Essays on the Profitability of Winter Farming Enterprises

by

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Abstract

Cover crops can boost soil productivity as they increase soil organic carbon levels, improve water infiltration and reduce soil erosion. In addition to the agronomic and environmental benefits, they can also provide additional revenue-generating opportunities for farmers such as winter annual grazing or selling of cover crop residues as a biofuel feedstock. The objectives of this dissertation are to study various factors affecting these revenue generating opportunities. The market for biofuel feedstock is not fully developed. Chapter 1 studies farmers' willingness to adopt this practice and develops an estimate of the price at which they are willing to sell the cover crop residues. Chapter 2 focuses on the agronomic and environmental aspects of biomass removal and the profitability of selling crop residues as a biofuel feedstock. Chapter 3 looks at winter annual grazing as an alternative revenue generating option provided by cover crops. It compares the risks and returns for a cattle owner who has the option of placing the cattle in a pasture before sending them to feedlot or to skip the pasture and send the cattle directly to the feedlot.

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Farmers' Willingness to Produce Cellulosic Biofuel Feedstocks:

Examining the Case for Cover Crops in the Southeast.

I. INTRODUCTION

Production agriculture has the potential of providing a renewable energy source in the form of cellulosic biofuel feedstocks for energy production (Rosillo-Calle et al., 2007). Technological advances are shifting biofuel feedstock production in the U.S. from grains to cellulosic sources. Carbon rich cellulosic materials can be obtained from a variety of sources such as crop residues (e.g. corn stover and wheat straw), perennial crops (e.g. switchgrass) and waste materials (e.g. forest residues) (Heid, 1984, Turnhollow, 1994). A potentially promising cellulosic source in the Southeast is high-residue cover crops, which have the potential of providing a sustainable biofuel feedstock source, while providing conservation benefits as well (Raper et al., 2009).

Harvesting of cover crop residues as a cellulosic biofuel feedstock source may provide an additional income stream for farmers in the Southeast. This area of the country is particularly suited for growing both heavy residue winter and summer cover crops (Clark, 2007). However, the decision to grow heavy residue cover crops as a biofuel feedstock may be complicated by the reduction in conservation benefits resulting from biomass removal from the soil surface. Leaving cover crop residues as mulch on the soil surface can provide both agronomic and environmental benefits, such as increased soil organic matter, decreased soil erosion, weed suppression and improved cash crop productivity (Snapp et al., 2005). Although these benefits may not be assigned a direct monetary value, it is necessary to compare the agronomic, economic and environmental benefits and costs, when considering growing a cover crop as a cellulosic biofuel feedstock source (Wilhelm et al., 2004).

To further complicate the decision-making process for farmers, markets for cellulosic biofuel feedstocks either do not exist or are still in the development stage. Prices for many cellulosic feedstocks have not yet been discovered. Some studies have focused on the economic, logistical and technical feasibility of producing alternative sources of biofuel feedstocks sources. These studies have provided break-even prices for alternative cellulosic sources that range between $30 to $45 per dry ton of cellulosic material (de La Torre Ugarte, et al., 2007; Gallagher et al., 2003; Graham, 1994; Graham et al., 2007; Heid, 1984; Perlack et al., 2005; Walsh et al., 2003). While break-even prices provide useful information, they do not take into account farmers' reservation price or the premium needed to take account of things such as foregone conservation benefits, risk aversion, uncertainty, and impacts on future cash crops.

In addition, a very limited amount of research, that too in the form of regional studies, has been conducted to understand the socio-economic factors influencing the adoption of alternative cellulosic sources and technologies (Bransby, 1998; Hipple and Duffy, 2002; Jensen et al., 2007). Kelsey and Franke (2009) studied Oklahoma market and are of the opinion that a major factor of non-adoptability to biofuel crops is lack of information. Producers desire more information about biofuel crop production thus increasing farm profitability by growing biofuel crops. Jensen et al., (2007) studied switch grass production in Tennessee as a bioenergy crop and found out that only 21% farmers were aware of using switchgrass as a bioenergy crop. They were also concerned that about the undeveloped market and need of technical assistance. Hipple and Duffy

(2002) reported that most Iowa farmers were cautious of making a commitment to grow switchgrass before knowing the outcome.

These regional studies of biomass supply have tended to ignore the socio-economic factors affecting farmers' willingness to produce alternative biofuel feedstock sources, including the timing, location and extent of adoption (Rajagopal and Zilberman, 2007). Since none of the studies have explored cover crop residues as an alternative, agricultural producers and policymakers do not have an accurate reflection of the prices at which these feedstocks would be available. This severely limits the decision-making ability of farmers in the Southeast, an area which has the potential to provide a broader range of potential cellulosic feedstock sources.

The purpose of this paper is to assess farmers' willingness to grow high residue cover crops as a cellulosic biofuel feedstock. Both the potential socio-economic factors influencing the adoption of such enterprises and price discovery for supplying cover crop residues are explored. A survey was conducted to gather agronomic, economic and socio-demographic information on farmers' cover crop decisions, as both a conservation practice and potential biofuel feedstock. A two-step modeling approach, following a multiple bounded contingent valuation methodology, was used to understand the agronomic, farm management and demographic factors affecting farmers' willingness to produce and harvest cover crop biomass as a biofuel feedstock source at different selling prices.

The remainder of the paper is organized as follows. Section two provides background concerning the benefits and costs of adopting cover crops for both conservation and biofuel purposes. This section examines some of the tradeoffs to be considered by farmers in order to decide whether they are willing to grow cover crops as a biofuel feedstock or not. The survey, data and explanatory variables used in the model are presented in section three. Section four details the conceptual and modeling frameworks, which is followed by the presentation of model results in section five. Section six provides concluding remarks and avenues for future research.

II. COVER CROPS FOR CONSERVATION AND BIOFUEL PURPOSES

Cover crops can boost soil productivity as they increase soil organic carbon levels, improve water infiltration and reduce soil erosion (Reeves, 1994; Wilhelm et al., 2004). These benefits are primarily realized in the form of improved cash crop yields from improved soil productivity following the cover crop (Lotter et al., 2003). Cover crops also play a role in improving weed suppression, nutrient cycling and cash crop yield stability (Lotter et al., 2003; Snapp et al., 2005; Creamer et al., 1996). However, cover crops can also negatively impact cash crop yields and nutrient depletion in case they interfere with cash crop production (Snapp et al., 2005).

Cover crop benefits are associated with the amount of residue left on the soil surface. Greater biomass production and greater retention of crop residues not only maintains soil productivity and health, but also improves cash crop productivity and economic viability (Wilhelm et al., 2004). Cover crop residue removal can raise various agronomic and environmental concerns, resulting in increased soil erosion, reduced crop productivity, decreased soil organic carbon levels and nutrient loss (Babcock et al., 2007; Hennessy, 2006; Wilhelm et al., 2004). Biomass removal may also negatively impact potential gains in cash crop yields attributed to higher residue levels from the cover crop, reducing potential crop revenues (Graham et al., 2007). Furthermore, removal of residues may result in loss or forfeiture of payments from conservation programs.

Despite various benefits and the potential for cost-share assistance, adoption of cover crops has been limited for various reasons. Singer (2008) reported that only 11% of the farmers in the Corn Belt grew cover crops during 2001-2005. Various factors affect the adoption rates of cover crops such as costs to plant and manage, and benefits from alternate practices (Lichtenberg, 2004). Farmers having a conservation plan for their farm and using conservation tillage are more likely to grow cover crops (Bergtold et al., 2008). In addition, financial incentives, from federal conservation programs[1], such as the Environmental Quality Incentives Program (EQIP) and Conservation Security Program (CSP) pay farmers to grow and retain cover crop residues to promote these conservation benefits.

Various studies have highlighted that the choice of cash crop plays a role in the choice of cover crop (Dabney and Reeves, 2001; Snapp et al., 2005). Bergtold et al. (2007) reported that farmers growing cotton, peanuts or soybeans are more likely to adopt cover crops. In addition, Bergtold et al. (2008) have reported that farmers having inadequate or adverse experience with cover crops are less likely to grow cover crops. Previous studies have shown that farmers are less likely to adopt conservation practices on rented land (Featherstone and Goodwin, 1993; Soule et al., 2000; Soule, 2001), and are more likely to adopt cover crops on land they own (Singer, 2008). Farmers with high gross farm sales may have a larger cash flow, providing these farmers with the ability to field test new conservation technologies, such as cover crops, on-farm (Bergtold et al., 2008).

Numerous studies have reported on-farm demographics with conflicting results. Several studies have reported that age has a negative effect on the adaptation of new technologies (Featherstone and Goodwin, 1993; Gould et al., 1989; Roberts et al., 1998; Wu and

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[1] For details of Federal conservation programs see http://www.nrcs.usda.gov/PROGRAMS/

Babcock, 1998). Uri (1999) reported that age and education have no impact on the adoption process, while others (Singer et al., 2007) argue that education has a positive effect. Gould et al., (1989) reported a negative impact from off-farm employment.

Farmers could adopt cover crops for multiple reasons. They might want to grow cover crops for conservation purposes, as a source of additional revenue generation, or a combination of both. The revenue generating opportunities from cover crops include hay production, winter annual grazing and biofuel feedstocks. Farmers choose the option that will provide the maximum returns to the resources being employed. Since, harvesting of cover crop biomass as a revenue generating enterprise may result in reduced conservation benefits, farmers need to compare the tradeoffs between these benefits and monetary gains from value added benefits of cover crop adoption.

Farmers planning to adopt cover crops as a biofuel feedstock will likely be concerned about long-term sustained demand for their feedstock, before making any changes to their crop production systems. These farmers are dealing with a developing market that increases the uncertainty of earning a profit. Rajagopal and Zilberman (2007) are of the opinion that farmers would supply the feedstock only if a contract is offered by feedstock processors of the bio-refinery. Factors that would affect a farmer entering into a contract include: pricing, acreage commitments, harvest timing, feedstock quality, yield variability, nutrient replenishment, conservation issues and harvesting/transport responsibilities (Altman et al., 2007; Epplin et al., 2007; Glassner et al., 1998; Larson et al., 2007; Stricker et al., 2000; Willhelm et al., 2004).

A biomass market will likely emerge, but demand is still unknown and prices are not yet determined. The decision to grow a biofuel feedstock will be made at the farm level. This generates the need for a farm level study to understand the decision-making factors, as well as to discover the price at which the farmer would be willing to supply alternative cellulosic biofuel feedstocks.

III. DATA

A mail survey, “Cover Crop Use on Southeastern Farms,” was conducted in fall 2007 by USDA, National Agricultural Statistics Service (NASS) in Alabama, on behalf of the USDA-Agricultural Research Service (ARS) and Auburn University. The mailing included an introductory letter from Auburn University requesting respondents to participate, a confidentiality disclaimer, the survey questionnaire, and a fact sheet. The factsheet was included to ensure that farmers had pertinent information about cover crops and their potential as a cellulosic biofuel feedstock, as well as details on costs and benefits of using cover crops. The survey was administered to gather information about cover crop adoption rates and management, as well as to assess farmers’ experiences and perceptions about cover crops and their uses. A primary focus of the survey for this study was aimed at identifying farmers’ willing to produce cover crops as a biofuel feedstock and to identify the price they would be willing to sell cover crop residues as a feedstock for ethanol production

The survey was sent to all qualified row crop producers in the state of Alabama, fulfilling two criteria; having more than 150 acres of row crops in production and a minimum of $50,000 in estimated total farm sales based on 2002 agricultural census data. The sample population consisted of 1312 farmers. Of these, 1162 farmers were administered surveys by mail. The remaining 150 surveys were administered by field enumerators, which were either conducted by an enumerator or mailed back by the respondent. A week after the first mailing, a phone follow-up was conducted for those surveys administered by mail. A second mailing was sent three weeks after, excluding those who had already returned the completed survey. A final phone follow-up was conducted a week after the second mailing. At this time, the respondents were also given the opportunity to complete the survey by phone.

In total, 362 completed surveys were collected, resulting in a response rate of 28% which is above the average response rate for mail surveys conducted in Alabama by USDA-NASS[2]. Out of these, 317 were considered usable due to data consistency and completeness. The summary statistics of the survey respondents as compared to the 2002 agricultural census data are shown in table 1.1. The measures in the table show that the demographics of survey respondents are representative of the entire sample population. The total harvested crop acreage in Alabama for farmers with more than 140 acres was 1,693,954 (USDA AG CENSUS, 2007). The harvested crop acreage of the farmers surveyed was 241,877 acres. Thus, the survey accounted for 14.28% of the crop acres harvested in the state.

To elicit farmers' willingness to produce cover crops as a biofuel feedstock, a two-step question was asked of participants (figure 1.1). The first part of the question was a binary choice, asking whether farmers were willing to produce cover crops as a feedstock for biofuel production. Responses to this question were used to understand the factors behind farmers' willingness to supply cover crop residues as a feedstock for biofuel production, to filter out those respondents who are unwilling to grow a cover crop for this purpose due to non-monetary reasons, and to avoid protest bids (Halstead et al., 1992). Those answering 'no', were asked for the reasons behind their unwillingness to grow cover crops. Respondent's answering 'yes' were presented with four different prices using a multiple bounded discrete choice format (see Welsh and Poe, 1998). They were asked to respond whether they would sell their cover crop residues at each price level.

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[2] Personal communication

Data for the variables used in the study and their summary statistics are provided in table 1.2. These variables are classified under different categories based on their inclusion in the survey, and include: conservation practices, farm characteristics, farmer's perception of cover crops and farmer demographics. Conservation variables focus on whether a farmer has a conservation plan on the farm, conservation program participation, and use of conservation tillage. Farm characteristics which might impact a farmer's decision include choice of cash crops, land dedicated to row crop production or pasture, income, and land ownership. Various advantages or disadvantages of cover crops as perceived by the farmer have a lot of weight in the farmers' decision. Desired cover crop characteristics whether agronomic or economic will influence the decision to adopt. For farmers who already incorporate cover crops into their crop systems, their existing experience with cover crops will shape their decision and provide an insight into willingness of farmers to modify their existing operations. These are all included as variables that will impact farmers' perception of adopting cover crops as a biofuel feedstock enterprise. Demographic variables include age, education, off-farm employment, and debt. The last variable reflects the financial situation of the farmer and would have a role in the decision making process as whether the farmers would be willing to invest additional monies or manpower into a new enterprise.

IV. CONCEPTUAL FRAMEWORK

Multiple bounded dichotomous choice (MBDC) methods provide a mechanism for assessing farmers' willingness to accept (WTA) a given price to supply or sell cellulosic biofuel feedstocks. (Cameron et al. 2002; Loomis and Ekstrand, 1997; Alberini et al., 2003). MDBC format is considered better to double bounded dichotomous choice since the respondent is able to see the full range of bids prior to his response this resulting in a consistent response strategy. The MBDC format has its limitations as the responses are sensitive to the range of bids shown. However, this limitation could be taken care of by leaving the upper end of the range open (Rowe et al., 1996)

Given that only farmers who were willing to grow cover crops as a biofuel feedstock were asked at what price they would do so, the conceptual framework must take into account the self-selection inherent in the question format. Thus, a two-step approach is used to model farmers' willingness to produce or supply cover crop residues as a biofuel feedstock. Recall, farmers were first asked if they were willing to grow cover crops as a biofuel feedstock. Farmers, who responded "yes", were then asked the MBDC question about price they would be willing to grow. Not taking account respondents' unwillingness to produce in the WTA component of the model could result in self-selection bias and generate inconsistent parameter estimates (Heckman, 1979; Maddala, 1983).

Following Calia and Strazzera (1999), a two-stage modeling approach is adopted. The first stage is designed as a selection criterion. At this stage, farmers indicate their choice whether to grow cover crops as a biofuel feedstock or not (Question #30 in figure 1.1). Those selected for the second stage by virtue of a positive reply to the first stage then take part in the elicitation stage, by determining the price they would be willing to accept (WTA) to sell their harvested cover crop residues. Selection and elicitation are actually two choices that are dependent on each other, but that are made simultaneously. Both choices can be written as a linear specification of two latent variables:

$$
\begin{aligned}
Y_1^* &= x_1'\beta_1 + u \\
Y_2^* &= x_2'\beta_2 + v \qquad (1)
\end{aligned}
$$

where Y_1* is a farmers' willingness to supply a particular quantity of cover crop residue as a biofuel feedstock; Y_2* is the price at which the farmer would sell the harvested cover crop biomass; x_1 and x_2 are vectors of agronomic, economic and social characteristics affecting the selection and elicitation decisions for each equation, respectively; and u and v are normally distributed random error terms. The sets of variables x_1 and x_2 represent different sets of explanatory variables as different factors would affect these two decisions, but both sets may have variables in common. The error terms u and v are assumed to follow a bivariate normal distribution, with zero mean, unit variance and are correlated (i.e. corr(u,v) = ρ).

The decision of a farmer to grow cover crops as a biofuel feedstock is observed as a binary variable, Y_1. That is:

$$Y_1 = \begin{cases} 1, & Y_1^* > 0 \\ 0, & Y_1^* \leq 0 \end{cases} \qquad (2)$$

Given u is assumed to be normally distributed; the selection stage can be modeled as a PROBIT model and represents the willingness to produce or supply decision made by the farmer. The explanatory variables specific to the selection model are included in table 1.3. These variables represent those factors that would affect the decision to adopt the enterprise or not. The PROBIT model was estimated and the standard errors were calculated using PROC LOGISTIC in SAS v9.1. Marginal effects for the explanatory variables were estimated at the mean of the explanatory variables following Greene (2003) using LIMDEP. Standard errors for the marginal effects were estimated using the delta method (Greene, 2003).

The second stage, elicitation, follows the selection stage and determines what price farmers would be willing to accept (WTA) to sell their harvested cover crop residues. Given the nature of the decision process and question format, Y_2 is only observed when $Y_1 = 1$. That is,

$$Y_2^* = \begin{cases} x_2'\beta_2 + v & if\ Y_1 = 1 \\ unobserved & if\ Y_1 = 0 \end{cases}$$

The elicitation stage is modeled as a multiple bounded dichotomous choice model following Welsh and Bishop (1993). In this framework, the farmer faces a set of prices ***t*** which they may be offered for their cover crop biomass**.** The probability that a farmer would sell biomass between the interval $t_k - t_l$ for $k > l$ is $\mathbf{P}\left(t_k > Y_{2,i}^* > t_l\right) = \mathbf{P}\left(Y_{2,i}^* < t_k\right) - \mathbf{P}\left(Y_{2,i}^* < t_l\right)$, where $\mathbf{P}\left(Y_{2,i}^* < t_k\right) = \mathbf{P}(x_{2,i}'B_2 + v_i < t_k) = G_k(x_2'\beta_2) = Z_k$, where *G* is the cumulative density function of *v* (and WTA) and assumed to be normally distributed with mean zero and unit variance. In the MBDC format, the farmer identifies the interval $t_k - t_l$ that they would switch from being willing to being unwilling to produce cover crops as a biofuel feedstock source. Now let Z_{U_i}represent the upper end of the identified price interval (i.e. t_k) and let Z_{L_i} represent the lower end of the interval (i.e. t_l). Then following Welsh and Bishop (1993), the log likelihood function of the MBDC model could be written as;

$$\ln(likelihood) = \sum_{i=1}^{N} \ln[\mathrm{Z}_{\mathrm{U_i}} - Z_{L_i}],$$

where, *N* is the number of respondents. Thus, the model ends up estimating the probability that a farmer would be willing to produce cover crops if the price falls in the interval $t_k - t_l$.

Recall, the format of the survey question and that a two-stage model was adopted due to the presence of self-selection bias. To correct for this, the model is adjusted following procedures outlined by Heckman (1979). The conditional expectation of Y_2^* given $Y_1 = 1$ is:

$$E(Y_2^* |\, Y_1 = 1) = x_2'\beta_2 + E(u|v > -x_1'\beta_1) = x_2'\beta_2 + \rho\sigma_2 \frac{\phi(x_1'\beta_1)}{\Phi(x_1'\beta_1)} \tag{3}$$

where, $\rho\sigma_2 \frac{\phi((x_1'\beta_1)}{\Phi(x_1'\beta_1)}$ represents the bias due to self-selection, ϕ is the standard normal probability density function, and Φ is the standard normal cumulative density function. Thus, following Heckman (1979) the inverse mills ratio $\lambda(x_1'\beta_1) = \frac{\phi((x_1'\beta_1)}{\Phi(x_1'\beta_1)}$, is estimated using the estimates of β_1 and included as an additional covariate in the elicitation model to correct for the self-selection bias. The results of the selection equation guide us to the reasons responsible for farmers' willingness to grow cover crops as a biofuel feedstock.

The elicitation MBDC model was estimated using PROC LIFEREG in SAS version 9.1. Since the predicted values of the endogenous variables are used for the estimation, the estimates of the covariance matrix of the parameters may be inconsistent (Maddala, 1983). To correct for this, a delete-*d* jackknife estimator was used to estimate the standard errors following Efron and Tibshirani (1986) with *d* equal to 10 percent of the data selected randomly without replacement over 1000 psuedo-random samples. The mean WTA was calculated using the fitted probabilities at the mean of the explanatory variables as $\sum_{k=1}^{K} \hat{Z}_k t_k$. The mean WTA was calculated for each pseudo-random sample and the standard error of WTA was estimated as the standard deviation of the vector of mean WTA across the pseudo-random samples.

V. RESULTS AND DISCUSSION

Of the farmers surveyed, 24 percent receive some form of cost assistance to grow cover crops. In our survey sample, 73 percent of farmers indicated that they have enough information to make decisions about cover crop selection, use and management. Out of these, 67 percent grew some form of cover crops at least once during the last 3 years as a soil conservation measure, for hay production, or for winter annual grazing of cattle. The average acreage produced with cover crops across all respondents was 216 acres. Fifteen percent of all respondents harvested cover crops for feed or grain, 28 percent of the respondents used it for winter annual grazing, and 9 percent or respondents used a combination of both. The remaining 48 percent grow cover crops for the agronomic and environmental benefits it offers to the following cover crops. While a large number grew cover crops for various reasons, cover crops were grown on only 28 percent of the total row crop acreage of the farmers surveyed[3]. Finally, of the farmers who grow cover crops, 52 percent of the farmers try to maximize the biomass produced from their cover crops in order to get as much residue as possible. These statistics have significance in explaining the results to the estimated models below.

Selection Stage:

The first stage of the model analyzes how various agronomic, economic, environmental and demographic factors affect farmers' decision to grow cover crop as a biofuel feedstock. The model showed a sensitivity of 97.8% and specificity of 88.3% for a farmer's decision to grow cover crops as a biofuel feedstock. The detailed results of the PROBIT model for this stage are presented in table 1.3.

Farmers who participate in the federal conservation programs such as CSP and EQIP are more likely to grow cover crops as a biofuel feedstock as they may already have experience in managing cover crops. Being enrolled in a federal conservation program can increase the likelihood of a farmer's willingness to grow cover crops a biofuel by 42% (EQIP) to 73% (CSP) Furthermore, if farmers can remove only a portion of the cover crop biomass to get additional revenue while continuing to qualify for conservation programmatic payments, then conservation payments may provide a mechanism for risk-averse farmers to cover part of the risk-premium for adopting this practice. Farmers who have a greater percentage of their farming

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[3] Information obtained from the survey conducted. Out of 317 respondents only 211 had grown cover crops in the last 3 years. Average cover crops acreage was only 217 acres as compared to row crop acreage of 763 acres. It is assumed that the survey findings are representative of the entire sample.

land involved in row crop operations are 65% more likely to grow cover crops as a biofuel feedstock given the potential revenue gain.

Farmers growing corn as a cash crop on their farms are more likely to grow cover crops as a biofuel feedstock. Survey results show that out of 178 farmers who grew corn in 2007, 40% altered their crop rotations to grow more corn due to increased demand for ethanol production. Farmers growing corn might have sold corn as a biofuel feedstock and are more likely to be aware of additional revenue generation opportunities by supplying additional cellulosic biofuel feedstock sources. Results show that farmers growing corn are 34% more likely to grow cover crops as a biofuel feedstock. Growing a cover crop can help maintain biomass levels on the soil surface and provide an alternative to harvesting corn stover as a feedstock source. Those farmers who desire high biomass as an essential cover crop characteristic have 50% higher likelihood to grow and sell that biomass as a biofuel feedstock. This characteristic potentially allows farmers to take advantage of partial stover removal, while reaping some of the conservation benefits from leaving residue on the soil surface. Furthermore, the amount of biomass generated by the cover crop is directly related to the amount of revenue the farmer will earn from selling it.

Some farmers perceive the high cost of cover crops as a disadvantage. These farmers may be aware of the benefits of cover crops, but are hesitant to grow them for financial reasons. For this reason, farmers are more likely to grow cover crops as a biofuel feedstock to offset the costs associated with cover crop adoption. Farmers who perceived cover crops as a high cost enterprise are 19 percent more likely to adopt them as a biofuel feedstock source. Those farmers who are of the opinion that cover crops help in increasing cash crop yields are also more likely to grow them as a biofuel feedstock by 39%. This would enable them to first reap the benefit of increased cash crop yields and then gain additional revenues by partial stover removal. Given the fluctuations in commodity prices over the past ten years, any additional income streams that help to stabilize income are likely to be more favorable to farmers.

Those farmers who are not willing to grow cover crops for agronomic reasons such as interference with cash crops are less likely to engage themselves in growing them as a biofuel feedstock due to their unfavorable past experiences. Results show that these farmers are 64% less likely to grow cover crops as biofuel feedstock. Similarly those farmers who are not willing to grow cover crops for production or economic reasons are less likely to grow cover crops to be used as a biofuel feedstock by 90%. Also, those farmers who have low debt are less likely (25%) to grow cover crops as a biofuel feedstock due to their unwillingness to acquire more debt (by investing in a new opportunity).

Elicitation Stage:

In the second stage, the elicitation model is used to predict the mean willingness to accept price for cover crop biomass to be sold as a biofuel feedstock. The model (see table1.4) evaluates the factors that affect the price at which the farmer would be willing to sell the cover crop biomass as the biofuel feedstock. The model further predicts that mean WTA is $54.62 per dry ton with an estimated standard error of $7.93, which is in line with the predicted prices in the literature. Aden et al., (2002) predicted a delivered price of $62 per ton to the refinery of which $14 was transportation costs, resulting in a selling price of $48 by the farmer. Brechbill and Tyner (2008) have calculated biomass costs to range between $39 and $46 for corn stover and $57 and $63 for switchgrass.

A number of factors affect a farmer’s WTA or price at which they would sell cover crop biomass as a biofuel feedstock source. Farmers who are enrolled in the EQIP program are more likely to sell biomass at a higher price. Under the EQIP program in Alabama, farmers are paid ($20/acre) for the introduction of re-seeding legumes into high residue conservation tillage systems[4]. Thus these farmers would lose their EQIP payments for growing non-legume cover crops as a biofuel feedstock and would demand a higher selling price to make it financially feasible for them.

However, those farmers who are enrolled in the CSP program can receive enhancement payments from the program for growing cover crops and maintain higher levels of residue cover on the soil surface. Given that the farmers may be able to remove a portion of the biomass and still meet the stated eligibility requirements, WTA for CSP participants is not as high. In addition, the payments from the CSP for cover crop adoption cover a portion of the production costs. Thus, these farmers have an opportunity to generate supplemental income and would be willing to sell biomass at a lower price.

Farmers with high income are likely to sell biomass at higher prices as they would engage in a new activity only if it results in significant revenue addition. Also, they may require a more significant commitment in resources and a larger management effort to undertake a new practice. Those farmers who desire high biomass as a cover crop characteristic for conservation purposes are likely more aware of the benefits of leaving biomass on the field. These farmers are likely to sell biomass at a higher price to compensate for the loss in agronomic and environmental benefits. Farmers with prior experience growing cover crops are likely to sell at a lower price as they are already have experience growing cover crops and can more easily adapt their operations to the new enterprise at less cost. Farmers who are of the opinion that cover crops help in increasing cash crop yields would sell biomass at a higher price as they might

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[4] Alabama EQIP practice and Payment Schedule. 2008

perceive a loss in yields by removing cover crop biomass. Older farmers are more likely to sell biomass at a higher price as they may be less willing to invest in a new enterprise, where as those farmers with at least a college education would be in a better position to compare the costs and benefits, potentially resulting in them willing to sell biomass at lower prices.

VI. CONCLUSIONS

The market for cellulosic feedstocks is still in the developing stage. The paper estimates a two-stage model using farmer data from Alabama to estimate farmer’s willingness to produce cover crops as a cellulosic biofuel feedstock. The first stage examines the farmer’s willingness to produce and sell cover crop biomass as a biofuel feedstock. Results show that farmers enrolled in conservation plans such as EQIP or CSP, those who have grown corn in last 3 years, have a higher percentage of acreage in the row crop operations, desiring high biomass from cover crops and those who perceive high cost of cover crop as a problem are more likely to grow cover crops as biofuel feedstock. Those farmers who have low debt or are not growing cover crops due to agronomic, production or economic reasons are less likely to adopt this practice.

The second stage examines the price at which a farmer would be willing to sell their cover crop biomass as biofuel feedstock. Model results indicate that using cover crops residues as a biofuel feedstock can provide an extra revenue generation opportunity for the farmers. Farmers may be willing to add this extra revenue generation opportunity in their cropping systems. Farmers enrolled in EQIP, having high income, desiring high biomass as a cover crop characteristic, believing that cover crop increases cash crop yield and are of higher age are more likely to sell cover crop biomass at a higher price. On the other hand, those enrolled in CSP, have higher percent of land rented, gown cover crop in last three years or have college education would be willing to sell cover crop biomass at a lower price.

Fifty-seven percent of the farmers surveyed have shown their willingness to produce a cover crop for biofuel production. Thus the results have reconfirmed the belief that cover crops could prove to be a sustainable source of cellulosic ethanol. The predicted mean willingness to accept price ($54.62) for the cover crop biomass is in line with the current market prices and signifies an acceptance both from the seller and buyer perspective.

The results of this model provide an insight into a market which is still in the developing stage and show that selling cover crop biomass as biofuel feedstock is feasible and farmers are willing to adopt this practice. Refineries would only be interested in establishing a plant if they are able to get a sustainable supply. Also, farmers would be willing to change their cropping patterns if they foresee a long-term revenue gain. Further, research is needed to understand and develop the contractual framework between the farmers and the refineries. More research also needs to be conducted into actual harvesting practices that would maximize the economic and agronomic benefits from cover crops.

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Table 1.1: Summary Statistics for Survey Respondents and Sample Population.

Variable		Survey	Population
Age		55.7	58.1
Gross Farm Sales			
	<$50,000	10.5%	not sampled
	$50,000-$99,999	19.5%	10.2%
	$100,000-$249,999	29.0%	32.7%
	$250,000-$499,999	21.3%	25.8%
	$500,000-$999,999	11.7%	19.9%
	> $ 1 Million	8.1%	11.5%
Race			
	White or Caucasian	98.2%	96.4%
	Black or African American	0.9%	1.7%
	American Indian	0.9%	0.9%
	All others	0%	1%
Row Crop Acreage		753 acres	878 acres
Total Acreage			

Source: Agricultural Census 2002, USDA-NASS

Table 1.2: Variable Description for Cover Crop Adoption Model (N = 317).

Variable	Description	Mean/ Frequency[a]
	Conservation Participation	
Conservation Plan	1, if farmer has a conservation plan on his farm, 0 otherwise	78.23%
EQIP	1, if farmer participates in the EQIP program, 0 otherwise	43.22%
CSP	1, if farmer participates in the CSP program, 0 otherwise	5.68%
CT	1, if farmer uses conservation tillage on his farm, 0 otherwise	77.92%
	Farm Characteristics	
Percent Row	Percent of land in the row crop operations	70 (0.3)
Percent Rent	Percentage of land rented by the farmer	60 -0.3
Corn	1, if farmer has grown corn in the last 3 years, 0 otherwise	64.04%
Cotton	1, if farmer has grown cotton in the last 3 years, 0 otherwise	63.72%
Peanuts	1, if farmer has grown peanuts in the last 3 years, 0 otherwise	45.43%
Soybeans	1, if farmer has grown soybeans in the last 3 years, 0 otherwise	41.96%
Income	Average yearly gross sales chosen from six given intervals	3.4 (1.4)
	Farmer Perception of Cover Crops	
Info Cover crops	1, if farmer has enough information to make cover crop decisions, 0 otherwise	73.19%
High Biomass	1, if farmer desires high biomass as a cover crop characteristic, 0 otherwise	17.98%
Nitrogen Fixation	1, if farmer desires nitrogen fixation as a cover crop characteristic, 0 otherwise	39.12%
High Cost	1, if farmer perceives high cost as a disadvantage for cover crops, 0 otherwise	53.31%
Harvest-Graze	1, if farmer harvests or grazes the cover crop, 0 otherwise	33.75%
Grown Cover Crops in 3 Years	1, if farmer has grown cover crops at least once in last three years, 0 otherwise	66.56%
Receive Cover Crop Cost share	1, if receives some cost share assistance for growing cover crops, 0 otherwise	15.77%

Table 1.2: Variable Description for Cover Crop Adoption Model (N = 317). Continued

Increase Cash Crop Yield	1, if farmer thinks that cover crops increases cash crop yields, 0 otherwise	31.23%
Not WTG Agronomy	1, if farmer doesn't grow cover crops for agronomic reasons, 0 otherwise	11.67%
Not WTG Prod-Econ	1, if farmer doesn't grow cover crops for production/economic reasons, 0 otherwise	32.49%
	Demographics	
Low Debt	1, if farmer perceives having low debt, 0 otherwise	54.26%
Off farm employment	1, if one or more members of the family work off-farm, 0 otherwise	51.42%
Age	Farmer's Age	55.4 (11.3)
College	1, if farmer has at least some college education, 0 otherwise	58.99%

[a] For discrete data frequency of response is reported. For continuous variables the standard deviation is reported in parenthesis

Table 1.3: Estimation Results for the Selection PROBIT Model.

Variable	**Parameter Estimate**[a] **(Standard Error)**	**Marginal Effect**[a] **(Standard Error)**
Intercept	0.4608 (1.3153)	0.1712 (0.4873)
Conservation plan	-0.4681 (0.3984)	-0.1797 (0.1533)
EQIP	1.1693*** (0.4463)	0.4241*** (0.1496)
CSP	3.9809*** (1.5412)	0.7264*** (0.1031)
CT	0.5324 (0.3657)	0.1834 (0.1150)
Percent Row	1.7520*** (0.6777)	0.6510*** (0.2522)
Percent Rent	-0.3848 (0.5589)	-0.1430 (0.2059)
Corn	1.0133*** (0.3696)	0.3425*** (0.1176)
Cotton	0.5040 (0.3821)	0.1805 (0.1312)
Peanuts	0.1188 (0.3956)	0.0442 (0.1484)
Soybeans	0.0147 (0.3787)	0.0054 (0.1408)
Income	-0.1447 (0.1469)	-0.0538 (0.0546)
Info Cover crops	0.0293 (0.3551)	0.0109 (0.1314)
High Biomass	1.3713** (0.5638)	0.5062*** (0.1745)
Nitrogen Fixation	-0.1027 (0.3284)	-0.0380 (0.1213)
High Cost	0.5277* (0.3192)	0.1929* (0.1144)
Harvest-Graze	0.7033 (0.5146)	0.2659 (0.1928)

Table 1.3: Estimation Results for the Selection PROBIT Model. Continued

Grown Cover Crops in last 3 Years	-0.3557	-0.1343
	(0.4964)	(0.1905)
Receive Cover Crop Cost share	0.3702	0.1424
	(0.8744)	(0.3430)
Increase Cash Crop Yield	1.0294**	0.3872**
	(0.4874)	(0.1745)
Not WTG Agronomy	-6.3292***	-0.6412***
	(1.6292)	(0.0918)
Not WTG Prod-Econ	-5.0347***	-0.8959***
	(0.8935)	(0.0422)
Low Debt	-0.6621*	-0.2446*
	(0.3622)	(0.1335)
Off farm employment	-0.2943	-0.1092
	(0.3547)	(0.1303)
Age	-0.0226	-0.0084
	(0.0152)	(0.0056)
College	0.2746	0.1008
	(0.3414)	(0.1250)
Fit Statistics		
Log Likelihood		-216.802
R^2		.6529
AIC		435.604
Number of Observations		317
Prediction Success		
Sensitivity = actual 1s correctly predicted		97.78%
Specificity = actual 0s correctly predicted		88.32%
Positive predictive value = predicted 1s that were actual 1s		91.67%
Negative predictive value = predicted 0s that were actual 0s		96.80%
Correct prediction = actual 1s and 0s correctly predicted		93.69%
Prediction Failure		
False pos. for true neg. = actual 0s predicted as 1s		11.68%
False neg. for true pos. = actual 1s predicted as 0s		2.22%
False pos. for predicted pos. = predicted 1s actual 0s		8.33%
False neg. for predicted neg. = predicted 0s actual 1s		3.20%
False predictions = actual 1s and 0s incorrectly predicted		6.31%

[a] ‘*’ indicates statistical significance at $P = 0.10$ level, ‘**’ at $P = 0.05$ level, and ‘***’ at $P = 0.01$.

Table 1.4: Estimation Results of the Elicitation (WTA MBDC) Model.

Variable	WTA Estimates^{a}(Standard Error)
Intercept	27.8717* (18.615)
Lambda	-26.9365** (12.703)
Conservation plan	-5.8618 (5.832)
EQIP	9.5934** (4.902)
CSP	-12.3264* (6.554)
CT	8.2446 (6.064)
Percent Rent	-10.8175* (7.275)
Corn	-3.3398 (5.129)
Cotton	3.2656 (5.037)
Peanuts	-1.1042 (4.577)
Soybeans	2.3685 (4.426)
Income	2.9354* (1.758)
High Biomass	15.2837*** (5.434)
High Cost	-1.5526 (4.081)
Harvest-Graze	5.6502 (5.189)
Grown Cover Crops in last 3 Years	-14.0436** (6.449)
Receive Cover Crop Cost share	-3.491 (5.754)
Inc Cash Crop Yield	7.9181* (5.205)
Low Debt	5.4312 (4.688)
Off farm employment	1.9862 (3.966)
Age	0.3032* (0.205)
College	-7.3426* (4.349)

Table 1.4: Estimation Results of the Elicitation (WTA MBDC) Model. Continued

Fit Statistics	
Log Likelihood	-248.806
Number of Observations	180

[a] '*' indicates statistical significance at $P = 0.10$ level, '**' at $P = 0.05$ level, and '***' at $P = 0.01$.

30. If you could (or already do) incorporate a cover crop into your current production system, would you be willing to produce a cover crop for biofuel production?

___ Yes ___ No

(*Please answer question 30a*) (if *NO, please SKIP to question 30b)*

30a. If yes, consider the option of growing a rye or wheat cover crop for ethanol production on your farm. The yearly average amount of biomass produced by such a cover crop for this purpose would be 4 to 6 tons per acre (dry-weight). The table below provides different prices per ton of cover crop biomass (dry-weight) that a bio-refinery might pay for this residue. For each price, indicate your willingness to produce a cover crop for ethanol production at the given price.

Price of cover crop biomass ($/ton)	Would you produce and sell the cover crop biomass/residue to a bio-refinery for ethanol production? (Please circle one answer for each row)		
$15	Yes	No	Do not know
$35	Yes	No	Do not know
$55	Yes	No	Do not know
$75	Yes	No	Do not know

30b. If no, why are you <u>not willing to grow a cover crop</u> for biofuel production? (*Mark all that apply*)

__ Too risky
__ Lower crop yields
__ Costs too high
__ Not enough time
__Lower soil organic matter
__Not enough information
__ Lower soil productivity
__ Less soil protection
__ Other (*specify*): ______

Figure 1.1: Selection and Elicitation (MBDC) Question from Survey

APPENDIX 1: SURVEY

Cover Crop Use on Southeastern Farms

A Survey of Conservation Practices, Cover Crop, and Biofuel Adoption

We need your help to improve the conservation research, programs and services that farmers receive from USDA-NRCS, other federal agencies, and state institutions, such as Auburn University.

Your views and experiences on conservation practices, cover crops, and biofuels will be summarized and used to recommend ways to improve conservation programs and services available to Alabama farmers, as well as to guide conservation agricultural research efforts that help to sustain and improve farming in Alabama.

The USDA – Agricultural Statistics Service has randomly selected names to be included in this study. **Your name and responses will remain strictly confidential**. The information you provide will be combined with reports from other farmers for statistical purposes. Auburn University will complete the final report for USDA.

Enclosed with this survey you will find an information sheet about cover crops in conservation systems and their potential as a biofuel feedstock. Please examine this sheet for your information and as a resource for the survey.

Please complete the survey as soon as possible and return it in the enclosed envelope which does not need a stamp. Thank You.

Contact: Patricia Duffy, Department of Agricultural Economics and Rural Sociology, Auburn University, (334) 844-5629, email: duffypa@auburn.edu.

CONSERVATION ON YOUR FARM

1. Do you have a conservation plan for your farm? 101 ___Yes^{1} ___ No^{2}

2. Do you participate in any of the following conservation programs administered by the USDA Natural Resources Conservation Service (NRCS)? (*Mark all that apply*)

102 ___ Environmental Quality Incentives (EQIP) 103 ___ Conservation Reserve Program (CRP)
104 ___ Conservation Security Program (CSP) 105 ___ Other (*specify)*:____________________

3. Do you use any of the following conservation practices?

Conservation Practice	Do you use this practice?	Have you received cost-share, incentive payments or income for using this practice?
Conservation Tillage	106 ___ Yes^{1} ___ No^{2}	107 ___ Yes^{1} ___ No^{2}
Filter or Buffer Strips	108 ___ Yes^{1} ___ No^{2}	109 ___ Yes^{1} ___ No^{2}
Wildlife Habitat	110 ___ Yes^{1} ___ No^{2}	111 ___ Yes^{1} ___ No^{2}
Precision Agriculture (Site-Specific, GPS, etc.)	112 ___ Yes^{1} ___ No^{2}	113 ___ Yes^{1} ___ No^{2}
Crop Nutrient Management	114 ___ Yes^{1} ___ No^{2}	115 ___ Yes^{1} ___ No^{2}
Integrated Pest Management	116 ___ Yes^{1} ___ No^{2}	117 ___ Yes^{1} ___ No^{2}

4. Where do you get information about conservation practices for your farm? (*Mark all that apply*)

118 ___ Extension Service
120 ___ Internet
122 ___ Field days/workshops
124 ___ USDA - Agricultural Research Service (ARS)
119 ___ State Universities
121 ___ Books, journals, magazines, flyers
123 ___ Other farmers
125 ___ USDA – NRCS

FARMING OPERATION

5. Of the total land you operate, how many acres are used:

a. to grow row crops? ………………201 __________ acres

b. for hay or forage production? ……202 __________ acres

c. as pasture for grazing livestock?...203 __________ acres

6. Considering the total land in your farming operation, how many acres:

a. are owned by you?.. 204 __________ acres

b. rented from others, including land used rent free?........................... 205 __________ acres

7. How many separate parcels of land do you operate?........................... 206 __________ parcels

8. Do you irrigate your crops? 207 ___ Yes[1] ___ No[2]

9. What is your typical crop rotation(s)? (*Please describe*) 208

____

10. What major crops are grown on your farm? Please indicate whether you have planted the listed crops in the past 3 years and the number of acres planted in 2007; also, indicate the predominant type of tillage practice(s) used for that crop during this period of time. In-row subsoiling refers to tillage practices such as Strip-till and Paratill that leave the majority of crop residues on the soil surface.

Crop	**Grown in the past 3 years?**	**Acres Planted in 2007**	**Predominant Tillage Practice(s) used over the past 3 years** (*Circle all that apply)* **1 - No Tillage** **2 - In-row Subsoiling** **3 - Disc / Chisel** **4 - Moldboard Plow** **5 – Other** (if other, please specify)
a. Corn	209 ___ Yes[1] ___ No[2]	210 _______ ac	211 1 2 3 4 5 _____________
b. Cotton	212 ___ Yes[1] ___ No[2]	213 _______ ac	214 1 2 3 4 5 _____________
c. Peanuts	215 ___ Yes[1] ___ No[2]	216 _______ ac	217 1 2 3 4 5 _____________
d. Soybeans	218 ___ Yes[1] ___ No[2]	219 _______ ac	220 1 2 3 4 5 _____________
e. Wheat	221 ___ Yes[1] ___ No[2]	222 _______ ac	223 1 2 3 4 5 _____________
f. Hay/Forage Crops	224 ___ Yes[1] ___ No[2]	225 _______ ac	226 1 2 3 4 5 _____________
g. Other (*specify*)-	227 ___ Yes[1] ___ No[2]	228 _______ ac	229 1 2 3 4 5 _____________

11. Including sales of crops, livestock, poultry and miscellaneous agricultural products (including the landlord's share) and government agricultural payments over the past 3 years, which category represents the **average** yearly total gross value of sales from this operation? (*Mark one*)

230 ___ Less than \$50,000^1
___ \$50,000 to \$99,999^2
___ \$100,000 to \$249,999^3
___ \$250,000 to \$499,999^4
___ \$500,000 to \$999,999^5
___ \$1,000,000 and over^6

11a. What percentage of sales in Question #11 comes from row crop production? 231 _________ %

COVER CROPS (*Please read the flyer that accompanied the survey about cover crops)*

12. Do you think you have enough information about cover crops to make decisions about cover crop selection, use and management?

301 ____ Yes^1 ____ No^2

13. Have you received information about crop selection, use or management from any of the following sources?

Source of Information	Received Cover Crop Information?	**If yes,** was the information helpful?
a. Local Co-op	302 ___ Yes^1 ___ No^2	303 ___ Yes^1 ___ No^2
b. Other Farmers	304 ___ Yes^1 ___ No^2	305 ___ Yes^1 ___ No^2
c. Agribusinesses, such as seed or chemical companies	306 ___ Yes^1 ___ No^2	307 ___ Yes^1 ___ No^2
d. University and/or Extension	308 ___ Yes^1 ___ No^2	309 ___ Yes^1 ___ No^2
e. National Resource Conservation Service (NRCS)	310 ___ Yes^1 ___ No^2	311 ___ Yes^1 ___ No^2
g. Agricultural Research Service (ARS)	312 ___ Yes^1 ___ No^2	313 ___ Yes^1 ___ No^2

14. If you were to (or already do) plant cover crops, what plant characteristics would you desire? (*Mark all that apply*)

314 ___ Fall Residue Cover
315 ___ Spring Residue Cover
316 ___ Nitrogen Fixation
317 ___ High Biomass Production
318 ___ Early Season Bloom
319 ___ Other (*specify*):______

15. What would you say are the advantages of using cover crops prior to growing your cash crop? (*Mark all that apply*)

320 ___ No benefits
321 ___ Reduces soil erosion
322 ___ Increases water storage
323 ___ Increases soil organic matter
324 ___ Suppresses weeds
325 ___ Reduces soil compaction
326 ___ Increases yield
327 ___ Increases profitability
328 ___ Lowers pest incidence
329 ___ Reduces production risk
330 ___ Decreases runoff
331 ___ Other (*specify*): ______

16. What are the main problems with using a cover crop on your farm? (*Mark all that apply*)

332 __ No problems 333 __ High cost 334 ___ Problems with weeds

335 __ Hinders spring planting 336 __ Use of more chemicals 337 ___ Reduced yields

338 __ More insect problems 339 __ Disease problems 340 ___ Depletes soil nutrients

341 __ Depletes soil moisture 342 __ Too risky 343 ___ Other (*specify*): ________

EXPERIENCE WITH COVER CROPS

17. Have you planted a cover crop in the past THREE years? 401 ___ Yes^{1} ___ No^{2} (***If No, Skip to Question #27, next pg.)***

17a. If YES, please indicate the type(s) of cover crops used and record the seeding rate, seed cost per acre, amount of nitrogen applied per acre (if applicable), and the cash crop planted afterward.

Cover Crop (*Please specify cover crop type and/or mixture)*	**Grown in the past 3 years?**	**Seeding Rate** (lbs/acre)	**Seed Cost** ($/acre)	**Nitrogen Fertilizer Applied** (lbs/acre)	**Cash Crop(s) Planted After Cover Crop**
Example: Rye	_X_Yes ___No	90	$22	30	Cotton
402 ______________	403 ___ Yes^{1} ___No^{2}	404 ________	405 ________	406 ________	407 ____________
408 _______________	409 ___ Yes^{1} ___No^{2}	410 ________	411 ________	412 ________	413 ____________
414 _______________	415 ___ Yes^{1} ___No^{2}	416 ________	417 ________	418 ________	419 ____________
Examples of cover crops include: Wheat, Rye, Oats, Triticale, Crimson Clover, Red Clover, Hairy Vetch, Ryegrass, Millet, & Other mixtures (such as Wheat / Rye mixes).					

18. How many acres did you plant in cover crops during the 2006-2007 growing season? 420 _____ acres

19. What method do you usually use to plant your cover crops? (*Mark one*)

421 __ Grain drill^{1} _ Aerial Seeding^{2} __Broadcast^{3} _ Custom Hire^{4} _ Other^{5} (*specify*): ________

20. How do you terminate or kill off your cover crops? (*Mark all that apply*)

422 ___ Tillage^{1} ___ Chemical^{2} (Burndown) ___ Crimper/Roller^{3}

21. How long do you wait after killing the cover crop to plant a cash crop? (*Mark one*)

423 ___ 1 week^{1} ___ 2 weeks^{2} ___ 3 weeks^{3} ___ 4 or more weeks^{4}

22. Do you harvest or graze your cover crop? (*Mark one*)

424 ___ Harvest for feed or grain^{1} ___ Winter Annual Graze^{2} ___ Neither^{3}

23. If you plant a legume cover crop, do you decrease the amount of nitrogen applied to your cash crop? (*Mark one*)

425 ___ Yes[1] ___ No[2] ___ Do not plant legume cover crops[3]

24. Do you try to produce as much biomass as possible from your cover crop in order to get as much residue as possible on the soil surface?

426 ___ Yes1 ___ No2 24a. **If yes**, how high do you grow your cover crop(s)?

427 _____ feet: Type of cover crop: 428 ____________________________

429 _____ feet: Type of cover crop: 430 ____________________________

25. Have you experienced an increase in cash crop yield after using a cover crop?

431 __Yes[1] (*Go to Question 25a*) __ No[2], I experienced a decrease or no change in cash crop yield.

25a. **If yes**, what crops and by how much did yield increase?

Crop: 432________________ increased by 433_______________ %

Crop: 434________________ increased by 435_______________ %

26. Have you received any cost sharing incentives for using cover crops? 436 ___Yes[1] ___ No[2]

26a. **If yes**, what was the source of these funds? 437 ______________________________

WILLINGNESS TO PRODUCE COVER CROPS *(If necessary, please read the flyer that accompanied this survey to assist with answering the following questions)*

27. Farmers plant cover crops to help improve cash crop productivity and yields. The following questions will present different possible costs of planting a cash crop and will ask you to mark the smallest acceptable gain in yield that would make it attractive to plant a cover crop at that cost. Or if you would not grow it, please mark "Would not grow".

a) If the cover crop costs **$15** per acre, what is the lowest yield increase from the cash crop that would make planting a cover crop attractive to you? (*Mark one*)

501__ 0%__ 5% __ 10% __ 15% __ 20% __Would not grow[7]

b) If the cover crop costs **$30** per acre, what is the lowest yield increase from the cash crop that would make planting a cover crop attractive to you? (*Mark one*)

502___ 0% ___ 5% ___ 10%___ 15%___ 20%___ Would not grow[7]

c) If the cover crop costs **$50** per acre, what is the lowest yield increase from the cash crop that would make planting a cover crop attractive to you? (*Mark one*)

503___ 0% ___ 5% ___ 10%___ 15%___ 20%___ Would not grow[7]

d) If the cover crop costs **$75** per acre, what is the lowest yield increase from the cash crop that would make planting a cover crop attractive to you? (*Mark one*)

504___ 0% ___ 5% ___ 10%___ 15%___ 20%___ Would not grow[7]

BIOFUELS (*Please read the flyer that accompanied the survey about biofuels)*

28. Do you use ethanol, bio-diesel, or a mixture to operate machinery or vehicles on your farm? (*Mark one*)

601 ___ Yes[1] ___ No[2] **(If NO, *Skip to Question #29*)**

28a. Do you receive cost-share assistance, incentive payments or income for use of these biofuels?

602 ___Yes[1] ___ No[2]

28b. How available are biofuels for purchase in your area? (*Mark one*)

603 ___ Readily available[1] ___ Somewhat hard to obtain[2]
___ Difficult to obtain[3] ___ Make my own biofuels[4]

29. Did you alter your crop rotations to grow more corn this year due to the increased demand for ethanol production?

604 ___ Yes[1] ___ No[2]

WILLINGNESS TO PRODUCE BIOFUEL FEEDSTOCKS *(If necessary, please read the flyer that accompanied this survey to assist with answering the following questions)*

30. If you could (or already do) incorporate a cover crop into your current production system, would you be willing to produce a cover crop for biofuel production?

701 ___ Yes[1] (*Please answer question 30a*) ___ No[2] **(if *NO, please SKIP to question 30b)***

30a. **If yes**, consider the option of growing a rye or wheat cover crop for ethanol production on your farm. The yearly average amount of biomass produced by such a cover crop for this purpose would be 4 to 6 tons per acre (dry-weight). The table below provides different prices per ton of cover crop biomass (dry-weight) that a bio-refinery might pay for this residue. For each price, indicate your willingness to produce a cover crop for ethanol production at the given price.

Price of cover crop biomass ($/ton)	**Would you produce and sell the cover crop biomass/residue to a bio-refinery for ethanol production?** (*Please circle one answer for each row*)		
702 $15	Yes[1]	No[2]	Do not know [3]
703 $35	Yes[1]	No[2]	Do not know [3]
704 $55	Yes[1]	No[2]	Do not know [3]
705 $75	Yes[1]	No[2]	Do not know [3]

30b. **If no,** why are you <u>not willing to grow a cover crop</u> for biofuel production? (*Mark all that apply*)

706 ___ Too risky
709 ___ Lower crop yields
712 ___ Costs too high
707 ___ Not enough time
710 ___ Lower soil organic matter
713 ___ Not enough information
708 ___ Lower soil productivity
711 ___ Less soil protection
714 __ Other (*specify*): _____

BACKGROUND

31. In what year did you begin to operate any part of your farm? $_{801}$ __ __ __ __ year [Example 1 9 7 5]

32. Are you or any member of your immediate family living with you employed off the farm? $_{802}$ _ Yes __No

32a. **If yes**, how many family members and how many hours per week on average are they employed off the farm? $_{803}$ _______ family members for $_{804}$_______ hours per week.

33. Considering all long-term, short term, secured or unsecured loans, what best describes the current debt level for your farm? (*Mark one*)
$_{805}$ ___ No debt[1] ___ Low debt[2] ___ Moderate debt[3] ___ High debt[4]

34. What is your (the farm operator's) gender? $_{806}$ ___ Male[1] ___ Female[2]

35. How old were you on your last birthday? $_{807}$ __________ years

36. What is your race? (*Mark one*)
$_{808}$ ___ White or Caucasian[1] ___ American Indian[2] ___ Black or African American [3]
___ Hispanic[4] __ Asian or Pacific Islander[5] ___ Other[6]: _________

37. What is the highest level of formal education you have completed? (*Mark one*)

$_{809}$ ___ Some high school[1] ___ High school or GED equivalency[2] ___ Trade school[3]
___ Some college[4] ___ College graduate[5] ___ Postgraduate[6]

COMMENTS

To better understand the needs of farmers, we would like to know what kind of information you may need about cover crops to make decisions about cover crop selection, use and management. Please provide any feedback you think is important in the space below.

FOR OFFICE USE ONLY Seq. # ________

Response		Respondent		Mode		Enum.	Eval.	Date			
1-Comp 2-Ref 3-Inacc 4-Office Hold	901	1-Op/Mgr 2-Sp 3-Acct/Bkpr 4-Partner 9-Oth	902	1-Mail 2-Tel 3-Face-to-Face 4-Left w/ Resp	903	904	905	906 DATE:	**DD** __ __	**MM** __ __	**YY** __ __

Balancing Feedstock Economics and Ecosystem Services

I. INTRODUCTION

Agro-ecosystems provide a range of services, which from an anthropocentric view; can be conceptualized as ecosystem services (de Groot et al., 2002). These ecosystem services have been categorized as: ‘provisioning’, ‘regulating ’, ‘cultural’, and ‘supporting’ (Millennium Ecosystem Assessment, 2005). Provisioning services include the production of food, fiber, feed and fuel. Regulating services include functions that regulate climate, air, water, and earth surface processes such as greenhouse gas balance, maintenance of the ozone layer, and regulation of hydrologic flows. Cultural services include aesthetic, spiritual, educational, and recreational benefits. Supporting services include nutrient cycling, soil formation, crop pollination, and natural pest control.

Ecosystem services at the farm level have been adversely affected by a number of factors related to biofuel production. The growing demand for energy, increasing energy costs, and the need to reduce reliance on fossil fuels and mitigate climate change are factors influencing the development and production of renewable fuels. Currently, corn grain is the primary feedstock for biofuel production in the U.S. and utilizes 24 percent of total U.S. corn grain production (RFA, 2009). The use of annual crops as biofuel feedstocks has resulted in an expansion of monocultural practices, puts pressure on land and water resources (Blanco-Canqui and Lal, 2009a; Spiertz and Ewert, 2009; Stonestrom et al., 2009). These pressures have resulted in government policy that promotes the use of alternative cellulosic biofuel feedstock sources

(Spiertz and Ewert, 2009). The Renewable Fuel Standard (RFS) program under the Energy Independence and Energy Security Act of 2007 requires that biofuel production reach 36 billion gallons (to be blended into transportation fuel) by 2022 (U.S. EPA, 2010). Of this requirement, 21 billion gallons are to be produced from “advanced biofuels” (U.S. EPA, 2010), which include cellulosic sources such as crop residues (corn stover and wheat straw), woody and herbaceous crops (miscanthus, poplar and switch grass), and forest residues (Blanco-Canqui and Lal, 2009a; Wright, 1994). Dicks et al. (2009) estimates that it would take 10.9 billion bushels of corn grain, 71 million tons of corn stover, and 56,200 tons of switchgrass, all covering 24.7 million acres of agricultural land to achieve this goal. Thus, bio-energy production on agricultural lands is likely to have a significant impact on the ecosystem services provided by agro-ecosystems.

Crop residues have received significant attention as a low-cost cellulosic feedstock that can provide a value-added benefit and additional income stream to farmers, but the impact on ecosystem services must be taken into account. Corn stover has been recognized as an abundant cellulosic feedstock with significant potential (Graham et al., 2007; Wilhelm et al., 2004). Removal of crop residues has been documented in the literature. Some of the adverse effects of removing crop residues include: soil organic carbon (SOC) loss (impacting greenhouse gas emissions), a decline in soil fertility and productivity (negative impact on nutrient cycle and nutrient losses), soil erosion, reduction of soil organism populations, reductions in water infiltration, and reductions in water quality (Anderson-Teixei et al., 2009; Blanco-Canqui and Lal, 2009a; Kim et al., 2009; Melillo et al., 2009; Tarkalson et al., 2009). Blanco-Canqui (2010) estimated that removal of crop residue could potentially reduce SOC pools by 0.4 tons per acre per year. Soil organic carbon provides a strong proxy for measuring soil health and productivity (Lal, 1997; Vasques et al., 2010). Higher levels of SOC can improve soil stability, nutrient availability, microbial activity, soil and crop productivity, which improves off-site benefits including reductions in soil erosion, leaching of pesticides and nutrients into water bodies, and emissions of greenhouse gases (Chan et al., 2002; Vasques et al., 2010; Wilhelm et al., 2004).

The purpose of this chapter is to examine the economic balance between the production of cellulosic biofuel feedstocks and ecosystem services at the farm level. Given the broad scope of this topic, a more focused discussion is provided concerning the use of crop residues, but attention is paid to other potential feedstocks. The broader link to the full range of ecosystem services mentioned above is made by providing a more focused analysis on the carbon impacts from biofuel feedstock production, but again this discussion is broadened to show the link between carbon and other ecosystem services. The tradeoff between biofuel feedstock production and ecosystem services is illustrated using a farm-level case-study examining the economics of harvesting corn stover and the subsequent impacts on soil organic carbon levels.

The remainder of the chapter is organized as follows. Section two provides a literature review of ecosystem service economics, cellulosic biofuel feedstock economics, and other research. Section three provides a farm-level case study examining the balance between production of biofuel feedstocks and ecosystem services. Section four examines potential challenges and opportunities for cellulosic biofuel feedstock production at the farm level that may enhance or sustain ecosystem services. Section five provides concluding remarks.

II. LITERATURE REVIEW

Ecosystem Service Economics

From an economic perspective, the provision of ecosystem services by agricultural producers depends on the degree to which these services influence economic risks and returns at the farm level. A major challenge is that, even though management decisions are made at the farm level, this is not necessarily the spatial scale at which ecosystem services are generated or where benefits are realized (Gottfried et al., 1996; Lant et al., 2005; Fischer et al., 2009). Many of the benefits generated by farm-level decisions occur off-farm. In addition, most ecological services are public goods, resulting in a lack of markets for these services (Lant et al., 2005). Typically, farmers do not receive direct income in the marketplace from production of ecosystem services. Over time this has begun to change with the introduction of a number of limited regulated markets for these services, which include markets for carbon sequestration (e.g. European Union Trading Scheme, Chicago Climate Exchange), water quality and biodiversity (Stanton et al., 2010).

Production of ecosystem services depends on the scale of analysis chosen, and is often sensitive to location. From the perspective of climate change mitigation, the value of a ton of sequestered carbon (C) is independent of where that ton is sequestered (Lant et al., 2005). However, if sequestering a ton of C changes the production of market products, this could affect market prices and result in changes in land use elsewhere, potentially resulting in higher net C emissions (Searchinger, et al., 2008). In contrast, ecological services related to biodiversity and wildlife habitat, are greatly affected by the spatial pattern of vegetative cover (Gottfried et al., 1996). Similarly, the spatial pattern of landscapes affects the flow of nutrients or sediments in surface waters (Gottfried et al., 1996), so the geographical pattern of land uses as well as total allocation among land uses may be important (Lant et al., 2005). This can result in a nonlinear relationship between land use and ecosystem services produced, and may require coordination of management across multiple farms (Lant et al., 2005). These spatial dependencies also mean that the economic optimum provision may include a mix of more intensive production in some areas (allowing some lands to be left wild) and extensive (nature-friendly farming practices) in others, and that neither the intensive or extensive solution is strictly preferred (Hennessy and Lapan, 2010).

However, some benefits of ecosystem services do occur at the farm level. It has been argued that supporting services are intermediate services that serve as inputs to the production of the provisioning outputs of food, fuel, and fiber (Wossink and Swinton, 2007). As such, these services have economic value to the farmer tied to the impacts of these services on production of marketable farm goods, either as changes in purchased input costs or the value of productivity changes. Due to this ‘jointness in production’, if production of agricultural goods and ecosystem services are complements, producers may have economic incentives to provide these services, even if the ecological services are not directly marketable (Wossink and Swinton, 2007). These complementarities may also reduce incentives needed to entice greater provision of ecosystem services (Wossink and Swinton, 2007). Although, it is often believed that provision of ecosystem services will require economic tradeoffs, this illustrates the potential for win-win opportunities when ecosystem services are complementary to production of agricultural goods. Maintaining soil C may be an example where production of ecosystem services and agricultural goods are complementary.

Cellulosic Biofuel Feedstocks and Ecosystem Services

The impact from harvesting crop residues, perennial grasses and wood biomass as cellulosic biofuel feedstocks has been a significant source of multi-disciplinary research. A brief review of research findings on the potential impacts on other ecosystem services is provided in table 2.1. While cellulosic biofuel feedstock production may provide an additional income stream for farmers, studies show adverse outcomes from residue removal may result. To sustain ecosystem services on the farm, some long-term studies have found that incorporating conservation practices (no tillage, cover crops and crop nutrient management) into farming systems may significantly reduce the effects from residue removal (Lafond et al., 2009; Hooker et al., 2005).

Much of the research has focused on crop residue removal. Crop residues left on the soil, provide a variety of ecosystem services, namely nutrient cycling, soil carbon sequestration, improvement of soil physical properties, erosion control and crop productivity (Lal, 2008). Soil carbon is the predominantly studied factor. A positive relationship between residue input, carbon sequestration and SOC pools has been established (Kong et al., 2005; Parton and Rasmussen, 1994; Paustian et al., 1992; Saffih-Hdadi and Mary, 2008). Hence, leaving crop residue in the soil results in higher SOC levels (Maskina et al., 1993; Wilhelm et al., 1986; Wilts et al., 2004), especially if accompanied with conservation practices (Allmaras et al., 2004). Another significant economic benefit of residue retention is higher potential cash crop yields, evidenced by improvements in soil properties as a result of higher SOC (Power et al., 1998). Higher levels of SOC can improve soil stability, nutrient availability, microbial activity, soil and crop productivity, as well (Chan et al., 2002; Vasques et al., 2010; Wilhelm et al., 2004).

Farmers' Willingness to Produce Biofuel Feedstocks and Biofuel Markets

The adoption process for biofuel crops and associated technologies is complex and risky. Agricultural producers are faced with the prospect of growing new and unfamiliar crops; harvesting crop residue from traditional crops with uncertain impacts on farm labor, equipment and soil resources; dealing with new crop and crop residue markets; and incorporating new technologies into their production systems (Rajagopal et al., 2007). A very limited number of studies have examined the adoption of alternative cellulosic biofuel feedstocks. Anand et al. (2008) examined the potential for harvesting winter cover crop residue (e.g. rye and wheat straw) in Alabama for cellulosic ethanol production. Bransby (1998), Hipple and Duffy (2002), and Jensen et al. (2007) have examined the adoption of switchgrass in Alabama, Iowa and Tennessee, respectively. Kelsey and Franke (2009) examined (in general) the potential for adoption of bio-energy crops in Oklahoma. The studies found that factors such as government programs, monetary incentives, education, irrigation, off-farm income, and conservation mindedness all had a significantly positive impact on adoption. On the other hand, factors such as farm size, land tenure arrangements, intense conservation behavior, risk, impacts on cash crop production practices, lack of bio-energy crop insurance, and lack of biofuel feedstock markets had a significantly negative impact on adoption. Of significance, is that the profitability of producing biofuel feedstocks versus other land-use alternatives was the most relevant factor impacting farmers' choices. Bransby (1998) reported that farmers would need $254 per acre of profit on average to plant switchgrass in Alabama, while farmers in Oklahoma indicated they would need an increase of $20 per acre to remove land from CRP to grow dedicated bio-energy crops (Kelsey and Franke, 2009). Anand et al. (2008) found that, for farmers willing to harvest cover crop residues as a cellulosic biofuel feedstock, the mean price that they would be willing to accept is $55 per dry ton.

Bransby (1998), Jensen et al. (2007) and Kelsey and Franke (2009) all indicate that farmers may be willing to enter into long-term contracts for biofuel production. Long-term contracts are a likely necessity to ensure adequate feedstock supplies for both processors and bio-refineries. Investments into biofuel conversion facilities are not likely, unless feedstock supply can be assured in the long-term (Rajagopal et al., 2007). Larson et al. (2007) examined different contracting arrangements between processors and producers where biomass price, yield and production cost risk is born entirely or shared by both parties. Biomass price and revenue varies between alternative contracting arrangements. Larson et al. (2007) found that contracts that provide a guaranteed biomass price or guaranteed gross revenue per acre, where a portion of the price and/or yield risk is assumed by the processor, provided the highest guarantee of biomass production at prices ranging from $40 to $80 per dry ton. As per the law of supply, higher biomass prices resulted in greater production, with risk-averse farmers requiring a higher price to produce. Epplin et al. (2007) examined alternative contracting arrangements in Oklahoma related to land leases and production contracts for the supply of biomass to refineries. They found that contracting prices under either scenario would range from $48 to $67, which corresponded with actual contracting bids for switchgrass production in a Tennessee study (Clark et al., 2007). Other significant contracting components that will affect the adoption of these practices and that need further examination, include contractual components concerning timeframes, acreage commitments, timing of harvest, feedstock quality issues, biomass harvesting responsibilities (e.g. custom harvesting), technical assistance, nutrient replacement costs, water use and conservation, as well as environmental stewardship considerations (e.g. soil erosion) (Altman et al., 2007; Epplin et al., 2007; Glassner et al., 1998; Larson et al., 2007; Stricker et al., 2000). Many of these contractual considerations will affect the adoption of biofuel feedstock alternatives and need to be considered more closely to ensure farmers' willingness to supply cellulosic feedstock sources in the long-term.

III. CASE STUDY

This section of the chapter examines a case study that tries to balance cellulosic biofuel feedstock production with ecosystem services at the farm level. The purpose of the case study is to examine the economic and environmental feasibility of harvesting corn stover for ethanol production. The case study uses experimental data from a research farm in Morris, MN.

A non-linear programming profit-maximization model was developed in EXCEL to determine optimal tillage practices and corn stover removal rates while giving consideration to environmental concerns, such as sustaining or improving soil quality and reducing soil erosion. Given the importance carbon plays in agro-ecosystems and the sustainability of a number of ecosystem services, soil organic carbon is used as a proxy for ecosystem service benefits provided by crop residues left on the soil surface.

Corn Stover as a Cellulosic Biofuel Feedstock

Corn stover has emerged as one of the potential major cellulosic biofuel feedstock sources for ethanol production in the U.S. (Wilhelm at el., 2004; Aden et al., 2002). Corn residue can provide as much as 1.7 times more carbon than residue produced by other crops such as barley, oats, sorghum, soybeans, sunflowers, and wheat (Allmaras et al., 2000). The harvesting of corn stover for biomass production may provide farmers an additional revenue generating source, but such an enterprise may result in both agronomic and environmental costs. These costs include: potential crop yield reductions, degradation in soil quality due to changes in SOC levels, and other adverse changes in soil properties (e.g. water infiltration, temperature, and nutrient balance) (Wilhelm et al., 2004). Wilhelm et al., (1986) showed that harvesting crop residues from the soil surface can result in lower corn yields due to lower soil organic matter content. Soil productivity is strongly related to soil organic matter content, which can be captured by a simple C mass balance and is affected by the amount of crop residue left on in the field, crop selection and rotation, and fertilization (Reicosky et al., 1995).

Though maintaining crop residues for soil and water conservation is important for sustainability purposes, there may be potential for partial corn stover removal as a biofuel feedstock enterprise, which may not significantly affect cash crop yields, and still help prevent soil erosion and maintain or increase soil organic matter (SOM) levels. Wilhelm et al. (2004) found that corn stover can be partially removed from the field for use in cellulosic ethanol production and removal rates will vary from site to site. Blanco-Canqui et al. (2006) found an increase in corn stover removal rates may have a positive, negative or neutral effect on corn yield due to climate, soil topography, tillage system adopted, and agri-ecosystem characteristics.

The Farm Model

The farm model is based on a risk-neutral farmer who is a profit maximizer deciding whether or not to harvest corn stover as a new cellulosic biofuel feedstock enterprise. The farmer is assumed to grow two cash crops in a fixed two-year rotation (corn-soybean) and has the choice of applying different tillage practices (no tillage, strip-till, chisel + disk, or moldboard plow). Table 2.2 provides an overview of the model including the farmer's objectives and the constraints the farmer is assumed to face.

The farmer's overall objective is to maximize profit, which is the net return from crop production (given the rotation) plus the net return from harvesting corn stover for cellulosic ethanol production. It is assumed that the variable costs for a tillage practice are held constant except for fertilizers which may change with biomass removal. The fertilizer costs are captured in each tillage practice based upon the amount of biomass removed. Given that corn stover is a byproduct of the cash crop, it is assumed the farmer does not incur any direct production costs for growing corn stover. The farmer would incur costs associated with harvesting, moving, loading, storage and transporting of corn stover if it is sold as a biofuel feedstock and depending on potential contractual obligations with the processor or bio-refinery (Epplin et al., 2007). The cost of additional nitrogen (N), phosphorus (P) and potassium (K) and estimated C replacement costs are tillage specific and are a function of the amount of the biomass removed and are discussed in detail in the next section. The inclusion of the cost of C in the objective function is to represent a cost for the loss in soil organic carbon.

The model has a number of constraints that incorporate the environmental objectives of the farmer to maintain soil organic carbon and incorporate impacts on cash crop yield and nutrient loss. Removing corn stover may result in lower crop yields due to lower soil productivity. These changes are modeled using crop yield response functions estimated using simulated data from the EPIC simulation model (Williams et al., 2006).

To maintain cash crop yields the farmer may need to replenish lost nutrients from the removal of crop biomass. Additional applications of N, P and K would be required to compensate for the nutrients lost due to biomass removal. Application rates for supplemental N are dependent on the amount of residue removed and are estimated from the EPIC application rates based on the auto-fertilization option applying N to meet crop needs. Application rates for P and K were 1.58 lbs/ton of stover removed and 13.48 lbs/ton of stover removed (Hoskinson et al., 2007).

Farmers' net returns from biomass operations are dependent on the amount of biomass harvested. One may expect higher profits with higher biomass removal rates. However, various constraints affect the amount of biomass that can be harvested. Current harvesting technologies may not allow all the biomass to be harvested. Furthermore, farmers concerned about soil erosion may use conservation tillage practices that require at least 30 percent residue cover remain on the soil surface to meet conservation standards and various conservation programmatic requirements. Another related environmental constraint is sustaining and improving soil organic matter levels. Reicosky et al. (1995) showed that soil organic matter levels can be summarized by measuring soil organic carbon (SOC). SOC changes in the model are assumed to be dependent upon the amount of biomass removed and are estimated using a response function. Again, the parameters for the SOC changes were estimated using EPIC simulation data. To maintain SOC levels, the change in SOC levels is constrained to be non-negative.

Experimental Data

Crop yield data (see table 2.4) were obtained from a tillage management study conducted at the USDA Agricultural Research Service Swan Lake Research Farm near Morris, MN. While the study design will be briefly described here, further details are available in Archer and Reicosky (2009). This 7 year experiment (1997-2003) studied a corn-soybean rotation with eight tillage systems in a randomized complete block design with five replications. The plot size was 9.1 m wide (12 rows, 76 cm row spacing) by 27.4 m long. Tillage treatments included No Till (NT), Moldboard Plow (MP), Chisel Plow (CP), and five strip till alternatives: Fall Residue Management (RM), Fall RM + Strip Till (ST), Spring RM, Spring RM + ST, and Fall RM + Subsoil. All crop and tillage treatments were present each year. Levels of herbicide application, fertilizer and seeding rates were kept the same for all practices following University of Minnesota Extension recommendations (Archer and Reicosky, 2009). Planting and harvest dates for all practices were also kept the same. Of the eight tillage practices, this study focused on NT, MP, CP and ST to compare two conventional and two conservation tillage systems using yield data from the experiment.

EPIC Modeling and Response Function Estimation

Simulation modeling was conducted using the EPIC model (Williams et al., 2006) with the i_EPIC interface (Gassman et al., 2003). Soil input data were from the SSURGO database (Soil Survey Staff, 2010), and daily weather data were from the University of

Minnesota West Central Research and Outreach Center in Morris, MN. Simulation was conducted for a period of 20 years using daily weather data for 1984 to 2003 for a Barnes loam soil, which is a common soil type in western Minnesota as well as eastern North Dakota and northeastern South Dakota. The aforementioned tillage systems study was predominantly conducted on this soil type. Model parameters were calibrated so that simulated 1997-2003 average corn and soybean yields matched average observed yields from the above described experiment within a range of ±5% for each of the tillage treatments in the field study.

Modeled management practices in the EPIC model were based on the management practices used in four of the tillage system treatments from the field study: moldboard plow (MP), chisel plow (CP), fall residue manager + strip tillage (ST), and no-till (NT). Corn stover harvest (or removal) treatments were simulated for 10 percent increments ranging from 0 to 90 percent of the above ground biomass. Simulated yields were then calibrated using actual yields for a more accurate representation of field conditions. The EPIC simulation output included the crop yields, SOC changes and amount of nitrogen application for each tillage practice to maintain crop yields. In addition, the same simulations were run without any supplemental N being applied to the cash crop to examine cash crop yield loss from residue removal.

The yield, N and SOC response functions given in table 2.2 were estimated in EXCEL using the simulated data obtained from the EPIC model. Statistical tests found that a linear relationship between the dependent variable and biomass removal rate provided the best fit. Response functions for SOC, Soybean, Corn and Nitrogen for all four tillage practices are shown in table 2.3.

Economic and Conservation Data

Crop budgets were tabulated for all four tillage practices following Lazarus and Selley (2007) and Archer and Reicosky (2009) (see table 2.5). Machinery costs were based upon Lazarus and Selley (2007) and costs for seeds, fertilizer and herbicides were the actual field costs. All costs are reported in 2008 prices. Annual prices for corn and soybean were five year averages (2003-2007) of the Minnesota price for each crop (USDA-NASS, 2010) and were $2.63bu/acre and $7.03bu/acre, respectively.

Costs for corn stover removal include harvesting (shredding, raking, baling, wrapping, moving), loading, storage and transportation. These costs were based upon Petrolia (2006) and are shown in table 2.6. Prices for nitrogen (0.49$/lb), phosphorus (0.58$/lb) and potassium (0.23$/lb) were based on five year (2003-2007) average prices (USDA-NASS, 2010). Although the carbon (C) lost due to biomass removal cannot be directly replenished, the costs for carbon replenishment were included in the model as an opportunity cost for reduced benefits due to lower SOC. Since, carbon prices vary widely amongst different sources, the base carbon price was assumed to be $0.01/lb. We later used a range of prices $0.01/lb to $0.20/lb in sensitivity analyses to reflect different pricing scenarios.

Since farmers using conservation tillage practices (e.g. no-till) should maintain at least 30 percent ground cover to maintain eligibility for conservation payments, maximum permissible limits for biomass removal were calculated using the National Agronomy Manual (USDA-NRCS, 2002). Note that this limit would not apply if a producer did not wish to maintain eligibility for conservation payments, but we use this limit to illustrate the potential impact of maintaining conservation payment eligibility. For corn a 30 percent residue cover translates into 950 lbs/acre of residue weight to be left on the field. The total biomass available on the field in our experiments is 6,600 lbs/acre. For no-till, the adjustments for over winter decay (87.5 percent retention) and planter/No-till coulter usage (85 percent retention) were made, resulting in a maximum removal rate of 80.65 percent. For Strip till, adjustments for anhydrous application (80 percent retention), over winter decay (87.5 percent retention) and planter/No-till coulter usage (85percent retention) were made resulting in a maximum removal rate of 76.45 percent. Limits on technically feasible harvest rates were not included in this analysis, so, for the conventional tillage practices, 100 percent removal was allowed. However, note that residue harvest rates are also limited indirectly in the model by the constraint that SOC changes be non-negative. This constraint will typically restrict maximum harvest rates within conventional tillage practices.

Contracting and Model Simulations

Various contract options between the farmer and a bio-refinery or intermediate processor in terms of farmer responsibilities for corn stover harvest are examined. Contracts are the likely market vehicle for emerging biomass markets and may be desired by both refineries and farmers to guard their investments. Refineries need a long-term sustainable supply, and farmers may require a strong commitment by bio-refineries to purchase their biomass. Five contractual cases are examined and based on farmer and bio-refinery responsibilities. They include:

Case 1: Farmer is responsible for harvesting, loading, transport and storage costs (HLTS).

Case 2: Farmer is responsible for harvesting, loading and transport costs (HLT). No storage costs are incurred as farmer would transport the biomass as soon as it is harvested.

Case 3: Farmer is responsible for harvesting and loading (HL) and the refinery would be responsible for transport of biomass.

Case 4: Farmer is only responsible for harvesting (H). The refinery would load and transport it.

Case 5: Farmer is not responsible for any production costs (None). The refinery would harvest, load and transport the biomass.

Case 2 represents the base case for simulations. These cases represent potential contracting situations which may arise between farmers and bio-refineries for corn stover production (Epplin et al., 2007; Rajagopal et al., 2007). Model results under each case provide an examination of the profitability of farmers under various contractual situations.

Simulations were then conducted to study the impact of changes in biomass prices and changes in carbon prices on farm profit. Variation in biomass prices would affect farmers' breakeven prices and their willingness to produce and sell biomass. A simulation with changes in carbon prices is also studied to see potential impacts of carbon replenishing costs although such technology doesn't presently exist. For all simulation runs, the distance to the refinery was assumed to be 50 miles. Following Sheehan et al., (2004) who stated that the corn stover prices should be in the range of \$46 to \$49 per dry ton for most refineries, we assumed an initial biomass selling price of \$50 per dry ton.

Results

Table 2.7 provides the results for the farm optimization model for Case 2 (the base case) at a biomass price of \$50 per dry ton for all the tillage practices examined. In addition, the results are shown for the case when supplemental N is applied and is not applied, meaning the farmer may take a yield loss. The results show that the farmer would maximize profit by adopting no-till and harvesting 80.65% of the available corn stover. The farmer would earn a profit of \$164.73/acre by not applying supplemental nitrogen and would make only \$148.53/acre by adding supplemental nitrogen. Thus, given N prices used in the model, the farmer would be better off not applying supplemental N to his crops. That is, the yield loss and subsequent revenue loss from harvesting crop biomass is less than the cost of the supplemental N. Given these findings, the remainder of the results assume no additional supplemental N is used. Within each tillage system, the economic incentive is to remove the maximum amount of residue allowable while meeting minimum residue and SOC requirements.

To examine the sensitivity of the results to the price of cellulosic biomass, this price was varied between $5 to $100 per dry ton for each of the contract cases described in the previous section. Results are shown in figure 2.1. Farmers would break even at a price of $5.10 per dry ton if the refinery agreed to harvest, load and transport at its expense (case 5). If the farmer had to incur all these costs and store the biomass (case 1), the break-even price would increase to $43.20. If the farmer decided not to harvest any biomass, then profits would be $146.15 per acre. In each case, profits are maximized with no residue removal for prices below the break even, and at the maximum allowable removal rate (subject to minimum residue and SOC constraints) for prices above the break even. Assuming a biomass selling price of $50 per dry ton, a farmer’s profits would range between $155 and $205.65 depending upon the biomass harvesting production costs incurred by the farmer. Similarly, profits would range between $221.54 and $272.18 per acre if biomass prices increased to $100 per dry ton.

Replenishing lost carbon in the soil is not possible using fertilizers, unlike N, P and K, due to technological limitations. In addition, soil productivity and health are dependent on the level of carbon in the soil. Thus, removal of potential carbon from entering the soil can be captured as a cost. The model incorporates the cost of carbon as an opportunity cost of reduced soil benefits from corn stover harvest. It also has implications for climate change policy in terms of providing a dollar figure for sequestered carbon. Carbon prices were varied in simulations between $0.01/lb to $0.20/lb ($20 to $400/ton). Results show that farm profits would vary between $155 and $206 per acre for the five cases (figure 2.2). The switch-over price at which a farmer would not harvest biomass due to the higher value of carbon in the soil for the five cases, HLTS, HLT, HL, H and none, would be $0.08, $0.14, $0.24, $0.26 and $0.42 respectively. Note that simulation model results showed SOC changes, and both corn and soybean yields were linear functions of residue removal rates (data not shown). As a result, net returns are linear in carbon prices, so profits are maximized by harvesting at the highest allowable rate for carbon prices below the switchover price, with no residue harvest for carbon prices above the switchover price.

Studying changes in profit by varying the biomass selling price can provide insight for policymakers and farmers when coupled with the impact of the percent of corn stover removed. Simulations were conducted to study changes in profit by varying the percent biomass removed from 0 to 100 percent and the biomass selling price from $0 per dry ton to $100 per dry ton. It was assumed that the farmer was responsible only for the shredding and the raking costs and all other production costs were paid by the refinery This has important policy implications as it allows calculations of farm payments using the biomass selling price.

The maximum permissible biomass a farmer using no till could remove while complying with the conservation tillage requirements would be 80.65 percent. Assuming a biomass selling price of $50 per dry ton, the farmer would earn a profit of $199.64 per acre. If the farmer decided to harvest all corn stover, then the profits would increase to $214.16 per acre. Thus, the farmer would need to be supplied a subsidy of $14.52 per acre to adopt conservation tillage practices with the biomass enterprise (figure 2.3).

This has important implications when considering ecosystem services. The above example illustrates how conservation programs, such as the Environmental Quality Incentives Program, could provide support for ecosystems services related to conservation (e.g. soil erosion, nutrient leaching, etc.) This type of analysis can be pushed further, to examine a policy to intensify the protection of ecosystem services. Consider the case, where policy makers wish to cap the maximum allowable biomass removal at 50 percent in order to intensify soil conservation efforts. In this case, a profit maximizing farmer would require a subsidy of $23 per acre to compensate voluntarily cap biomass removal at 50 percent (figure 2.3).

Corn stover removal for ethanol production may prove to be a profitable enterprise for farmers. Model results indicate the use of conservation tillage practices, may provide an opportunity for farmers to profitably produce bioenergy feedstocks while increasing ecosystem services as measured by SOC. Placing limits on crop residue harvest amounts could further increase SOC; however these limits would tend to reduce farm profitability and might require incentives for voluntary adoption. The modeled potential for conservation tillage practices to allow for sustainable crop residue harvest will need to be confirmed by field research, particularly since impacts of conservation tillage practices on SOC are not incontrovertible (Baker et al., 2007).

IV. CHALLENGES AND OPPORTUNITIES

Factors other than net returns likely influence adoption. Our case example showed NT to by the most profitable tillage system with crop residue harvest. In addition, field research has indicated NT is more profitable than MP, and is competitive with CP without crop residue harvest (Archer and Reicosky, 2009), yet adoption of NT is limited in the study region. This may indicate that producers will be reluctant to adopt NT in production of biofeedstocks even if it was more profitable.

While crop residue removal and carbon sequestration may be seen as incompatible, our case example shows it may be possible, with appropriate changes in tillage practices. Other research suggests that it is possible to balance both in integrated systems (Milder, et al., 2008). These integrated systems must take the multitude of ecosystem services into consideration to be sustainable (Mapemba et al., 2007). Thus, the goal is to develop integrated crop production systems that improve or sustain soil organic carbon levels. This can potentially be obtained through the integration of proper conservation practices, including: crop nutrient management (Allmaras, 2004; Kaur et al., 2008; Lemke et al., 2010; Wilts, et al., 2004), soil amendments (Kelly et al., 1997), crop rotation (West and Post; 2002), conservation tillage (Hooker et al., 2005; Chan et al., 2002) and residue management (Abrahamson et al., 2009).

An alternative to the use of crop residues for bioenergy feedstock is the use of perennials such as switchgrass or miscanthus. It has been suggested that the use of perennials could help increase ecological services while meeting feedstock needs (Atwell et al., 2010; Jordan et al., 2007; Paine et al., 1996). Indeed, production and use of perennials as bioenergy feedstocks has been shown to decrease net greenhouse gas emissions (Adler et al., 2007; Schmer, et al., 2008; Tilman et al., 2008), and decrease erosion, nitrogen leaching and denitrification relative to annual crops (Vadas et al., 2008). However, a key factor is the direct and indirect effects on land use, as this has implications for global services such as net greenhouse gas emissions (Searchinger et al., 2008) or local services such as natural pest control services (Landis et al., 2008). If perennials are grown on existing cropland, this could result in forest or other sensitive lands being converted to crop production increasing greenhouse gas emissions on the newly converted lands (Searchinger et al., 2008). Also, it is difficult for perennial biomass crops to be economically competitive with annual crops on productive land (James et al., 2010).

Although, there are some cases where perennial/annual crop rotations may be viable (Vadas et al., 2008).

Many have suggested that perennial bioenergy crops (e.g. switchgrass or miscanthus) and/or short rotation woody crops be grown on sensitive, marginal, degraded, idle or abandoned lands (Blanco-Canqui, 2010; Campbell et al., 2008; Lemus and Lal, 2005; Paine et al., 1996; Tilman et al., 2008). Since these lands often have low productivity for annual crop production or are not currently used for crop production, using these lands for perennial biomass energy crops would reduce or eliminate the need to bring additional lands into annual crop production. Also, these are the lands where perennial biomass production is likely to be more economically produced (McLaughlin et al., 2002; Walsh et al., 2003).

Cover crops, such as small grains, grown for conservation purposes may provide another cellulosic biomass source, as an alternative to crop residues (e.g. corn stover). While a portion of the cover crop residue (e.g. rye straw) would be harvested, the cover crop will still likely provide a myriad of conservation benefits, while still helping to maintain residue levels in conservation cropping systems. Cover crops can boost soil productivity as they increase soil organic carbon levels, improve water infiltration and reduce soil erosion (Reeves, 1994; Wilhelm et al., 2004). These benefits are primarily realized in the form of improved cash crop yields from improved soil productivity following the cover crop (Lotter et al; 2003). Cover crops also play a role in improving weed suppression, nutrient cycling and cash crop yield stability (Lotter et al; 2003, Snapp et al; 2005, Creamer et al; 1996). The decision to grow heavy residue cover crops as a biofuel feedstock may be complicated by the reduction in conservation benefits resulting from biomass removal from the soil surface. Although these benefits may not be assigned a direct monetary value, it is necessary for the farmer to weigh the agronomic, economic and environmental benefits and costs, when considering growing a cover crop as a cellulosic biofuel feedstock source (Wilhelm et al., 2004).

Anand et al. (2008) examined the willingness of farmers in Alabama to supply cover crop residue as a biofuel feedstock source. Fifty-seven percent of the farmers surveyed indicated they would be willingness to produce a cover crop for biofuel production. The results provide some basis that farmers are willing to supply cover crops residues at the right price. Modeling results indicated that the minimum price farmers would be willing to accept for a dry ton of rye or wheat straw (when used as a cover crop) is $54.62, which is in line with the other predicted market prices. They assume that the farmer would be responsible for harvesting and transporting the stover to the refinery.

Within all of these systems, moderate volumes of biomass may be harvested for biofuel production, differing on a site-by-site basis. The determination of the volumes and frequency of biomass or residue removal that is sustainable without adversely affecting SOC pools and ecosystem services is site specific and needs to be determined (Cherebini and Ulgiati, 2010; Lafond et al 2009; Wilhelm et al., 2004).

While SOC may serve as a proxy for the provision of many ecosystem services, there are many other ecosystem services that were not included in the case example, many of which would be spatially dependent. This greatly complicates analysis that would lead to a full accounting of ecosystem services. In addition to the externality aspects of ecosystem services, this complexity and uncertainty in quantifying ecosystem services serves as a cause for market failure in the provision of these services (Yang et al., 2010). Hence, there is a need to improve our capacity to quantify impacts of our actions along with appropriate measures of uncertainty (Carpenter, et al., 2009).

V. CONCLUSIONS

Our case example showed the potential for corn stover to be harvested for bioenergy, providing both positive economic returns and increasing ecosystem services, as measured by changes in SOC, if NT practices were adopted. Our results also quantified economic incentives necessary to further increase provision of ecosystem services. However, the results were for a single site, with a single soil type. Changes in SOC are tied directly to the ecosystem services of climate regulation which is not sensitive to where C sequestration occurs. Changes in SOC have other potential ecosystem service effects which are sensitive to location (e.g. effects on water quality and quantity). In addition, bioenergy feedstock production can have impacts on a wide range of other ecosystem services. In evaluating potential for bioenergy production to increase provision of ecosystem services, it will be important to include multiple sites and multiple ecosystem services, and include spatially sensitive impacts.

Our case example analyzed net returns and ecosystem impacts for several contract alternatives. However, the analysis did not include uncertainty. Contract provisions will be particularly important under uncertainty, as will be potential impacts of bioenergy production on economic and ecosystem risks. This is an important area for future analysis as is inclusion of factors other than economics that may influence adoption of biofeedstock production alternatives.

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Table 2.1: Reported Effects of Biomass Harvesting and/or Removal in the Literature for Alternative Biofuel Feedstock Sources.

Cellulosic Biomass Feedstock	Reported Impact from Biomass/Residue Removal	Source
Corn stover	Loss of Soil Organic Carbon	Gabrielle and Gagnaire (2008); Anderson-Teixeira (2009); Wilts et al. (2004); Allmaras et al. (2004); Blanco-Canqui and Lal (2009b)
	Reduction in soil aggregate stability	Blanco-Canqui et al. (2006)
	Reductions in soil microbiology	Blanco-Canqui and Lal (2007)
	Soil compaction and soil erosion	Blanco-Canqui and Lal (2007); Mickelson et al. (2001)
	Decrease in soil water retention	Blanco-Canqui and Lal (2007)
	Nutrient removal (N, P, K)	Blanco-Canqui and Lal (2009b); Propheter and Staggenborg (2010)
	Decrease in cash crop yields	Wilhelm et al, (1986)
Wheat straw	Loss of Soil Organic Carbon	Saffih-Hdadi and Mary (2008); Cherebini and Ulgiati, (2010); Gabrielle and Gagnaire (2008)
	Reduction of soil aggregate stability	Black (1973)
	Nutrient removal (N,P,K)	Black (1973)
	Decrease in cash crop yields	Gabrielle and Gagnaire (2008)
Perennial grasses	Reduction of greenhouse gas emissions	Schmer et al. (2008)
	Change in SOC -Increase or no change -Loss in SOC with excess removal	Tilman et al. (2008) Liebig et al. (2008); Skinner (2008)
	Nutrient removal (N,P,K)	Propheter and Staggenborg (2010)
Woody crops	Loss of Soil Organic Carbon	Blanco-Canqui (2010)

Table 2.2: Farm Optimization Model.

Component	Functional Representation	Description
Farming Objective		
Maximize Profit	$\Pi_j = \left[\sum_{i,j} D_{i,j} \left(Y_{i,j} p_i^c - w_{i,j}^c \right) \right] + \left[\begin{array}{l} (p^b b_j R) - (H^b + L^b b_j R + S^b b_j R \\ + T^b b_j Rd + N_j^c + P_j^c + K_j^c + M_j^c) \end{array} \right]$	The profit function represents the net return from crop production plus the net return from harvesting corn stover as a cellulosic biofuel feedstock.
Model Constraints		
Yield Response	$Y_{i,j} = \alpha_{i,j} + \beta_{i,j} R \quad \forall (i, j)$	These functions estimate cash crop yield for corn and soybeans based on corn stover removal rates and tillage practice used.
Nutrient Accounting	$N_j^c = \phi_j + \sigma_j R \quad \forall\ j$ $C_j = \gamma_j + \delta_j R \quad \forall\ j$	These functions estimate the amount of nitrogen to maintain crop yields (to be replaced) and the loss in soil organic carbon.
Residue Retention	$R \le \eta_j$	This constraint limits the amount of corn stover that can be removed from the field.
Change in Soil Organic Carbon	$C_j \ge 0 \quad \forall\ j$	This constraint requires that the change in soil organic carbon levels remain positive or at current levels
Nonnegativity	$R \ge 0$	Biomass removal rates cannot be negative.

Notation Used:

b_j = Amount (tons/acre) of corn stover produced using tillage *j;*

C_j = Annual average change in SOC in lbs/acre/year for tillage practice *j*

$D_{i,j}$ = Dummy variable indicating the choice of tillage practice *j* for crop *i*;

d = Distance to the refinery

H^b = Harvesting costs for corn stover ($/acre);

i = Crop Index: Soybean or corn;

j = Tillage Index: No tillage, strip-till, chisel + disk, or moldboard plow;

K_j^c = Cost of Potassium application;

L^b = Loading costs of corn stover ($/ton);

M_j^c = Estimated cost of replacing lost carbon in soil;

N_j^c = Cost of additional nitrogen application to maintain yields;

p^b = Price ($) per unit for corn stover;

p_i^c = Price ($) per unit for crop *i*;

P_j^c = Cost of Phosphorus application;

Table 2.2: Farm Optimization Model. Continued

R = Percent corn stover removed per acre;
S^b = Storage costs of corn stover (\$/ton);
T^b = Cost of transporting corn stover (\$/ton/mile)
$w^c_{i,j}$ = Variable cost for producing cash crop i using tillage practice j (\$/acre);
$Y_{i,j}$ = Yield per acre of crop i using tillage practice j;
η_j = Maximum permissible level of biomass that can be removed for tillage practice j;
$\alpha, \beta, \phi, \sigma, \gamma$ and δ are estimable parameters.

Table 2.3: Response Functions for Soil Organic Carbon (SOC), Soybean, Corn and Nitrogen for all Four Tillage Practices.

	MP[1]	**ST[1]**	**CP[1]**	**NT[1]**
Nitrogen Supplement				
SOC	55.80-251.42R	410.83-378.31R	234.40-293.97R	374.60-360.28R
	(R^2 =0.9984)	(R^2 =0.9999)	(R^2 =0.9985)	R^2 = (0.9913)
Soybean	45.91-0.09R	43.93+0.42R	45.36+0.09R	44.03+0.34R
	(R^2 =0.9262)	(R^2 =0.9413)	(R^2 =0.8804)	(R^2 =0.8196)
Corn	158.81-0.15R	161.84+0.39R	159.70-0.03R	157.34+0.46R
	(R^2 =0.8649)	(R^2 =0.6298)	(R^2 =0.0529)	(R^2 =0.8054)
Nitrogen	196.83+56.16R	201.84+53.85R	201.80+55.83R	196.73+54.91R
	(R^2 =0.9994)	(R^2 =0.9997)	(R^2 =0.9995)	(R^2 =0.9997)
No Additional Nitrogen				
SOC	53.08-252.53R	414.01-380.16R	234.61-293.58R	373.86-360.24R
	(R^2 =0.9992)	(R^2 =0.9999)	(R^2 =0.9985)	(R^2 =0.9917)
Soybean	45.91-0.09R	43.93+0.42R	45.36+.09R	44.03+0.34R
	(R^2 =0.9372)	R^2 = (0.9427)	(R^2 =0.8679)	(R^2 =0.8215)
Corn	158.86-0.73R	161.79-0.34R	159.71-0.76R	157.37-0.24R
	(R^2 =0.9936)	(R^2 =0.7660)	(R^2 =0.9721)	(R^2 =0.6907)

[1]MP: Moldboard Plow, ST: Strip Till, CP: Chisel Plow, NT: No-Till

Table 2.4: Average Crop Yields at Swan Lake Research Farm near Morris, MN. 1997-2003.

Tillage Practices	Soybean Yield (Bu/acres)	Corn Yield (Bu/acres)
Moldboard Plow	45.90	158.79
Fall residue mgmt and strip till	43.96	161.63
Chisel Plow	45.37	159.72
No-Till	44.09	157.27

Source: Archer and Reicosky, 2009

Table 2.5: Cash Crop Cost Budgets for Corn and Soybean, 2008 ($/ acre).

Tillage System	No-till	Moldboard Plow	Chisel Plow	Fall RM + Strip Till
Corn Production:				
Labor	6.89	11.34	9.77	8.67
Repairs	7.54	11.58	9.18	8.73
Diesel Fuel	6.51	13.62	10.39	10.29
Seed, Fertilizer, Herbicide	112.46	112.46	112.46	112.46
Interest	5.03	5.84	5.43	5.37
Depreciation	19.83	32.10	27.47	28.41
Drying Fuel	40.90	39.12	36.21	39.10
Total Operating Costs	199.17	226.06	210.91	213.05
Overhead	14.73	24.98	21.04	21.28
Total Cost	213.90	251.05	231.94	234.33
Soybean Production:				
Labor	6.32	12.04	10.46	8.10
Repairs	6.46	11.35	9.12	7.65
Fuel	5.76	13.89	11.23	9.52
Seed, Fertilizer, Herbicide	70.82	70.82	70.82	70.82
Interest	2.11	3.12	2.72	2.45
Depreciation	16.01	30.53	26.78	24.54
Drying Fuel	1.11	0.66	0.67	0.69
Total Operating costs	108.59	142.40	131.81	123.77
Overhead	12.16	24.54	21.59	18.67
Total Cost	**120.75**	**166.94**	**153.40**	**142.44**

Source: Archer and Reicosky, 2009

Table 2.6: Biomass Costs for Corn Stover Removal.

Operation	COST		
Shredding[1]	10.63	$/acre	
Raking[2]	6.80	$/acre	
Baling	12.67	$/acre	
Wrapping	4.60	$/ton	
Moving	4.57	$/ton	
Loading	3.10	$/ton	
Storage	7.31	$/ton	
Transportation	0.303	$/ton/mile	w/in 25 miles of plant
	0.198	$/ton/mile	26-100 miles from plant
	0.16	$/ton/mile	>100 miles from plant

Source: Petrolia, 2006

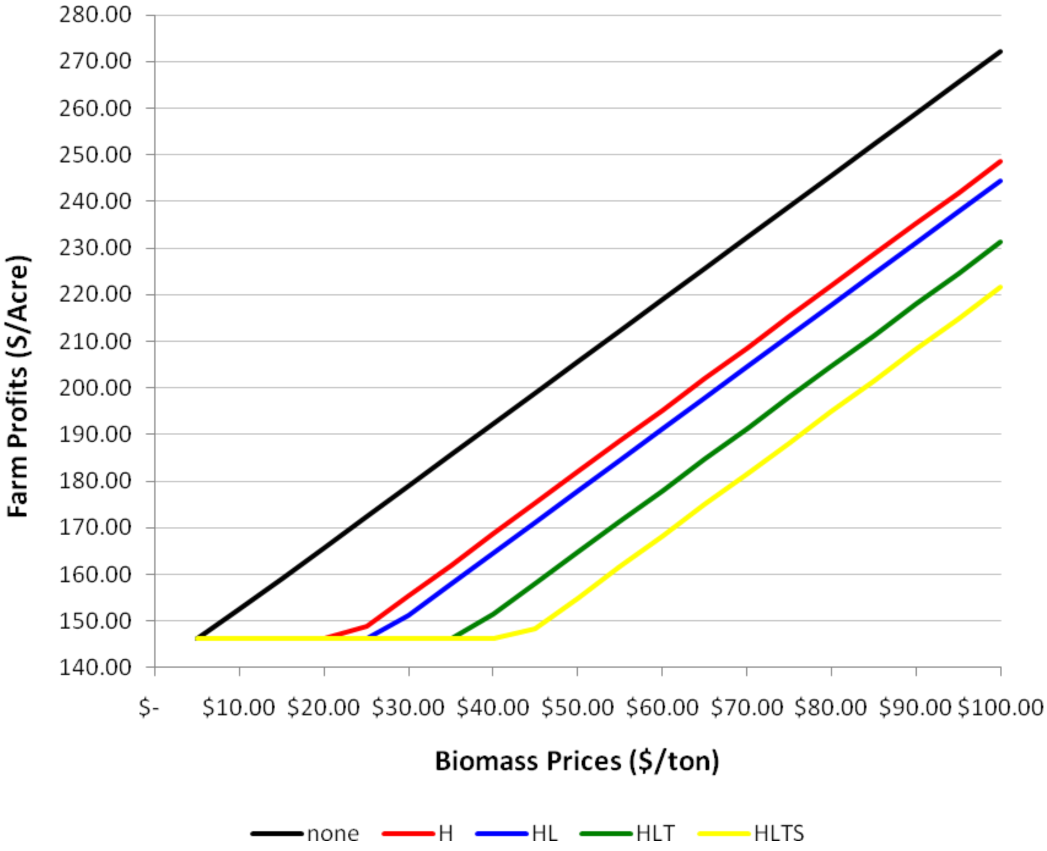
[1] Assumed this was done in conventional till (CT) regardless of whether biomass harvested. For Strip Till (ST) it is assumed this would only be used if raking (>30% harvest)

[2] Assumed this would only be used for >30% harvest, otherwise could just bale the windrow.

Table 2.7: Comparison of Farm Profits under Different Tillage Practices.

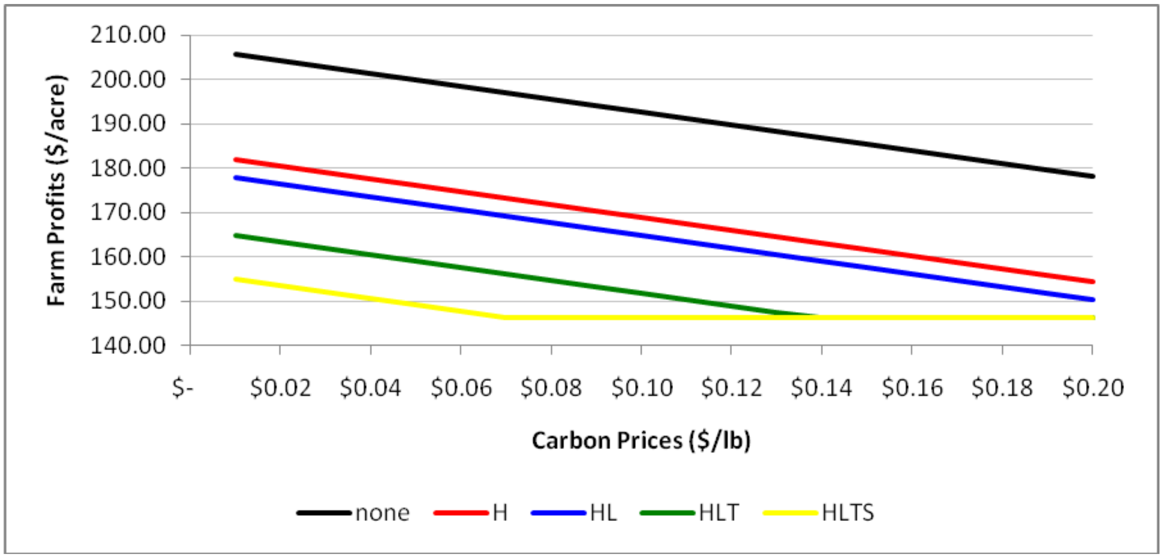
Tillage System	**MP[1]**	**ST[1]**	**CP[1]**	**NT[1]**	**MP[1]**	**ST[1]**	**CP[1]**	**NT[1]**
	------ Nitrogen Supplement-------				--------No Additional Nitrogen ------			
% BM Removed	0.22	0.76	0.80	0.81	0.21	0.76	0.80	0.81
SOC (lb/acre)	0.00	121.62	0.00	84.03	0.00	123.38	0.00	83.32
Corn Profit ($/Acre)	35.04	46.59	44.57	52.24	33.91	45.98	43.98	50.47
Soybean Profit ($/Acre)	77.83	84.32	82.99	95.37	77.83	84.32	82.98	95.37
Biomass Profit ($/Acre)	0.08	2.21	12.30	1.83	2.68	18.06	23.28	18.89
Total Profit	**112.96**	**132.19**	**139.86**	**148.53**	**114.42**	**148.37**	**150.25**	**164.73**

[1] MP: Moldboard Plow, ST: Strip Till, CP: Chisel Plow, NT: No-Till



None: Farmer is not responsible for harvesting, loading, transport and storage costs
H: Farmer is responsible only for the harvesting costs
HL: Farmer is responsible for harvesting and loading costs
HLT: Farmer is responsible for harvesting, loading and transport costs
HLTS: Farmer is responsible for harvesting, loading, transport and storage costs

Figure 2.1: Change in Farm Profits with Change in Biomass Prices.



None: Farmer is not responsible for harvesting, loading, transport and storage costs
H: Farmer is responsible only for the harvesting costs
HL: Farmer is responsible for harvesting and loading costs
HLT: Farmer is responsible for harvesting, loading and transport costs
HLTS: Farmer is responsible for harvesting, loading, transport and storage costs

Figure 2.2: Change in Farm Profits with Change in Carbon Prices.

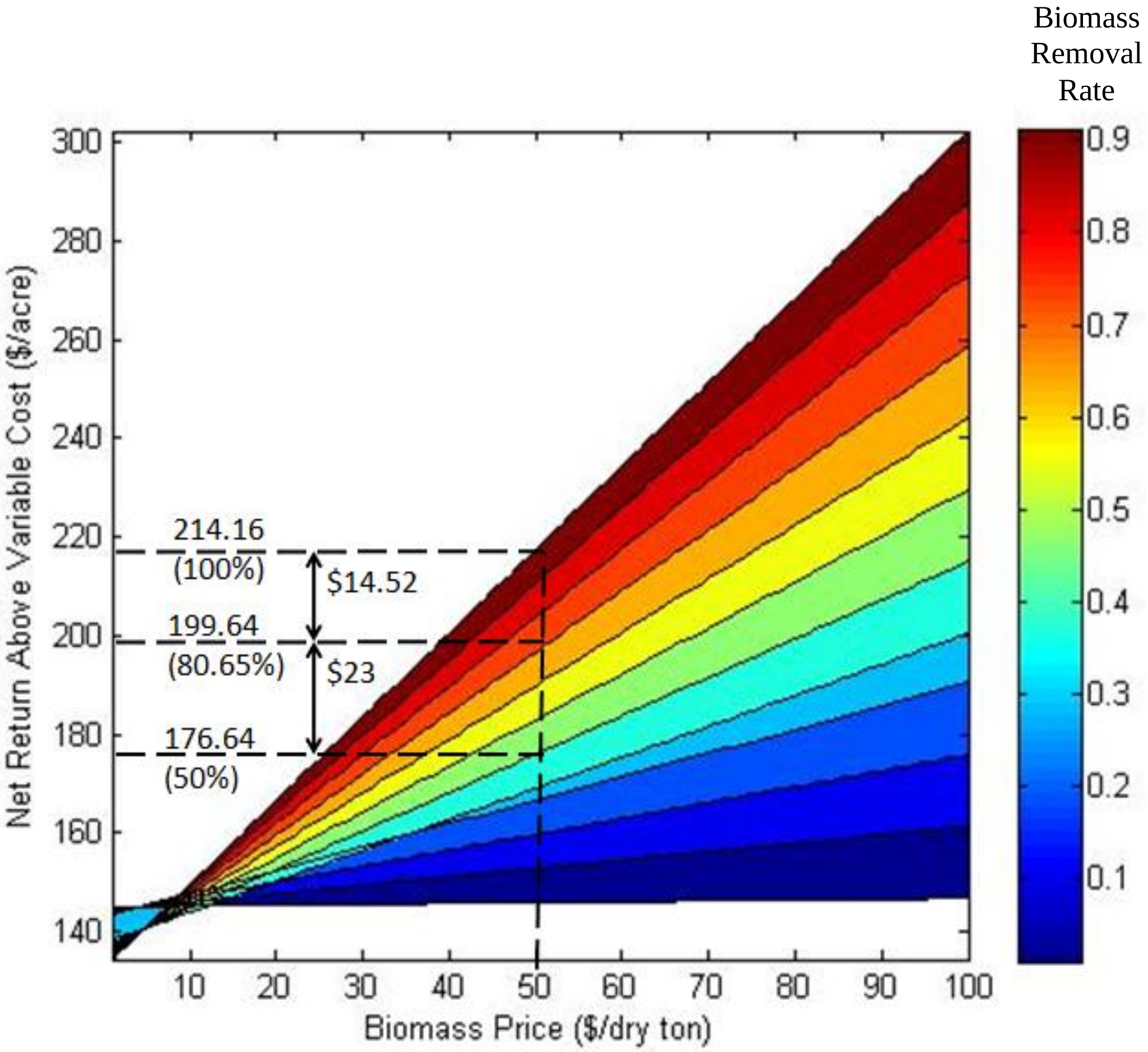


Figure 2.3: Response Surface of Farm Profit Versus Biomass Price Showing Removal Rate Contours for a Case Farm Responsible for Harvesting of the Biomass.

Risks and Returns for Cattle Owners under Contract Grazing

I. INTRODUCTION

Traditionally, stocker production has been an integrated operation. Producers breed calves, wean them and put them on a pasture. Calves graze on the pasture consuming feed high in roughage (e.g. oats, ryegrass, rye, millet) for 90-180 days. After that they are given a concentrated feed (e.g. corn) for another 100-200 days based upon their weight till they are ready for slaughter.

Integrated operations are capital intensive. Johnson et al. (1987) reported the cost of back-grounding 200 steers on a 100 acre farm on ryegrass would be $50,000 for animal purchase and an additional $10,000 for forage production. Moreover, the operator has to take both production risk and price risk. Production risk arises as a result of variability in weight gain of cattle due to agronomic and climatic factors. Variability exists in both the purchase and selling prices of cattle due to market forces resulting in a price risk. Cattle prices have always been very volatile (Spreen and Arnade, 1984). The cattle owner has limited options of reducing price risks by opting for cattle futures or forward contracting (Harrison et al., 1996)

Since the mid-twentieth century, the use of grazing contracts in cattle production has become very common in the cattle industry (Anderson et al., 2004). In this case, a pasture owner does not need to breed or purchase calves and incur heavy investments. Pasture owners could allow cattle owners to graze their animals on the pasture for a fee, which is usually in the form of a set amount per unit of weight gain. Thus, contract grazing provides a revenue-generating opportunity for those pasture owners whose cattle purchasing opportunity is limited due to cash flow concerns (Zaragoza-Ramírez et al., 2008)

With the option to contract graze we define two new categories of operators: a) pasture owners, who do not own any cattle and allow cattle owners to graze cattle on their pasture; and b) cattle owners, who own cattle but don't own any pasture. The cattle owners would purchase weaned calves and then contract for the pasture owner to add weight to them. The term "integrated operator" in this paper refers to an operator who owns both the cattle and the pasture.

Contract grazing presents an opportunity to the cattle owner to reduce fixed investment costs. This means low entry and exit costs. Although, being a cattle owner is less profitable than being an integrated operator (Anderson et al., 2004), it is advantageous in the form of less capital requirements.

Many previous studies in contract grazing have been forage studies comparing the risks and returns of a pasture owner to a cattle owner and/or integrated operator. Zaragoza-Ramírez et al., (2008) have suggested traditional cattle ownership to be more profitable than contract grazing assuming there are no investment limitations. Johnson et al. (1987) showed that an integrated cattle owner has larger profits than a non-integrated cattle owner, with only slightly higher levels of risk; whereas risk for the cattle owner is substantially higher than the pasture owner. Most studies have shown that contract grazing presents lower risk to the pasture owner as compared to total ownership under an integrated program (Anderson et al., 2004; Harrison et al., 1996; Johnson et al., 1987). Little research has compared different strategies for cattle owners in terms of risk and returns. No previous study has examined options available to the cattle owner to lower risks.

The objective of this paper is to study the factors affecting risk and profitability for the cattle owner and to assess various options available for reducing risk. Critical decision factors for the cattle owner include the initial weight at which to buy the cattle, the duration for which they are kept in the pasture and the duration for which they are kept in the feedlot. Johnson et al. (1987) have noted that weight gains in pasture vary from year to year whereas they are predictable in feedlots. As a secondary objective, the paper compares the risks and returns in an alternative case where the cattle owner bypasses the pasture and places cattle directly at the feedlots.

II. DATA

This section describes data used in the study.

Pasture data

The data for cattle weight gain on pasture used in this study were collected from various field experiments (PRN# 2007-118) conducted over four years (2006-2009) at the Beef Cattle Unit of the Alabama Agricultural Experiment Station's E.V. Smith Research Center, Shorter, AL. For each year, weaned cattle were weighed and randomly placed on different paddocks on the pasture using a completely randomized design. The cattle grazed continuously throughout the grazing period and were weighed approximately every 28 days. A total of 854 cattle were studied over four years with an average starting weight of 530 lbs and an average ending weight of 790 lbs resulting in an average daily gain (ADG) of 2.6 lbs/day. The details of the forages, stocking rates, grazing days and treatment are shown in table 3.1.

Data from different experiments were used to represent one source of risk to the cattle owner. Under contract grazing, a cattle owner enters into a contract with a pasture owner to place cattle on pasture and then pays the pasture owner a fixed amount per pound of weight gain. The contract generally specifies pasture practices such as types of forages fed, stocking rates, additional feed/supplements given, implants and immunizations given. In reality, however, in spite of the contract, the pasture owner actually has complete control of pasture practices (Mcfarland, personal communication, 2009). Forages might vary year to year depending on choices of the pasture owner. The pasture owner would also control practices such as stocking rate or feeds/supplements. For example, in the case of a good forage crop, the pasture owner might skip the supplements or may increase the stocking rate. Similarly, if the crop is poor the pasture owner might provide additional supplements/implants if the cost of supplements/implants per pound of weight gain is less than the value of the additional gain.

In sum, although profits of both the pasture owner and cattle owner depend upon the weight gained by the cattle, only the pasture owner has control of the pasture practices. To reflect actual risk presented to the cattle owner, the data must be randomly collected over different years, using different forages with differences in pasture practices such as feeds/supplements, implants, and immunizations.

Feedlot data

Contrary to pasture practices, a feedlot presents a controlled environment for the cattle. At the feedlot, cattle are not affected by the amount or quality of forage. Year, weather and rainfall have little or no effect as cattle are fed a predetermined ration. For the feedlot, the cattle owner has complete control and can decide what is fed to the cattle. Most feedlots will provide details on individual cattle basis.

The data for the feedlot operations were obtained from the Alabama Pasture to Rail Program conducted by Alabama Cooperative Extension System (ACES) every year (ACES, 2010). This retained ownership program provides individual post-weaning growth, carcass and health information to cattle owners. Under this program, cattle owners consign cattle having an average weight between 600 and 850 lbs. Cattle are weighed, tagged and graded at the shipping point. The cattle are then sent to Decatur County Feed Yard, Oberlin, KS. Upon arrival, cattle are fed starter ration and free choice hay. Cattle are managed on an individual basis rather than by the pen, which means feed and weight gain records of individual animals are maintained.

Depending on the back fat, cattle could be harvested over a two to seven month period. The cattle are sold upon reaching approximately 0.4 inch back fat. Cattle are sold individually based upon carcass characteristics to Cargill on a negotiated grid which is based on yield and quality grade (USDA yield grade 3 calves grading). Premiums and discounts are added to individual carcass data. The quality grade of cattle is determined by the quality of fat on the cattle. The variation in quality also presents a risk to the cattle owner.

The data contained starting weights, number of days on feedlot, expenses on feed, ending weight and selling price of each individual animal. Data for a total of 489 cattle were collected over three years, 183 cattle for 2006, 86 cattle for 2007 and 220 cattle for 2008. The average starting weight was 660 lbs. Cattle gained an average of 606 lbs over 182 days resulting in an ADG of 3.29 lbs/day.

Price Data

Cattle purchase price data for the state of Alabama were obtained from ACES publications (Prevatt and Todd, 1997; Prevatt et al., 2008). A total of 21 years of data (1986-1996 and 1998-2007) was used for four weight ranges; 400-500 lbs, 500-600 lbs, 600-700 lbs and 700-800 lbs for medium and large number 1 grade feeder steers. Cattle prices for each category were adjusted to the 2007 prices using the consumer price index (CPI). Actual individual selling price data were available from the feedlot for each animal sold.

III. MODEL

A stochastic simulation model using Simulation and Econometrics to Analyze Risk (SIMETAR) software was used to empirically estimate the return on investment (ROI) distributions for a cattle owner. SIMETAR is an Excel™ add-in for conducting complex stochastic simulation models for decision making and risk analysis. The ROI function is given by the ratio of total profit to total costs.

$$\text{ROI} = \pi/C \qquad (1)$$

where π is the profit function and C is the cost function.

The profit function (π) is represented by:

$$\pi = N^* (S - C) \qquad (2)$$

where N represents number of animals. S is the selling price of the animal ($) and is stochastic.

The Cost function (C) is represented by:

$$C = (CPP^*Wt)+TC_p+(WG_p^*CP_p)+TC_f+(WG_f^*CF) \qquad (3)$$

where CPP is the stochastic purchase price of a weaned animal ($/lb); Wt is the average weight of the animal purchased; TC_p is the transportation cost to transport the weaned animal to the pasture ($); WG_p is the stochastic weight gained by the animal at the pasture (lbs); CP_p is the contract price ($/lb) for weight gained at the pasture and is varied across a range of prices for the analysis; TC_f is the transportation cost to transport the animal from pasture to feedlot ($); WG_f is the stochastic weight gained by the cattle at the feedlot (lbs) and CF is the stochastic feed cost per pound of weight gained for the animal at the feedlot ($/lb).

An empirical distribution was estimated and used to simulate CPP. Prices for each weight range were reflected as a ratio to the base weight (400-500lbs). This ensured that each simulation reflected the decline in prices ($/lb) for heavier animals. Average feed cost (CF) per pound of weight gained for the animal at the feedlot is also estimated similarly using an empirical distribution.

Linear regressions were performed to estimate ending weights at the pasture and feedlot respectively (WG_p and WG_f) and to ascertain the impact of variables such as starting weight, and number of days on the ending weight. The estimations of WG_p and WG_f are discussed in detail further below in the section named estimated relationships.

The final selling price (S) of the animal is dependent on the quality of fat on the animals. The fat gained on the feedlot is of higher quality than that from the pasture operations due of the nature of the feed given to the cattle. To capture this variable into the analysis, a quality variable was created to reflect the fat gained at the feedlot by taking a ratio of weight gained on feedlot to the starting weight of the animal. Linear regression was performed to see the effect of starting weight, quality, year and number of days on feedlot on the selling price. The estimation is discussed in detail further below in the section named estimated relationships.

Assumptions

For the pasture study, the grazing data were divided into three subgroups to study different scenarios with starting weights ranging between 400-500 lbs, 500-600 lbs, and 600-700 lbs. Summary statistics for the three weight ranges are presented in table 3.2. It is assumed that the cattle owner would purchase the cattle within a radius of 300 miles of the pasture. A radius of 300 miles is assumed based on personal communication with a cattle owner in Alabama (McFarland, personal communication, 2009) and also due to the fact that it would cover most of areas supplying weaned cattle in Alabama, Mississippi, Georgia and Northern Florida. Transportation costs were obtained from the feedlot data from the pasture to rail program using actual transport costs for transporting animals from the pasture to feedlot. They were calculated to be $3.1 per mile for a truck load. A weight loss of 2% during transportation applied to the data (McFarland, personal communication, 2009). Cattle in the above three categories were grazed for 100, 95 and 90 days respectively so that the average ending weights will be ~~at~~ approximately 700 lbs, 800 lbs and 900 lbs respectively. These ending weights are realistic, given the starting weights, and correspond to the typical starting weights at the feedlot and also match the conditions of the Alabama pasture to rail program.

Feedlot data were divided into six categories. The first three are for the above mentioned scenarios where the animals are taken from pasture and sent to the feedlot. The remaining three categories were created for placing the cattle directly onto the feedlot skipping the pasture. The average starting weights for these categories are approximately 550 lbs, 650 lbs and 750 lbs. The summary statistics for the feedlot data are in table 3.3.

A contract price of $0.30/lb for the pasture grazing was assumed for the base scenario keeping in line with the equal return grazing fee[5] of $0.3080/lb found by Anderson et al. (2004).

Estimated Relationships

Linear regression was performed to ascertain how starting weight, number of days and year affect the ending weight of the animal and to obtain the predicted ending weight for the cattle while in pasture and feedlot. The relationship between ending weight to starting weight, number of days and year were assumed to be linear. Since, weight gain at the feedlot is not

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[5] equal return grazing fee is the fee at which both pasture owner and cattle owner would have equal returns.

affected by the weather; year did not have any significant effect on the weight gain and was excluded from the final regression results. The regression results for the weight gain at pasture and feedlot are given in table 3.4 and table 3.5, respectively.

Linear regression was performed to see the effect of year, starting weight, quality and number of days on pasture on the selling price. Although year does not have an effect on the weight gain, it would affect the selling price due to market cycles. Equation 4 was estimated using ordinary least squares (figures in parentheses are the estimated standard errors of the coefficients).

$$\begin{array}{llllll} S = & -37824.76 & + 18.64*Y & + 421.81*Q & + 1.51*SW & + 0.87*D \\ & (11416.18) & (5.68) & (33.05) & (0.07) & (0.20) \end{array} \qquad (4)$$

$R^2 = 50.8\%$

where, S is the selling price of the animal, Y is the year, Q is the quality of the animal, SW is the starting weight of the animal and D is the number of days on feedlot.

IV. RESULTS

The ROI data were simulated with 500 iterations using SIMETAR. Profit/loss and return on investments (ROI) for all categories described above were calculated and compared for a batch of 100 cattle. Table 3.6 provides results of the simulation, including ROI. The results show that buying lighter animals and feeding them in pastures before sending them to feedlot is the most profitable option. The most profitable option for the base scenario was to purchase the animals with an average weight of 450 lbs, put them in a pasture for 100 days followed by 220 days on feedlot to earn an average of 7.83% ROI. The ROI for the remaining five categories are 5.47%, 2.44%, 2.42%, 1% and -0.15% respectively as shown in table 3.6.

To compare risk for the six scenarios, a stop light chart was created (figure 3.1). The probabilities of different ranges of ROI are depicted in the stoplight chart. The red shaded area in each bar represents the probability of a negative ROI. The green area represents the probability of an ROI>10%. The yellow area would be the probability that the ROI lies between 0% and 10%. The results show that most profitable option in the base scenario above is also the least risky option. In this scenario, the probability of having an ROI more than 10% is 45% and the farmer would still incur losses 28% of the times. This also shows that at a contract price of $0.30 /lb, there is a 28% to 43% chance of incurring a loss any given year depending on the starting weight of cattle. This is in line with 36% chance of losing money any year found by Johnson et al. (1987).

The results highlight that at a contract price of $0.30 /lb returns for buying heavier cattle (600-700lbs) and putting them on pasture before taking them to feedlot are quite comparable to buying lighter cattle (500-600lbs) and placing them directly on to feedlot. This shows a possibility that at a higher grazing contract a cattle owner might skip the pasture route and place cattle directly on to the feedlot. This possibility is studied in detail in the following subsection.

Effect of Contract Price:

The simulations were re-run with different contract grazing prices, for a case where cattle are bought at an average starting weight of 550 lbs. We compared the profitability and risk at five different contract prices ($0.20/lb, $0.30/lb, $0.40/lb, $0.50/lb and $0.60/lb). The ROI for the contract prices of $0.20, $0.30, $0.40, $0.50 and $0.60 were 7.08%, 4.73%, 2.48%, 0.32% and -1.75% respectively, for cattle that were contract grazed before going to the feedlot. By contrast, the ROI for going directly to the feedlot was 2.42%. Further sensitivity analysis showed that the “break-even” contract grazing price was $0.41/lb. At prices above this level, it is more profitable for the cattle owner to place the cattle directly on the feedlot.

The stop light chart (figure 3.2) in this scenario shows that by placing 550 lbs average weight cattle directly on to the feedlot, the probability of a positive ROI would be 58% of which 29% would provide more than 10% ROI. In comparison, at a contract price of $0.40/lb the probability of a positive ROI is 57% although the probability of a ROI more than 10% is 33% in this case.

Decision to skip pasture:

To further study a cattle owner’s preferences regarding skipping the pasture and placing cattle directly on the feedlot, a stochastic dominance analysis was performed. Stochastic dominance analysis (Hadar and Russell, 1969) is a technique used to compare probability distributions to study risk efficient action choices. The first and second degree dominance tables are shown in table 3.7. The second degree dominance table shows that feedlot option is dominated by 20 cents, 30 cents and 40 cents which suggests that at higher contract prize for grazing, the cattle owner would be better off by skipping the pasture and placing the animals directly at the feedlot.

Stochastic efficiency with respect to a function (SERF) is another technique used to order risky alternatives using their certainty equivalents (CE) for alternative absolute risk aversion coefficients (ARACs) where CE is the amount accepted in lieu of a higher but uncertain amount. The stochastic efficiency chart (figure 3.3) also confirms that the feedlot is the 4th preferred option after the contract rates of 20 cents, 30 cents and 40 cents respectively.

V. CONCLUSIONS

The results of the study show that it is always more profitable to buy lighter cattle than heavier cattle in spite of the fact that lighter cattle command a premium in the market. Also the probability of positive ROI decreases with the higher starting weights of the cattle. At the current contract prices, it is more profitable for the cattle owners to send the cattle to pasture before sending them to feedlot. However an increase in the contract prices might encourage the cattle owners to skip the pasture altogether and put cattle directly onto the feedlot.

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Table 3.1: Experiment Details for Pasture Data (E V Smith Research Center, Shorter, AL)

Year	Cattle	Forages	Stocking Rates (head/acre)	Grazing Days	Treatments
2006	185	Marshall Rye Grass Gulf Ryegrass Rye Oats	1, 1.2, 1.5, 1.6, 2	78, 82	Implants/No-implants Hay/No-Hay
2007	228	Marshall Rye Grass Gulf Ryegrass Wheat MaxQ Fescue	1.2, 1.6, 2, 2.5, 3	113,114	Implants/No-implants Till/No-Till
2008	222	Marshall Rye Grass Gulf Ryegrass Wheat MaxQ Fescue	1.4, 1.5, 2, 2.5, 2.6, 3	112, 113	Implants/No-implants Till/No-Till
2009	219	Marshall Rye Grass Gulf Ryegrass Marshall Rye Grass + Wheat MaxQ Fescue	1.4, 1.5, 2, 2.5, 2.6, 3	91	Implants/No-implants

Table 3.2: Summary Statistics for Pasture Data (E V Smith Research Center, Shorter, AL) (2006-2009)

Weight Range	Number of Animals	Average Starting Weight (lbs)	Average Ending Weight (lbs)	Average Weight Gained (lbs)	Average Days on Pasture	Average Daily Gain (lbs)
400-500lbs	412	463	717	254	98	2.61
500-600lbs	439	546	807	260	101	2.59
600-700lbs	438	639	919	280	106	2.63

Table 3.3: Summary Statistics for the Feedlot Data (Decatur County Feed Yard, Oberlin, KS) (2006-2008)

Number of Animals	Average Starting Weight (lbs)	Average Ending Weight (lbs)	Average Weight Gained (lbs)	Average Days on Feedlot	Average Daily Gain (lbs)	Average Feed Cost ($/lb)	Average Quality Score[1]	Average Selling Price ($/lb)
Animals from pasture								
146	699	1288	591	176	3.29	0.62	0.85	1174.78
76	793	1353	560	171	3.24	0.66	0.71	1232.59
44	890	1425	535	161	3.29	0.76	0.6	1267.44
Animals directly put into Feedlot								
136	556	1202	644	191	3.36	0.61	1.16	1077.05
158	649	1248	601	182	3.24	0.61	0.93	1132.57
130	749	1321	574	172	3.28	0.64	0.77	1206.76

[1] Calculated as ratio of weight gained in Feedlot to starting weight

Table 3.4: Regression Results for the Weight Gained at the Pasture.

Variable	**Coefficient Estimates for Starting Weight Range**		
	400-500 lbs	**500-600lbs**	**600-700lbs**
# of Animals	419	439	438
Intercept	64163.94	65514.08	63545.72
	(6997.75)	(6998.28)	(14657.83)
Year	-32.03	-32.66	-31.81
	(3.50)	(3.50)	(7.30)
Days on Pasture	3.13	2.84	2.98
	(0.28)	(0.27)	(0.57)
Starting Weight	1.17	1.07	1.43
	(0.16)	(0.24)	(0.24)
R^2	42%	40%	49.30%

Figures in parentheses are the standard errors,

Table 3.5: Regression Results for the Weight Gained at the Feedlot

Dependent Variable	Pasture and Feedlot			Feedlot only		
	Starting Weight Range					
	700-800lbs	**800-900lbs**	**900-1000lbs**	**550-650lbs**	**650-750lbs**	**750-850lbs**
# of animals	146	76	44	136	158	130
Intercept	267.42 (191.44)	551.39 (194.8)	764.78 (152.32)	69.02 (172.19)	366.21 (172.43)	771.62 (195.44)
Days on Pasture	1.61 (0.26)	0.98 (0.29)	0.11 (0.41)	1.74 (0.27)	2.37 (0.23)	1.16 (0.27)
Starting Weight	1.05 (0.25)	0.80 (0.24)	0.72 (0.14)	1.44 (0.29)	0.70 (0.25)	0.47 (0.24)
R^2	24.5	23.5	41.8	31.1	40.7	13.8

Table 3.6: Returns on Investment (ROI) for 100 Cattle under Different Starting Weights and Different Feeding Options

	PASTURE AND FEEDLOT			FEEDLOT ONLY		
Weight Range (lbs)	**400-500**	**500-600**	**600-700**	**500-600**	**600-700**	**700-800**
Animal Purchase						
Number of Animals	100.00	100.00	100.00	100.00	100.00	100.00
Purchase Price ($/lb)	1.26	1.14	1.05	1.14	1.05	0.99
Avg. Purchase Weight (lb)	450.00	550.00	650.00	550.00	650.00	750.00
Total Purchase Cost ($)	56,600	62,480	68,406	62,480	68,406	74,412
Pasture Costs						
Avg. St. Weight (lb)	441.00	539.00	637.00	NA	NA	NA
Transport Costs ($)	862.89	1,054.64	1,246.39	NA	NA	NA
Days on Pasture	100.00	95.00	90.00	NA	NA	NA
Average Ending Wt (lbs)	708.95	800.54	884.40	NA	NA	NA
Contract Price ($/lb)	0.30	0.30	0.30	NA	NA	NA
Contract Payments ($)	8039	7846	7422	NA	NA	NA
Feedlot Costs						
Starting Wt	694.77	784.52	866.71	539.00	637.00	735.00
Transport Costs	5,506.60	6,217.97	6,869.38	4,271.99	5,048.72	5,825.44
Days on Feedlot	220.00	190.00	160.00	220.00	200.00	180.00
Average Ending Wt (lbs)	1,358.53	1,378.86	1,409.23	1,222.47	1,284.68	1,335.79
Feed costs ($/lb)	0.66	0.71	0.80	0.64	0.63	0.67
Quality	0.96	0.76	0.63	1.27	1.02	0.82
Total feed cost ($)	43,643	42,076	43,437	43,810	41,096	40,297
Profit and Loss						
Predicted Sale Price ($)	1,226.01	1,251.79	1,294.08	1,122.95	1,147.34	1,193.61
Simulated Sale Price ($)	1,236.24	1,262.24	1,304.89	1,132.32	1,156.92	1,203.58
Total costs ($)	114,651	119,675	127,381	110,562	114,550	120,535
Total Sales ($)	123,624	126,224	130,489	113,232	115,692	120,358
Profits ($)	8,973	6,550	3,108	2,670	1,141	-177
ROI	**7.83**	**5.47**	**2.44**	**2.42**	**1.00**	**-0.15**

Table 3.7: Estimates of First and Second Degree Stochastic Dominance

First Degree Dominance (FDD)

	20 cents	**30 cents**	**40 cents**	**50 cents**	**60 cents**	**Feedlot**
20 cents FDD				FDD	FDD	
30 cents FDD						
40 cents FDD					FDD	
50 cents FDD					FDD	
60 cents FDD						
Feedlot FDD					FDD	

Second Degree Dominance (SDD)

	20 cents	**30 cents**	**40 cents**	**50 cents**	**60 cents**	**Feedlot**
20 cents SDD		30 cents	40 cents	50 cents	60 cents	Feedlot
30 cents SDD			40 cents	50 cents	60 cents	Feedlot
40 cents SDD				50 cents	60 cents	Feedlot
50 cents SDD					60 cents	
60 cents SDD						
Feedlot SDD				50 cents	60 cents	

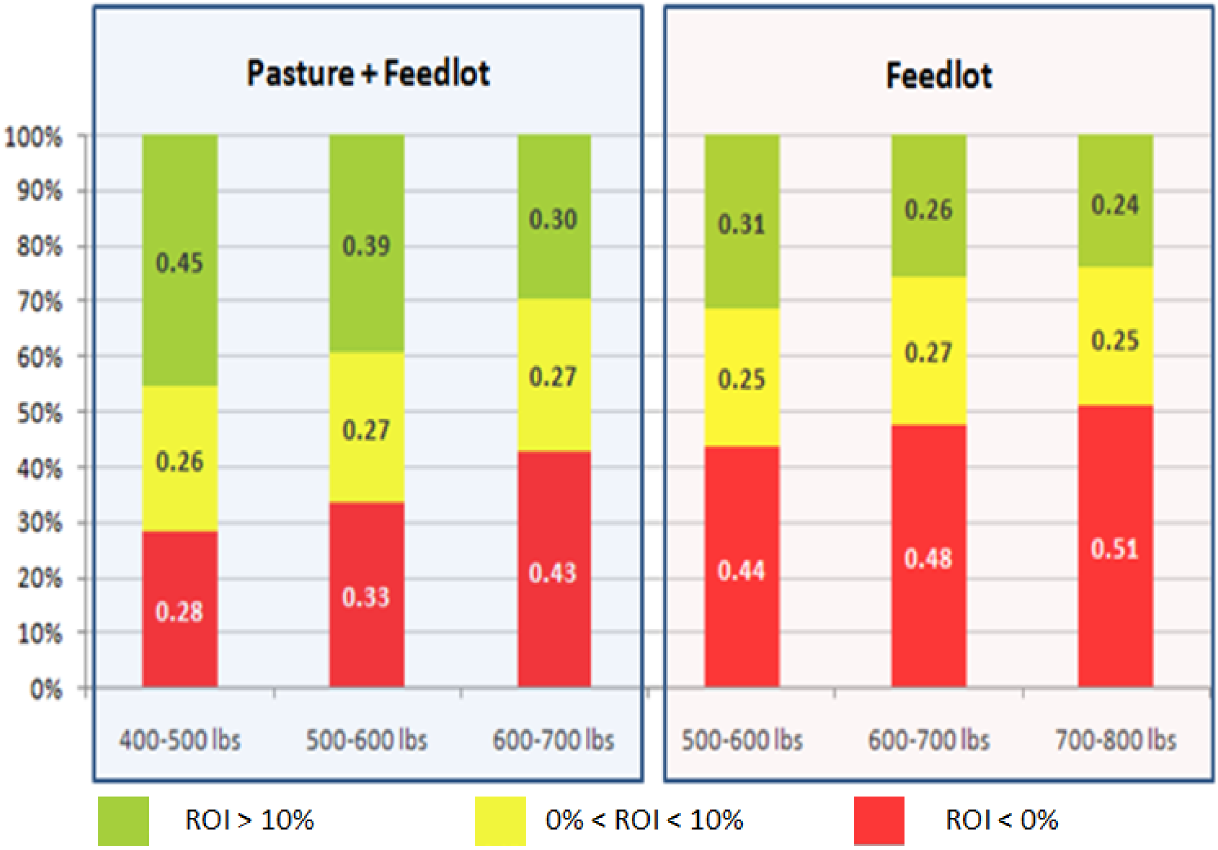

Figure 3.1: Stoplight Chart Comparing Return on Investments under Different Starting Weights and Feeding Options.

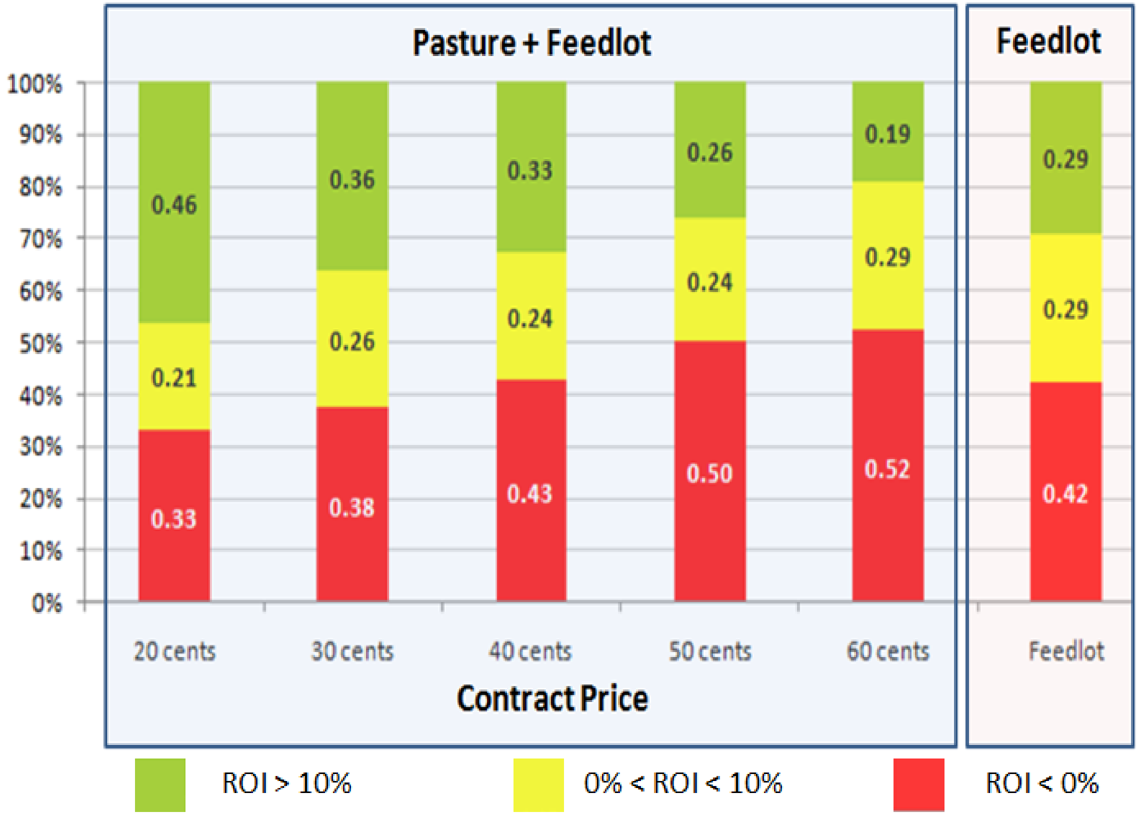

Figure 3.2: Stoplight Chart Comparing Return on Investments under Different Contract Pricing and Feeding Options.

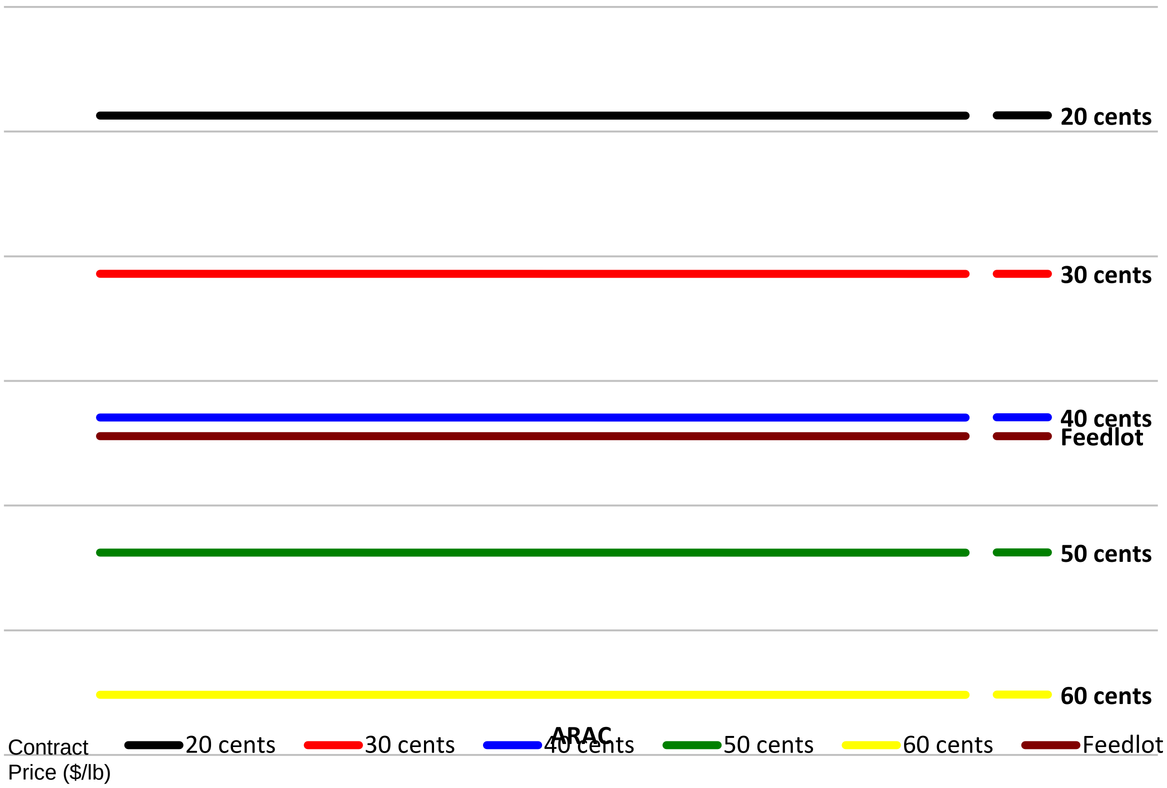

Figure 3.3: Stochastic Efficiency With Respect to a Function (SERF) Assuming a Negative Exponential Utility Function