,657	13,456	17,593
Carroll County Total in tons			120,470	139,068	181,816
50-99	-	-	-	-	-
100-199	52	64	12,239	14,128	18,471
200-499	16	150	9,156	10,569	13,818
>500	-	-	-	-	-
Washington County Total in tons			21,395	24,698	32,289

Notes:

[a] Farm size categories included from Table 1 are those with pasture acreage ranges including 400 acres. Even though herd size categories are the same across counties, the reported stocking rates in acres per cow resulted in no farms from the smaller cow herd sizes in Benton and Washington County as stocking densities were higher than in Carroll County.

[b] Total number of acres per farm size category per average size farm freed for switchgrass production. Calculated as the difference between estimated current farm pasture acres [based on average county stocking density (Table 1)] and pasture acres required with the 3.1 acre per cow stocking density estimated by FORCAP. Numbers are adjusted further to reflect farm size distribution errors as discussed in the text.

[c] Low, medium and high yields for switchgrass were 4.34, 5.01 and 6.55 dry tons/acre as explained in footnote b to Table 5.

Table 7. Total potential switchgrass supply and carbon sequestration at three different yield levels from all three counties (Benton, Carroll, and Washington)

		Switchgrass		
		Low	**Medium**	**High**
Switchgrass Yield	tons/acre	4.34	5.01	6.55
Total Switchgrass Supply[a]	tons/year	149,916	173,059	226,255
Daily supply[b]	tons/day	416	481	628
Net GHG Sequestration Rate[c]	lbs/ton of switchgrass	23	45	79
Total Carbon Sequestration[d]	tons/year	1,719	3,923	8,986

Notes:
[a] The sum total of switchgrass available from all three counties listed in Table 6.
[b] Total switchgrass supply divided by 360 plant working days.
[c] The rate of net GHG sequestration from switchgrass production.
[d] The annual amount of net GHG sequestration due to switchgrass production.

Chapter IV

IV. Conclusions

Summary

Cattle enterprises continuously face pressure from multiple internal and external forces. Meeting as many objectives as possible, management practices must be altered in such a way that the financial viability of the enterprise is maintained. Rising input costs, increasing efficiencies, and managing risk are major internal forces that producers have to balance in order to remain in business. However, the external forces of resource scarcity, increased environmental concerns, and extreme weather due to climate change must also be balanced. Cattle producers must look beyond simply improving beef efficiencies if they are to meet the demand for sustainable beef production. To be a sustainable enterprise, they must improve productivity, efficiency, their environmental impact, and quality of life simultaneously (National Academy of Science, 2010).

The two preceding articles aim to determine if increasing cattle grazing efficiency and incorporating switchgrass production on a cow-calf farm can i) improve the producers' financial returns and reduce their income risk; ii) provide a reliable source of lignocellulosic material for biofuel plants; and iii) decrease the farm's carbon equivalent emissions. The articles also provide insight to the switchgrass price and yield at which producers would benefit from the inclusion of switchgrass production and incorporates BCAP and CO payments into the analysis.

It is determined that switchgrass production, combined with the cow-calf operation, could provide benefits to producers, without lowering their beef output, by increasing financial returns, reducing their income risk, and decreasing the GHG emissions from the farm. However, these benefits are heavily dependent on switchgrass yield and the farm-gate price producers receive. A sensitivity analysis reveals that as BCAP and or CO payments increase/decrease producers would require a lower/higher yield to breakeven with the alternate scenario of increasing cow numbers. However, carbon sequestration decreases/increases as required yield decreases/increases. As such, research devoted to increasing average switchgrass yield in a variety of climate types and soil profiles would not only benefit biofuels plants and growers but also the environment; perhaps to a greater extent than BCAP and a CO program.

Limitations

This research is limited in scope and scale due to studying only one farm size and operation type in a single region. Varying either or both operation size and region could have considerable impacts on available haying equipment along with average switchgrass yield. Variations in regional climates, soil profiles, switchgrass variety, and cattle breeds all influence the results described within. For instance, a change in location from northwest Arkansas to southwest Arkansas would undoubtedly alter forage mix and soil profile along with annual rainfall and average temperatures. This would ultimately change average switchgrass and forage yield which would alter producer income, expense, and GHG emissions. The state average annual hay yield, utilized to determine annual changes in forage availability due to drought, likely underestimates these changes and local drought and hay yield would offer more accurate estimates. Efforts to use biophysical simulation for estimating weather effects on grazing performance using GRAZE were unsuccessful (Parsch and Loewer, 1995).

Further Research

The limitations of this research suggest future research options; modeling different farm sizes in the four-county region would provide insight to a minimal farm size requirement where these results hold true. This would afford the researcher the flexibility to model county specific management practices, forage composition and growth, along with climate and soil differences. Data availability on land quality and related farm size are a problem in this regard as farm ownership and location are private information. Nonetheless, case studies of farm operations would provide insights for policy makers in conjunction with biophysical simulation similar to what the GRAZE model were updated to run with current computer operating systems.

Further, this research studied switchgrass solely as a bioenergy crop; however, switchgrass also serves as a plausible forage crop. As such, research could be expanded to study the tradeoffs between producer returns, available biomass, and GHG emissions of grazing the switchgrass in early summer followed by harvesting as an energy crop in late fall. Rogers et al. (2014) studied grazing switchgrass combined with harvesting as a bioenergy crop. However, they did not have a GHG emissions component in their study to holistically determine economic and environmental tradeoffs.

Chapter three suggests that switchgrass could potentially be planted on lower quality land as BCAP subsidies and a CO program would allow adoption at lower average yields, and thus lower carbon sequestration. This would be an unintended consequence. To fully understand these implications, however, more than one producer must be analyzed. The aggregation of BCAP and CO programs across a variety of farms and varying environmental conditions across space promises to be a difficult task.

Ultimately, for producers to be interested in growing switchgrass as a bioenergy crop, there must be a market for it. Bio-energy companies may find it easier to source switchgrass from dual-purpose production settings such as cattle farms than from cropland. Providing multiyear contracts instill producer peace of mind knowing they have a guaranteed market for their switchgrass and offer bio-refineries reassurance that they would have a steady source of biomass. This research chose to incorporate switchgrass in such a way that it did not compete with current food production and as such did not account for the possibility that some farms may choose to convert their entire operation to switchgrass production depending on price, yield, income risk, and time allocation requirements. However, this complete conversion may be a real possibility.

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This memorandum is to certify that Jennifer L. Lutes has performed at least 51% of the work associated with work entitled "Modifying a Cow-Calf Biophysical Simulation Model for Analyses of Alternative Enterprises". Should you have any questions, please feel free to contact me at 479-575-6838 or mpopp@uark.edu.

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