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# Diurnal Changes in Alfalfa Quality Effects on Expected Producer Returns

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**Abstract**

Alfalfa hay prices vary according to premiums and discounts assigned by quality grade. Relative Feed Value (RFV) tests can be used to assess hay quality. Through a field trial in Southern Utah, we measure RFV quality differences from cuttings at various treatment times during the day and conduct a simulation analysis to evaluate expected changes to returns per acre between the cutting times. Outcomes indicate that alfalfa harvested at 12:00 pm compared to 8:00 am increases average RFV by 7.3 points. As a result, gross revenue increases by $16.95 per acre and an equivalent increase occurs in net returns for operations without cutting constraints.

**Keywords:** hay quality, photosynthesis, relative feed value, simulation

**JEL codes:** Q13, Q13, Q19

## Introduction

Alfalfa hay prices vary according to premiums and discounts assigned based on quality. The USDA separates alfalfa quality into four main categories: "Supreme," "Premium," "Good," and "Fair." These categories rely on the Relative Feed Value (RFV) calculation that converts the alfalfa nutritive value into a single index for ease of quality grading. Profit-maximizing producers are keenly aware of the potential to increase profits when higher quality grades are achieved. Factors known to influence average alfalfa quality include climate, soil type, location, and age of the current stand. Some research indicates laboratory-estimated nutritive value differences and animal-consumption preference differences between alfalfa cut in the morning (AM) as compared to alfalfa cut in the afternoon (PM) (Mayland and Shewmaker, 1999; Mayland, et al., 2005; Burns, Fisher, and Mayland, 2007). However, past research has focused primarily on changes in total nonstructural carbohydrates rather than diurnal changes in RFV. The latter has significant economic implications as the RFV value determines the grading by which premiums and discounts are paid to producers.

Noting this gap in the literature, our objectives are to: 1) determine the effect on RFV of AM- compared to PM-cut alfalfa hay grown in the West, and 2) evaluate the expected change in revenues or returns per acre of AM- relative to PM-cut alfalfa through an empirical analysis. Accomplishing these objectives can provide alfalfa producers in the region with valuable information to help them make informed decisions when cutting their hay to help further maximize profits.

The quality of alfalfa is essential because it can significantly affect the price farmers receive. "Supreme" quality hay has a RFV >185, "Premium" of 170-185, "Good" of 150-170, and "Fair" of 130-

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150. The RFV value should reflect how well animals are expected to eat and digest a particular forage when fed as the sole energy source (Ralph Ward, 2008). RFV is a function of Acid Detergent Fiber (ADF) and Neutral Detergent Fiber (NDF). ADF estimates the least digestible part of alfalfa because it includes cellulose and lignin, low ADF concentrations are preferred. NDF estimates the structural component of alfalfa (cellulose, hemicellulose, and lignin) and increases as the plant matures; low NDF is also preferred. As mentioned, prices vary according to quality grade. Over the course of 2022, the four grades ranged, on average, from $450 per ton for "Supreme" to $285 per ton for "Fair." (USDA Hay Report, 2022). The difference of $165 per ton would represent the marginal revenue per ton increase if producers were to increase quality from fair to supreme within the year. Given that approximately 23.4 million tons of alfalfa were produced in the 11 western states in 2022 (USDA NASS, 2023), this suggests that quality improvement can add substantial revenue for western alfalfa producers. However, increases in quality of this magnitude would undoubtedly require production changes beyond just the time of cutting. Additionally, while the marginal change from fair to supreme quality in 2022 was $165 per ton, on average, across multiple years, this difference would be expected to be of a much smaller magnitude (in the range of $30-$50 per ton) as 2022 saw unprecedented prices for high quality alfalfa. This smaller expected change in marginal revenue still represents potential to increase revenue from alfalfa hay sales in the region.

*Literature*

Alfalfa producers face many risks, including financial, production, price, policy, and human risks. Some of these risks can be controlled directly or mitigated by the producer whereas others can only be influenced indirectly by the producer. Our objective focuses on diurnal changes in alfalfa quality and the associated changes to expected revenue when comparing alfalfa cut at 8:00 am, 12:00 pm, and 4:00 pm. Thus, this objective focuses on the potential to mitigate production and price risk by strategically cutting alfalfa at a time of day that helps ensure the highest quality (i.e., price) is obtained.

Past studies demonstrate that alfalfa's maturity level at harvest is the best way to ensure good quality, with the highest nutritive value associated with alfalfa hay cut directly before the budding period (Karayilanli and Ayhan, 2016). As the plant continues to mature, cellulose deposition in the secondary wall increases (Jung, 1989), which adds more structure to the plant to resist lodging but decreases digestibility (Jung and Lamb, 2003). Cozzi et al. (2005) found a negative correlation between the lignin content and digestibility. This suggests an optimal time to cut alfalfa based on the plant's growth stage but provides no evidence of the time of day that may be optimal to maximize quality.

Other studies suggest that diurnal nutritive value changes in alfalfa hay exist with total nonstructural carbohydrates (TNC) increasing for hay cut later in the day as opposed to early morning (Shewmaker and Mayland, 1999; Mayland et al., 2005; Burns, Fisher, and Mayland, 2007). The research demonstrates, as stated by Mayland et al. (2005, pp. 1), "net photosynthesis, respiration and translocation in growing plants cause a circadian rhythm in forage quality. Soluble sugar concentrations increase in plants during the day causing a dilution in ADF and NDF and an increase in RFQ and RFV." Much of the research focuses on identifying differences in soluble sugar concentrations and TNC, with a particular focus on animal science applications by identifying animal preferences for AM- vs. PM-cut hay. Research has often found that PM-cut hay is preferred among various livestock species (Fisher, Mayland, and Burns, 2002; Mayland et al. 2005; Burns, Fisher, and Mayland, 2007). Thus, a gap exists in the literature as no previous studies have focused on the expected financial impacts to the alfalfa producer of hay cut at varying times of the day.

**Data and Methods**

Data were collected from multiple random samples of first and second cuttings from an alfalfa farm in Southern Utah (Cedar City). This farm grows between 1,200 and 1,800 acres of alfalfa every season, depending on crop rotations, and uses precision technology throughout the entire harvesting process to increase efficiency. The climate in Cedar City is described as warm, dry, with mostly clear summers and freezing, snowy, and partly cloudy winters. The farming season in Cedar City starts in May and ends in September. Annually, the average amount of rainfall is 11.31 inches, and the average snowfall is 49 inches (US Climate Data, 2023). Alfalfa farmers in Cedar City raising dairy-quality hay get an average of four harvests every season.

Alfalfa samples were gathered on May 27 and July 4, 2022, the day before the fields were cut for their first and second cuttings respectively. For the first cutting, thirteen clippings (sub-samples) were taken for three individual samples gathered at 8:00 am, 12:00 pm, and 4:00 pm from field one. Three additional samples were taken for second cuttings at the same treatment times but with fifteen clippings taken for each sample from field two. The weight of each clipping was approximately 100 grams. For the first and second cuttings, one-square-foot plots were designated from which to take three clippings. For example, clipping one was taken out of the same square foot for 8:00 am, 12:00 pm and 4:00 pm samples. This allows for direct comparison of clippings while controlling for variables such as soil moisture and quality[5]. A three-inch block was used to measure the distance from the ground and determine where to make the cuts on the stems to ensure consistency across clippings. The clippings were weighed to ensure that approximately 100 grams were gathered and placed into paper sacks in a cooler with ice to slow the respiration process. Once gathered, the samples were placed into a drying oven for three days at 120 degrees Fahrenheit to remove moisture content. After three days, the paper sacks were labeled and shipped to the lab (Rock River Laboratory, Inc.) for analysis.

Data analyzed and reported for each sample included RFV, crude protein, ADF, NDF, lignin, sugar water-soluble carbohydrates (WSC), and total digestible nutrients (TDN). Summary statistics for these variables for all samples and cuttings are included in Table 1.

To accomplish our first objective, the data were analyzed to test for statistical differences in the means of the variables gathered between the samples and cuttings. All data were analyzed using the MIXED procedure of SAS® (version 9.4; SAS Institute Inc., Cary, NC), with "treatment" (time of cutting) and "cutting" (1st or 2nd) included as main effects while "clipping" was included as a random variable in the model[6]. The variables that were analyzed include RFV, Crude Protein, ADF, NDF, Lignin, Sugar WSC, and TDN. A P-value of ≤ 0.05 was considered significant.

[5] While the experimental design has elements of randomization, it is not a completely randomized design which is a limitation of this study.

[6] A cutting-time interaction was also investigated and was not found to be statistically significant. Additionally, because the first and second cuttings were taken from different fields, the effects of such an interaction would not be interpretable. Thus, this interaction was not included in the analysis.

To accomplish the second objective, a stochastic simulation model was used to evaluate the expected gross revenues per acre associated with cutting at the various treatment times. The expected gross revenue for the *i*th treatment time was calculated as:

(1) $$Gross\ Revenue_i = [Yield \bullet (Price|Q)_i]$$

where $Yield$ is the yield measured in tons per acre, $Price$ is the price of alfalfa ($/ton) and is conditional on the quality, $Q$ (i.e., RFV) with higher quality grades associated with increased prices. All variables within equation (1) were allowed to vary stochastically. The distribution for yield was selected according to 'best fit' through minimization of the Akaike Information Criterion (AIC). Data for yield was taken from actual yield measurements on the trial farm over the past three years for one field and five years for the other. Hay prices specific to Utah are not consistently or reliably reported, especially by quality grade. For this reason, data for '$Price$' was gathered from The Hoyt Report (2022) for the years 2017-2021 (California prices). The prices gathered were determined to correlate well with the local prices received on the farm across the study years. Within the simulation analysis, a distribution was fit for the combined supreme and premium price series as supreme prices were not consistently reported. A separate distribution was fit for 'good' alfalfa prices. Both the 'supreme and premium' and 'good' price distributions relied on triangle distributions with the minimum and maximum values taken as observed in the data, while the 'most likely' value was set as the mode of each respective price series. The '$Q$' (quality) distributions were fit to the observed RFV data for each treatment time and cutting and were selected by minimization of the AIC. The assumed distributions for the simulation analysis are described in further detail in Table 2. Comparing the results of equation (1) for the 12:00 pm- and 4:00 pm-cut hay with the 8:00 am-cut hay can demonstrate the expected changes in gross revenue per acre by varying the cutting time from AM to PM. This comparison is accomplished by simulating the changes in expected gross revenue per acre for the 12:00 pm and 4:00 pm treatments with the 8:00 am treatment time as in equations 2 and 3 respectively.

(2) $$Gross\ Revenue_{12:00\ pm} - Gross\ Revenue_{8:00\ am}$$
(3) $$Gross\ Revenue_{4:00\ pm} - Gross\ Revenue_{8:00\ am}$$

Where $Gross\ Revenue_{8:00\ am}$, $Gross\ Revenue_{12:00\ pm}$, and $Gross\ Revenue_{4:00\ pm}$ are the expected gross revenues of the 8:00 am-, 12:00 pm-, and 4:00 pm-cut hay treatment times as calculated using equation (1)[7]. Equations (2) and (3) are simulated over 10,000 iterations using Palisades @Risk Decision Tools Suite 7.6 (2019).

**Results and Implications**

Results from the analysis of variance are contained in Table 3, with the least square means for the main effects of treatment time and cutting compared. Results demonstrate that compared to the first cutting, the second cutting had statistically significant (P-value ≤ 0.05) increases in RFV, crude protein, and TDN, with decreases observed in ADF, NDF, and lignin. No statistically significant

[7] Change in gross revenue here is synonymous to change in net return/profit, as we assume little to no change in costs associated with change in cutting timing during the day.

difference was observed between cuttings for sugar WSC. As for differences among treatment times, RFV was found to be highest for the 12:00 pm cutting time with an increase in the LS mean of 7.32 RFV points compared to 8:00 am. The 4:00 pm cutting time was also shown to have increased RFV compared to 8:00 am, though the difference of 4.5 RFV points was not found to be statistically significant. We also observed decreased ADF and NDF for hay cut at 12:00 pm and 4:00 pm compared to 8:00 am. Though these observed differences are not all statistically significant in this small sample, the results do align with previous literature demonstrating decreases of ADF and NDF throughout the day and help to strengthen the current findings (Shewmaker and Mayland, 1999; Mayland et al., 2005; Burns, Fisher, and Mayland, 2007). Sugar WSC and TDN were increased for the 12:00 pm and 4:00 pm cuttings compared to 8:00 am. Taken together, these results suggest that higher quality alfalfa (increased RFV and TDN) would be expected for alfalfa cut later in the day (PM) as opposed to morning (AM).

The marginal increases in nutritive value for noon-cut hay are expected to increase gross revenue per acre for producers compared to hay cut at 8:00 am. Figures 1 and 2 contain the simulated cumulative distribution functions (CDFs) comparing the change in expected gross revenue for 12:00 pm-cut hay and 4:00 pm-cut hay, respectively, with 8:00am-cut hay (equations (2) and (3)).

The simulation results demonstrate that the expected mean changes in gross revenue per acre from cutting at 12:00 pm as compared to 8:00 am are $16.95/acre and $14.77/acre for the first and second cutting respectively (Figure 1). The expected mean changes in gross revenue from cutting at 4:00 pm as compared to 8:00 am are also positive (Figure 2) at $14.78/acre and $13.46/acre for the first and second cutting, respectively. The results in both Figures 1 and 2 also demonstrate that there is a large probability of 8:00 am-cut hay producing gross revenue equal to those expected from hay cut at 12:00 pm and 4:00 pm. This is intuitively understood as even if 12:00 pm- and 4:00 pm-cut hay produce hay with marginally higher RFV values on average compared to 8:00 am-cut hay, this marginal increase is not always sufficient to push the expected hay quality to a higher grade (i.e., price). However, the greatest takeaway from the simulation results is that for AM- or PM-cut hay, the probability that the producer will see increases to revenue when switching from AM- to PM-cut hay is marginally larger than the probability that the revenue would decrease given the same change. This suggests PM-cut hay has greater potential to increase profitability for alfalfa producers in the region and should be considered as a strategy change. Research surrounding these types of management strategies that add quality to a product without altering production costs provide producers with valuable information to increase potential profitability and decrease risk.

This type of management change may be constrained due to scale of the operation and the need to cut all hay produced during the limited optimal maturation window of alfalfa. However, adoption of a PM-cut hay strategy need not be mutually exclusive of all other cutting times. The findings of this study suggest there is a marginal benefit to cutting alfalfa later in the day as opposed to 8:00 am. Even while recognizing possible constraints, if producers can adjust a portion of their cutting timing to take advantage of this perceived marginal benefit, the average RFV score would be expected to increase as well as the probability for increased gross revenue as compared to a strategy that does not prioritize noon-cut hay. Of course, this result may be constrained by the availability of buyers at higher quality. Thus, some marketing risk exists associated with producing hay of an increased average quality as producers may not have access to suitable buyers willing to pay premiums for better quality. Yet, there are little to no expected increases to costs of production associated with cutting time strategy. Therefore, the producer faces little downside risk with increased upside potential from altering the cutting time strategy to cut later in the day.

## Conclusion

The objectives of this study were to; 1) determine the effect on RFV of AM-cut compared to PM-cut alfalfa hay grown in the West, and 2) evaluate the expected change in revenue per acre of AM-compared to PM-cut alfalfa through an empirical simulation analysis. Our results demonstrate that hay cut at 12:00 pm as opposed to 8:00 am has a higher RFV and is thus expected to increase average gross revenue for alfalfa producers if the hay is marketed based on quality improvements associated with increased nutritive value. The empirical simulation results demonstrate that producers could receive increases in average gross revenue for first and second cuttings of $15.86/acre when alfalfa is cut at 12:00 pm as compared to 8:00 am. Further research is necessary to add robustness to these results as this trial uses a relatively small sample size in one location in Southern Utah. Switching cutting times from AM (8:00 am) to PM (12:00 pm) is a relatively simple production change that may provide producers with increased revenue with little to no expected change in costs. Thus, producers should consider PM-cut hay if their individual production system can accommodate the change to help maximize profitability.

## References

Burns, J. C., D. S. Fisher, and H.F. Mayland. 2007. "Diurnal Shifts in Nutritive Value of Alfalfa Harvested as Hay and Evaluated by Animal Intake and Digestion." Crop Science 47(5): 2190–2197. doi: 10.2135/cropsci2007.02.0072.

Cozzi, G., M. Dorigo, F. Gottardo, P. Berzaghi, and I. Andrighetto. 2005. "Effects of Alfalfa Germplasm and Stage of Maturity on Digestive Process and Productive Response of Dairy Cows Fed Alfalfa Hay-Based Diets." Italian Journal of Animal Science 4(3): 211–221. doi: 10.4081/ijas.2005.211.

Fisher, D. S., H. F. Mayland, and J. C. Burns. 2002. "Variation in Ruminant Preference for Alfalfa Hays Cut at Sunup and Sundown." Crop science 42(1): 231–237. doi: 10.2135/cropsci2002.2310.

Jung, H. G. 1989. "Forage Lignins and their Effects on Fiber Digestibility." Agronomy Journal 81(1): 33–38. doi: 10.2134/agronj1989.00021962008100010006x.

Jung, H.-J. G., and J. A. F. S. Lamb. 2003. "Identification of Lucerne Stem Cell Wall Traits Related to In Vitro Neutral Detergent Fibre Digestibility." Animal Feed Science and Technology 110(1-4): 17–29. doi: 10.1016/j.anifeedsci.2003.08.003.

Karayilanli, E. and V. Ayhan. 2016. "Investigation of Feed Value of Alfalfa (Medicago Sativa L.) Harvested at Different Maturity Stages." Legume Research 39(2): 237-247. doi: 10.18805/lr.v0iOF.9292.

Mayland, H. F., and G. E. Shewmaker. 1999. "Diurnal Cycling in Forage Quality." United States Department of Agriculture, Agricultural Research Service, Northwest Irrigation & Soils Research Laboratory. https://fyi.extension.wisc.edu/forage/diurnal-cycling-in-forage-quality/

Mayland, H., P. Gregorini, D. Mertens, B. Taylor, J. Burns, D. Fisher, T. Ciavarella, K. Smith, G. Shewmaker, and T. Griggs. 2005. "Diurnal Changes in Forage Quality and Their Effects on Animal Preference, Intake, and Performance." In Proceedings of California. Alfalfa & Forage Symposium, 35th, Visalia, CA. 12–14 December, 2005. University of California, Davis. 223–230.

Palisades @Risk Decision Tools Suite. 2019. Available at http://www.palisade.com/risk/.

Rock River Laboratory, Inc. 2022. Watertown, WI 53094. http://rockriverlab.com/.

Shewmaker, G. E., and H. F. Mayland. 1999. "Daily Changes in Alfalfa Forage Quality." In Proceedings of California Alfalfa Symposium, 29th, Fresno, CA. 8-9 December, 1999. UC Cooperative Extension, University of California, Davis. 68-73.

US Climate Data. (2023). Cedar City, Utah accessed at: https://www.usclimatedata.com/climate/cedar-city/utah/united-states/usut0038
USDA Hay Report. 2022, April 12. AMS 2904 - Agricultural Marketing Service. Direct Hay Report. Retrieved April 26, 2022, from https://www.ams.usda.gov/mnreports/ams_2904.pdf

USDA NASS, 2023. "Hay, Alfalfa-Production Measured in Tons." Retrieved February 28, 2023, from https://quickstats.nass.usda.gov/

Ward, R. 2008, February 14. "Relative Feed Value (RFV) vs. Relative Forage Quality (RFQ)." Retrieved July 20, 2022, from https://www.foragelab.com/Media/RFV_vs_RFQ-CVAS%20Perspective.pdf

## Tables

**Table 1. AM- vs. PM-Cut Alfalfa Summary Statistics for Key Variables**

| Statistic | RFV | Crude | ADF | NDF | Lignin | Sugar WSC | TDN |
|---|---|---|---|---|---|---|---|
| | **1st Cutting 8:00 am** | | | | | | |
| Mean | 190.38 | 22.82 | 25.86 | 33.70 | 5.85 | 12.07 | 62.27 |
| Std. Dev. | 12.31 | 1.10 | 1.20 | 1.72 | 0.35 | 0.38 | 0.68 |
| Minimum | 173.00 | 21.06 | 24.06 | 30.74 | 5.32 | 11.29 | 61.14 |
| Maximum | 212.00 | 24.65 | 27.60 | 36.21 | 6.27 | 12.66 | 63.39 |
| | **1st Cutting 12:00 pm** | | | | | | |
| Mean | 192.69 | 22.69 | 25.73 | 33.34 | 5.88 | 12.42 | 62.32 |
| Std. Dev. | 11.30 | 1.20 | 1.09 | 1.50 | 0.29 | 0.37 | 0.51 |
| Minimum | 179.00 | 21.30 | 23.44 | 30.50 | 5.42 | 11.92 | 61.62 |
| Maximum | 215.00 | 24.63 | 27.08 | 35.26 | 6.26 | 12.99 | 63.27 |
| | **1st Cutting 4:00 pm** | | | | | | |
| Mean | 191.85 | 22.42 | 25.74 | 33.46 | 5.80 | 12.64 | 62.48 |
| Std. Dev. | 12.48 | 1.30 | 1.05 | 1.68 | 0.25 | 0.44 | 0.51 |
| Minimum | 175.00 | 20.42 | 23.56 | 30.01 | 5.44 | 11.80 | 61.42 |
| Maximum | 219.00 | 24.46 | 27.21 | 36.00 | 6.30 | 13.50 | 63.29 |
| | **2nd Cutting 8:00 am** | | | | | | |
| Mean | 193.13 | 23.74 | 25.38 | 33.42 | 5.78 | 11.54 | 62.17 |
| Std. Dev. | 13.91 | 0.72 | 1.54 | 1.84 | 0.41 | 0.84 | 1.21 |
| Minimum | 170.00 | 22.44 | 22.06 | 30.04 | 5.14 | 10.25 | 60.46 |
| Maximum | 222.00 | 24.93 | 27.77 | 36.77 | 6.44 | 13.35 | 64.76 |
| | **2nd Cutting 12:00 pm** | | | | | | |
| Mean | 204.80 | 24.10 | 24.27 | 32.01 | 5.47 | 12.29 | 63.11 |
| Std. Dev. | 20.71 | 1.20 | 1.75 | 2.52 | 0.45 | 0.89 | 1.25 |
| Minimum | 174.00 | 22.26 | 20.75 | 27.25 | 4.58 | 10.66 | 61.35 |
| Maximum | 248.00 | 26.40 | 26.77 | 36.33 | 6.18 | 13.86 | 65.32 |
| | **2nd Cutting 4:00 pm** | | | | | | |
| Mean | 200.27 | 23.49 | 24.42 | 32.54 | 5.48 | 12.43 | 62.93 |
| Std. Dev. | 13.42 | 0.83 | 1.38 | 1.70 | 0.31 | 0.59 | 1.03 |
| Minimum | 180.00 | 21.76 | 22.47 | 29.92 | 4.97 | 11.53 | 61.12 |
| Maximum | 222.00 | 24.84 | 26.70 | 35.12 | 6.08 | 13.44 | 64.28 |

**Table 2. Simulation of Expected Gross Return Assumed Distributions of Stochastic Variables**

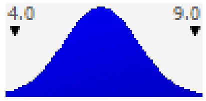
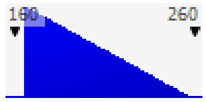
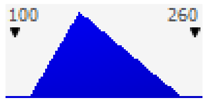
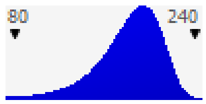
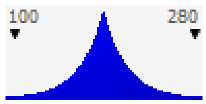
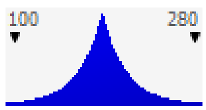
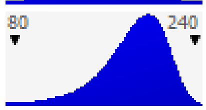
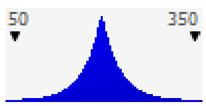
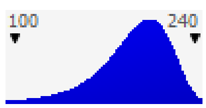
| Variable Name | Graph | Distribution | Min | Mean | Max |
|---|---|---|---|---|---|
| Yield |  | Normal | -∞ | 6.4 | +∞ |
| Supreme & Premium Hay Price |  | Triangle | 170.0 | 197.8 | 253.5 |
| Good Hay Price |  | Triangle | 119.8 | 174.1 | 242.5 |
| 1st Cutting 8:00 am RFV |  | Extreme Value | -∞ | 180.5 | +∞ |
| 1st Cutting 12:00 pm RFV |  | Laplace | -∞ | 189.5 | +∞ |
| 1st Cutting 16:00 pm RFV |  | Laplace | -∞ | 188.5 | +∞ |
| 2nd Cutting 8:00 am RFV |  | Extreme Value | -∞ | 184.1 | +∞ |
| 2nd Cutting 12:00 pm RFV |  | Laplace | -∞ | 196.5 | +∞ |
| 2nd Cutting 16:00 pm RFV |  | Extreme Value | -∞ | 191.3 | +∞ |

**Table 3. ANOVA Analysis for the Effect of Cutting Alfalfa Hay at 8:00 am, 12:00 pm, and 4:00 pm on RFV, Crude Protein, ADF, NDF, Lignin, Sugar WSC, and TDN**

| Effect | RFV | | Crude Protein | | ADF | | NDF | | Lignin | | Sugar WSC | | TDN | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Treatment Time | | | | | | | | | | | | | | |
| 8:00 am | 191.10 | b | 23.27 | a | 25.67 | a | 33.64 | a | 5.83 | a | 11.76 | b | 62.18 | b |
| 12:00 pm | 198.42 | a | 23.40 | a | 25.02 | a | 32.72 | b | 5.68 | ab | 12.31 | a | 62.70 | a |
| 4:00 pm | 195.60 | ab | 22.94 | a | 25.11 | a | 33.06 | ab | 5.65 | b | 12.50 | a | 62.68 | a |
| Cutting | | | | | | | | | | | | | | |
| 1st | 190.68 | b | 22.63 | b | 25.85 | a | 33.63 | a | 5.87 | a | 12.29 | a | 62.30 | b |
| 2nd | 199.40 | a | 23.78 | a | 24.69 | b | 32.66 | b | 5.58 | b | 12.09 | a | 62.74 | a |

*Notes: Mean values for fixed effects within a column followed by different letters (a and b) are significantly different (P= 0.05).*

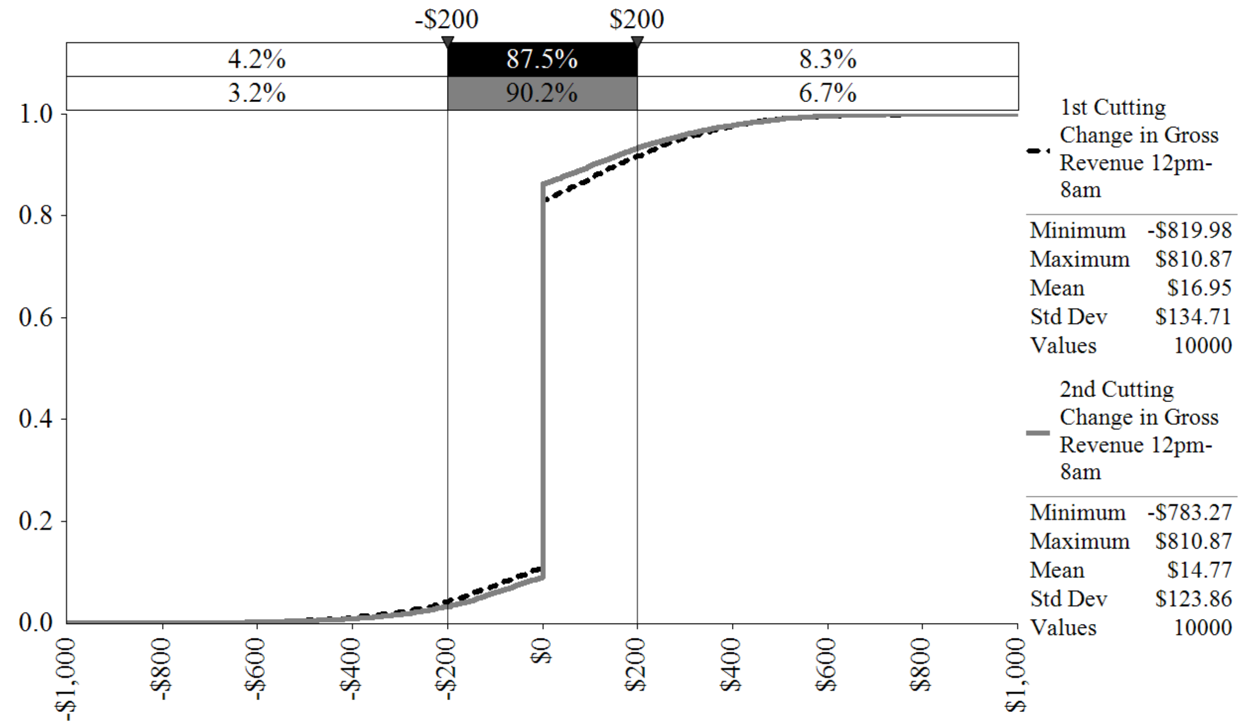



**Figure 1. Cumulative Distribution Functions (CDFs) Comparing the Change in Expected Gross Revenue for 12:00 pm-cut Hay vs. 8:00 am-cut Hay for First and Second Alfalfa Cuttings in Southern Utah**

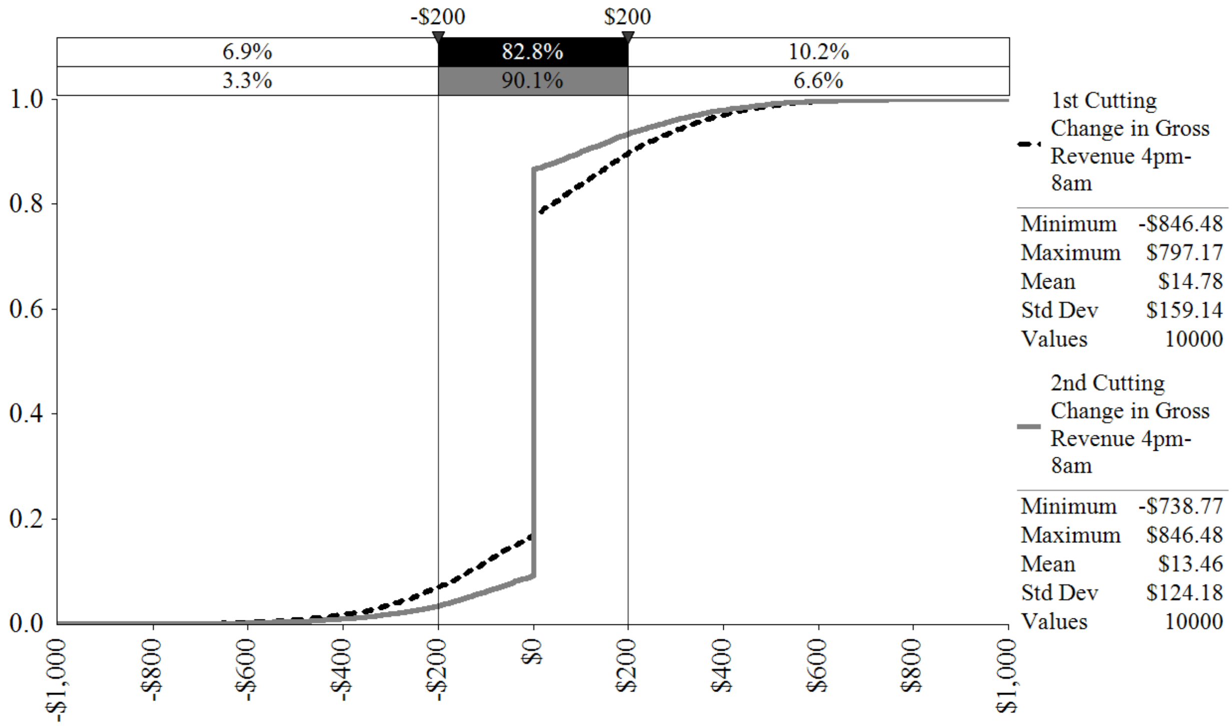



**Figure 2. Cumulative Distribution Functions (CDFs) Comparing the Change in Expected Gross Revenue for 4:00 pm-cut Hay vs. 8:00 am-cut Hay for First and Second Alfalfa Cuttings in Southern Utah**