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Evaluating Returns to Cool Season Grass Quality Characteristics for Niche Equine Feed Markets

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This study examines the impact of cool season grass quality characteristics on pricing and net returns in niche equine feed markets. A hedonic analysis of Timothy grass hay prices in Nevada was performed to determine the implicit values of its quality characteristics. A Monte Carlo simulation was then conducted to estimate the distribution of net returns to improving grass hay quality characteristics. Results show that the presence of foreign matter had the largest impact on grass hay price, followed by seller reputation and hay color. However, for risk-averse producers, enhancing seller reputation and grass hay color are the preferred strategies for increasing net returns.

Key Words: cool season grasses, niche markets, quality characteristics, risk analysis

As the equine industry places an increasing emphasis on high quality forage, horse breeders, trainers, and owners are transitioning their equine feed mix from a traditional diet composed strictly of alfalfa to a diet of grass or alfalfa/grass mixes augmented with mineral and energy supplements. Although alfalfa is normally higher in protein and energy than most grasses, it is more likely to cause digestive problems in horses than grass (Evans and McKendrick, 2006). Grass hays are also richer in calcium and trace minerals than alfalfa and are the preferred feed for sedentary or idle horses. Additionally, grass hays tend to be more palatable for horses, resulting in less feed waste. As the transition to a grass-based equine diet continues, horse owners, breeders, and trainers will experience an increasing need for quality grasses. The expanding market for grasses could provide an important niche market and diversification strategy for traditional alfalfa hay producers.

Cool season grasses, such as Orchard and Timothy hay, are primarily grown in Nevada, Utah, California, Oregon, and Washington. Nevada's climate and soil

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conditions are conducive to the production of high quality cool season grasses, which are grown mainly in north-central and northeastern Nevada. Cool season grasses are principally marketed based on appearance attributes and seller reputation, as opposed to other hays, which are marketed based on chemical composition (Blank, Orloff, and Putnam, 2001). Appearance attributes are evaluated through the use of sensory analysis (visual, olfactory, etc.) rather than near infrared reflectance (NIR) or grading standards. Any discoloration, deformity, or presence of undesirable materials detracts substantially from the value of the product. Buyers inspect the hay before the transaction is complete and set a price at that time based on their perception of the hay's quality. Pre-harvest marketing contracts, which designate a quantity and price, are rarely used. Premium grass hays for horses sell for two to three times the price of premium grade alfalfa hay.[1] However, low quality product is unacceptable in this niche market and must be sold at expense recovery prices or as cattle feed. Nevada cool season grasses are shipped to buyers in Nevada and California, a distance ranging from 200 to 400 miles.

The purpose of this study is to estimate the impact on pricing and net returns of cool season grass quality characteristics and seller reputation for equine feed markets. As Ward (2004) points out, price and quality relationships are important to both hay producers and buyers. Hay producers may benefit from an improved understanding of the price and net return impacts of grass hay characteristics as they relate to producer management decisions such as cutting schedule, pest management, harvesting techniques, and machinery selection, as well as storage investment. Producer knowledge of the influence of visual quality characteristics on pricing and net returns for this perennial crop will inevitably lead to production efficiencies and improved producer decision making in this competitive niche market (Blank, Orloff, and Putnam, 2001).

Modeling Quality Characteristics in Agriculture

The hedonic pricing model was first used by Waugh (1928) in an application to the vegetable market, and was expanded through studies by Houthakker (1951) and Gorman (1956). More recently, hedonic price analyses have been conducted on the market for cotton and cottonseed (Bowman and Ethridge, 1992; Misra and Bondurant, 2000), wine (Schamel, 2006; Steiner, 2004), tuna (McConnell and Strand, 2000), broodmares (Neibergs, 2001), and veal (Loureiro and McCluskey, 2000).

There is currently no published research on valuing grass hay quality characteristics, or the value of grass hay in specialty feed markets. Previous research has concentrated primarily on alfalfa intended for use in the dairy industry (Pardew,

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[1] "The Nevada Weekly Hay Report" for January 15, 2010, shows the weekly average price for Nevada Timothy grass hay at $290/ton and the weekly average price for premium alfalfa hay at $110/ton (USDA/Agricultural Marketing Service, 2010).

1988; Ward, 1994; Rudstrom, 2004; Hopper, Peterson, and Burton, 2004). Pardew (1988) examined the effects of quality characteristics and marketing services on alfalfa prices in Nevada, including variables designed to address such factors as the form of the hay (cubed, chopped, or baled), associated transportation costs, cooperative sales, county of production, cut date, sales agreement data, and payment dates. The emphasis on marketing services and payment agreements coincided with the USDA's Federal Grain Inspection Service change to quality standards for hay and NIR availability. It was thought that these two factors would increase the availability of hay quality information to hay buyers. Pardew found that cubed alfalfa hay produced in certain counties had an effect on price, while the variables related to marketing factors were found to be significant, but small in magnitude.

More recently, Rudstrom (2004) performed a hedonic price analysis of dairy quality hay sold at auction in Stearns County, Minnesota, from 2000 to 2002. Rudstrom's study was in response to the shift in dairy farms from producing all their own feedstuff to focusing mainly on livestock and outsourcing feed production. Rudstrom sought to better understand what effect hay quality and packaging have on the price of hay sold to dairy farmers. High quality hay is a necessary input for top milk production in dairy cows, while bale size and type are factors which can influence the purchasing decisions of dairy hay buyers. Using a semilog hedonic pricing model, Rudstrom found that relative feed value (RFV) and cutting have positive effects on the price of hay, while moisture content, large bales, and medium round bales have a negative effect on the price of dairy-quality hay.

Hopper, Peterson, and Burton (2004) used a hedonic pricing model to study the effects of quality on the price of alfalfa hay using auction data from Wisconsin. This study was similar to Rudstrom's work in that it focused mainly on the chemical composition of hay, and used such characteristics as RFV, crude protein (CP), acid and neutral detergent fiber (ADF and NDF, respectively), bale type/size, and tonnage of the lot. It was found that the models which used direct, as opposed to aggregate, nutritional values more accurately predicted price. The authors also suggest that individual markets use market-specific quality measures, as previous studies indicate that premiums and discounts associated with hay quality characteristics vary over time and location.

As is evident from the discussion of prior studies, little research has been conducted on valuing hay quality characteristics determined through sensory analysis, especially grass hays. Further, these studies focus on point estimates of characteristic values and do not incorporate risk by looking at the distribution of net returns related to quality characteristics and the impact on positive net return probabilities.

Data Overview

The data for this study were collected through a mail survey of 1,000 randomly selected horse owners in Nevada in 2005 (representing 20% of all registered horse

Table 1. Survey Sample Statistics (*N* = 325)

Parameter	Mean / Percentage
Location:	
Northwest Nevada	37%
"Other" Nevada	24%
Southern Nevada	15%
Northeast Nevada	12%
California, Oregon, Utah	1%
Did not specify	11%
Type of Respondent:	
Companion	67%
Breeder	13%
Rancher	10%
Boarder/Trainer	8%
Racehorse Owner	2%
Business Ownership:	
Sole Proprietorship	64%
Partnership	11%
LLC	4%
S Corporation	3%
C Corporation	< 1%
Other/Did not specify	18%
Horse Ownership:	
Number of horses owned	8
Grass Hay Purchases:	
Timothy hay purchased in 2004 (tons)	42
Currently Use Purchasing Contracts:	
Yes	10%
No	90%
Perform Visual Inspection Prior to Sale:	
Yes	76%
No	24%
Local Purchases:	
Purchase hay from Nevada vendors	85%

owners in the state). Horse owners included breeders, boarders, trainers, and ranchers, as well as racehorse and companion horse owners. Surveys were returned by 325 owners, yielding a response rate of 33%.

The survey asked for demographic information, such as business location, business type, type of horse ownership, number of horses, and hay purchase preferences. Complete survey sample statistics can be found in table 1. The majority of respondents (67%) identified themselves as companion horse owners, 13% as horse breeders, 10% as ranchers, 8% as horse boarders and/or trainers, and

Table 2. Summary Statistics of Variables (*N* = 288)

Variable	Description	Mean	Std. Dev.	Min.	Max.
Price	Price ($/ton)	175.85	58.787	65	375
Nutrition	Nutritional value of hay (scale 1–4)	3.58	0.673	1	4
Color	Color of hay (scale 1–4)	2.81	1.085	1	4
Leafiness	Leafiness of hay (scale 1–4)	1.98	1.138	1	4
Digestibility	Dummy = 1 if considered digestible	0.07	0.260	0	1
Supplier	Dummy = 1 if previous purchase from supplier	0.86	0.343	0	1
Foreign Matter	Dummy = 1 if foreign matter present	0.79	0.407	0	1

the remaining 2% as racehorse owners. Eighty-eight percent of the respondents were located in Nevada, while 1% were located in California, Oregon, or Utah. The remaining 11% did not specify their location. Respondents were asked if they visually inspect or have a third party visually inspect cool season grasses prior to purchase. Seventy-six percent stated they do visually inspect hay before purchase. Only 10% purchase cool season grasses on forward marketing contracts with producers. Finally, 85% purchase cool season grasses from Nevada vendors.

Additionally, respondents were asked to list the per ton price paid for their primary shipment of Timothy hay in 2004. They were provided with a list of six primary Timothy hay quality characteristics and were asked to rate the degree of presence of these characteristics in their shipment. Three of the six quality characteristics in their shipment (color, nutrition, and leafiness) were ranked on a scale of 1 to 4, where 1 represents the lowest rating and 4 denotes the highest rating. For the remaining three quality characteristics (digestibility, supplier, and foreign matter), respondents were asked to simply respond “yes” or “no” as to the existence of the characteristic in their hay shipment. A description of each of the quality characteristics is given below, and the summary statistics are described in table 2. As not all respondents fully answered this section of the survey, the sample size decreased to 288.

As noted previously, cool season grasses in Nevada are not evaluated by NIR, but rather through sensory analysis, such as visual and olfactory inspection. Kline, Porr, and Cardina (2000) score hay quality characteristics by digestibility (30%), leafiness (30%), color (10%), and foreign matter (30%)—including mold, dust, etc. Based on their evaluation criteria and those of Caddel and Allen (2003), we have included digestibility, leafiness, color, foreign matter, overall nutritional content, and previous purchase with supplier as potential determinants of cool season grass prices in Nevada.

The variables *Nutrition*, *Color*, and *Leafiness* were rated by respondents on a scale of 1 to 4. The four-point rating classification follows the scale developed by

Caddel and Allen (2003).[2] The variable *Nutrition* represents the nutritional value of the hay and is related to the mineral, protein, and energy levels provided. Nutrition is visually evaluated by the maturity of the hay and its color. The mean value of 3.58 indicates the hay in question was perceived to be of high nutritional content. The variable *Color* represents the "greenness" of the hay being purchased. The greenness of hay is an indication of the levels of vitamin A and riboflavin. Based on the mean value of 2.81 for the color characteristic, the average bale of hay purchased was of higher green color. The variable *Leafiness* represents the leafiness of the hay. The leaves of hay contain the protein and other nutrients that horses require. Hay with shattered leaves or high stem content is not as valuable in this market. The mean value of 1.98 for leafiness reveals the hay in question was slightly stemmy.

The variables *Digestibility*, *Supplier*, and *Foreign Matter* were reported by respondents on a "yes" or "no" basis and each has been converted to a binary variable. For *Digestibility*,[3] a value of 1 would indicate the grass hay was highly digestible. The mean value of 0.07 for the digestibility aspect suggests the hay in question was not considered digestible. For *Foreign Matter*, a value of 1 would indicate a notable presence of foreign matter in the hay. Foreign matter may include mold, weeds, insects, dust, etc. The hay under consideration contained notable foreign matter, as denoted by the mean value of 0.79.

The variable *Supplier* represents whether or not the horse owner previously purchased hay from the current supplier. The mean value of 0.86 indicates that the majority of the hay in question was purchased by buyers who had made a previous purchase from their supplier. This variable was included to assess the impact of supplier "reputation," reflecting the assertion of Shapiro (1983) that consumers form expectations of current quality based upon the quality of the same good experienced in the past. If the buyer/seller relationship has a significant effect on price, hay producers will benefit from cultivating current customer relationships by focusing on the needs and satisfaction of their current customers, as well as potentially erecting switching barriers similar to those of customer loyalty and frequent flyer programs (Patterson and Smith, 2003). Switching barriers increase the consumer cost of switching to another input or service provider. The literature (e.g., Homans, 1958; Bennis et al., 1964) shows that consumers examine the cost/benefit ratio when deciding whether or not to maintain a current relationship. Thus, when switching costs outweigh the benefits, the relationship will continue, even when the consumer is not completely satisfied with the service and/or product. Costs often include loss of special treatment, risk perceptions resulting from lack of experience with another provider, search costs, the need to explain preferences, and sunk costs of the current relationship.

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[2] For example, a color rating would include: 1 = brown or black, 2 = yellow to brownish, 3 = light green/ slightly brown, and 4 = natural green color. A leafiness rating would include: 1 = stemmy, 2 = slightly stemmy, 3 = leafy, and 4 = very leafy.

[3] Grass hay digestibility is determined by hay maturity, where mature hay is less digestible and exhibits reduced levels of protein and phosphorus. Maturity is evaluated by inspecting the coarseness of the stems and seed head development. Digestibility is normally rated as "too mature" or not, which is why a binary variable was used.

The Hedonic Model

Hedonic analysis models price as a function of the quality and quantity attributes of a particular product (Rosen, 1974). The attributes may be considered elements of utility maximization for consumers or production inputs for firms. In this case, the hedonic pricing approach implies that the price of cool season grass hay, $P(\mathbf{Z})$, is a function of the prices of n individual characteristics, such that $P(\mathbf{Z}) = p(Z_1, \ldots, Z_n)$. The price of each characteristic can be determined through regression of the price of the cool season grass hay onto the characteristics.

A semilog hedonic model was used for this analysis. Linear, log-linear, and Box-Cox transformed specifications were also examined, but the semilog model was found to have the best fit due to the nonseparability of hay quality characteristics (Rudstrom, 2004). The semilog specification allows the marginal value of each characteristic to serve as a nonlinear function of the other hay characteristics. The data were tested for heteroskedasticity using the Breusch-Pagan/Cook-Weisberg routine in STATA. The model was estimated as:

$$(1)\qquad \ln(\mathit{Price}) = \beta_0 + \beta_1(\mathit{Nutrition}) + \beta_2(\mathit{Digestibility}) + \beta_3(\mathit{Supplier}) + \beta_4(\mathit{Color}) + \beta_5(\mathit{Foreign\ Matter}) + \beta_6(\mathit{Leafiness}).$$

The semilog model specification prevents the interpretation of the coefficients as the direct effect on the price of grass hay; it is necessary to transform the coefficients into marginal values. In a semilog hedonic price analysis, the marginal value of the characteristics scaled from 1 to 4 (*Nutrition*, *Color*, and *Leafiness*) is defined as the change in price given a one-unit change in the characteristic, and is the implicit price of that characteristic. The marginal value of the *i*th characteristic is given as follows:

$$(2)\qquad \Delta p_i = \frac{\begin{bmatrix} \left(E[p \mid x_i = 2] - E[p \mid x_i = 1]\right) + \\ \left(E[p \mid x_i = 3] - E[p \mid x_i = 2]\right) + \\ \left(E[p \mid x_i = 4] - E[p \mid x_i = 3]\right) \end{bmatrix}}{3}.$$

The marginal value of a dummy variable (*Digestibility*, *Supplier*, and *Foreign Matter*) is the difference in predicted price when calculated with and without the *i*th characteristic, with marginal value defined as the change in price due to the presence of the characteristic versus its absence, and shows the implicit price of the characteristic. The marginal value is calculated at the mean value of the other characteristics as:

$$(3)\qquad \Delta p_i = E\left[p \mid x_i = 1\right] - E\left[p \mid x_i = 0\right].$$

Table 3. Hedonic Parameter Estimates (OLS regression) and Marginal Values (*N* = 288)

Variable	Coefficient	Standard Error	Marginal Value ($/ton)
Nutrition	0.083**	0.033	14.04
Color	0.115***	0.029	19.54
Leafiness	0.080***	0.027	13.61
Digestibility	0.134	0.090	23.96
Supplier	0.347***	0.053	51.46
Foreign Matter	−0.315***	0.072	−58.27
Constant	4.269***	0.150	—
R^2 = 0.3532			

Note: Single, double, and triple asterisks (*,**,***) denote statistical significance at the 10%, 5%, and 1% levels, respectively.

Hedonic Model Results

The cool season grass price predicted by the model was $165.79 per ton, slightly lower than the mean price of $175.85 per ton paid by survey respondents. Table 3 presents the parameter estimates and associated standard errors, as well as the marginal values. All of the included variables were statistically significant at a 10% minimum, with the exception of *Digestibility*. The coefficients on *Nutrition*, *Digestibility*, *Supplier*, *Leafiness*, and *Color* were positive and significant, and the coefficient on *Foreign Matter* was negative and significant. Thus, all of the variables displayed the expected sign. The R^2 was estimated at 0.3532, indicating these six variables explain approximately 35% of the variation in product price. Factors such as storage facilities for the seller and transportation and storage services for buyers may be important. For example, producers commented to the authors that if they do not have a permanent storage structure, such as a barn, buyers will not even look at their grass hay. Also, many buyers prefer to have the producer store the hay for them and only deliver it when needed. Pardew (1988) found seller-paid transportation had a significant effect on price in the alfalfa hay industry.

The marginal value of *Color* at $19.54/ton indicates that a one-unit increase in the color rating of grass hay will increase the price by just fewer than $20 per ton. Of the continuous variables, grass color had the highest price impact. Essentially, moving from a rating of 2 to a rating of 4 for greenness would increase the price by $39.08 per ton. Hay producers might ensure greener hay by decreasing the probability of rain exposure via harvesting with the aid of location-specific weather monitoring systems and/or storage techniques that reduce moisture and sun exposure to the hay.

As the marginal value of *Nutrition* is $14.04/ton, a one-unit increase in the perceived nutritional content (from 2 to 3, for example) will increase the per ton price by $14.04. The marginal value of *Leafiness* is $13.61/ton, indicating that a one-unit increase in the perceived leafiness of grass hay will increase its selling price by over $13 per ton. Since leafiness was rated low in the survey sample, hay producers could increase their pricing by $40.83 per ton by increasing the leafiness rating of their product from a 1 to a 4. Hay producers may cut down on leaf loss by not raking or baling overly dry cuttings.

The marginal value on *Foreign Matter* shows that the presence of foreign matter will decrease the price of grass hay by $58.27/ton—the highest price impact among the discrete variables. This finding is not surprising, as the ingestion of foreign matter including insects (such as beetles) and mold can make horses ill, while the presence of weeds and dust serves as an indication of poor quality and/or poorly stored hay. This result is in accord with Ward's (2004) similar analysis of alfalfa hay which showed that weed presence percentages of 5% decrease the alfalfa per ton price by $26, or approximately 25%.

Finally, the marginal value for *Supplier* is $51.46/ton, indicating that having made a previous purchase with the supplier had the second highest impact on price of the discrete variables. The rationale for this premium structure is likely due to reputation, a result of product and/or provider service satisfaction, or switching barriers (as explained in Patterson and Smith, 2003).

Risk Analysis

The hedonic estimation provides only a deterministic result or average change in the cool season grass hay price, which ignores risk or variability. Marginal values are point estimates instead of estimates of probability distributions. Such distributions provide useful insight concerning the risks related to cool season grass production strategies, as risk-averse producers likely would not prefer large variability in grass hay prices and net returns.

In this section, we seek to investigate the economic feasibility in terms of net returns to cool season grass production using a Monte Carlo simulation model similar to that used by Richardson et al. (2007). The simulation model is developed based on the results of the hedonic analysis, which has not yet been considered in the literature. The stochastic variables, which are defined as variables the decision maker cannot control (Richardson, 2006), in the simulation model are the grass hay price, the yield, and the variable cost to cool season grass production. The net return per acre, π, from producing cool season grass is given by:

$$(4) \qquad \tilde{\pi} = (\tilde{P} - \tilde{C}) * \tilde{Y} - F,$$

where tildas denote stochastic variables, P is the grass hay price ($/ton), C is the variable cost ($/ton), Y is the hay yield (tons/acre), and F is the fixed cost ($/acre). The grass hay price is decomposed into six components as in the hedonic equation, including nutrition, color, leafiness, digestibility, presence of foreign matter, and supplier reputation. Thus, stochastic grass hay price is rewritten as:

$$\ln(\tilde{P}) = \hat{\beta}_0 + \sum_{j=1}^{6} \hat{\beta}_j X_j + \tilde{e}, \tag{5}$$

where coefficients (β) are estimated in the hedonic model (table 3). Hence, risk analysis results would be similar to and consistent with the hedonic model results because the net return in equation (4) is closely and positively correlated with the grass hay price in equation (5). If the risk-neutral producer is considered, results would be identical to the previous section as these producers do not consider risk in their decision making.

The source of risk or the stochastic component $(\tilde{e})$ cannot be explained by the hedonic analysis and is assumed to be $\tilde{e} \sim \text{iid}\, N(0, \sigma_e^2)$. The source of risk $\tilde{e}$ is forecasted by simulating from the probability distribution used to generate $\tilde{P}$. The original price data and their corresponding simulated prices using equation (5) are graphed as a cumulative distribution function (CDF) on a common axis in figure 1. As observed from this graph, the original price data are nearly the same as the simulated data, confirming the simulation forecasts the correct distribution.

The grass hay yields and costs of production data are required to complete the economic feasibility simulation in equation (4). The cool season grass yield and cost information is obtained by combining forage production and cost information from Eureka County, Nevada (Curtis and Riggs, 2007) with "other hay" from Kettle, Myer, and Breazeale (1999), and Breazeale (2007). Based on these references, we presume the grass hay yield is a minimum of three tons/acre, a maximum of six tons/acre, with an average of five tons/acre. The simulation for the yield is completed using the Gray, Richardson, Klose, and Schumann (GRKS) distribution.[4] The GRKS distribution is useful to generate random variables when minimum information about the distribution exists (Richardson, 2006; Evans and Stallmann, 2006). The variable cost (operating cost) used the GRKS distribution for similar reasons, and yielded a minimum of \$80/ton, a maximum of \$140/ton, with an average of \$124/ton. Fixed cost is assumed to be \$223/acre and does not change over the simulation.

Simulation Results

All stochastic variables are simulated by running 1,000 iterations to compute the net return in equation (4) and generate the CDF as shown in figure 2. (Note that the 1,000-iteration simulation generates a distribution similar to the normal distribution

[4] The GRKS distribution is similar to triangular distribution. The distribution was developed to simulate "subjective probability distribution" with minimal data (Richardson, 2006, chap. 5, p. 3). The GRKS distribution has the following useful properties: 50% of observations are less than the midpoint; 95% of the simulated values are between the minimum and the maximum; 2.2% of the simulated values are less than the minimum and more than the maximum (Evans and Stallmann, 2006, p. 175).

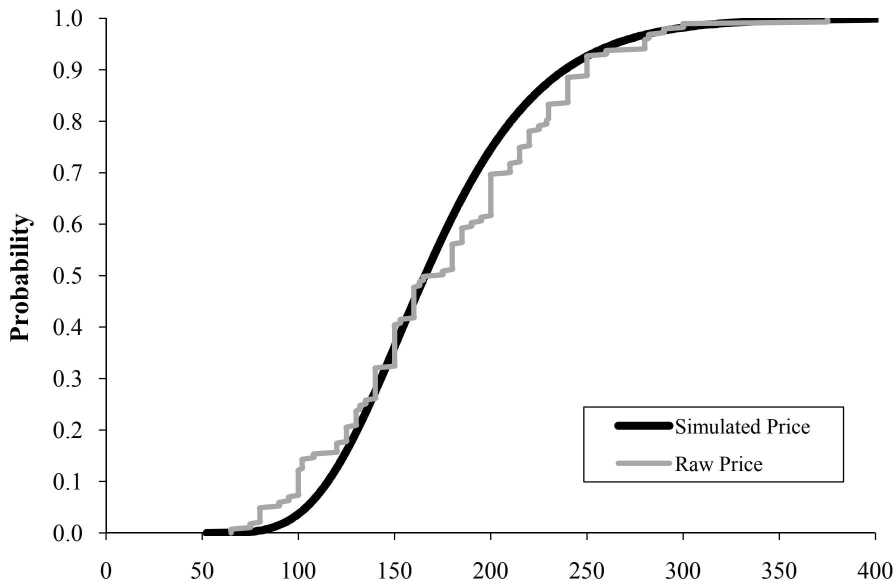

Figure 1. Comparing raw price CDF to simulated price CDF for validation

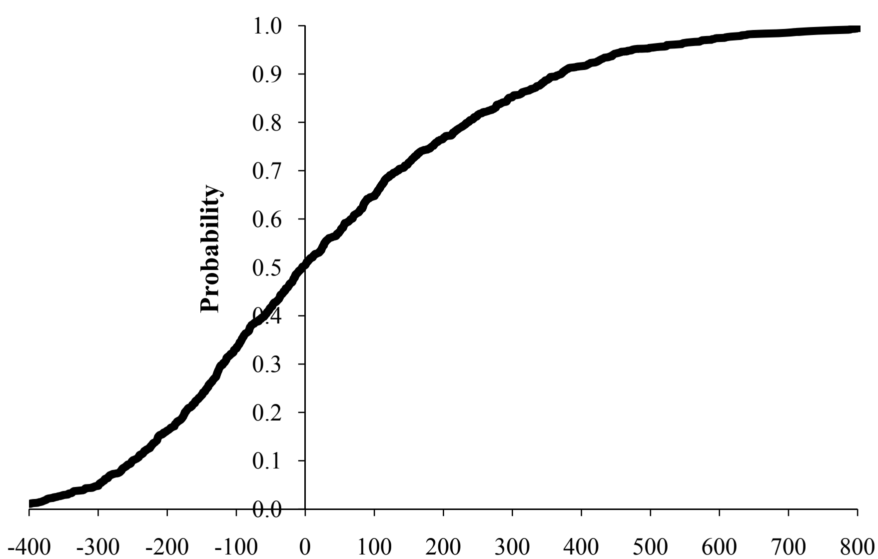

Figure 2. Cumulative distribution function of net returns ($/acre)

Table 4. Summary of Simulation Net Returns ($/acre)

Strategies	Mean	Standard Deviation	Minimum	Negative Net Return
Base	34.90	250.90	−593.31	50.50
Increasing nutrition by 10%	61.07 [74.97]	267.67 [6.68]	−547.77	46.76
Enhancing color by 10%	61.25 [75.49]	266.02 [6.03]	−506.55	47.86
Enhancing leafiness by 10%	49.45 [41.70]	258.76 [3.13]	−605.81	48.33
Enhancing digestibility by 10%	45.18 [29.45]	257.48 [2.62]	−518.68	48.83
Reducing presence of foreign matter by 10%	82.71 [136.98]	274.80 [9.53]	−532.82	42.52
Improving supplier's reputation by 10%	88.77 [154.34]	266.66 [6.28]	−493.93	42.09

Note: Values in brackets [ ] denote % change from "Base."

of π even if different types of distributions are used—for example, GRKS for the hay yield and the variable cost.) The base scenario is the simulation of equation (4) with stochastic grass hay prices generated from equation (5) using estimates in table 3. The average net return from the base simulation is $35/acre and the standard deviation is given by $251/acre. The probability of negative net return is 50.5%, implying a high degree of risk in cool season grass hay production.

We further investigate several opportunities to increase net returns from grass hay production. We propose improving each hedonic characteristic variable by 10%. Note that the presence of foreign matter is decreased by 10% because it has a negative impact on grass hay pricing. Each strategy is simulated 1,000 times step-by-step to compute net returns. The results are reported in table 4. Each strategy increases net return over 30%. Improving supplier reputation increases net return by 154% compared to the base scenario.

However, the comparison of mean net returns for each strategy does not include the risk or variability in net returns. Ranking risky alternatives can be done in several ways—for example, comparing standard deviation, maximin or minimax criteria, using certainty equivalences (Hardaker, 2000), or applying stochastic dominance (Meyer, 1977). We use the stochastic efficiency with respect to a function (SERF) approach based on discussions in Hardaker et al. (2004b). The SERF designates a rank of risky alternatives in terms of certainty equivalents for a specified range of risk-aversion coefficients with predetermined (decision maker's) utility function based on the following rules:

(6) $F(\pi)$ preferred to $G(\pi)$ at $ARAC$ if $CE_F > CE_G$,
$F(\pi)$ indifferent to $G(\pi)$ at $ARAC$ if $CE_F = CE_G$, or
$G(\pi)$ preferred to $F(\pi)$ at $ARAC$ if $CE_F < CE_G$,

where $F(\pi)$ and $G(\pi)$ are CDFs of net returns from two risky alternatives, CE indicates the certainty equivalences, and $ARAC$ is the absolute risk-aversion coefficient.

To visualize comparison results, we calculate the risk premiums relative to the base scenario, i.e., the difference between each scenario's certainty equivalence from the base scenario. The definition of risk premium is expressed by:

(7) $$RP_{scenario,base,ARAC} = CE_{scenario,ARAC} - CE_{base,ARAC} \;\; \forall \, ARAC.$$

The risk premium for the base scenario is zero over all the risk-aversion coefficients by construction, i.e., $RP_{base,base,ARAC} = CE_{base,ARAC} - CE_{base,ARAC}$. Figure 3 summarizes the risk premiums at various absolute risk-aversion coefficients (ARACs), assuming a negative exponential utility function.[5] When ARAC = 0, the decision maker is risk neutral; higher values of ARAC imply risk-averse decision makers. We select relative risk-aversion coefficients from zero to three (as suggested by Anderson and Dillon, 1992) and convert the absolute risk-aversion coefficients using average net return, ranging from 0 to 0.03. In other words, an ARAC greater than 0.03 in figure 3 indicates the decision maker is very risk averse.

As displayed in figure 3, a strategy improving supplier reputation is the most preferred regardless of the decision maker's risk attitude. However, strategies rank differently over risk-aversion coefficients. For example, decreasing foreign matter is less preferred at high risk-aversion coefficients, as this strategy results in a larger variability on grass hay pricing and thus net returns. This is a key result of the risk analysis which focuses on variability, as well as average impact.

Table 5 summarizes the rank of each strategy based on the SERF approach. Strategy rankings using additional criteria are reported for comparison purposes. Number 1 in the table indicates the most preferred strategy under the corresponding criterion. Number 7 implies the least preferred strategy. Overall, improving supplier reputation is the optimal strategy, followed by reducing foreign matter

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[5] The negative exponential utility function is given by $U(\pi) = 1 - \exp(-ARAC*\pi)$, where $ARAC > 0$ (Hardaker et al., 2004a). The negative exponential utility function exhibits constant absolute risk aversion (CARA), which is given by ARAC. This function has been used in decision analysis extensively. Note that this function can be estimated from a single certainty equivalent (CE), and it is particularly useful in analysis where the distribution of returns is normal (Hardaker et al., 2004a). The CE of a risky prospect is the sure sum with the same utility as the expected utility of the prospect. In other words, the CE over risk-aversion coefficient is given by $CE(\pi, ARAC) = U^{-1}(\pi, ARAC)$. The CE depends on the type of utility function. The CE for the negative exponential utility function is calculated as follows [Hardaker et al., 2004a, p. 257, equation (3)]:

$$CE(\pi, ARAC) = \ln\left[\left(\frac{1}{n}\sum_{i=1}^{n}\exp(-ARAC\,\pi_i)\right)^{1/ARAC}\right].$$

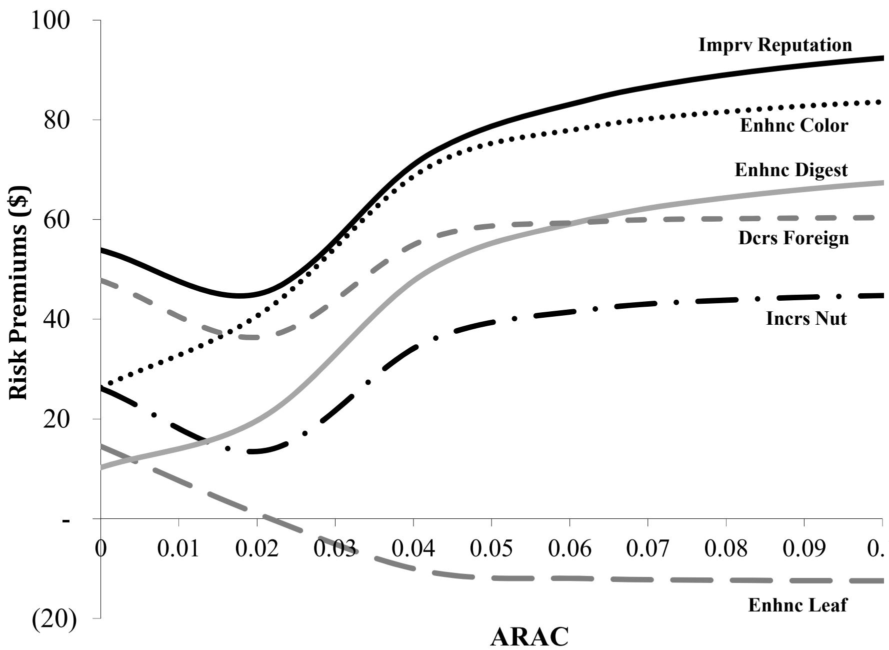

Figure 3. Stochastic efficiency with respect to a function (SERF) among strategies: Risk premiums relative to base scenario assuming negative exponential utility

Table 5. Summary of Rankings

					SERF [b]		
Strategies / Criteria	Mean	Mini Max	CV	$P(\pi > 0)$ [a]	Risk Neutral	Rather Risk Averse	Very Risk Averse
Base	7	6	7	7	7	7	6
Increasing nutrition	4	5	4	3	4	5	5
Enhancing color	3	2	3	4	3	2	2
Enhancing leafiness	5	7	5	5	5	6	7
Enhancing digestibility	6	3	6	6	6	4	4
Reducing foreign matter	2	4	2	2	2	3	3
Improving supplier reputation	1	1	1	1	1	1	1

[a] Probability of nonnegative net return.
[b] SERF = stochastic efficiency with respect to a function.

and enhancing color. The rankings of enhancing leafiness, enhancing digestibility, and increasing nutrition strategies are dependent upon the magnitude of risk aversion.[6]

Summary and Conclusions

As the equine industry places more emphasis on high quality hays, owners are transitioning horses to a diet of cool season grasses or alfalfa/grass mixes augmented with mineral and energy supplements. Cool season grasses are marketed based on appearance attributes, as opposed to other hays, which are marketed based on chemical composition. Appearance attributes are evaluated through the use of sensory analysis (visual, olfactory, etc.). Thus, it is important for producers to understand which quality aspects of grass hay evaluated through sensory inspection will increase the product price and final net returns to production. A hedonic price analysis was used to determine the implicit value of each of six grass hay quality characteristics. A Monte Carlo simulation incorporating risk was then conducted to evaluate which quality characteristics reduced the probability of negative returns, as well as strategies for increasing net returns under different risk-aversion coefficients.

The hedonic results of this study indicate that the presence of foreign matter has the largest impact on grass hay pricing, followed by supplier reputation and color. However, when risk is introduced, we see that supplier reputation and foreign matter decrease the probability of negative net returns, and improving supplier reputation is the best strategy for all levels of risk aversion, placing decreasing foreign matter in second place. Thus, we observe that the risk assessment differs somewhat from the point estimation of the hedonic model. In fact, for a very risk-averse producer, enhancing color is actually the second best alternative, placing reduction of foreign matter in third place in terms of importance.

Maintaining a green color and/or minimizing leaf damage may be achieved through management strategies such as constructing hay storage facilities and/or maintaining a fleet of used harvesting equipment. These strategies will decrease the probability of weather damage and cut grass hay on-field time. Pest management strategies focused on decreasing the presence of insects in cut or baled grass hay may also be beneficial. The benefits in terms of increased revenue would have to be compared with resulting cost changes. For example, using the Eureka County, Nevada, forage production costs and returns budget (Curtis and Riggs, 2007), we find that increasing the grass hay price from $165.79/ton to $204.87/ton (moving from a 2 to a 4 greenness rating) and adding two hay barns (cost of $136,000 paid over 25 years) increases annual farm net returns from $9,712.97 to $57,613.50. Additionally, converting from one new tractor to four used tractors

[6] Although it was not statistically significant at the conventional significance levels in the hedonic analysis, the *Digestibility* variable was added to the risk analysis as it may not be ignored due to its *P*-value of 0.137.

and increasing the grass hay price from $165.79/ton to $206.62/ton (moving from a 1 to a 4 leafiness rating) increases annual farm net returns from $7,649.68 to $60,238.50.

The impact of a previous relationship with the supplier is likely the result of reputation built on previous purchases and the quality of the Timothy hay of those purchases. Because 24% of the survey respondents did not visually inspect the grass hay before purchase, the reputation of the producer (seller) may have been substituted for the inspection. This result may serve as motivation for hay producers to cultivate positive customer relations, as loyal customers become less price sensitive and tend to increase their expenditures over time. Fulfilling specific customer needs, frequent communication, and full information are essential to cultivating loyal customers (Anton, Camarero, and Carrero, 2007). Moreover, hay producers may wish to consider erecting switching barriers for current customers, such as special or preferential treatment on choice of cutting or delivery services, maintenance of customer preference information, etc. Finally, providing grass hay quality ratings to potential new buyers may be beneficial. Quality rating information will likely reduce the "unknown risk" for potential customers, and hence reduce the switching costs of moving away from competitors.

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