Economic Potential of Swine Effluent in Intensified Forage Systems in the Southern Plains

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Abstract

The projected long-run increase in corn prices from $2.50 to $3.50 per bushel is expected to have a similar effect on feed prices, pushing up feed costs by as much as 50 percent. With feed costs on the rise, increasing forage production through more intensive management techniques becomes a potentially viable option. This study uses experimental data from a seven-year study in the Oklahoma Panhandle to assess the economic feasibility of intensifying forage production. Four commonly used forage grasses in the region were field tested using two alternative fertilizer sources – swine effluent and urea. The results found that only the two cool season grasses – orchard grass and wheatgrass – generated positive economic returns under intensification. The two warm season grasses – Bermuda grass and buffalo grass – had negative economic returns. Both swine effluent and urea provided similar results based on average economic returns. When risk was included in the analysis, however, urea would be the preferred choice for risk-averse producers.

Introduction

Over the past few decades, farming systems in the Southern Plains of the U.S. have evolved primarily into a wheat-cattle mixed farming system (Biermacher, Epplin, and Keim, 2005). Livestock has a primary role in farming in the region, with livestock earnings comprising as much as, and often more of, farm income than crops (Wright et al., 2010). An ongoing challenge for producers in the Southern Plains is providing an adequate supply of forage throughout the year (Gillen and Berg, 2005). Failure to satisfy forage needs results in increased purchased feed costs and reduced revenue from lower weight gain (Rao, Coleman, and Mayeus, 2002). The climate of the Southern Plains enables the open grazing of cattle throughout most of the year, with both warm and cool season forages available throughout both summer and winter months (Philips et al., 2003). Seasonal shortfalls in forage production typically occur during the early summer months of May and June when cool season forage supplies are depleted and the warm season grasses have not matured, placing upward seasonal pressure on feed prices (Rao, Northrup, and Mayeus, 2005).

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Recent shocks in the energy and corn price markets have affected the mixed farming systems through both higher fertilizer and feed prices, including corn prices that are projected to reach $3.75 per bushel by 2011 (Lalman, 2010). The energy shocks will also have an impact on the livestock side of farm operations. Feed prices have trended upward along with corn prices, increasing by 35 percent over the past five years (Lalman, 2010). In Oklahoma, feed costs now account for 53 percent of animal production costs and are expected to rise even further (Lalman, 2010). Feedlots have responded by discounting cattle prices for underweight animals, providing producers with added incentives to add weight to their cattle before selling them to feedlots (Peel, 2006).

As the value of forage increases over the long-run, producers will search for new production systems to increase forage productivity and lower feed costs. One potential alternative is to intensify forage production through improved management techniques (Haney et al., 2001; Evers and Gabrysch, 1993). Forage constraints in the Southern Plains are generally water and soil fertility (Newton et al., 2003). In many parts of the Southern Plains irrigation is available to more intensively produce forage, but the recent run-up in energy prices places a premium on fertilizer costs (Park et al., 2010). As fertilizer prices increase, the use of animal manure becomes feasible. The Oklahoma Panhandle is a region where concentrated animal feeding operations (CAFO) have increased in size and number, which through manure supplies could provide a comparative advantage for producers in the region (Park et al., 2010). Swine production in the Oklahoma Panhandle has increased dramatically over the past two decades since restrictions on corporate farming were eased in 1991, with a 164-fold increase in hog population from 1991 to 2007 (USDA, 2007). An unavoidable consequence of the dramatic growth in the swine industry is the massive amount of animal waste produced that has raised environmental concerns at both the regional and national levels (Carreira, 2004). The capacity of the swine industry to supply soil nutrients is substantial. In a typical year, CAFO's produce enough swine manure to supply the nitrogen needs of all 98,000 acres of irrigated corn in the Oklahoma Panhandle, in addition to 42 percent of its nitrogen needs for wheat.

When swine effluent is applied as manure at rates based on plant nutrient requirement, positive economic benefits can be realized by replacing more costly inorganic fertilizer sources without compromising the environment. Recently, animal manure has been considered as an economically viable alternative (substitute) to inorganic fertilizer due to unprecedented prices of commercial fertilizer as discussed in previous studies (Carreira, 2004; Nunez and McCann, 2004; Norwood, Luter, and Massey, 2005; Zhang, 2003; Park et al., 2010). In the Southern Plains, Park et al. (2010) showed that two organic fertilizers – beef manure and swine effluent – are economically adequate substitutes for chemical fertilizers (i.e., anhydrous ammonia) when applied on irrigated corn in the Oklahoma Panhandle. Manure's economic viability is highly dependent on shipping costs; however, since the low concentration of nutrients in animal waste makes them much more expensive to transport than inorganic fertilizers. Swine effluent, for instance, can be profitably shipped up to 25 miles, and poultry litter 150 miles (Park et al., 2010; Penn et al., 2011). As a result, animal waste has been over-applied on crop land in areas nearby to feedlots and where other concentrated animal feeding operations are located, which has led to environmental concerns (Park et al., 2010). An ongoing need, therefore, is to identify new uses for animal waste; in the Oklahoma Panhandle, intensifying forage production using swine effluent is one possible alternative.

The use of animal manure has also been found to provide agronomic benefits, including the build up of both macro- and micro-nutrients (N, P, K, S, Ca, Mg), increased stocks and mobilization of soil organic carbon (Ndayegamiye and Cote, 1989), enhanced soil fertility and soil aeration (Sparling et al., 2003), and increased presence of beneficial microorganisms (Karlen, Andrews, and Doran, 2001). Such agronomic benefits have been found on both row crops (Kwaw-Mensah and Al-Kaisi, 2006; McAndrews et al., 2006; Loria et al., 2007; Paschold et al., 2008) and forages (Adeli and Varco, 2001; Brink et al., 2003; Adeli et al., 2005). The positive influence of animal manure on agronomic conditions is in sharp contrast to negative consequences that inorganic fertilizers have on soils over the long term, e.g., soil acidification and the depletion of soil organic matter and micronutrients.

Given the availability of swine manure in the Oklahoma Panhandle and surrounding region, one option for producers is to apply swine manure on forage to intensify production. Along with irrigation, which is typically available on most farms, an intensified forage production system can alleviate the two major constraints in the region: low soil fertility and soil moisture. The objective of this study is to investigate the economic potential of swine effluent-irrigated forage production systems in the Oklahoma Panhandle. An economic model was constructed based on the data collected from seven years of field trials of four alternative forage production systems in the Oklahoma Panhandle. The field trials intensified the production of forage using irrigation and applied nitrogen. Due to the large supply of swine waste in the area, the field trials tested the efficacy of SE versus commercial fertilizer, urea. Since significant yield variability was observed from the field trial data a stochastic efficiency model was employed to analyze the economic potential of each forage production system in a risky situation.

Materials and Methods

A long-term forage experiment was conducted at the Oklahoma Panhandle Research and Extension Center (OPREC) near Goodwell, OK (36°35 N, 101°37 W, elevation 992 m) for seven years from 1999 to 2005. A total of 28 grass production strategies were tested using an experimental design that included combinations of three factors: forage type, N source, and N rate. This design included four grass species (Bermuda grass, buffalo grass, orchard grass, and wheatgrass), four N application rates (0, 50, 150, and 450 lbs. N per acre), and two sources of nitrogen fertilizers (swine effluent and urea). The experimental plots used a split-plot design with four replications for each of the 28 grass production strategies. In the first year of the experiment, each plot was randomly assigned to one of the strategies. Since residual effects (e.g., nutrient carry-over) were expected to have a significant effect on production outcomes, each strategy was maintained in the same plot throughout all seven years of the experiment. Swine effluent was obtained from a local anaerobic single-stage lagoon near the research station, the same type of effluent available to producers. Swine effluent and urea were applied at equivalent N rates of 50 and 150 lbs. N per acre after the first monthly cutting in June. The 450 lbs. N per acre rate was split into two applications; the first application came after the first cutting in June and the second just after the second cutting in July. All plots were fully irrigated under a center-pivot irrigation system following standard practices used by producers in the region. The swine effluent was field-applied through the center pivot system as part of the June and July irrigation water applications.

Table 1 reports summary statistics of dry matter yields for each of 28 forage production systems, listing their mean, standard deviation, minimum, and maximum values[1]. The long-term distribution of forage dry matter yields over the seven years of the study revealed significant yield variability, with coefficients of variation (CV) that reached as high as 0.60 (Table 1). In that extreme case, the CV of 0.60 indicates that quite often (33% probability) the forage yield will be either 30 percent above or below the mean value. Dry matter yield variability was found to increase at the higher applied N rates from 150 to 450 lbs. per acre across all forage species (Table 1). Specifically, the highest variation of dry matter yield was found in Bermuda grass for all four equivalent N rates with CV values ranging from 0.31 to 0.60, while the lowest variation was found in orchard grass with an average CV of 0.24 (Table 1). However, no difference was found in the overall variation between nitrogen sources. S wine effluent had higher forage yield variations than urea in Bermuda grass and wheatgrass, while urea had higher variations in buffalo grass and orchard grass than the other two forage grasses (Table 1).

Agronomists have often found that animal manure has greater yield uncertainty than inorganic fertilizers when manure is used as the primary source of applied nutrients (Carreira et al., 2004). Nutrient content in the manure is affected not only by the method of storage and application, but also by the timing of land application. Substantial amounts of nitrogen can be lost to ammonia volatization, particularly in hot and windy regions such as the Oklahoma Panhandle. The breakdown of NH4 into plant usable nitrogen forms with manure is a process that while understood by agronomists, occurs at unpredictable rates. Leaching and immobility of N can also be an issue with animal manure, and if manure is applied at rates above those needed for plant nutrient requirements, manure can potentially impair soil quality and yield performance. S uch yield uncertainty and nutrient losses can place animal manure at a competitive disadvantage with inorganic N sources that supply the soil profile with N in more usable, readily available forms for the plant.

Risk Analysis

The observed dry matter yield variability suggests that risk could be an important aspect of decision making, i.e. when choosing among the alternative forage types (Hazell and Scandizzo, 1974). For producers, the practical implication of risk is that higher yields and higher economic returns can only be obtained by taking on greater variability, e.g., by increasing their exposure to risk. A large body of economic literature has studied how decisions are made in risky situations. Most conclude that producers factor in both the mean and variance of economic returns when choosing among alternatives by discounting variability (Markowitz, 1952; Sandmo, 1971; Batra and Ullah, 1974; Just and Pope, 1979; Pope, Chavas, and Just 1983). This translates in more useful terms to producers having to find an acceptable trade off between mean and variance of economic returns. Such a trade off will usually require producers to choose an alternative that has a lower mean economic return in order to reduce variability and minimize exposure to risk (Robinson et al.,1984). An important characteristic of risk management is that individuals express varying degrees of risk aversion, i.e., each decision maker will make the risk trade-off according to their unique preferences (Pratt, 1964). The risk premium is a commonly used measure of an individual's level of risk aversion; it is a measure of how much mean income an individual willingly gives up to reduce income variability as part of the risk trade off.

When risk is deemed present, optimal alternatives should be selected based on the statistical distribution of net economic returns, i.e., both the mean and variance of economic returns should be considered as important to producers (Richardson, 2003). Within farm management, previous studies have found that including risk made a significant difference in determining optimal cropping systems for producers. Anderson (2000) argued that most farm managers have an aversion towards risk, and either implicitly or explicitly discount risky alternatives in favor of more stable ones when making decisions. DeVuyst and Halvorson (2004) evaluated 13 alternative cropping systems – across various crops, tillage practices, and N rates – using a stochastic dominance approach to evaluate the risk of each alternative. Their analysis determined that seven out of thirteen systems contain significant levels of risk compared to the other five, and would not be preferred by risk averse producers. The stochastic dominance approach also found that the cropping system with the highest mean return would not be the preferred alternative when risk is factored into decision making since it had a high level of variance compared to other alternatives. Dahl, Wilson, and Nganje (2004) also adopted stochastic dominance techniques to evaluate the economic returns under risk of sixteen wheat varieties to growers (and end-users). Their results found that incorporating risk into the analysis enabled them to identify two of the wheat varieties as generating significantly higher economic returns and less variability compared to the other fourteen alternatives. Both of those studies indicate how risk can provide more efficient recommendations since risky alternatives can be eliminated. Since ignoring risk can lead to naïve and less realistic solutions, and the yield data had large variability, a risk model was developed in this study. The next section briefly describes the model; a more detailed explanation (and formulation) is provided in the Appendix.

Risk-Simulation Model

A risk model was developed using the forage production data gathered from the long-term OPREC field experiment. A multivariate simulation was conducted using SIMETAR software to empirically construct the probability distribution of the forage yields for each of the 28 irrigated forage-fertilizer production systems included in the experiment. The probability distribution is the primary risk component of the simulation since it quantifies how yields are dispersed about the mean. Based on the observed data, the SIMETAR simulation used standard normal probability distributions for modeling the forage yields of each grass type. The SIMETAR simulation was successfully validated by comparing simulation output to the OPREC field experimental results using t-tests ($P<0.05$) on the mean values of the observed dry matter yields and their variance (Appendix 3). The probability distributions were used, along with the cost data from Table 2, to calculate the distribution of economic returns faced by producers. From that distribution, the mean economic return and its variance were calculated for each alternative. The risk trade offs among the forage alternatives were assessed using an economic model that maximized the expected utility of income. The expected utility model can be interpreted as maximizing an objective function that includes both the mean and variance of economic returns, an extension of models that maximize only the mean of economic returns, such as linear programming. The trade off between the mean and variance of economic returns is established by a risk coefficient (ARAC) that places a penalty on the variance of economic returns (but not on the mean). To account for individual differences in risk aversion, the expected utility model considers a wide range of risk coefficient values (i.e., ARAC) that place more severe penalties on variance as the level of risk aversion is increased.

The forage alternatives are compared to one another using the certainty equivalent (CE), which measures how much value, in monetary terms, an individual places on an alternative factoring in the effects of risk (Hardaker, 2004). In essence, the CE can be viewed as the risk-discounted value of an alternative that results from penalizing the variance of economic returns. It is instructive to note that if no risk is present (i.e., zero variability), then the CE is equal to the mean economic return; introducing risk into the alternative reflects how much the economic value is reduced relative to the risk-free case. Since risk averse individuals penalize variance, risky alternatives with high variability in economic returns will have lower CE values compared to less risky alternatives. Hence, we present the results of the risk model in the next section using CE since it provides a convenient way to compare forage alternatives against each other when risk is present. Using pair-wise comparisons, the best forage alternative is identified by selecting the alternative with the highest CE.

This section has provided only a brief discussion of the risk model. For the interested reader, a more complete treatment of the risk model is presented in Appendix 4, including a mathematical formulation.

Production Costs and Forage Budgets

Production budgets for each forage production system are developed based on Haque et al. (2008) (Appendix 1 and 2). Input prices for the establishment costs, such as nitrogen fertilizer and seeds, were modified according to each forage production system. Total establishment cost was amortized for 10 years in the annual production budget for each forage production system (Table 2). The application cost of swine effluent for the three N application rates for different forages was modified based on a recent study by Park et al. (2010). Across all four grass types, Bermuda grass has the highest average production cost whereas orchard grass has the lowest production costs. However, both warm season grasses have substantially higher production costs than the cool season grasses. Buffalo grass has a variable production cost of $419.67 per acre and Bermuda grass has a variable cost of $291.43 per acre (Appendix 1). As noted, the cool season grasses had lower costs of $147.59 per acre and $157.06 per acre for orchard grass and wheatgrass. The higher production costs for warm season grasses are from the hay cutting costs. Warm season grasses are harvested in June and July whereas the cool season grasses are grazed, eliminating the need to harvest. Harvest costs for each warm season grass are adjusted in the simulation since harvest costs are proportional to DM yield, which varies in the simulation.

Different market prices of dry matter yields for each of four grasses were adopted to calculate the distribution of net economic returns based on the following assumptions. First, Buffalo grass is more valuable than Bermuda grass because it is higher in protein and second, cool season grasses such as orchard grass and wheatgrass have a much higher price due to the seasonality in the forage markets. In the winter, forage supplies dwindle when less is growing and the winter forages fetch a premium since they are much higher in protein than the summer forages. Monetary values of dry matter yields for two cool season grasses such as orchard grass and wheatgrass were determined assuming the orchard grass and wheatgrass are close to the quality of wheat pasture according to the previous studies on forages (Ishrat, Epplin, and Krenzer, 2003; Krenzer et al., 1996; Tumusiime et al., 2010). In terms of warm season grasses, hay prices from the most recent Oklahoma Hay Report were used assuming that buffalo grass is premium quality grass hay and Bermuda grass is only good quality grass hay. The predicted prices of one ton of dry matter yields are $52.50, $62.50, $90.00, and $90.00 for Bermuda grass, buffalo grass, orchard grass, and wheat grass, respectively. The predicted price of urea is $0.44 per N lb. in urea, corresponding to a price of $0.20 per lb. for urea (ICIS 2010).

Results

The two warm season forage types – Bermuda grass and buffalo grass – had significantly higher overall dry matter yields than the cool season forages, orchard grass, and wheat grass (Table 1). Bermuda grass had the highest overall dry matter yield of 7.29 tons per acre, which was 11.1 percent higher than the overall buffalo grass yield of 6.48 tons per acre. The overall yield differences were much larger when the warm season grasses were compared to the cool season ones (Figure 1). Bermuda grass had yields that were on average 62.7 percent higher than the yields of wheat grass at 4.48 tons per acre, and 55.1 percent higher than the yields of orchard grass at 4.70 tons per acre (Table 1). For buffalo grass, its yields averaged 44.6 percent higher than wheat grass and 37.9 percent higher than orchard grass (Table 1).

In terms of nitrogen source, there was no significant difference ($P<0.05$) in DM forage yield between swine effluent and urea (Figure 1). When averaged across all years of the experiment and the four N rates, swine effluent produced a DM yield of 5.71 tons per acre and urea a DM yield of 5.49 tons per acre (Figure 1). Within each forage type there was also no significant difference in DM yield between swine effluent and urea, i.e., no significant interaction between nitrogen source and forage type. Applying nitrogen at a rate of 450 lbs. N per acre produced DM yields that were significantly higher ($P<0.05$) than the other rates for both swine effluent and urea (Table 1). There was no significant difference ($P<0.05$) however, between applying either 50 or 150 lbs. N per acre on either swine effluent or urea (Figure 1). The lowest DM forage yields were found for the control plot, consistent with prior expectations (Figure 1).

Economic Results

We begin with the risk-neutral case to establish which alternatives are preferred when risk is ignored, and then introduce risk into the analysis in the next section to investigate whether it would affect choices. The mean economic return per acre of each forage production system is shown in Tables 3 and 4 for the risk-free case. Swine effluent provided better economic performance than urea on the warm season grasses, with average economic returns for Bermuda grass and buffalo grass that were significantly higher ($P<0.05$) than those from applying urea (Table 3). According to the economic model, SE applied with 450 lbs. of N on Bermuda grass generated an average return of $125.46 per acre that was significantly higher (P<0.05) than any of urea alternatives, which had a maximum return of $100.65 when 150 lbs. of N was applied (Table 3). A similar result was found for buffalo grass (Table 3). SE applied with 450 lbs. of N on buffalo grass generated an average return of $33.94 per acre that was significantly higher (P<0.05) than any of urea's alternatives, which had a maximum return of $15.36 when 150 lbs. of N was applied (Table 3).

The effect of N source was different, however, on the cool season grasses where there was no significant difference in economic returns between swine effluent and urea (Table 4). When applied at a rate of 50 lbs. per acre on orchard grass, urea generated its highest average return of $304.91 per acre which was not significantly different (P>0.05) than swine effluent's highest return of $297.19 per acre from applying 450 lbs. N per acre (Table 4). Likewise, economic returns between urea and swine effluent were also not significantly different for wheatgrass. When applied at a rate of 50 lbs. per acre on wheatgrass, urea generated its highest economic return of $305.02 per acre which was not significantly different (P>0.05) than swine effluent's highest return of $301.33 per acre from applying 450 lbs. N per acre (Table 4).

The cool season grasses (orchard grass and wheatgrass) generated significantly higher net returns per acre than the warm season grasses (Bermuda grass and buffalo grass) (Table 3 and 4). The average economic return of the cool season grasses was $274.17 per acre, which was considerably higher than the average returns of the warm season grasses that averaged $36.64 per acre. This is an interesting result since the dry matter yields of warm season grasses were found to be significantly higher in the field trials than those of the cool season grasses (Table 1). The difference between yield and economic performance can be explained by both the higher market prices and lower variable costs of the cool season grasses that compensated for the lower yields.

The performance of swine effluent, based on the mean economic returns, had mixed results when compared to urea. In a recent study by Park et al. (2010), swine effluent was more profitable than commercial fertilizer on irrigated corn in the Oklahoma Panhandle. This may indicate that an increase in gross income by higher market prices of the cool season grasses, due to seasonal constraints on forage, has a greater effect on returns enabling swine effluent to generate the greater returns only when applied on the warm season grasses.

The economic results indicate a difference in the economically optimal application rates of the fertilizers as compared to the biophysical optimum. Table 1 suggests that all of the grasses could respond to higher fertilizer levels as marginal physical products did not reach zero. The economic model finds, however, that urea applications beyond 150 lbs. per acre would never be economically efficient since the marginal value product declines at an application rate of 150 lbs. of N per acre. For swine effluent however, the economic model suggests that higher fertilizer levels could generate higher returns since the marginal value product (MVP) has not yet decreased. At such higher fertilizer levels it is possible that swine effluent could have significantly higher dry matter yields than urea.
Based on average economic returns, the economic model is not able to provide a single best alternative, but it is able to conclude that cool season grasses perform better than warm season grasses. Four alternatives from the cool season grasses emerge as generating the highest economic return. These alternatives include orchard grass applied with 450 lbs. of swine effluent, orchard grass applied with 50 lbs. of urea, wheatgrass applied with 450 lbs. of SE and wheatgrass applied with 50 lbs. of urea (Table 4). While there were slight differences in economic returns between them, ranging between $297.19 and $305.03 per acre, the differences were not significant (P<0.05). In the next section, the risk model is used to investigate whether risk would have any effect on the ranking of the forage alternatives.

Stochastic Simulation Results

Simulation results for each of 28 forage production systems are presented as cumulative distribution functions (CDFs) of net return per acre in Figure 2. The CDF graphs on the vertical axis the probability of net returns being less than (or equal to) a particular level of net returns on the horizontal axis. Four panels are included in Figure 2 to show the CDFs of forage production systems for the two warm season grasses as well as the two cool season grasses.

Warm season grasses have a much greater chance of negative returns than cool season grasses (Figure 2). The negative returns of the warm season grasses are evident in Figure 2 since they begin on the left side of the vertical axis where economic returns are negative. All fourteen warm season grass alternatives have a probability of negative returns, ranging from a minimum of 14 percent with BMU150 (Bermuda grass under urea at 150 lb. per acre) to a maximum 74 percent with BUS50 (Buffalo grass under swine effluent at 50 lb. per acre). In contrast, only four cool season grass alternatives failed to earn a positive return, and had more modest probabilities of negative returns that ranged between four and 10 percent (Figure 2). The CDF curves provide an initial indication that warm season grasses are more risky than cool season grasses, but the performance of the alternatives on the positive (right) side of the vertical axis is also important.

Selecting the best alternative by visual inspection of the CDF curves is not possible except in limited cases where one curve lies completely to the right of the others, i.e., first-order dominance. Typically CDF curves intersect, or cross, each other. This indicates that one alternative will have lower returns in poor outcome years, but will outperform the other alternative in better outcomes. This is the usual case in risk analysis since higher potential returns require increased investment costs that can't be recovered in bad outcome years but eventually payoff in good outcome years. Choosing between two alternatives that have crossed each other is based on an individual's risk preferences since there are trade-offs between obtaining higher payoffs at the risk of having a greater chance of low (negative) returns. The certainty equivalents (CEs), therefore, were used for ranking competing forage production systems when the CDF curves crossed one another (see Methods section above). Figure 3 graphs the CEs of all 28 forage production systems across a range of absolute risk aversion coefficients (ARAC) parameters according to the grass species. For a given risk aversion coefficient located on the horizontal axis, the alternative with the highest CE is considered to be the best for that risk level.

Including risk provides some additional and useful information compared to the risk neutral case. For warm season grasses, SE applied with 450 lbs. of N was the best choice when risk was not considered (Table 3). Including risk averse preferences in the analysis reveals, however, that for increasingly risk averse producers the difference between SE450 and UR150 declines until there is no significant difference between them (Figure 3). This occurs when the risk coefficient (ARAC) reaches 0.01, which represents only a modest level of risk aversion. Hence, while SE450 would be preferred based on expected returns, factoring in risk aversion weakens this result. With risk included in the model, the increased variability in applying SE results is discounted, reducing the value of swine effluent to risk-averse producers. This higher level of risk discounting with swine effluent is indicated by the relatively rapid decline in CE values for swine effluent compared to urea that causes the SE450 and UR150 curves to converge at a risk aversion level (ARAC) of about 0.01.

The CE curves confirm that the warm season grasses have more risk associated with them than the cool season grasses (Figure 3). The warm season grasses have much steeper slopes associated with their CE curves compared to the cool season grasses, indicating that the value of warm season grasses are more heavily discounted due to higher levels of risk. This implies that producers would need to trade more of their expected returns to reduce variability with the warm season grasses than the cool season ones. For example, producers with an AR risk aversion coefficient of 0.02 would have a risk premium of $135 with Bermuda grass, calculated as the difference between the expected return of $150 and the CE value at ARAC = 0.02. Hence nearly two-thirds of the expected returns would be traded to get rid of the risk through reducing variability (Figure 3). With either of the cool season grasses the trade off is less extreme. For orchard grass, the risk premium is substantially lower than warm season grasses. The same type of producer with an ARAC risk coefficient of 0.02 would only need to trade off $80 per acre, or equivalently 22 percent of expected returns, in order to reduce risk (Figure 3). Moreover, a further indication of the riskiness of the warm season grasses is the negative CE values. Those negative values mean that producers would only select the alternative if they were paid to do so, with the payment given by the absolute value of the CE. For example, producers with an AR risk coefficient of 0.02 would only produce buffalo grass if they received a subsidy of $22 per acre (Figure 3).

Including risk preferences in the economic analysis provides additional information that is particularly useful with cool season grasses. In the risk neutral case, for orchard grass there was no significant difference between the economic returns generated by swine effluent when applied at 450 lbs. N per acre (ORS450) and when urea was applied at 50 lbs. N per acre (ORU50), which is evident by the closeness of their CE curves where they intersect the vertical axis (Figure 3). When risk aversion is included in the analysis, however, urea applied with 50 lbs. N per acre becomes the preferred alternative. At increasing levels of risk aversion, swine effluent has more variability and hence larger risk discounting than urea that lowers CE values for swine effluent compared to urea. This is illustrated by the ORS450 (swine effluent applied 450 lbs. N per acre) and ORU50 (urea applied 50 lbs N per acre) curves moving apart in Figure 3 as risk aversion is increased. At an ARAC value of 0.01, urea applied at 50 lbs. N per acre has a significantly higher CE value than swine effluent applied 450 lbs. N per acre, and has become the preferred alternative for orchard grass.

The risk analysis also indicates that the untreated orchard grass has the least amount of risk associated with it. The slope of untreated orchard grass is more shallow than wheatgrass and the two fertilized alternatives. At higher levels of risk, with ARAC values greater than 0.02, the untreated (control) orchard grass alternative becomes as preferred as ORU50 (Figure 3). The lower risk associated with the untreated plots is explained by their lower production costs and investments compared to the fertilized alternatives. Moreover, the added risk that producers take on when they adopt intensive production is consistent with and could potentially explain why producers currently gravitate towards untreated forage production.

Risk aversion had a similar effect on wheatgrass, the other cool season grass. Initially, without risk, there was no significant difference between swine effluent applied at 450 lbs. N per acre (ORS450) and urea applied at 50 lbs. N per acre (ORU50) as indicated by their curves intersecting the vertical axis at ARAC = 0, the risk neutral case (Figure 3). When risk aversion is included in the analysis, however, urea applied at 50 lbs. N per acre (ORU50) becomes the preferred alternative as it did with orchard grass. At increasing levels of risk aversion, swine effluent has more variability and larger risk premiums than urea that results in higher risk premiums and lower CE values for SE compared to urea as illustrated by the ORS450 (swine effluent applied at 450 lbs. N per acre) and ORU50 (urea applied at 50 lbs. N per acre) curves moving apart (Figure 3). At even a modest ARAC values of 0.009, urea applied at 50 lbs. N per acre (ORU50) has become the preferred alternative. Swine effluent is also somewhat more risky when applied on wheatgrass than orchard grass as indicated by the steeper slope of the wheatgrass CE curve (Figure 3).

The increased risk associated with applying swine effluent as nitrogen fertilizer is consistent with other studies that have also found organic sources to be more risky (Carreira, 2004). This result shows the need to include risk in the economic analysis since swine effluent and urea performed equivalently when only the mean economic returns were considered. Since measuring producers' actual risk aversion coefficients is costly and difficult, forecasting the expected use of swine effluent is not practical. The results do, however, indicate that intensifying forage production with modest quantities of fertilizer, applied at an equivalent rate of 50 lbs. N per acre, would be profitable with the increased value of forage that is likely to be maintained over the long run.

In terms of two nitrogen sources at different nitrogen application rates, urea is found to be preferred at the low nitrogen rate while SE is at the highest nitrogen rates. At the medium nitrogen rate, urea is preferred but only in the unusual case by a risk-seeking decision maker. This is consistent with some results from Park et al. (2010) that the application of SE at the high nitrogen rate of 450 N lbs. per acre generated the highest economic returns in the corn production in the AVOVA analysis. This can be explained by the fact that the per unit based (here per pound) application costs of SE decrease significantly as nitrogen rates increase due to the very low (i.e., ignorable) marginal cost of SE.

Conclusions

The results of this study provide useful information to evaluate the risk and economics of intensive forage production systems under four alternative types of forage and two alternative nitrogen sources so that farmers will be able to make better informed production decisions. Intensifying the production of cool season grasses appears to be an economically viable option for producers in the Southern Plains according to the model results. Seasonal constraints on forage production drive up prices of cool season grasses, providing cool season grasses with better marketing opportunities than warm season grasses. When combined with lower production costs and more stable yields, cool season grasses have higher returns and less risk than warm season grasses, which often have negative returns. The performance ranking of each forage species is, however, dependent on the decision maker's attitude towards risk. Urea was found to have less risk than swine effluent and would be the preferred choice for even modestly risk averse producers.

Future research will be required to explore different types of warm and cool season forages to identify a wider range of options for producers. This should include investigating other types of management options including herbicides, integration into crop rotations, and other types of animal manure particularly beef. This could also provide solutions to producers from a wider range of farming systems beyond the Oklahoma Panhandle and Southern Plains.

Endnotes

[1] The acronym indicating alternatives of forage production systems are given by the following convention. The first two letters indicate grass species: BM=Bermuda grass, BU=buffalo grass, OR=orchard grass, WH=wheatgrass. One letter in the middle of acronym stands for nitrogen source: S=SE, U=urea, C=control. Finally, the number shows N application rates of 0, 50, 150, and 450 N lb per acre.

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Figure 1. Dry matter forage yields illustrating effect of nitrogen source, application rate, and forage type

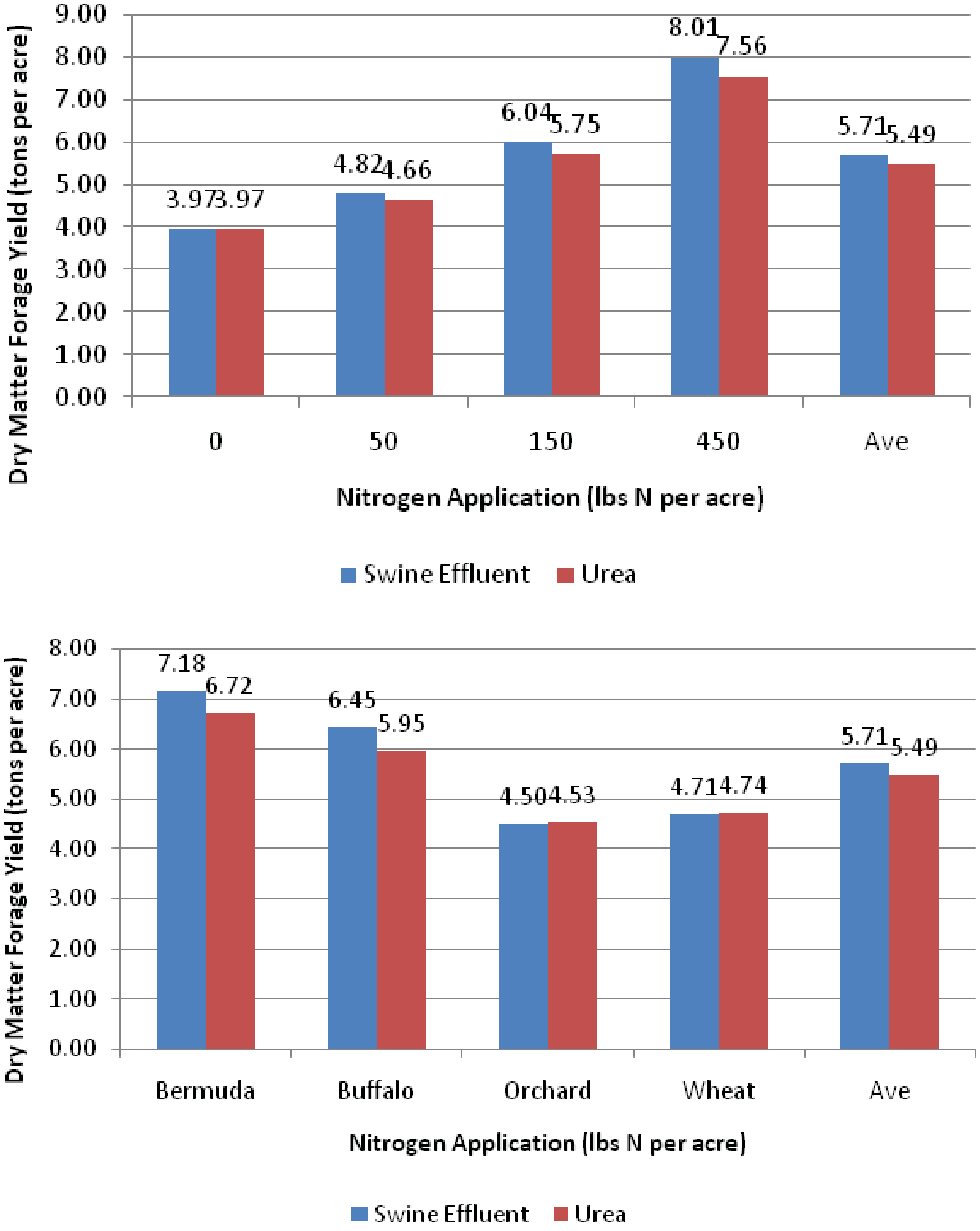

Figure 2. Cumulative distribution function of net returns for four forage species in Texas County, Oklahoma

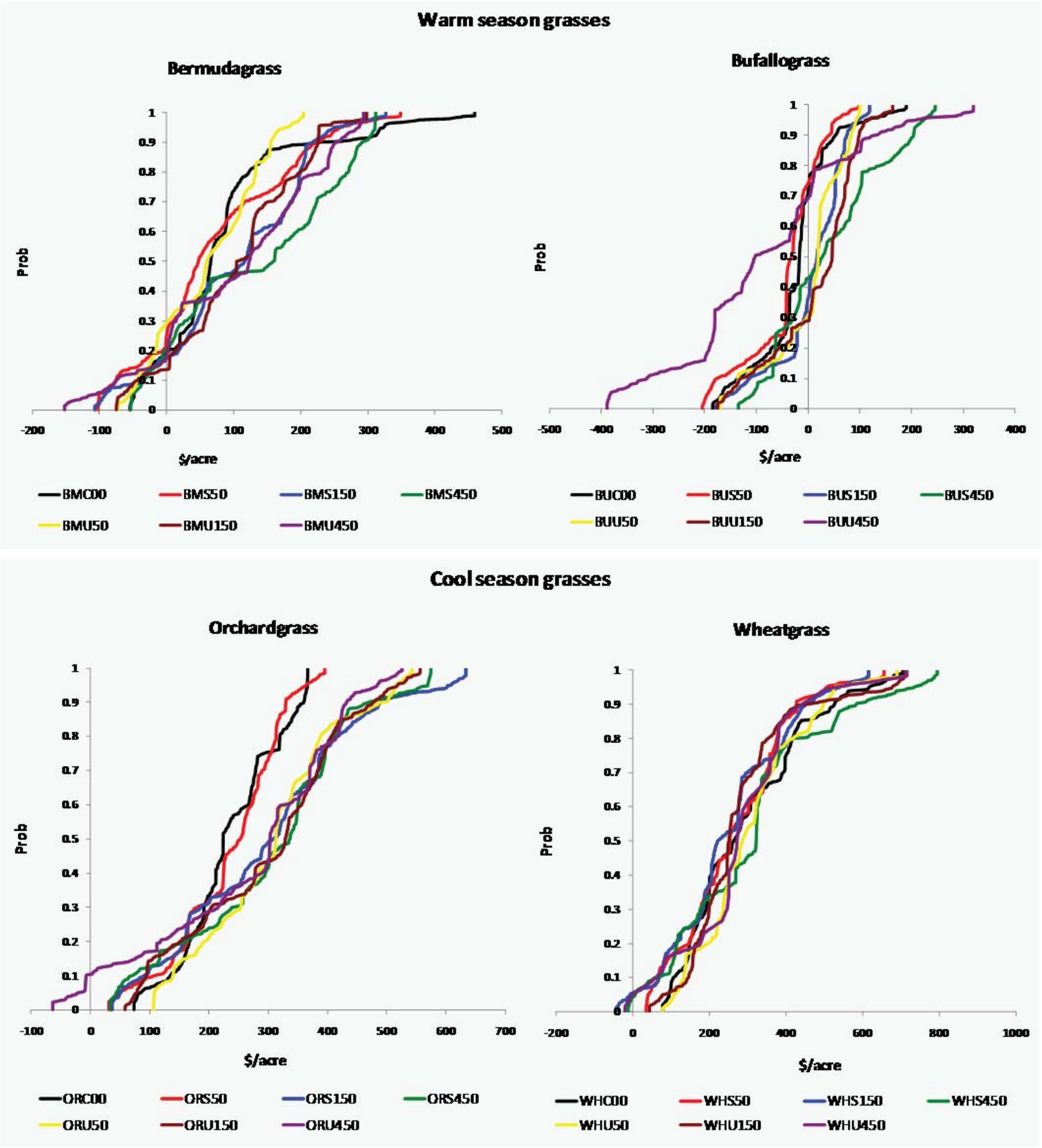

Figure 3. Certainty equivalents (CEs) for net return for four different grass species in Texas County, Oklahoma

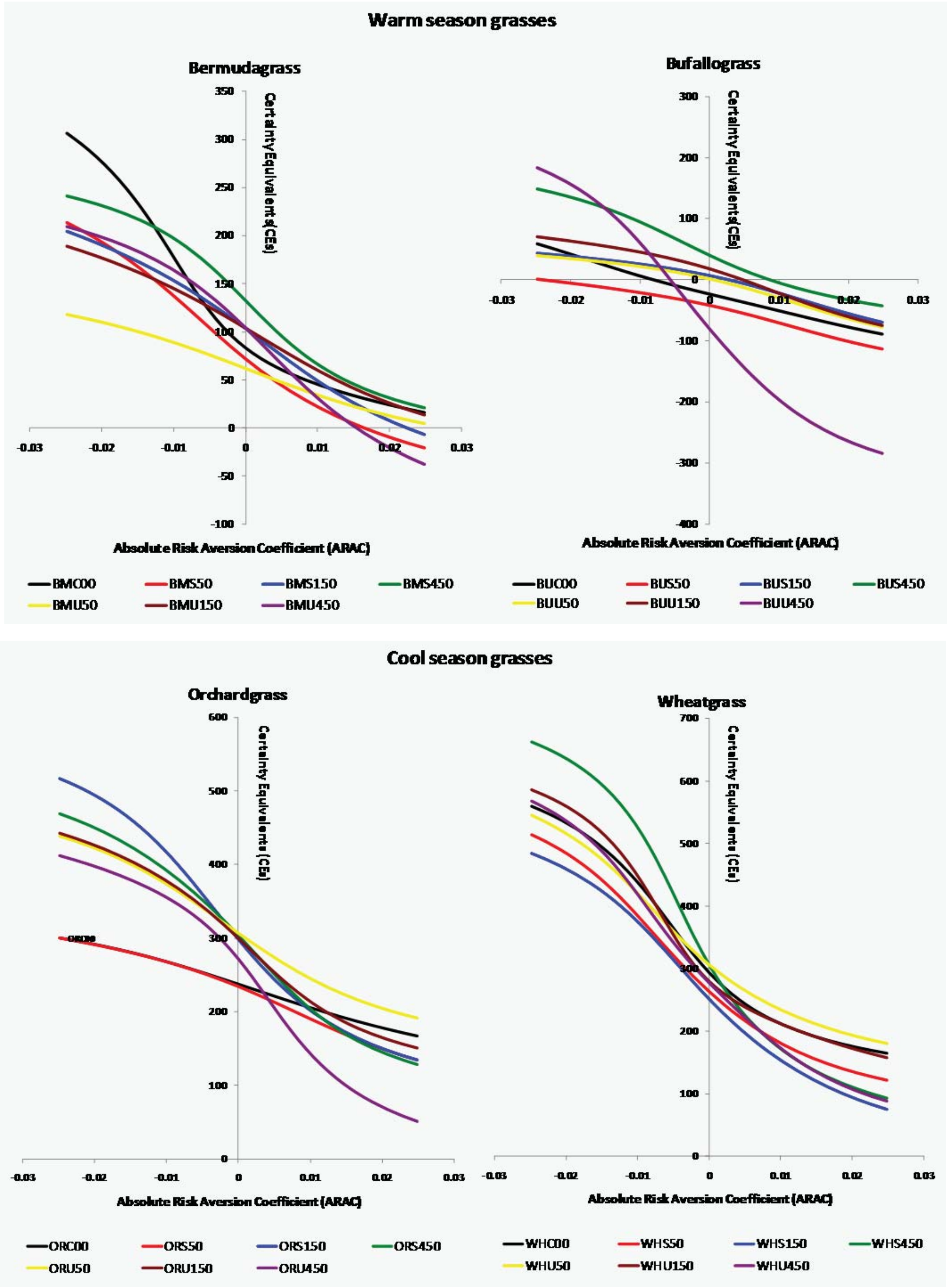

Table 1. Summary statistics of dry matter yield (tons per acre) for four grasses, 1999-2005, Texas County, Oklahoma

Item	BMC00	BMS50	BMS150	BMS450	BMU50	BMU150	BMU450	BUC00	BUS50	BUS150	BUS450	BUU50	BUU150	BUU450
Mean	4.51	5.89	7.67	10.63	4.64	6.99	10.73	4.24	5.18	6.96	9.41	5.34	6.69	7.54
StDev	2.69	2.08	2.64	3.35	2.07	2.42	3.29	1.43	1.40	1.46	2.28	1.55	1.64	2.63
Min	0.89	2.36	3.03	6.40	1.56	2.83	5.52	1.28	2.18	3.87	6.96	2.04	3.26	4.98
Max	9.32	7.77	10.53	15.11	7.06	9.35	14.58	5.32	6.33	8.39	13.08	6.70	8.64	12.44
CV	0.60	0.35	0.34	0.32	0.45	0.35	0.31	0.34	0.27	0.21	0.24	0.29	0.25	0.35

Year	ORC00	ORS50	ORS150	ORS450	ORU50	ORU150	ORU450	WHC00	WHS50	WHS150	WHS450	WHU50	WHU150	WHU450
Mean	3.22	3.88	4.97	5.92	4.28	4.73	5.90	3.92	4.32	4.54	6.07	4.39	4.57	6.09
StDev	0.72	0.69	1.47	1.40	1.01	1.26	1.59	1.01	1.24	1.10	1.97	1.22	1.18	1.29
Min	2.31	2.90	2.45	3.29	2.48	2.29	2.76	2.74	3.06	2.90	3.96	3.41	3.12	3.98
Max	3.99	4.56	6.22	7.32	5.29	5.93	7.33	6.00	6.83	6.42	9.61	6.73	6.88	8.17
CV	0.22	0.18	0.30	0.24	0.24	0.27	0.27	0.26	0.29	0.24	0.32	0.28	0.26	0.21

* BM: Bermuda grass, BU: buffalograss, OR: orchardgrass, WH: wheatgrass, C: Control, S: Swine Effluent, U: Urea, 00: 0 N lb. per ac., 50: 50 N lb. per ac., 150: 150 N lb. per ac., 450: 450 N lb. per ac.

Table 2. Estimated establishment costs for each of four forage species, $/acre

Items	Unit	Quantity	Price per unit ($)	Bermuda grass	Buffalo grass	Orchard grass	Wheat grass
Machinery operations							
Tillage							
Moldboard plow	acre	1	12.50	12.50	12.50	12.50	12.50
Tandem disk	acre	2	8.75	17.50	17.50	17.50	17.50
Fertilizer and Chemical Application							
Spraying herbicide	acre	1	4.00	4.00	4.00	4.00	4.00
Applying nitrogen	acre	1	3.75	3.75	3.75	3.75	3.75
Planting							
Cultipack	acre	1	7.00	7.00	7.00	7.00	7.00
Grain drill	acre	1	10.00		10.00	10.00	10.00
Sprigger	acre	1	50.00	50.00			
Total machinery cost				94.75	54.75	54.75	54.75
Operating inputs							
Seeding							
Bermuda grass sprigs	lbs.	30	2.75	82.50			
Buffalo grass seed	lbs.	50	21.00		1050.00		
Orchard grass seed	lbs.	5	2.57			12.85	
Wheatgrass seed	bu.	15	4.99				74.85
Chemical							
Herbicide (2,4-D)	pt.	1.5	1.90	2.85	2.85	2.85	2.85
Nitrogen							
Bermudagrass	lbs.	30	0.21	6.41			
Buffalograss	lbs.	30	0.21		6.41		
Orchardgrass	lbs.	60	0.21			12.82	
Wheatgrass	lbs.	60	0.21				12.82
Annual Operating Capital							
Bermuda grass	$	186.51	0.07	13.06			
Buffalo grass	$	1114.01	0.07		77.98		
Orchard grass	$	83.27	0.07			5.83	
Wheatgrass	$	145.27	0.07				10.17
Total operating inputs				104.81	1137.24	34.34	100.58
Land rental	acre	1	35.00	35.00	35.00	35.00	35.00
Total machinery, input and land rental cost	$			234.56	1226.99	124.09	190.43
Establishment cost, amortized for 10 years at 7%	$		0.07	33.40	174.70	17.67	27.11

[a] Machine operation prices from Haque et al. 2010.

[b] Haque et al. 2010 for bermudagrass, www.seedland.com for buffalograss, www.utahsee.com and www.seedland.com for orchardgrass, and www.sharpseed.com for Tall wheatgrass, Jose.

Table 3. Non-stochastic net return per acre for forage production systems under warm season grasses, Texas County, Oklahoma, assuming Average DM yields for 2010

Forage	NS	NR	Code	Gross Income	Variable Cost	Harvest Costs	Net return
				--------------------------------$/ac--------------------------			
Bermuda Grass	Control	0	BMC00	236.81	68.40	83.57	84.84
	SE	50	BMS50	309.35	132.20	105.68	71.47
	SE	150	BMS150	402.53	168.31	134.07	100.14
	SE	450	BMS450	557.94	251.04	181.44	125.46
	SE_Mean						99.02
	UR	50	BMU50	243.65	95.95	85.65	62.04
	UR	150	BMU150	366.91	143.03	123.22	100.65
	UR	450	BMU450	563.56	284.27	183.15	96.13
	UR_Mean						86.28
BM_Mean							90.05
Buffalo Grass	Control	0	BUC00	265.08	209.70	79.26	-23.88
	SE	50	BUS50	323.49	273.50	94.21	-44.22
	SE	150	BUS150	434.93	309.61	122.74	2.58
	SE	450	BUS450	588.27	392.34	162.00	33.94
	SE_Mean						-2.57
	UR	50	BUU50	333.56	237.25	96.79	-0.48
	UR	150	BUU150	418.14	284.33	118.44	15.36
	UR	450	BUU450	470.95	425.57	131.96	-86.58
	UR_Mean						-23.90
BU_Mean							-16.78

Table 4. Non-stochastic net return per acre for forage production systems under cool season grasses, Texas County, Oklahoma, assuming Average DM yields for 2010

Forage	NS	NR	Code	Gross Income	Variable Cost	Harvest Costs	Net return
				--------------------------------$/ac---			
Orchard Grass	Control	0	ORC00	290.08	52.67	0.00	237.41
	SE	50	ORS50	348.93	116.47	0.00	232.46
	SE	150	ORS150	447.40	152.58	0.00	294.82
	SE	450	ORS450	532.50	235.31	0.00	297.19
	SE_Mean						274.83
	UR	50	ORU50	385.13	80.22	0.00	304.91
	UR	150	ORU150	425.42	127.30	0.00	298.12
	UR	450	ORU450	531.42	268.54	0.00	262.88
	UR_Mean						288.64
OR_Mean							266.96
Wheat Grass	Control	0	WHC00	352.91	62.11	0.00	290.80
	SE	50	WHS50	388.47	125.91	0.00	262.56
	SE	150	WHS150	408.99	162.02	0.00	246.77
	SE	450	WHS450	546.08	244.75	0.00	301.33
	SE_Mean						270.29
	UR	50	WHU50	394.69	89.66	0.00	305.02
	UR	150	WHU150	411.18	136.74	0.00	274.44
	UR	450	WHU450	547.66	277.98	0.00	269.68
	UR_Mean						283.05
WH_Mean							281.38

Appendix 1. Estimated costs of production per acre for warm season grasses

	BMC00	BMS50	BMS150	BMS450	BMU50	BMU150	BMU450	BUC00	BUS50	BUS150	BUS450	BUU50	BUU150	BUU450
Establishment	33.40	33.40	33.40	33.40	33.40	33.40	33.40	174.70	174.70	174.70	174.70	174.70	174.70	174.70
Fertilizer App Cost														
Urea	0.00	0.00	0.00	0.00	3.75	3.75	3.75	0.00	0.00	0.00	0.00	3.75	3.75	3.75
Swine Effluent		59.63	93.37	170.69					59.63	93.37	170.69			
Sub-total	0.00	59.63	93.37	170.69	3.75	3.75	3.75	0.00	59.63	93.37	170.69	3.75	3.75	3.75
Operating Input														
Urea	0.00	0.00	0.00	0.00	22.00	66.00	198.00	0.00	0.00	0.00	0.00	22.00	66.00	198.00
Annual Operating Capital	0.00	4.17	6.54	11.95	1.80	4.88	14.12	0.00	4.17	6.54	11.95	1.80	4.88	14.12
Sub-total	0.00	4.17	6.54	11.95	23.80	70.88	212.12	0.00	4.17	6.54	11.95	23.80	70.88	212.12
Machinery Operation [a]														
Harvesting (mowing)	8.25	8.25	8.25	8.25	8.25	8.25	8.25	8.25	8.25	8.25	8.25	8.25	8.25	8.25
Harvesting (raking)	3.15	3.15	3.15	3.15	3.15	3.15	3.15	3.15	3.15	3.15	3.15	3.15	3.15	3.15
Harvest (Bailing)	72.17	94.28	122.67	170.04	74.25	111.82	171.75	67.86	82.81	111.34	150.60	85.39	107.04	120.56
Sub-total	83.57	105.68	134.07	181.44	85.65	123.22	183.15	79.26	94.21	122.74	162.00	96.79	118.44	131.96
Land Rental	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00
Total Production cost	151.97	237.88	302.38	432.48	181.61	266.25	467.42	288.96	367.71	432.35	554.34	334.04	402.78	557.54

[a] Harvesting cost for warm season greases were calculated with historical DM yields for forage production systems.

Appendix 2. Estimated costs of production per acre for cool season grasses

	ORC00	ORS50	ORS150	ORS450	ORU50	ORU150	ORU450	WHC00	WHS50	WHS150	WHS450	WHU50	WHU150	WHU450
Establishment	17.67	17.67	17.67	17.67	17.67	17.67	17.67	27.11	27.11	27.11	27.11	27.11	27.11	27.11
Fertilizer App Cost														
Urea	0.00	0.00	0.00	0.00	3.75	3.75	3.75	0.00	0.00	0.00	0.00	3.75	3.75	3.75
Swine Effluent		59.63	93.37	170.69					59.63	93.37	170.69			
Sub-total	0.00	59.63	93.37	170.69	3.75	3.75	3.75	0.00	59.63	93.37	170.69	3.75	3.75	3.75
Operating Input														
Urea	0.00	0.00	0.00	0.00	22.00	66.00	198.00	0.00	0.00	0.00	0.00	22.00	66.00	198.00
Annual Operating Capital		4.17	6.54	11.95	1.80	4.88	14.12	0.00	4.17	6.54	11.95	1.80	4.88	14.12
Sub-total	0.00	4.17	6.54	11.95	23.80	70.88	212.12	0.00	4.17	6.54	11.95	23.80	70.88	212.12
Machinery Operation														
Harvesting (mowing)														
Harvesting (raking)														
Harvest (Bailing)														
Sub-total														
Land Rental	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00
Total Production cost	52.67	116.47	152.58	235.31	80.22	127.30	268.54	62.11	125.91	162.02	244.75	89.66	136.74	277.98

Appendix 3. Validation of the simulated yield multivariate distribution

	BMC00[a]	BMS50	BMS150	BMS450	BMU50	BMU150	BMU450	BUC00	BUS50	BUS150	BUS450	BUU50	BUU150	BUU450
t test of simulated means vs. historical means														
P values	0.98	0.99	0.98	0.97	0.95	1.00	0.97	0.91	0.89	0.90	0.99	1.00	0.98	1.00
F test of simulated variances vs. historical variances														
P values	0.32	0.40	0.39	0.36	0.44	0.38	0.34	0.42	0.39	0.43	0.49	0.38	0.42	0.51

	ORC00	ORS50	ORS150	ORS450	ORU50	ORU150	ORU450	WHC00	WHS50	WHS150	WHS450	WHU50	WHU150	WHU450
t test of simulated means vs. historical means														
P values	0.99	0.97	0.99	0.96	0.98	0.95	0.95	0.94	0.99	0.99	0.99	0.99	1.00	1.00
F test of simulated variances vs. historical variances														
P values	0.42	0.50	0.53	0.42	0.39	0.45	0.37	0.34	0.46	0.52	0.46	0.41	0.43	0.40

[a] The acronym indicating alternatives of forage production systems are given by the following convention. The first two letters indicate grass species: BM=Bermuda grass, BU=buffalo grass, OR=orchard grass, WH=wheatgrass. One letter in the middle of acronym stands for nitrogen source: S=SE, U=urea, C=control. Finally, the number shows N application rates of 0, 50, 150, and 450 N lb per acre.

Appendix 4. Risk modeling

The distributions of the net economic returns from alternative forage production systems were constructed through the multivariate empirical (MVE) distribution simulation from SIMETAR. The simulation model defined economic returns as:

$$(1)\quad PI_{sij} = \begin{cases} P_{hi} \times \tilde{Y}_{sij} - \{P_U \times N_{sij} + \tilde{Y}_{sij} \times HC_i + UA_{sij} + OPC_{sij}\} \; if \; s = urea \\ or \\ P_{hi} \times \tilde{Y}_{sij} - \{\tilde{Y}_{sij} \times HC_i + MA_{sij} + OPC_{sij}\} \quad if \; s = swine\ effluent \end{cases}$$

where $\tilde{Y}_{sij}$ is stochastic dry matter yield for forage type *i,* N rate *j*, and N source *s*; P_{hi} is price for hay *i* ; P_U is price of urea ; HC_i is harvesting cost per ton only for Bermuda grass and buffalo grass; UA_{sij} and MA_{sij} are the application costs of urea and SE, respectively; and OPC_{sij} is other operating costs including establishment cost, machinery operation, annual operating capital and rental. A stochastic variable in the model, $\tilde{Y}_{sij}$, was constructed in SIMETAR and used to construct the distribution of net economic returns for alternative forage production systems. The multivariate empirical (MVE) distribution was used in this study for two reasons. One is that dry matter yields were found to be highly correlated with each other and the MVE is able to construct joint probability distributions that maintain observed levels of multivariable correlation. The other is that simulated values for prices and yields are truncated variables, i.e. they are by nature always greater than or equal to zero, conditions which the MVE is able to satisfy. Parameters for the MVE distribution were determined using historical dry matter yield data from the long-term field trials. Validation of the simulated yield multivariate distribution is presented in Appendix 3, validating that the simulated mean and variances are statistically equal (P<0.05) to the historical data in Table 1.

Appendix 4. Risk modeling (cont'd.)

Stochastic efficiency analysis of net income

The decision maker's risk preferences, i.e. the trade-off between mean income and the variance of income, are characterized using an income utility function. A negative exponential utility function, which exhibits constant absolute risk aversion (CARA), was used in this study. The use of negative exponential function is considered appropriate in this study since: (1) the exact shape of the income utility function is unobservable, but the negative exponential has the general characteristics that conform to how producers are expected to make decisions; (2) the specific level of decision maker's risk aversion is not defined and the negative exponential can handle a range of risk preferences through varying it's shape using a single parameter; and (3) absolute risk aversion with respect to either wealth or income can be modeled with the coefficients of absolute risk aversion under the negative exponential function (Hardaker et al.,2004). The negative exponential utility function is given by the following functional form:

$$(1)\ U(w) = -\exp\left(-r_a w\right)$$

where w is the random wealth variables and r_a is the Pratt-Arrow measure of the absolute risk aversion, defined as $r_{\mathrm{a}} = -U''(w)/U'(w)$. The unique characteristic of constant absolute risk aversion (CARA) is that choices are not affected by changes in total wealth or income (Grové,2006). The lower and upper boundary of absolute risk aversion (r_{a}) is calculated based on the relation between absolute risk aversion and relative risk aversion (r_{r}) mentioned in Hardaker et al. (2004).

Appendix 4. Risk modeling (cont'd.)

The ordinal nature of the utility of income makes it difficult to interpret the calculated utility. Therefore, the certainty equivalent (CE), which is consistent with the concept of income utility, was used for convenience. Due to the one-to-one relationship between the CE and the income utility function, the maximization of CE is equivalent with the maximization of income utility (Hardaker et al., 2004). The CE of the negative exponential function is obtained by taking the inverse of the utility function as given by the following:

$$(1)\ CE(w) = \frac{\ln(-\mathrm{E}U(w))}{-r_a}.$$

Probability distributions of net economic returns for each forage production system were simulated using the results of the simulated yields from SIMETAR. Since the probability distributions of economic returns contain the inherent risk associated with each alternative, pairwise comparisons were made between the alternatives using the certainty equivalent (CE). When making the comparisons in this type of risky environment, higher CE values are preferred over lower ones. The value of the CE can be viewed as indicating the overall value a producer would associate with an alternative factoring in both the expected return less a discount for the variance associated with the alternative. In addition, the risk premium, which is the amount of money a decision maker who is willing to pay to reduce variability, can be easily calculated with SERF by simply subtracting the CE from one alternative from the CE of another alternative.