THE IMPACT OF SWITCHGRASS PRODUCTION ON OKLAHOMA HAY MARKETS

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CHAPTER I

INTRODUCTION

Switchgrass (*Panicum virgatum*, **L.**) is a native grass species to much of the USA (Ferland, 2002). It is a warm season perennial that commonly grows in the native prairies of central North America (Boon and Groe, 1990).

Switchgrass production in Iowa diminished dramatically between 1930 and 1980 as all but 12,000 of the state's 12,000,000 hectares of prairies was plowed and subsequently planted to introduce species of crops (Smith 1981; Thompson 1992). The loss of switchgrass and the rest of the prairie flora occurred because few farmers or agronomists in Iowa perceived switchgrass, or any of the common prairie plants, as potentially valuable crops. Apart from the far western states, switchgrass occurs naturally throughout the contiguous USA (Moser and Vogel 1995). Switchgrass is an upright growing species capable of producing high dry matter, though it possesses rhizomes and is traditionally used as a forage and conservation crop (Ferland 2002).

Switchgrass is traditionally used as forage and conservation crop (Ferland 2002), and has been identified as a model plant for biomass production based on its productivity in various environments in the United States (Cushman and Turhollow 1991; Sanderson et al. 1996).

Dicks et al. (2008) reported that, to meet the mandate of the Renewable Fuel Standard in the Energy Independence and Security Act of 2007 requirement of 36 billion gallons of ethanol production in the year 2022, 24.7 million acres would be used to produce 109 million tons of switchgrass in 2025. Using only the 450 million acres of cropland currently available in the United States, the increased switchgrass acreage would reduce hay acres by 15.4 million, leading to a 13.1 million head reduction in beef cows.

The federal mandate, together with the comparative advantage and the potentials of switchgrass will switch most of the cropland used for hay to the production of switchgrass.

This research will determine the potential impact of switchgrass production on Oklahoma hay markets.

Background

Understanding the hay market is important because of the significance of hay to the economy of the agriculture sector. Information about acreage, yield, and price can help hay producers in anticipating the demand for their product, livestock producers in comprehending the supply of their major input, and policymakers in predicting the effects of proposed policies on the hay market. The emerging potential of switchgrass is a concern for hay markets because of the probability that farmers may use their land to produce switchgrass rather than hay if switchgrass is more profitable.

Because reliable information on hay market price response was not available for the study by Dicks et al, the predicted effect on beef cows came from a simplistic estimate that reduced beef cow numbers based solely on the tons of forage reduced. In that study, forage was reduced as land was shifted to switchgrass. Since each cow needs approximately 1,000 pounds of forage per month, replacing forage with switchgrass-for-ethanol would correspondingly reduce the number of cows that could be produced unless cow prices increase substantially. To fully understand the impacts of biofuel mandates on cattle markets a linkage between cattle numbers and hay prices needs to be established. Previous estimates of the effect of biofuel mandates on hay and livestock markets (such as those by Dicks et al. 2008) did not consider the price impacts on those markets because good information was not available. This research will provide more realistic estimates of those effects by more fully considering the price responsiveness of producers to competing alternatives for a limiting resource, land. Increased profitability of switchgrass production will bid resources (especially land) away from hay production.

Farmers aim to maximize returns and will look for alternative crops that will yield higher profits. The findings from this research will help hay and livestock producers and policymakers better anticipate changes in the market for hay in Oklahoma as switchgrass production increases.

Objectives

The overall objective of this thesis is to determine the potential impact of increased switchgrass production on Oklahoma hay markets.

Specific objectives are to**:**

1) determine the demand for hay in Oklahoma;
2) determine the impact of the level of hay production in surrounding states on Oklahoma hay price; and
3) determine the production options between hay and switchgrass in Oklahoma based on profitability.

CHAPTER II

LITERATURE REVIEW

This chapter provides a brief background on switchgrass and hay markets and their potential contributions to the economy of the agricultural sector. It reviews the limited studies related to switchgrass and hay markets.

Potentials of switchgrass production

In recent years switchgrass has shown great potential for use in the production of fuel ethanol from cellulosic biomass (Lynd et al. 1991). Research in Alabama demonstrated that very high dry matter yields can be achieved with switchgrass in the southern USA (Maposse et al. 1995). Farmers in this area can therefore produce switchgrass for either biomass or forage.

When combining its uses of forage, conservation, and biofuel production, farming systems based on switchgrass could become an economic boon for farmers interested in sustainable and profitable farming enterprises (Ferland 2002). Switchgrass has been identified as a model plant for biomass production based on its productivity in various environments in the United States (Cushman and Turhollow 1991; Sanderson et al. 1996).

An ideal biomass system would consist of one warm-season and one cool-season perennial grass, a legume, and an annual warm-season grass (Cushman and Turhollow, 1991). Despite such ecologically sound advice, virtually all work in the past decade has emphasized switchgrass alone (McLaughlin et al. 1997).

The commercialization of cellulosic-based ethanol (ethanol that comes from feedstocks such as switchgrass, corn stover, wheat straw, and wood products residues) could have an even greater impact on the agricultural industry (Epplin 1996). Potential conversion rate of 75 gallons or more from each ton of switchgrass coupled with expected switchgrass yields of 4-6 tons/acre have led to excitement over the future role of dedicated biofuel crops in the regions agriculture.

President George W. Bush mentioned switchgrass in both his 2006 and 2007 State of the Union speeches (Whitehouse 2007). He announced the ambitious “20 in 10” initiative that calls for reducing gasoline demand 20% in 10 years by producing 35 billion gallons of ethanol (which would replace roughly 15% of gasoline), and improving the Corporate Average Fuel Economy (CAFE) standards to reduce demand by 8.5 billion gallons of gasoline, or 5% of the current demand.

What will be the impact on other crops – including hay, and thus livestock production - of converting a greater part of Oklahoma farmland into switchgrass? Oklahoma biofuel production would exceed currently available feedstock, even when competing uses for livestock are ignored (Kenkel and Ragan, 2007). They note that, biofuel production could stimulate a substantial increase in feed grain production. This shift would have major impacts on the livestock industry since much of the production would come from land currently used for hay and pasture production shifting into feed grains (Kenkel and Ragan, 2007). Similarly, cellulosic ethanol technologies could greatly increase ethanol production, which would impact existing crop and forage production.

Policy issues

The Renewable Fuel Standard mandates in the Energy Independence and Security Act of 2007 (EISA 2007) will require 36 billion gallons of ethanol to be produced in 2022, 16 billion gallons of which is to be produced from cellulosic feedstocks. To meet this mandate, 24.7 million acres would be used to produce 109 million tons of switchgrass in 2025. Using only the 450 million acres of cropland currently available in the United States, the increased switchgrass acreage would reduce hay production by 15.4 million hay acres leading to a 13.1 million head reduction in beef cows (Dicks et al. 2008). The most emphasized crop for this purpose is switchgrass. Research sponsored by the Bioenergy Feedstock Development Program at the Oak Ridge National Laboratory evaluated more than 30 species of crops on research plots on a wide range of soil types in more than 30 sites across seven states (Wright 2007). Based on these trials, switchgrass was selected as a model species.

The wide support from Americans for expansion of the ethanol industry led to the expansion of the Renewable Fuels Standard (RFS) mandated in the Energy Independence and Security Act of 2007 (EISA 2007). This wide support was the result of the optimism associated with achieving energy independence and rural economic development (Herndon 2008), but was apparently enacted without critical assessments of the agricultural impacts of attempting to achieve them. In particular, reduced hay production will likely increase hay prices which could make hay less affordable to livestock farmers, with a secondary consequence of reduced livestock numbers.

Impacts of Switchgrass Production on Pasture Land, Cattle herd and Hay Price

The overwhelming majority of range and pasture acres are used to produce forage to feed roughly 100 million cattle and calves. A biofuel industry would bid resources from current use with possible negative impacts on some agricultural sectors. Dicks et al. (2008) found that the majority of the land required to meet the biofuel potential would be converted from land currently producing hay, cotton and wheat in the southeast. Converting this land to biofuel feedstock would negatively impact the cattle industry since hay production and marketing would be affected, and hay prices would rise. This research will determine the impact of switchgrass production on hay markets in Oklahoma.

What is hay?

Hay is one of the methods of preserving forage crops for use by livestock at a future date when feed is scarce. Legumes and grasses, including cereals, are the main hay crops. The crops meant for hay preparation are harvested just before flowering or at the early flowering stage when the crops are leafy, more nutritious, and less fibrous and have lower water content. There is also standing hay or in-field-hay which is conserved by allowing the crops to dry while standing in the field

Because grains are consumed by both humans and animals, reducing grain consumption by animals by using grain as a food supplement, with hay as the main food, reduces the total demand for grains and thus costs to the livestock producers. In many instances, livestock are able to access forage crops through pasture grazing. However, most forage crops are not available throughout the year, so preserving some of the forage as hay for use in the dormant season ensures animal feed security and help prevent over-reliance on grains.

Demand and supply for hay

Understanding interactions between supply and demand for hay is important because of hay's significance to the agricultural sector and the economy, and because hay is an important crop on highly erodible soils (Bazen et al. 2008).

Hay production in the U.S. was 145.67 million tons valued at $18.78 billion with an average price of $157 per ton (USDA National Agricultural Statistics Service 2008). Tennessee has the most erodible cultivated cropland in the United States (Denton, 2000), so hay is one of the most economically important crops produced in the state (U.S. Department of Agriculture, 2004). Cross (1999) observed that the upward trend in Tennessee hay acreage since 1980 is due to an increasing number of farmers who were searching for alternative production activities, such as hay, pasture and livestock, to replace row crops on erodible soils. Hay ranked tenth in value of receipts in Tennessee at $49.25 million in 2006 and cattle and calf production ranked first at $500 million. In 2003, hay ranked second in value of production at $262 million and averaged $248 million over a five year period from 2002 to 2006. Underscoring the importance of hay in Tennessee was the state's national ranking of fourth in the production of other hay (excluding alfalfa) at 4.25 million tons in 2006 (U.S. Department of Agriculture 2007).

Characteristics of hay markets must be understood in order to be able to quantify the demand and supply relationship for hay, since hay markets are usually localized due to the weight and bulky physical characteristics of hay (Basen et al. 2008).

Although hay is not a homogeneous commodity, in most livestock production situations, the various types of forages that are used to produce hay are close substitutes, with the exception of alfalfa hay. Alfalfa is a differentiated hay product used mostly by dairy and equine producers, but its price tends to move proportionally with other hay prices. Thus, for modeling purposes alfalfa and other hay can be aggregated as in Shumway's (1983) study of Texas field crops and treated as a composite commodity (Nicholson 2005) called hay. In 2002, 47,000 operations within Texas produced forage, while on the demand side, 50,000 operations were involved in beef and dairy production with another 24,000 equine operations (U.S. Department of Agriculture 2004).

Even though there are no national and state central markets for hay (Cross 1999), buyers and sellers seem to be aware of the current prices in their area (Bazen et al. 2008). Hay producers are typically assumed to be price takers (Shumway 1983) because of the large numbers of sellers and buyers. Even though hay and livestock producers have avenues for price determination in the short run, they have little information about what causes supply and demand for hay to change from year to year (Bazen et al. 2008).

Hay Price Determinants

The quality of hay produced should affect the price buyers will pay for it. Thus the price and quality relationship is important to both producers and buyers. Producers must know the quality of their hay to accurately estimate its value and realistically formulating an asking price. Livestock producers, on the other hand, must know the quality of hay in order to assess its value as a production input and to accurately develop a realistic bid price. Even though there are objective measures of hay quality, most hay buyers use subjective evaluation such as visual appearance, feel and smell to determine quality grade.

The type of hay whether alfalfa, grass, wheat or a combination of all, could affect its price. In Oklahoma, while alfalfa hay price ranges from $90 to $200 per ton depending on bale size and quality, wheat hay and grass hay in similar condition ranges from $85 to $130 per ton and $55 to $100 per ton respectively (Oklahoma Department of Agriculture 2009).

Price of hay can also be affected by current and past stocks. Hay stocks stored on farms as of May 1, 2009 totaled 22.1 million tons, up 2% from 2008. Disappearance from December 1, 2008 to May 1, 2008 totaled 81.6 million tons, compared with 82.5 million tons for the same period in 2009. Hay stocks decreased from 2008 across most of the Great Plains and Rocky Mountain States. Texas and Oklahoma had the largest decrease due in part to lower hay production in 2008. In addition, dry weather during the fall and winter 2008 resulted in poor pasture conditions which increased supplemental hay feeding (NASS-USDA, Louisiana Farm Reporter 2009). Thus hay price in these states were comparatively higher in 2008 than 2009.

Recent Hay Production Levels in Oklahoma

Even though there have been intermittent fluctuations, Oklahoma hay production has been increasing since the late 1940s (Figure 3). In Oklahoma, 3.14 million and 2.91

million acres of hay were harvested in 2007 and 2008, respectively. Oklahoma hay production was estimated to be 6.858 million tons in 2007 and 5.536 million tons in 2008, with an average price of $74/ton in 2007 and $111/ton in 2008.

CHAPTER III

METHODOLOGY

Conceptual Framework

The overall objective of this research is to determine the impact of switchgrass production on Oklahoma hay markets. Agricultural producers and land owners will decide whether to produce switchgrass or hay, considering the net economic returns of each. The research assumes a profit maximizing firm chooses whether to produce switchgrass or other hay crops.

The demand equation for hay is modeled using ordinary least squares (OLS) estimates while the profitability decision on whether to produce hay or switchgrass is modeled using linear programming (LP).

The demand equation is an inverse demand function with hay price as the dependent variable, That equation is used to predict the hay price which used in the LP model as the objective value for hay.

Data Sources

Data on hay production, price of hay, cattle and calves inventory, beef cow inventory, and soybean price for Oklahoma, as well as Texas and Arkansas, were obtained from USDA-NASS. Figures 1 to 8 show the trend in the various data across specific periods of time. The initial OLS equation (tables 1 and 2) was estimated using data from 1949 to 2008. However due to the problems of multicollinearity and unexpected signs of some of the estimated coefficients, data from 1974 to 2008 were used for hay price (PHAY), hay production (HPROD), and soybeans price (PSOYBEAN) while data from 1975 to 2009 were used for beef cow inventory (BCOW). Beef cow numbers are reported on January 1, so those numbers are assumed here to most closely apply to data for the previous year.

Hay Demand

Konyar and Knapp (1990) modeled price of hay as a function of alfalfa production, feed, livestock prices, and animal inventory. Blake and Clevenger (1984) modeled quantity as a function of corn price and a trend. Bazen et al. (2008) modeled Tennessee hay price as a function of hay production, price of soybean, cattle and calf inventory, income, and time trend and found all variables attaining their expected signs.

Blake and Clevenger (1984) and Myer and Yanagida (1984) observed that an inverse demand function with hay price as the dependent variable is appropriate when supply is predetermined. Hay supply could be predetermined by the current year plantings, harvesting and weather.

For this study, the inverse demand function was specified as:

PHAY = f(TIME, HAYPROD, PSOYBEAN, BCOW)

with the empirical form as :

$$PHAY_t = \beta_0 + \beta_1 TIMEt + \beta_2 HAYPROD_t + \beta_3 PSOYBEAN_t + \beta_4 BCOW_{t+1} + e_t$$

Where PHAY is the annual price of hay (\$/ton) in Oklahoma; TIME is a time trend with 1974 = 1, 1980 = 2,…, and 2008 = 35; HAYPROD is Oklahoma hay production other than alfalfa (1,000 tons); PSOYBEAN is Oklahoma soybean price (\$/bu); and BCOW is Oklahoma beef cow inventory (1,000 head) on January 1 of the following year; e_t is a random error; β_i (i = 0,…, 5) and are parameters to be estimated; t is a subscript for the current year; and t+1 is a subscript for the following year.

Demand Hypothesis

The coefficient of HAYPROD (β_2) was expected to be negative in order to be consistent with a negatively sloped industry demand curve (Blake and Clevenger 1984; Myer and Yanagida 1984). The higher the price of the commodity, the lower the quantity of the commodity to be demanded.

The coefficient of PSOYBEAN is hypothesized to be positive. Soybean price was considered in the model to represent the price of a substitute (protein supplement). Thus the price of soybeans is expected to be positively related to the hay price. Prices of ingredients in feed rations tend to move together because the ingredients are generally good substitutes (Blake and Clevenger 1984).

The coefficient of BCOW is expected to be positive. An increase in the price of beef would act as an incentive for livestock producers to increase input use (Nicholson, 2005) as they build their herds. Thus beef cow producers would build their herds in anticipation for future profits which will consequently increase their demand for hay, thus, increasing the price of hay.

A time trend (TIME) was included in the model to capture the effects of other time-related variables not included in the model that have influenced hay prices. The trend variable also captures the positive trend in $PHAY_t$ over time (Figure 6).

Statistical Procedure

The demand equation was initially estimated using ordinary least squares (OLS) with 60 observations from 1949 to 2008. However there was a multicollinearity problem. A plot of the Pearson Correlation Coefficient indicated a high correlation coefficient between HPROD and PSOYBEAN; TIME and HPROD; TIME and PSOYBEAN; HPROD and BCOW, and TIME and BCOW as 0.75180, 0.90781, 0.80137, 0.66675, and 0.75324 respectively. The TIME variable created most of the correlation problem; however its removal from the model left a poor fit as TIME variable itself was highly significant in the model, as seen from tables 1 and 2 below.

Table 1. OLS Estimate with time (data from 1949 to 2008).

Variables	Estimates	Standard Errors	t-values	P-values
INTERCEPT	25.38990	6.17711	4.11	0.000
TIME	1.67663	0.15736	10.65	0.000
HPROD	-0.00930	0.00184	-5.06	0.000
PSOYBEAN	5.39353	0.89522	6.02	0.000
BCOW	-0.00381	0.00162	-2.36	0.022
R^2	0.92			

Table 2. OLS Estimate without time (data from 1949 to 2008).

Variables	Estimates	Standard Errors	t-values	P-values

INTERCEPT	-11.13990	8.91378	-1.25	0.216
HPROD	0.00569	0.00205	2.77	0.007
PSOYBEAN	7.62750	1.50980	5.05	0.000
BCOW	0.00165	0.00266	0.62	0.538
R^2	0.76			

With the TIME variable in the estimation, the coefficient of BCOW had an unexpected sign (negative), but deleting the TIME variable made the coefficient of BCOW insignificant in the model. Also without the TIME variable, HPROD assumed a positive sign violating the negatively sloped industry demand curve assumption (Blake and Clevenger 1984; Myer and Yanagida 1984).

A plot of each variable against time indicated a sharp trend change in the mid 1970s which can be seen in Figures 1 through 4.

In order to avoid the change in trend in the mid 1970s the demand was re-estimated using data for hay price (PHAY), hay production (HPROD), and soybean price (PSOYBEAN) from 1974 to2008 and beef cow data (BCOW) from 1975 to 2009.

The Pearson correlation coefficient did not indicate problem with multicollinearity among independent variables. However, the BCOW variable was not significant. In addition, several of the variables exhibited strong trends so the data were transformed using a log-log specification. The data were checked for autocorrelation to see if the variables were serially correlated using Durbin-Watson statistics. Durbin-Watson statistics of 2.288 did not reject the null hypothesis of no autocorrelation. Thus, the equation was estimated with OLS.

The Oklahoma hay price (PHY), time trend (TIME), ratio of Oklahoma hay production to Oklahoma beef cow inventory (OKHC), Oklahoma soybean price, and ratio of Texas hay production to Texas beef cow inventory(TXHC) were estimated using Oklahoma hay price as the dependent variable to find out the effect on Oklahoma hay price (Table 8).

The final model developed for Oklahoma hay demand was tested on some states that border Oklahoma (Kansas, Texas, and Arkansas) to find out the validity of the model in those states (Tables 9,10, and 11).

Profit Maximization using Linear Programming Model

Farmers would like to maximize profit based on the available resources. The emergence of switchgrass production will offer Oklahoma farmers the opportunity to produce alternative crops by comparing the profitability levels of each crop based on price and the opportunity cost of inputs. Therefore, producers will be able to select the crop unit that maximizes profit. Thus, the LP model would be used to determine the profit maximizing levels of hay and switchgrass subject to constraint resources.

The standard form of the LP model to maximize the production of hay and switchgrass subject to a land constraint is:

Maximize $Z(H, S) = P_H H + P_S S$

Subject to:

$A_{11}H + A_{12}S \leq \text{Land} \Rightarrow$ Units of Land.

$H \geq 0, S \geq 0$

Where: Z = value to be maximized (objective function value);

H = optimal level of hay to be produced;

S = optimal level of switchgrass to be produced;

P_H = the marginal change in the value of the objective function Z resulting from a unit change in level of hay production;

P_S = the marginal change in the value of the objective function Z resulting from a unit change in the level of switchgrass production;

A_{11} = the amount of land required to produce a unit of hay; and

A_{12} = the amount of land required to produce a unit of switchgrass.

The Lagrangian form of the model is as follows:

$$\underset{Max}{Z}(X_j, P_i) = \sum_{j=1}^{n} C_j X_j + \sum_{i=1}^{m} P_i \left(b_i - \sum_{j=1}^{n} a_{ij} X_j\right)$$

Where: P_i = the Lagrangian multiplier (shadow price) of resources i

Set j includes the n activities. Set i includes the m constraints.

a_{ij} = the input-output coefficient, the amount of resource i required to produce a unit of activity j

b_i = the initial quantity of resources or constraint b available for allocation to the alternative activities, for i = 1, 2, …, m.

C_j = the amount of change in the objective function value, Z, for a one-unit change in the level of activity j

X_j = the optimal quantity of activity j to be produced.

Switchgrass and Hay Yields and Acreage Requirements

The opportunity cost of land, and the expected yield and price per unit will determine the production options between hay and switchgrass for this study.

Switchgrass yield is estimated to range from 2.23 tons per acre, as reported by Perrin et al. (2008) from field level studies in the northern plains to 6.45 tons per acre, as budgeted by Garland (2008) for Tennessee. Perrin et al. (2008) originally estimated production costs of $60 per ton based on field level studies but they reported a cost of $54 per ton based on extrapolated costs over a ten year stand life.

Epplin et al. (2007) reported a switchgrass yield from 3.75 tons per acre to 6.50 tons per acre, with an estimated farm gate production cost between $37 per ton and $53 per ton. The lowest cost of $37 per ton from their study depended critically on the assumption that harvest could extend over at least eight months. The extended harvest season allows for a substantially lower investment in harvest machines resulting in lower fixed costs per harvested ton and also lower storage costs.

Fuentes and Taliaferro (2002) reported switchgrass yields from variety trials conducted over seven years at two locations in Oklahoma. They found an average annual yield of 7.2 tons per acre from stands that included a combination of varieties Alamo and Summer. Haque et al. (2008) reported a mean annual yield of 5.5 tons per acre with one harvest per year and production cost of $47 per ton for Oklahoma. Based on their estimate of 5.5 tons per acre, 0.182 acre of land will be required to produce a ton of switchgrass. Table 12 includes a summary of switchgrass yield and production cost estimates from various studies. Some of these were reported by Epplin (2009). The table indicates that yield estimates for switchgrass production in Oklahoma and Tennessee are higher than those from other states. Thus, Oklahoma and Tennessee are very promising for switchgrass production and can bid land away from some of the traditional crops including hay.

Determining the yield and acreage requirement for hay is difficult because hay is not as homogeneous as other crops. Grass hay can be produced from a variety of grasses which have different growth requirements, thus producing different yields. This characteristic makes it difficult to aggregate hay yield and acreage requirement as a single crop. Although, USDA/NASS reports the annual aggregate yield per acre of hay as a single crop but this does not reflect the actual yield of the individual grass species used in producing the hay. USDA/NASS reports a mean annual all-hay yield of 1.8 tons per acre from 2000 to 2008. In 2008, USDA/NASS reported 2,600,000 harvested acres of hay (all-hay minus alfalfa). Haque et al. (2008) estimated the mean annual yield (dry tons per acre) of Burmudagrass, Lovegrass, and Flaccidgrass in Oklahoma to be 3.38, 3.53, and 4.5, respectively, for one harvest per year; and 4.8, 4.28, and 4.98, respectively, for two harvests per year. These figures are the means calculated from the means reported based on quantities of nitrogen per acre application. The respective costs of production ($/ton) are 57.00, 50.50, and 50.25 for one harvest per year; and 48.25, 48.75, and 48.25 for two harvests per year. If these grasses are produced as grass mix hay, they would have aggregate yields of 3.80 tons per acre for one harvest a year and 4.69 tons per acre for two harvests a year with production costs of $52.58 per ton for one harvest and $48.42 per ton for two harvests. Based on the yield from the two harvests a year, one ton of dried hay mix will require 0.213 acre of land.

Switchgrass and Hay Prices

Data and information on switchgrass prices are not currently available because markets for biomass are absent for much of the United States. Some studies including Bangsund et al. (2008) have estimated breakeven farm-gate switchgrass prices. However, for a switchgrass cropping systems to become commercially viable, the price paid to producers per ton of biomass must be high enough to bid land away from traditional farm enterprises, rather than simply offsetting production costs. Recent studies in Oklahoma indicate good switchgrass yields with comparatively lower production costs (table 13). Thus an attractive switchgrass price will likely bid away land currently used to produce some traditional crops including hay.

Oklahoma hay prices have been fairly stable over time, though there have been short-term fluctuations in response to production levels. USDA/NASS reports a mean annual all-hay price of $83.11 per ton from years 2000 to 2009. This study estimates the 2008 Oklahoma grass hay price to be $91.50 per ton.

The LP Procedure

The LP model was used to maximize returns from the production of hay and switchgrass. Excel Solver was used to indicate the production of hay and switchgrass that will yield maximum profit based on the available resource (land) holding all other factors constant. The objective function of the LP model is as follows:

Maximize $Z = P_H H + P_S S$

Subject to: $A_{11}H + A_{12}S \leq \text{Land}$

To produce one dry ton of switchgrass, 0.182 acre of land is required, while 0.213 acre of land is required to produce one dry ton of hay that is sold for $91.50. The study assumes total available land is 2,600,000 acres as reflected in the 2008 report from NASS-USDA as the harvested acres of hay (excluding alfalfa). Switchgrass price information is rarely available in Oklahoma and therefore, the price of switchgrass will be parameterized in this modeling process. A switchgrass price that is lower than that of the hay price will be used and then parameterized to find the point at which it will make switchgrass more profitable than hay.

CHAPTER IV

FINDINGS

Demand Equation

The Pearson Correlation matrix (Table 3) did not show any problem of multicollinearity, suggesting that the demand equation can be represented by a recursive model. Using a log-log specification, the Durbin-Watson statistic of 2.288 led to failing to rejcet the null hypothesis of no autocorrelation. Thus, the demand equation was estimated with OLS (Table 4).

All coefficients were significant at the 5% level with the appropriate signs. The negative sign of the coefficient for hay production confirms a negatively sloped demand curve in which quantity demanded increases as price decreases. Soybeans price appeared to be positively related to the hay price because they are substitutes. An increase in the soybeans price relative to the hay price creates an incentive for beef cow producers to feed their cows more hay, thus increasing hay demand which will result in an increase in the price of hay. An increase in the beef cow inventory leads to an increase in their demand for hay with a consequent increase in the price of hay.

The coefficients of the variables represent marginal changes in the price of hay with respect to a unit change in the respective variable. Therefore, a unit increase in the level of hay production will cause a $0.30 decrease in the price of hay, and hay price increases \$0.26 and \$0.67, respectively, for one unit increases in the soybean price (PSOYBEAN) and the beef cow inventory (BCOW).

The final inverse demand function obtained from the OLS is;

$$Ln(PHAY_t) = \beta_0 + \beta_1 Ln(TIME_t) + \beta_2 Ln(HPROD_t) + \beta_3 Ln(PSOYBEAN_t) + \beta_4 Ln(BCOW_{t+1}) + e_t$$

Price flexibilities show the degrees of responsiveness in the price of hay (PHAY) to a percentage change in hay production, price of soybeans, and beef cow inventory (table 5). It should be noted that the slopes of the log-log specifications are the direct estimates of (constant) elasticities (Johnston and DiNardo, 1997), but for inverse demand functions with log-log specifications, the coefficients of the independent variables are the price flexibilities as used in Bazen et al. (2008). Thus a one-percentage increase in the level of hay production will cause approximately a 0.30% decrease in the price of hay. A one-percent increase in soybeans price was associated with a 0.26% increase in the price of hay, and a one-percent increase in beef cow inventory was associated with a 0.67% increase in the price of hay. Hay price is unresponsive to time, hay production, soybeans price, and beef cow inventory.

Texas hay production and the ratio of Texas hay production to Texas beef cow inventory were alternatively added to the Oklahoma model and both appeared to be more significant in the model than Oklahoma hay production.

Figure 10 compares the levels of Oklahoma hay production, Texas hay production, and Arkansas hay production with Oklahoma hay price. The production levels in these states appear to move in the same direction. The higher the quantity of hay produced in these states, the lower the price of hay in Oklahoma.

Hay Price Predictive Model for Oklahoma

Table 4 shows the parameter estimates of the inverse demand for Oklahoma hay production with hay price (PHAY) as the dependent variable and time trend (TIME), hay production (HPROD), soybeans price (PSOYBEAN), and beef cow inventory (BCOW) as dependent variables, which is conceptually given as;

$$LNPHAY_t = \beta_0 + \beta_1 LNTIME_t + \beta_2 LNHPRODt + \beta_3 LNPSOYBEANt + \beta_4 LNBCOWt_{+1} + e_t \qquad (1)$$

Empirically, equation (1) becomes,

$$LNPHAY_t = 0.24735 + 0.31964(LNTIME_t) - 0.29971(LNHPROD_t) + 0.25578(LNPSOYBEAN_t) + 0.66724(LNBCOW_{t+1}) + e_t \qquad (2)$$

Where e_t is described as white noise since $\sum e_t = 0$. Thus, Oklahoma hay price could be predicted by equation (2). Users of this model should be reminded that the time variable was from 1 to 35 (1974=1, 1975=2,.., 2008=35), therefore, any number of years from 2008 that would be predicted must be added on to 35 for the time variable and so for 2009, the time variable would be 36. Thus this model estimates 2008 grass hay price to be $91.50.

LP Results

Analyses were based on only a land constraint and prices while holding all other factors constant. Table 13 summarizes the results from the LP procedure using excel solver. At a price of $91.50/ton for hay and $77.50/ton for switchgrass, it would be profitable to produce hay instead of switchgrass. Parameterizing the price of switchgrass by adding $0.10 to $77.50 while holding hay price constant results in a switch-over point of $78.20/ton as switchgrass price. Thus switchgrass production becomes profitable over hay at the price of $78.20/ton. Estimates were also based on the assumption that switchgrass has lower cost of production than hay.

Table 13 again shows that, parameterizing hay and switchgrass prices at the same rate above the switch-over prices switched production back and forth between hay and switchgrass. Switchgrass production appears to be profitable over hay production where switchgrass price reaches $13.30 below the price of hay. The reason is that the land requirement/ton for switchgrass is less than that of hay. It should be noted that this result could also have been obtained from a simple budgeting model.

CHAPTER V

CONCLUSION

Hay demand in Oklahoma can be represented by a recursive model of an inverse demand function with hay price as the dependent variable and time trend, level of hay production, soybean price, and beef cow inventory as independent variables.

Oklahoma hay price appeared to be unresponsive to the quantity of hay produced which may be attributed to a number of factors. The bulky nature of hay makes it less likely to be transported to places where prices may be higher. Similarly, livestock farmers have less incentive to buy hay from far places, thus making it difficult for hay price to be affected by the quantity of hay produced. The organization and the structure of the hay markets are not strong enough to control prices due to factors such as spatial intensity, and also there are no such organized markets like auctioning. Also hay is priced according to a number of factors such as species of grass, quality, and size of bale, thus it makes it difficult to keep track of its price as a single commodity. Also some livestock farmers may produce their own hay to feed their herd and the value of such levels of production may not be perfectly reflected in the overall price of hay. Furthermore, the unresponsiveness of the hay price to a change in the quantity of hay produced is an indication that the Oklahoma hay price is fairly stable.

Also, Oklahoma hay prices may be dependent on the quantity of hay produced in surrounding states. Oklahoma hay price appeared to be dependent on Texas hay production as well as Arkansas hay production. An increase in the quantity of both Texas and Arkansas hay production causes a decrease in the price of Oklahoma hay price. However, the inverse demand function for Oklahoma cannot exclusively and perfectly be used for any of the surrounding states of Oklahoma by using the same variables used for Oklahoma in estimating the inverse demand function for these states since the hay price in these states may be dependent on different variables.

Switchgrass production could possibly be more profitable than hay production even when the switchgrass price is below the hay price because switchgrass requires less land per unit of production. It is therefore likely that farmers who produce hay for sale may switch their land currently used for hay production to switchgrass production when the federal mandate of biofuel production becomes fully operational, thus creating strong markets for feedstock.

The consequent effect would be that hay production would be reduced, causing an increase in the hay price, thus making it less affordable to beef cow farmers. Beef cow numbers would be reduced causing increases in beef prices overtime. It is unlikely that all lands currently used to produce hay would be shifted to switchgrass production because some livestock farmers will still produce hay to feed their own herds.

REFERENCES

Analysis Center, The University of Tennessee, Knoxville, TN.

Bangsund A. Dean, Eric A. DeVuyst, and Larry F. Leistritz. "Evaluation of Breakeven Farm-gate Switchgrass Prices in South Central North Dakota." Agribusiness and Applied Economics Report No. 632-5, August 2008. Available at http://agecon.lib.umn.edu/

Bazen Ernest, Roland K. Roberts, Jon Travis, and James A. Larson. "Factors Affecting Hay Supply and Demand in Tennessee."Selected Paper Presented at the Southern Agricultural Economics Association Annual Meeting, Dallas, Texas, February 2-5, 2008.

Blake, M. J., and T. Clevenger. (1984). "A linked annual and monthly model for forecasting alfalfa hay prices." Western Journal of Agricultural Economics 9, 195-99.

Boon, W. and H. Groe. 1990. Nature's Heartland – Native Plant Communities of the Great Plains. Iowa State University Press, Ames.

Branes, D.A. Miller, and C.J. Nelson (eds.), Forages. Vol 1. An Introduction to Grassland Agriculture. Iowa State University Press, Ames.

Brechbill, S.C. and W.E. Tyner. 2008. The Economics of Biomass Collection, Transportation, and Supply To Indiana Cellulosic And Electric Utility Facilities. Purdue University Dept. of Agricultural Economics Working Paper #08-03.

Cushman, J.H. and A.F. Truhollow. 1991. Selecting herbaceous energy crops for the Southeast and Midwest/Lake States. P. 465-480. In: D.L. Klass (ed.) Energy from biomass and waste, XIV. Institute of Gas Technol., Chicago, IL.

Cross, T. L. (1999). "Marketing Hay in Tennessee." The University of Tennessee Agricultural Extension Service Publication PB1638.

Dicks, Michael R., Ugarte De La Torre Daniel, Hellwinckel Chand and Campiche Jody L.. " Land Use Implications of Expanding Biofuel Demand," 2008.

Duffy, M. 2007. Estimated Cost for Production, Storage and Transprotation of Switchgrass. Ames, Iowa: Department of Economics, Iowa State University PM 2042.

Epplin, F.M. 1996. “Cost to Produce and Deliver Switchgrass Biomass to an Ethanol-Conversion Facility in the Southern Plains of the United States.” Biomass and Bioenergy 11(6):459-467.

Epplin, F.M. “Biomass: Producer Choices, Production Costs, and Potential.” Paper Prepared for Presentation at the Transition to a Bioeconomy: The Role of Extension in Energy conference. June 30-July 1, 2009, Little Rock, Arkansas.

Epplin, F.M., C.D. Clark, R.K. Roberts, and S. Hwan. 2007. “Challenges to the Development of a Dedicated Energy Crop.” American Journal of Agricultural Economics 89-5:1296-1302.

Ferland, Chris. (2002). “Switchgrass for Co-generation Fuel Feasibility.” Center for Agribusiness and Economic Development.

Fuentes, R.G., and C.M. Taliaferro. 2002. ‘Biomass Yield Stability of Switchgrass Cultivars.” In J. Janick and Whipkey, eds. Trend in New Crops and New Uses. Alexandria VA: ASHS Press, pp. 276-282.

Garland, C.D. 2008. Switchgrass Annual Production Budget: 10 Year Planning Horizon. Knoxville, TN, University of Tennessee.

Haque Mohua, Francis M. Epplin, Sijesh Aravindhakshan, and Charles Taliaferro. “Cost to ProduceCellolosic Biomass Feedstock: Four Perennial Grass Species Compared.” Selected paper prepared for presentation at the Southern Agricultural Economics Association Annual Meeting, Dallas, TX, February 2-6, 2008.

Hellwinckel, C.M., and D. De La Torre Ugarte. (2006). Unpublished data, Agricultural Policy.

Herndon, Cary W. JR., “The Ethanolization of Agriculture and the Roles of Agricultural Economists,” Journal of Agricultural and Applied Economics, 40,2 (August 2008): 403-414.

Johnston Jack and DiNardo John, “Econometric Methods,” Fourth Edition, page 45.

Kenkel Phil and Ragan Holly, “The Impact of BiofuelProduction on Crops Production in the Southern Plains,” Presented at “Biofuels, Food and Feed Tradeoffs”, St. Louis MO, April 12-13, 2007.

Khanna, M., B. Dhungana, and J. Clifton-Brown. 2008. “Cost of producing miscanthus and switchgrass for bioenergy in Illinois.” Biomass and Bioenergy 32(6):482-493.

Konyar, K. and K. Knapp. “Dynamic Regional Analysis of the California Alfalfa Market with Government Policy Impacts.” Western Journal of Agricultural Economics 15,1(1990): 22-32.

Lynd L.L., Cushman R.J. Nichols and Wyman C.F.. 1991. "Fuel Ethanol from Cellulosic Biomass," Science 231:1318-1323

McLaughing, S.B. 1988. "Forage Crops as Bioenergy Fuels: Evaluating the Status and Potential," Proc. VXIII International Grassland Congress, Winnipeg Canada (in press), June 8-10, 1997.

Mooney, D.F., R.K. Roberts, B.C. English, D.D. Tyler, and J.A. Larson. 2009. "Yield and Breakeven Price of 'Alamo' Switchgrass for Biofuels in Tennessee. Agronomy Journal (forthcoming).

Moser L.E. and K.P. Vogel. 1995. Switchgrass, Big Bluestem and Indiangrass. P. 409-420. In: R.F.

Myer, G. L. and J. F. Yanagida, (1984). "Combining annual econometric forecasts with quarterly ARIMA forecasts: A heuristic approach." Western Journal of Agricultural Economics 9, 200-06.

NASS-USDA Louisiana Farm Reporter, Volume 09 Number 10, May 18, 2009. http://www.nass.usda.gov/la

Oklhoma Dept. of AG-USDA Market News Service, Thu Sep 24, 2009. http://www.ams.usda.gov/mnreport/ok_gr310.txt

Perrin, R., K. Vogel, M. Schmer, and R. Mitchell. 2008. "Farm-Scale Production Cost of Switchgrass for Biomass." BioEnergy Research 1:91-97.

Sanderson M. A. and D.D. Wolf. "Morphological Development of Switchgrass in Diverse Environments," Agron. J., 1996. 88:908-915.

Smith D.D. 1981. Iowa prairie: An endangered ecosystem. Proc. IA. Acad. Sci. 88:7-10.

Vadas, P.A., K.H.Barnett, D.J. Undersander. 2008. "Economics and Energy of Ethanol Production from Alfalfa, Corn, and Switchgrass in the Upper Midwest, USA." Bioenergy. Res. 1:44-55.

Wang, C. 2009. Economic Analysis of Delivering Switchgrass to a Biorefinery from both the Farmers' and Processors Perspectives. M.S. Thesis. Knoxville, TN.: The University of Tennessee, Department of Agricultural Economics.

APPENDICES

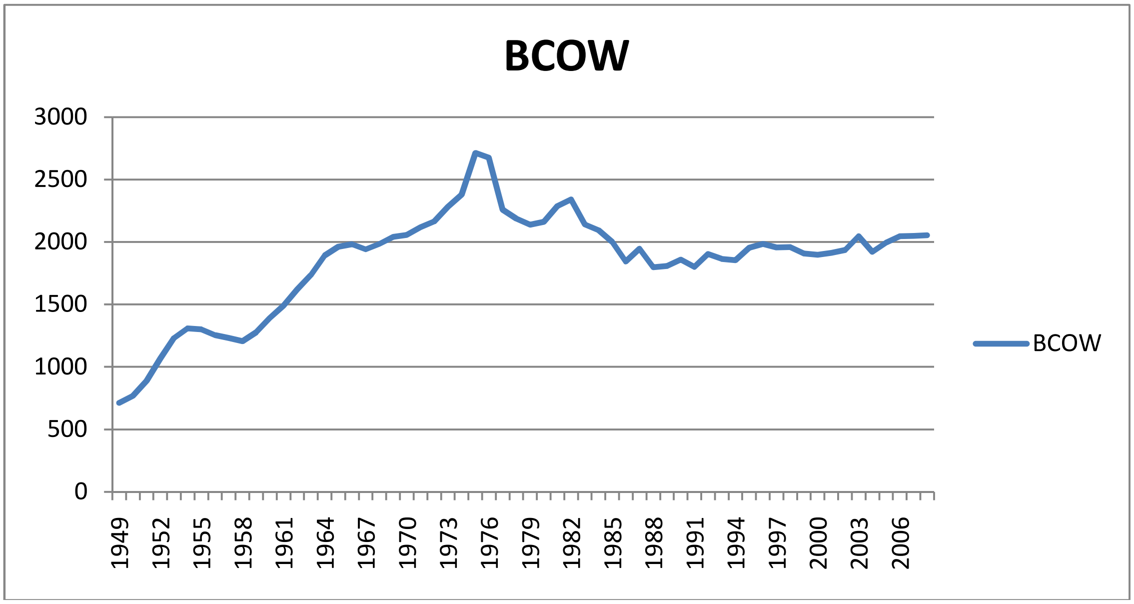

Figure 1. Oklahoma Beef cow Inventory (1000 head) from 1949 to 2008.

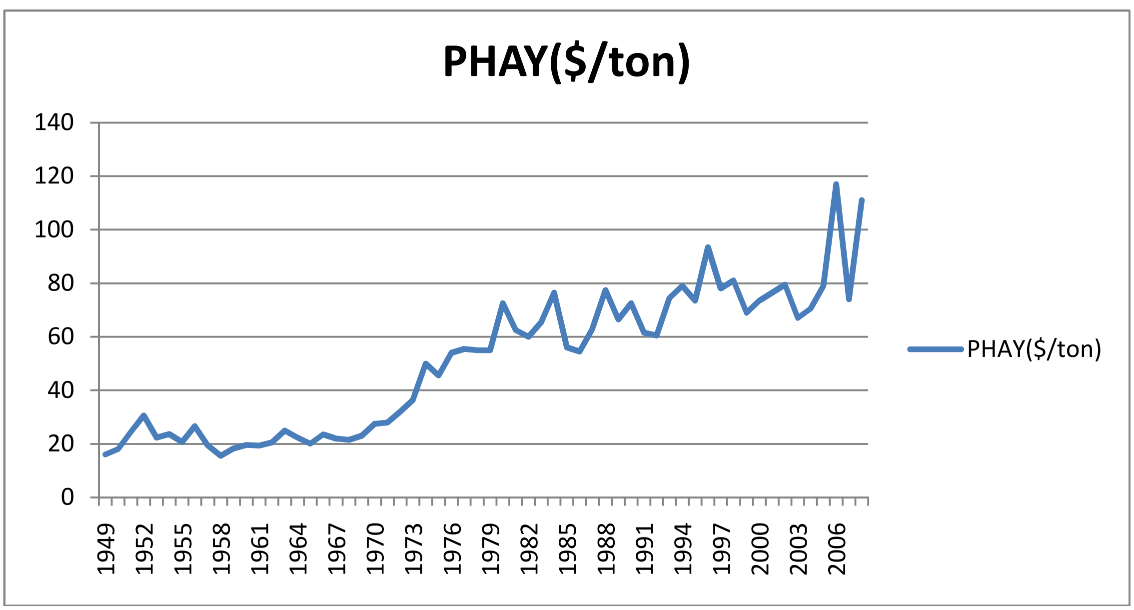

Figure 2. Price of hay against time from 1949 to 2008 in Oklahoma.

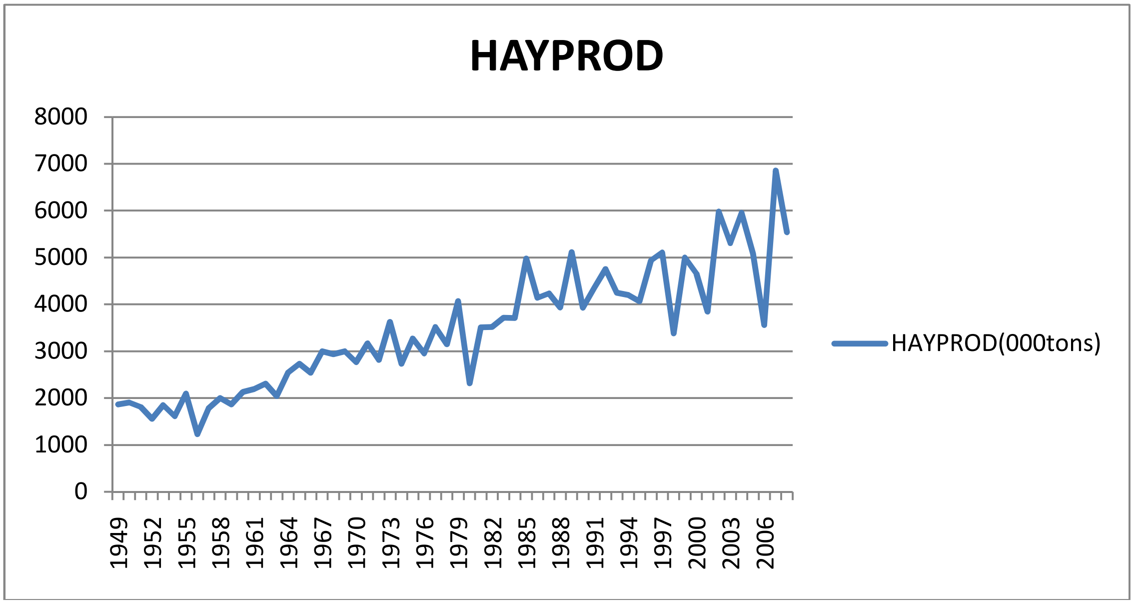

Figure 3. Oklahoma hay production from 1949 to 2008.

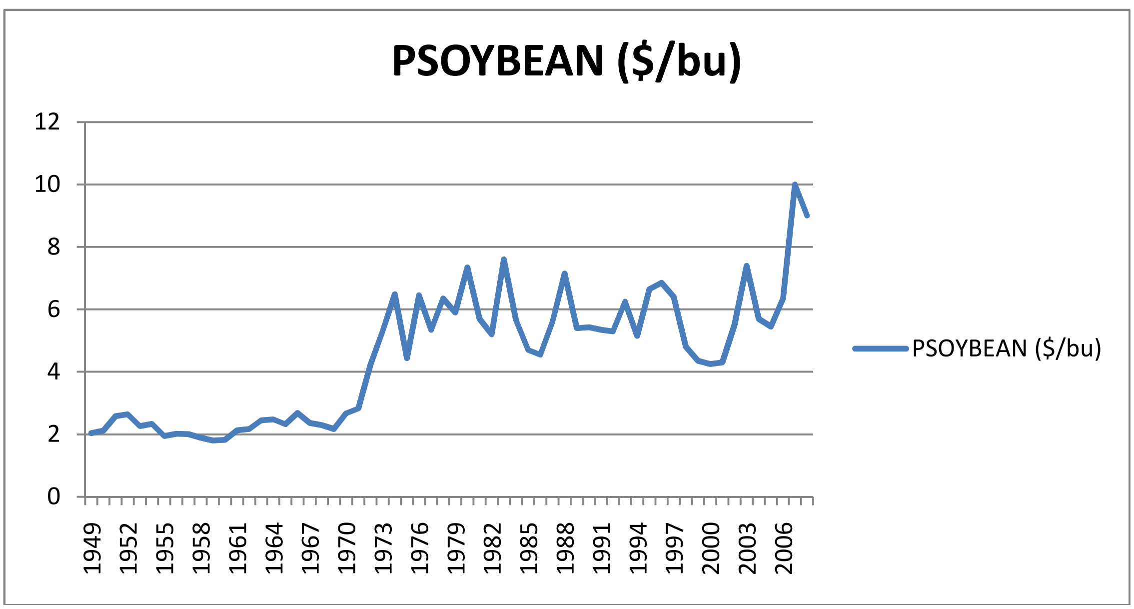

Figure 4. Oklahoma Soybean price from 1949 to 2008.

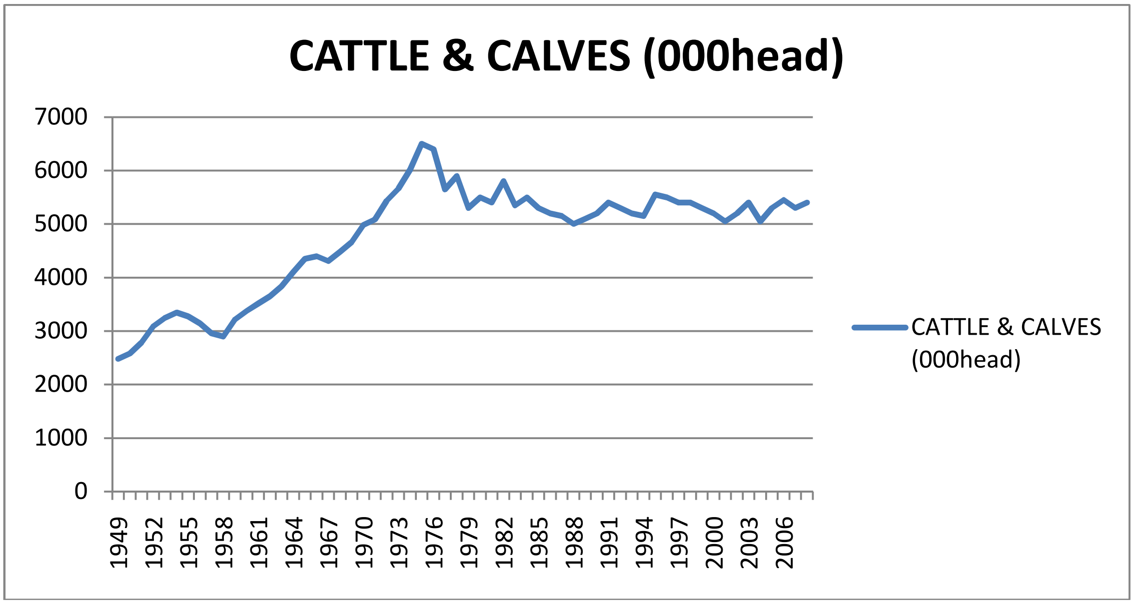

Figure 5. Oklahoma cattle and calves inventory from 1949 to 2008.

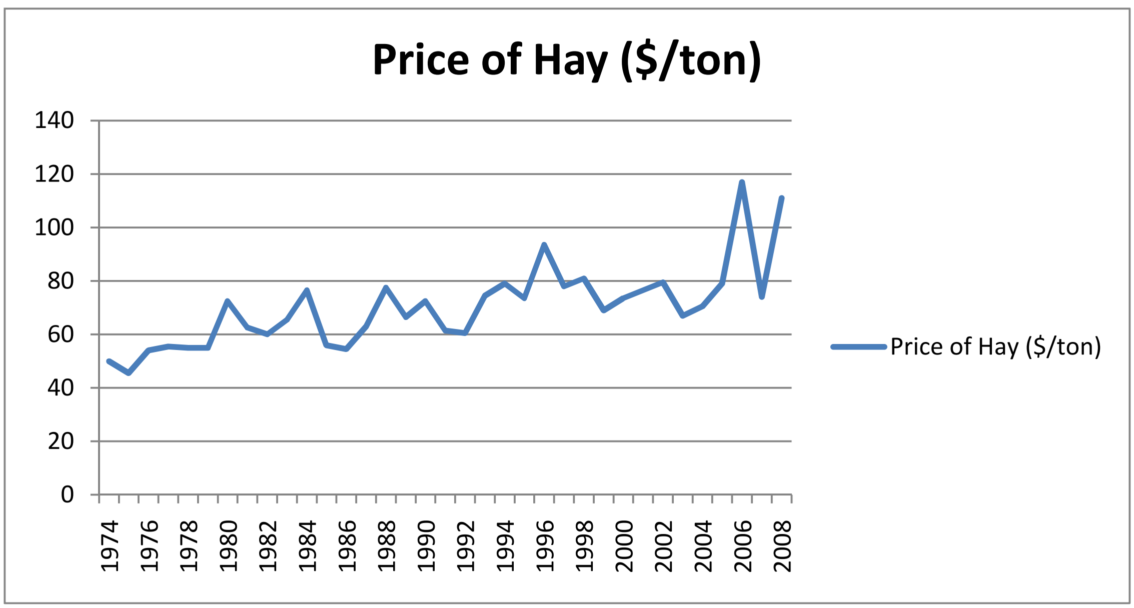

Figure 6. Oklahoma hay price from 1974 to 2008.

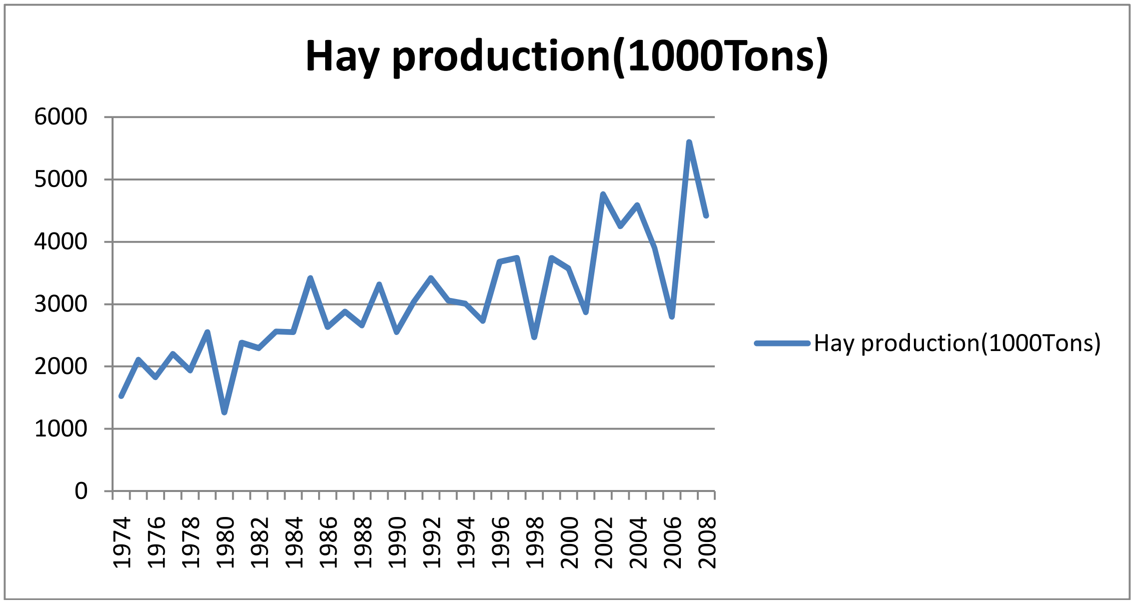

Figure 7. Oklahoma hay production (Without Alfalfa) from 1974 to 2008.

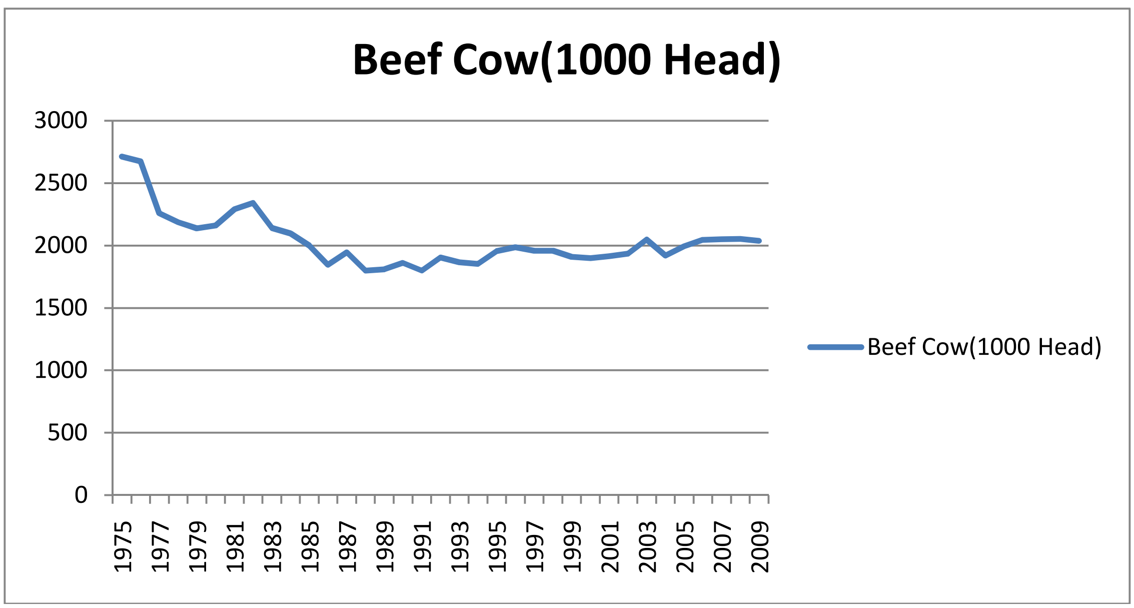

Figure 8. Oklahoma Beef Cow Inventory (1000Head) from 1975 to 2009

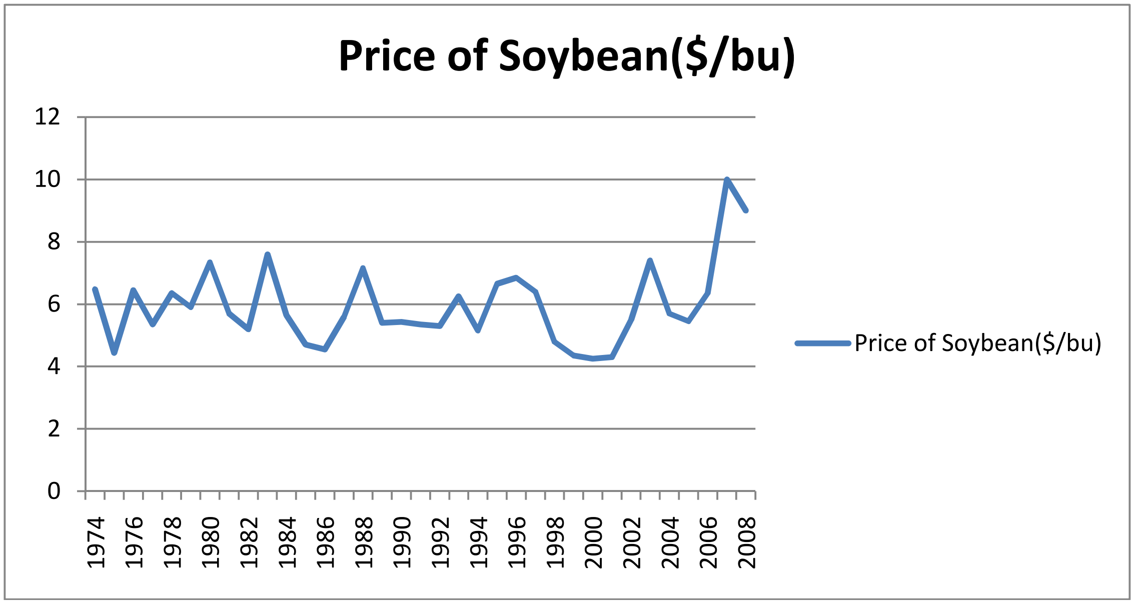

Figure 9. Oklahoma Soybean price ($/bu) from 1974 to 2008.

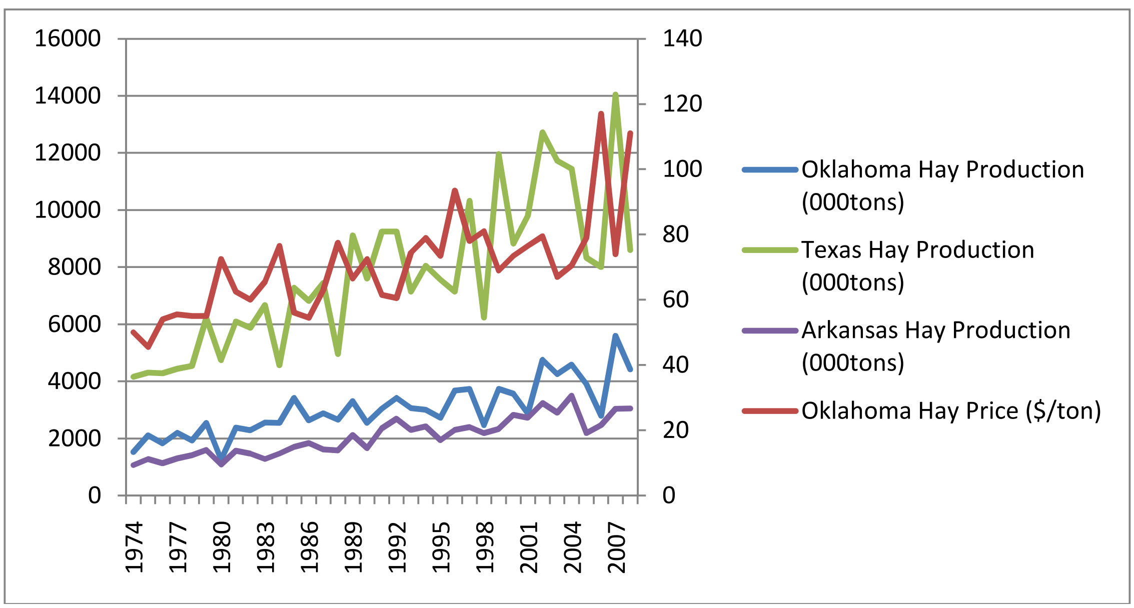

Figure 10. Oklahoma hay production, Texas hay production, Arkansas hay Production, and Oklahoma hay price from 1974 to 2008.

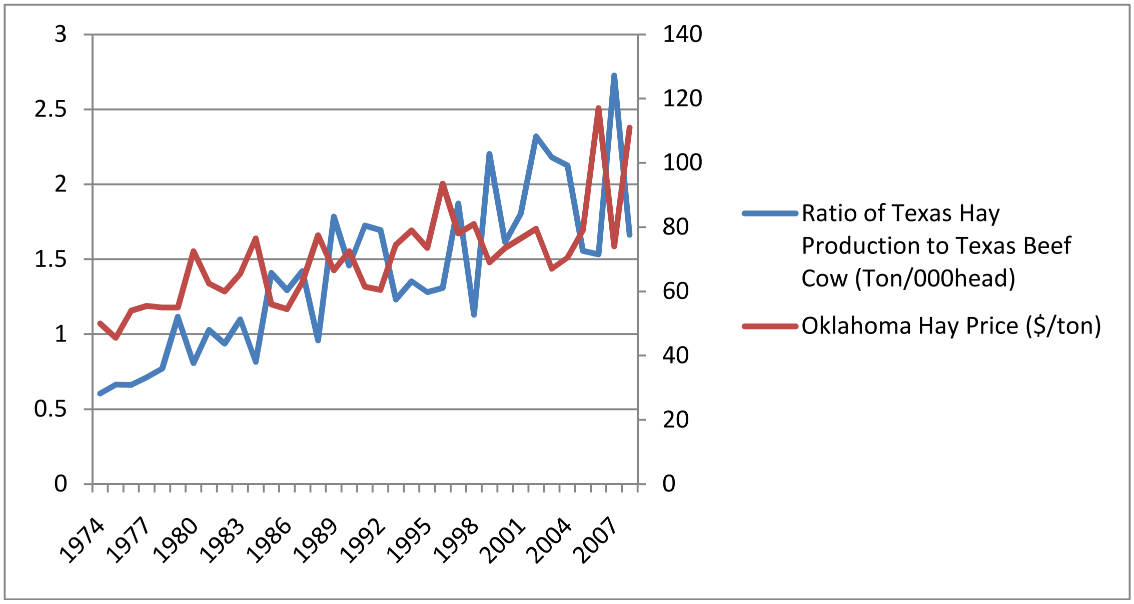

Figure 11. Ratio of Texas Hay Production To Texas Beef Cow inventory, and Oklahoma Hay Price.

Table 3. Pearson Correlation coefficients among independent variables. The values with superscripts are the respective p-values.

	HPROD	PSOYBEAM	BCOW
HPROD	1.00000	0.27981 0.1035[a]	-0.45515 0.0060[b]
PSOYBEAN	0.27981 0.1035[c]	1.00000	0.09380 0.5920[d]
BCOW	-0.45515 0.0060[e]	0.09380 0.5920[f]	1.00000

Table 4. OLS estimates of inverse demand function for hay in Oklahoma with hay price (PHAY) as the dependent variable.

Variables	Estimates	Standard Errors	t-values	P-values
INTERCEPT	0.24735	2.39581	0.10	0.9185
LNTIME	0.31964	0.04693	6.81	0.0001
LNHAYPROD	-0.29971	0.09716	-3.08	0.0044
LNPSOYBEAN	0.25578	0.09665	2.65	0.0128
LNBCOW	0.66724	0.30857	2.16	0.0387
R^2	0.7496			
F-VALUE	22.45			
OLS DW	2.288			

Table 5. Hay price flexibilities among independent variables.

Variables	Hay price flexibility
TIME	0.32
HAYPROD	-0.30
PSOYBEAN	0.26
BCOW	0.67

Table 6. Inverse demand function for Oklahoma with hay price as the dependent variable and the ratio of Oklahoma hay to Beef cow inventory (OKHC), time, Oklahoma soybean price (PSOYBEAN) and the ratio of Texas hay production to Texas beef cow inventory (TXHC) as independent variables.

Variables	Estimates	Standard Errors	t-values	P-values
INTERCEPT	2.99355	0.17628	16.98	0.0001
LNTIME	0.33289	0.04371	7.62	0.0001
LNOKHC	-0.16818	0.11492	-1.46	0.1537
LNPSOYBEAN	0.27533	0.08866	3.11	0.0041
LNTXHC	-0.24333	0.11205	-2.17	0.0379
R^2	0.77			
F-VALUE	25.62			

Table 7: OLS estimates for inverse demand for Texas with price of hay as the dependent variable and time trend(TIME), hay production (TXHPROD), soybean price (TXPSOYBEAN), and beef cow inventory (TXBCOW) as the independent variables.

Variables	Estimates	Standard Errors	t-values	P-values
INTERCEPT	6.24848	4.87698	16.98	0.6165
LNTIME	0.28512	0.06338	7.62	0.0001
LNTXHPROD	-0.22618	0.12962	-1.46	0.0677
LNTXPSOYBEAN	0.42035	0.12090	3.11	0.0804
LNTXBCOW	-0.16740	0.54022	-2.17	0.0310
R^2	0.72			
F-VALUE	18.92			

Table 8: OLS estimates for inverse demand for Arkansas with price of hay as the dependent variable and time trend(TIME), hay production (ARHPROD), price of soybean (ARPSOYBEAN), and beef cow inventory (ARBCOW) as the independent variables.

Variables	Estimates	Standard Errors	t-values	P-values
INTERCEPT	4.07395	2.64296	1.54	0.1337
LNTIME	0.13688	0.07241	1.89	0.0684
LNARHPROD	0.03369	0.14207	0.24	0.8142
LNARPSOYBEAN	0.35094	0.13969	2.51	0.0175
LNARBCOW	-0.19025	0.39486	-0.48	0.6334
R^2	0.61			
F-VALUE	11.84			

Table 9: OLS estimates for inverse demand for Kansas with price of hay as the dependent variable and time trend(TIME), hay production (KSHPROD), price of soybean (KSPSOYBEAN), and beef cow inventory (KSBCOW) as the independent variables.

Variables	Estimates	Standard Errors	t-values	P-values
INTERCEPT	-1.26262	3.32174	-0.08	0.6556
LNTIME	0.24216	0.06402	3.78	0.0002
LNKSHPROD	0.01767	0.19585	0.09	0.4915
LNKSPSOYBEAN	0.39873	0.13791	2.89	0.0678
LNKSBCOW	0.40502	0.37653	1.08	0.2375
R^2	0.70			
F-VALUE	17.25			

Table 10: OLS estimates for inverse demand for Oklahoma with price of hay as the dependent variable and time trend, hay production, Texas hay production, price of soybean, and beef cow inventory as the independent variables.

Variables	Estimates	Standard Errors	t-values	P-values
INTERCEPT	0.20228	2.11707	0.10	0.9245
LNTIME	0.38268	0.04627	8.27	0.0001
LNCI	0.83828	0.27830	3.01	0.0053
LNPSB	0.20985	0.08671	2.42	0.0220
LNHAYPROD	-0.08184	0.11140	-0.73	0.4685
LNTXHPROD	-0.34619	0.11278	-3.07	0.0046
R^2	0.81			
F-VALUE	24.88			

Table 11. Estimates of switchgrass yield and farm gate production costs.

Source	Year	Location	Matured Yield (tons/acre)	Farm Gate Cost ($/ton)
Bangsund et al.[d]	2008	ND	3.06	37.78
Brechbill-Tyner	2008	IN	5.00	45
Duffy	2007	IA	4.00	82
Epplin	1996	OK	4.00	23
Epplin et al.	2007	OK	3.75-6.50	37-53
Garland	2008	TN	6.45	62(excluding land charge)
Khanna et al.	2008	IL	2.58	82
Haque et al.	2008	OK	5.5 and 6.2[a]	46 and 47[b]
Mooney et al.	2009	TN	6.2-7.9	42-63
Perrin et al.	2008	ND,SD	2.23	54
Vadas et al.	2008	WI	4.84	53
Wang	2009	TN	6.0-7.8	66-77 [c]

[a] 5.5 tons/acre yield estimate is based on one harvest per year and 6.2 tons per acre yield estimate is based on two harvests per year.
[b] $46/ton cost estimate is based on two harvests and $47/ton cost estimate is based on one harvest per year.
[c] Estimates include delivery cost.
[d] Estimates are averages from soil productivity classes, described as low, average, and high.

Table 12. Results from the LP using excel solver.

PRICE OF HAY	OPTIMAL VALUE OF HAY	PRICE OF SWITCHGRASS	OPTIMAL VALUEOF SWITCGGRASS	OJECTIVE FUNCTION VALUE
91.5	12206572.77	77.5	0	1116901408
91.5	12206572.77	77.6	0	1116901408
91.5	12206572.77	77.7	0	1116901408
91.5	12206572.77	77.8	0	1116901408
91.5	12206572.77	77.9	0	1116901408
91.5	12206572.77	78	0	1116901408
91.5	12206572.77	78.1	0	1116901408
91.5	0	78.2	14285714.29	1117142857
91.6	12206572.77	78.2	0	1118122066
91.6	0	78.3	14285714.29	1118571429
91.7	12206572.77	78.3	0	1119342723
91.7	0	78.4	14285714.29	1120000000
91.8	12206572.77	78.4	0	1120563380
91.8	0	78.5	14285714.29	1121428572
91.9	12206572.77	78.5	0	1121784038
91.9	0	78.6	14285714.29	1122857143
92	12206572.77	78.6	0	1123004695

Table 13. List of variables and their interpretations

Variables	Interpretation
PHAY	Oklahoma hay price ($/ton)
HPROD	Oklahoma hay production (all hay minus alfalfa) (1000 tons)
PSOYBEAN	Oklahoma soybeans price ($/bu)
BCOW	Oklahoma beef cow inventory (1000 head)
TIME	Time trend
TXHPROD	Texas hay production (all hay minus alfalfa) (1000 tons)
AKHPROD	Arkansas hay production (all hay minus alfalfa) (1000 tons)
KSHPROD	Kansas hay production (all hay minus alfalfa) (1000 tons)
OKHC	Ratio of Oklahoma hay production to beef cow inventory
TXHC	Ratio of Texas production to beef cow inventory
TXPSOYBEAN	Texas soybean price ($/bu)
TXBCOW	Texas beef cow inventory (1000 head)
AKPSOYBEAN	Arkansas soybean price ($/bu)
AKBCOW	Arkansas beef cow inventory (1000 head)
KSPSOYBEAN	Kansas soybean price ($/bu)
KSBCOW	Kansas beef cow inventory (1000 head)

VITA

KWAME ACHEAMPONG

Candidate for the Degree of

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Name: Kwame Acheampong Date of Degree: December, 2009

Institution: Oklahoma State University Location: Stillwater, Oklahoma

Title of Study: THE IMPACT OF SWITCHGRASS PRODUCTION ON OKLAHOMA HAY MARKETS

Pages in Study: 44 Candidate for the Degree of Master of Science

Major Field: Agricultural Economics

Scope and Method of Study: Ordinary Least Square estimation was used to determine the inverse demand function for hay in Oklahoma with price of hay as the dependent variable and time trend, hay production, price of soybean, and beef cow inventory as the independent variables. Linear Programming model was used to determine the production options between hay and switchgrass based on the economic returns of each and subject to a land constraint.

Findings and Conclusions: Oklahoma hay price is fairly stable and unresponsive to the amount of hay produced, partly because some farmers may be producing their own hay to feed their livestock. Oklahoma hay price partly depend on the amount of hay produced in the surrounding states of Oklahoma. Finally, switchgrass production could be more profitable than hay production even at a point when switchgrass price is below the price of hay because switchgrass requires less land to produce the same unit as hay, and switchgrass has lower production cost than hay.

ADVISER'S APPROVAL: Dr. Brian D. Adam