



## Impacts of Different Fertilizers on Restoration Establishment of East Texas Equine Pastures

CAROLINA DE LEON<sup>1</sup>, BRIAN OSWALD<sup>2\*</sup>,  
CANDIS SCALLAN<sup>1</sup> and LELAND THOMPSON<sup>1</sup>

<sup>1</sup>Department of Agriculture, Arthur Temple College of Forestry and Agriculture, Stephen F. Austin State University, Nacogdoches, Texas, USA.

<sup>2</sup>Department of Forestry, Arthur Temple College of Forestry and Agriculture, Stephen F. Austin State University, Nacogdoches, Texas, USA.

### Abstract

In Texas, USA, approximately 6475 km<sup>2</sup> are used for horse-related purposes, supporting an equine population of over 748,000. Due to overgrazing or lack of active management, many pastures not reaching maximum forage production. This study evaluated the effects of organic and inorganic fertilizer treatments on improved Bermudagrass and other vegetation in equine pastures in East Texas. The experiment was conducted at the Stephen F. Austin State University Equine Center in Nacogdoches, Texas, on three overgrazed pastures. Organic treatments consisted of equine/horse manure and broiler poultry litter, while the inorganic fertilizer treatment was a commercial 13-13-13 fertilizer, all rates were adjusted based on pasture-specific nutrient requirements. Initial vegetation cover was assessed using Daubenmire cover classes in September 2024. After treatment application, followed by a 60-day growing period (September 2024 to November 2024). Final measurements included biomass and percent cover measurements. Data analysis was conducted using R Studio, with  $\alpha = 0.10$ . Biomass results showed that vegetation type was a significant factor in all cases except in pasture 3, where no variables (treatment, vegetation, or their interaction) were significantly different, while in the other two pastures, all other vegetation combined (Mean = 868 kg ha<sup>-1</sup>) was significantly less than Bermudagrass (2253 kg ha<sup>-1</sup>) biomass. Pasture 2 had a significant negative interaction between Poultry litter and other vegetation. Assessing all pastures together also found Bermudagrass was significantly greater (2053 kg ha<sup>-1</sup>) than the other vegetation combined (1209 kg ha<sup>-1</sup>). Bermudagrass



### Article History

Received: 08 July 2025  
Accepted: 02 September 2025

### Keywords

Bermudagrass;  
Biomass;  
Commercial Fertilizer;  
Horse Manure;  
Poultry Litter;  
Vegetation Cover.

**CONTACT** Brian Oswald ✉ [boswald@sfasu.edu](mailto:boswald@sfasu.edu) 📍 Department of Forestry, Arthur Temple College of Forestry and Agriculture, Stephen F. Austin State University, Nacogdoches, Texas, USA.



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Doi: <http://dx.doi.org/10.12944/CARJ.13.2.23>

increased in cover at the expense of the other vegetation, with the horse manure-vegetation interaction being significantly positive for pasture 3 and for the combined pastures, with the horse manure plots supporting greater other vegetation, possibly because the manure contained viable seeds. While commercial fertilizer was effective in establishing bermudagrass, the use of organic fertilizers such as poultry litter or horse manure for long-term pasture maintenance may be a more cost-effective and sustainable method.

### Introduction

Horses (*Equus caballus*) have been grazing the land for thousands of years; today, domesticated horses in the USA are usually kept in pastures. In Texas, it is estimated that 6475 km<sup>2</sup> are owned or leased for horse-related uses.<sup>1</sup> Fertilization from commercial fertilizers to natural fertilizers made from organic material is a common approach in pasture management to provide maximum herbage yield and long-term. Organic fertilizers will typically require a higher volume application rate than commercial fertilizers, which are designed to provide needed nutrients in small volumes, reducing the price and workload for farmers and ranchers.<sup>1</sup> Pasture management is important to ensure healthy pastures, but most pasture management practices are derived from research done on cattle. Regardless of the type of animal, stocking rate and carrying capacity are the most common measures used in pasture management. How horses impact the land, utilize the land, and graze the land is completely different to cattle.<sup>2</sup> Rotational grazing is one of the most used techniques in pasture management,<sup>2</sup> and on native rangeland is used to maintain or increase the presence and vigor of the desired plant species; the theory is that higher quality preferred species become predominant. However, bermudagrass (*Cynodon dactylon*) does not increase in quantity with rotational grazing, and instead the goal of rotational grazing on them is better utilization or allowing for other management practices.<sup>3</sup>

Overgrazing is a major problem in equine pastures because horses are selective grazers. Cattle can overgraze a pasture, but leave a larger leaf area of the plant in the ground when compared to horses, so the plants eaten by the cows have a larger chance of growing while using minimal stored energy when compared to grass eaten by horses, which are more likely to have little leaf area left and must utilize energy stores.<sup>2</sup>

The purpose of any restoration effort is to reestablish the land's structural characteristics, species composition and ecological processes, and can be a short- or long-term process, depending on the past impacts on the land and the end goal of the restoration project. In equine pastures, the most common concerns are overgrazing, soil compaction, non-native grass species, and weed invasions. Grazing exclusions and grazing management are the most common solutions introduced in the restoration process.<sup>4</sup> Other vegetation improvement projects, such as reseeding and weed control can be used, but are expensive.

Pasture management and restoration usually involve fertilizing with either organic material, such as horse manure and chicken litter, or commercially produced fertilizers. While horse manure is often used as a fertilizer in horse farms, horses typically will choose not to eat where there is manure, so the methods used when applying manure must be carefully considered to prevent overgrazing and uneven grazing. Not only do horses avoid manure piles, but they have a minimum grazing distance from the manure, typically about 1-meter,<sup>5,6</sup> and pastures managed with the spread of manure had higher levels of K. Stabilizing bioavailable carbon in the horse manure would have to be done before using or applying it to a pasture for the best results. Because of the large amounts of bioavailable carbon in horse manure, it cannot be used as the only source of nitrogen, the same as broiler chicken litter.<sup>7</sup> Broiler chicken (*Gallus gallus domesticus*) litter is used year-round on pasture lands, but can result in nutrient losses and potential unfavorable environmental impacts, especially during the winter months.<sup>8</sup> The biggest concern with it being used is the effects it may have when it is affected by runoff and the runoff water quality; however, the nutrient concentrations in surface runoff are more dependent on the number of rainfalls since application of the fertilizer than on the

quantity of rainfall or runoff. Excessive Phosphorus loss from agricultural fields is another major concern when applying it as a fertilizer. Commercial fertilizer is simple and effective and can come in dry, liquid, or slow-release forms, and can provide both macro- and micro-nutrients to the soil when applied.<sup>9</sup>

Bermudagrass is native to Africa and is considered one of the most important grasses in the Southern United States. It was introduced for its rapid growth and grazing tolerance.<sup>10</sup> Bermudagrass is a warm-season perennial grass that can tolerate a wide range of soil types and pH levels. Although bermudagrass seed is capable of high yields, it must have appropriate levels of fertilizer to ensure Nitrogen, Phosphorus, and Potassium do not become limiting factors.<sup>11</sup> Bermudagrass can tolerate a heavier degree of grazing than native rangeland forages because of its rapid regrowth capabilities. In Texas, bermudagrass is often used in pastures, and once bermudagrass is established, it can provide dependable pastures for years with proper fertility and management.<sup>12</sup>

The goal of this study was to determine the effects three different fertilizers (horse manure, poultry litter, and commercial fertilizer) have on forage production in depleted East Texas equine pastures. The specific objective was to assess forage production differences between the three fertilization treatments within the initial 60-day growing period to provide options to landowners to consider when restoring depleted pastures.

## Materials and Methods

### Site Description

Texas is classified as a humid subtropical climate, receiving 45 to 55 inches of precipitation annually, has a frost-free period of 230 to 240 days, and is classified as “not prime farmland”. Based on the USDA web soil survey,<sup>13</sup> most of the area used in this study consists of gravelly clay loam. The Stephen F. Austin State University Equine Center is located in Nacogdoches, TX, and is an approximately 32.4 ha equestrian facility with fourteen pastures, three were used in this study. The pastures used for this experiment were completely free of grazing from January to December 2024. Thirty six plots were distributed with twelve plots within each pasture; each 1.8 x 1.8 m, pin flags were used to mark each

corner of the plot, and a 6.1 m buffer was established between each plot. Plots were systematically arranged but treatments were randomly assigned.

### Treatments

Soil samples were randomly collected within each pasture were submitted to the Soil, Plant, and Water Analysis Laboratory at Stephen F. Austin State University in January 2024, and provided an analysis of the soil pH, ppm of Nitrate (N), Phosphorus (P), Potassium (K), Calcium, Magnesium, Salinity, Sulfate, Iron, Manganese, Zinc, and Copper. Recommendations provided were specific for improved Bermudagrass establishment. Pasture 1 was recommended to have applied 10.8 kg ha<sup>-1</sup> of N, 5.5 kg ha<sup>-1</sup> of P<sub>2</sub>O<sub>5</sub>, and no additional K<sub>2</sub>O; Pasture 2 was recommended 5.5 kg ha<sup>-1</sup> of N, 10.1 kg ha<sup>-1</sup> of P<sub>2</sub>O<sub>5</sub>, and 7.3 kg ha<sup>-1</sup> K<sub>2</sub>O, and Pasture 3 was recommended 10.1 kg ha<sup>-1</sup> of N, 11.0 kg ha<sup>-1</sup> P<sub>2</sub>O<sub>5</sub>, and 9.2 kg ha<sup>-1</sup> of K<sub>2</sub>O.

All sites were treated twice with Roundup Ready-To-Use Weed and Grass Killer to kill present forage, including buffer zones, and applied in both February and May 2024. After both herbicide applications, the area was rototilled to turn over the soil and prepare for seeding. A final rototill was performed before Bermudagrass seed (*Cynodon dactylon* 'Mirage 2') was spread in June 2024 using a drop push-seeder. The seed was spread in two different directions, N to S and W to E, to ensure complete coverage of the entire experimental area, including the buffer zones.

The horse manure was obtained at the Stephen F. Austin State University Equine Center; when the horse manure was applied in September 2024, the manure had been composting for at least 6 months. The broiler poultry litter was obtained from the Stephen F. Austin Poultry Center. At the time of application, the poultry litter had composted for a minimum of 6 months. The horse manure and poultry litter had a nutrient analysis performed to determine what nutrients they provided and to obtain a rate of application; the analysis was done at the Soil, Plant, and Water Analysis Laboratory at SFASU (Table 1). The commercial fertilizer was Sta-Green 18.1 kg ha<sup>-1</sup> of 13-13-13 All-purpose fertilizer. All treatment application rates were calculated following the N recommendations of soil test reports of the three individual pastures and the nutrient analysis.

One last bush hog took place a few days before treatment applications to allow the fertilizer to reach the ground without vegetation interference. Fertilizer treatments were randomly assigned and applied in September 2024.

**Table 1: Results of the organic fertilizer analysis; testing was performed at the Soil, Plant, and Water Analysis Laboratory at Stephen F. Austin State University.**

	Units	Horse Manure	Chicken Litter
Nitrogen (N)	%	0.96	2.25
Carbon (C)	%	16.50	27.10
C to N Ratio	%	17.20	12.00
Phosphorus (P)	%	0.35	1.66
P as P <sub>2</sub> O <sub>5</sub>	%	0.80	3.81
Potassium (K)	%	0.26	4.17
K as K <sub>2</sub> O	%	0.31	5.03
Calcium (Ca)	%	2.56	4.48
Magnesium (Mg)	%	0.28	0.98
Sulfur (S)	%	0.20	0.85
Sodium (Na)	%	0.03	1.36
Iron (Fe)	Mg kg <sup>-1</sup>	16.20	14.90
Manganese (Mn)	Mg kg <sup>-1</sup>	365	798
Zinc (Zn)	Mg kg <sup>-1</sup>	190	876
Copper (Cu)	Mg kg <sup>-1</sup>	71	1300

#### Data Collection

Each plot contained two (0.30 x 0.61m) subplots outlined using PVC pipe at opposite plot corners which were used as the sampling plots for all data collection, located at the top right and bottom left of each plot when facing West. Initial observations were made in September 2024 before bush hogging and fertilizer applications. The initial data included cover (%), measured using the Daubenmire cover classes,<sup>14</sup> and the vegetation height (cm) by species.

After treatment, plots were left to grow undisturbed for 60 days. The final measurements taken in November 2024 included cover (%) & height (cm) by species. In addition, biomass was collected; the clippings were taken at ground level and separated into two categories, Bermudagrass (BG) and Other (OTH). The clippings were placed in paper bags, labeled

(Pasture #, Plot # & Treatment (P = Poultry Litter, H = Horse Manure, C = Commercial, R = Control), Subplot #, and BG (Bermudagrass) or OTH (Other), then dried in a Despatch LBB series lab oven for 48 hours at 60 °C ±5 °C. After the 48 hrs. the paper bags were removed from the ovens and measured for biomass in grams (g) of clippings, then expanded to a kg ha<sup>-1</sup> for statistical analysis.

#### Statistical Analysis

Total biomass in kg ha<sup>-1</sup> and percent cover differences after the 60-day growing period was analyzed using the R programming language.<sup>14</sup> The data was analyzed by individual pastures and all three pastures combined, accounting for differences in soil, topography, and vegetation of the pastures. The number of observations per treatment-vegetation group was not uniform in the biomass measurements, ranging from 1 to 6 samples for individual analysis and 6 to 18 samples for the analysis including all pastures. The analysis of cover has uniform samples of 6 for individual pastures and 18 for the analysis of all pastures. This variability was accounted for when calculating standard deviations and standard errors and is a result of several subplots that only contained one type of vegetation.

For analysis, vegetation was either bermuda grass or other vegetation, and treatments were either one of four categories: C (commercial), H (horse manure), P (broiler poultry litter) & R (control). A Shapiro-Wilk normality test was used to determine the distribution of data, VIF (variable inflation factor) was used to check for collinearity problems, and an Asymptotic one-sample Kolmogorov-Smirnov test, along with a test for location of quantiles via qqam, were used to find the appropriate models for the data. Analysis of Variance (ANOVA) ( $p < 0.10$ ) was used to test the effects of the fertilizers, vegetation, and the interaction between the fertilizers and vegetation on the biomass and percent cover. Tukey's test was used to identify differences between the variables found to be significant in the ANOVA test.

#### Results

In addition to bermudagrass, 23 additional herbaceous species were found in the plots, and were combined for analysis as "other vegetation".

**Table 2: Biomass for all three pastures. N= Sample Size, Mean, C = Commercial Fertilizer; H = Horse Manure Fertilizer; P = Poultry Litter Fertilizer; R = Control. BG = Bermudagrass; OTH = All Other Vegetation. Same letter following the means within each pasture are statistically the same.**

Treatment	Vegetation	N	Mean (kg ha <sup>-1</sup> )
	<b>Pasture 1</b>	<b>1</b>	
C	BG	6	1687.59a
C	OTH	4	600.25b
H	BG	6	1461.73a
H	OTH	5	1758.37b
P	BG	6	1126.86a
P	OTH	3	681.38b
R	BG	6	1659.69a
R	OTH	5	882.79b
	<b>Pasture 2</b>	<b>2</b>	
C	BG	6	2414.10a
C	OTH	6	1224.91b
H	BG	6	3490.19a
H	OTH	4	1176.69b
P	BG	6	3803.62a
P	OTH	1	126.67b
R	BG	6	2386.38a
R	OTH	4	500.41b
	<b>Pasture 3</b>	<b>3</b>	
C	BG	6	1300.61a
C	OTH	3	1466.47a
H	BG	6	1417.58a
H	OTH	5	1737.60a
P	BG	6	2272.11a
P	OTH	2	2255.69a
R	BG	6	1619.24a
R	OTH	4	1283.80a
	<b>All Pastures</b>		
C	BG	18	1800.77a
C	OTH	13	1088.45b
H	BG	18	2123.02a
H	OTH	14	1584.76b
P	BG	18	2400.86a
P	OTH	6	1117.44b
R	BG	18	1888.44a
R	OTH	13	1046.14b

### Biomass

In pasture 1, vegetation significantly ( $p = 0.04$ ) differed, but treatments and the interaction did not. Mean biomass varied across treatments and vegetation types (Table 2), as Bermudagrass was significantly greater

than the other vegetation. Bermudagrass biomass was highest with the commercial fertilizer treatment, while the poultry litter plots had the lowest mean. In pasture 2, differences in vegetation ( $p = <0.001$ ) and the interaction between treatments were

significant. The interaction between broiler poultry litter and other vegetation was significant ( $p = 0.06$ ), as the effect of other vegetation on biomass was negative. The highest biomass for bermudagrass was observed with the P fertilizer treatment, while the control plots had the lowest mean. Other vegetation also had smaller means, with the commercial fertilizer treatment having the highest mean and poultry litter having the lowest. In pasture 3, no variable or interaction was significant. The highest mean for Bermuda grass was observed in the plots with the P fertilizer treatment, while the control plots had the lowest mean. When all three pastures were combined, Bermudagrass was significantly greater than the other vegetation ( $p = <0.01$ ), treatments ( $p = 0.21$ ), and the interaction between vegetation and treatment were not significant ( $p = 0.68$ ). The highest mean for Bermudagrass was observed with the poultry litter fertilizer, and the commercial fertilizer had the lowest mean (Table 2).

#### Percent Cover

Percent cover change was measured as a difference between the final measurement minus the initial measurement. Since the vegetation is paired, when Bermudagrass increased, other vegetation decreased by the same amount, and vice versa. In pasture 1, vegetation was significant ( $p = 0.001$ ) as other vegetation declined in cover, but treatments ( $p = 1.0$ ), and the interaction between vegetation and treatment were not significant ( $p = 0.22$ ). The highest change in cover was under the commercial

fertilizer treatment (51.67%), while control plots had the lowest change (25.00%) in cover (Table 3). Although there is variation in the mean values, Bermudagrass consistently showed a trend of increasing cover as opposed to other vegetation. As in pasture 1, vegetation in pasture 2 was significant ( $p = 0.01$ ), treatments ( $p = 1.0$ ), and the interaction between vegetation and treatment were not significant ( $p = 0.21$ ). Mean cover varied across treatments, with the highest change in cover under the commercial fertilizer treatment, while the horse manure treatment had the lowest change in cover (Table 3). Bermudagrass consistently showed a trend of increasing cover except for the commercial fertilizer treatments, which had a slight but significant decrease in Bermudagrass cover and an increase in other vegetation (6.67%). In pasture 3, the interaction between vegetation and treatment was significant ( $p = <0.01$ ), but treatments were not. Other vegetation cover was statistically negative. Additionally, the interaction between horse manure and other vegetation was statistically significant and positive, suggesting that the effect of horse manure differed based on vegetation type, with an increase in cover observed in non-bermudagrass vegetation. The highest mean change in cover was the commercial fertilizer treatment, while horse manure resulted in the lowest change in cover (Table 3). Mean cover varied by vegetation type and fertilizer treatment, with the poultry litter and control treatments displaying the most similarities.

**Table 3: Percent cover for all three pastures. N= 6 for all measurements of percent cover. C = Commercial Fertilizer; H = Horse Manure Fertilizer; P = Poultry Litter Fertilizer; R = Control. BG = Bermudagrass; OTH = All Other Vegetation. Same letter following the means within each pasture are statistically the same. Since the vegetation is paired, when Bermudagrass increased, other vegetation decreased by the same amount, and vice versa.**

Treatment	Vegetation	Mean Cover Change (%)
<b>Pasture 1</b>		
C	BG	51.67a
C	OTH	-51.67b
H	BG	33.33a
H	OTH	-33.33b
P	BG	46.67a
P	OTH	-46.67b
R	BG	25.00a
R	OTH	-25.00b

<b>Pasture 2</b>		
C	BG	-6.67b
C	OTH	6.67a
H	BG	10.00a
H	OTH	-10.00b
P	BG	13.33a
P	OTH	-13.33b
R	BG	6.67a
R	OTH	-6.67b
<b>Pasture 3</b>		
C	BG	68.33a
C	OTH	-68.33c
H	BG	15.00ab
H	OTH	-15.00bc
P	BG	55.00a
P	OTH	-55.00c
R	BG	55.00a
R	OTH	-55.00c
<b>All Pastures</b>		
C	BG	37.78a
C	OTH	-37.78b
H	BG	19.44a
H	OTH	-19.44b
P	BG	38.33a
P	OTH	-38.33b
R	BG	28.89a
R	OTH	-28.89b

With all pastures combined, vegetation ( $p = <0.001$ ) and the interaction between vegetation and treatment were significant ( $p = 0.10$ ); treatments were not significant ( $p = 1.0$ ). Other vegetation as cover was significantly negative, while the interaction between horse manure and other vegetation was statistically positive, suggesting that the application of horse manure may have facilitated the increase in other vegetation cover. The highest mean change in cover was the Poultry litter treatment, and horse manure treatments had the lowest change in cover (Table 3); Bermudagrass consistently showed a trend of increasing cover dominance.

### Discussion

These pastures have been consistently overgrazed and overstocked for at least the past five years. To restore these equine pastures, multiple variables should be considered, although reseeding and weed control are often the most common restoration methods used in pastures, they can be costly and labor-intensive. The Stephen F. Austin State

University Equine Center has made strong efforts to severely reduce the stocking rate and introduce a grazing system that is adjusted to the pastures' stocking rate, recovery time, vegetation availability, and tailored to the grazing animals on the land.<sup>4</sup> Fertilizer treatments were considered an additional approach to begin improving these pastures, using a variety of fertilizer forms to assess which would be most beneficial.

When all plots were analyzed together, poultry litter and bermudagrass had the highest recorded biomass. However, poultry litter also had the largest variation between pastures. The high variation may be a result of a smaller sample size compared to other groups, which ranged between 13 to 18 samples. On the other hand, calculations for cover were based on uniform sample sizes. The highest cover changes occurred with commercial fertilizer with an increase in Bermudagrass cover for pasture 1, with poultry litter resulting in a decrease in Bermudagrass cover for pasture 2,

and again the commercial fertilizer resulting in an increase in Bermudagrass cover for pasture 3. Analysis of all pastures showed the highest change in cover occurred from poultry litter resulting in an increase for Bermudagrass. The horse manure in all of the pastures had the lowest change in cover in Bermudagrass. Poultry litter demonstrated the highest biomass yield and cover change. Our results were similar to those found in previous studies in the United States and in Africa.<sup>14,15</sup>

Other aspects that may have affected the biomass and cover were not only the nutrients required, which were provided by the organic fertilizers, but also environmental factors such as precipitation and climate, and the timing of the fertilizer applications.<sup>17</sup> According to [tylertexasweather.com](http://tylertexasweather.com), the average precipitation in September 2024 was 1.09 in., the average precipitation in October 2024 was 1.63 in., and the average precipitation in November 2024 was 4.3 in. September typically has an average of 2.88 in., while October has an average of 4.76 in. In 2024, when the 60-day growing period took place from September to November, the precipitation levels were well below average, which could have negatively impacted both vegetation biomass and cover. The timing of the fertilizer applications could also have an impact on the resulting yield. Previous research found that bermudagrass had the highest yield when the plots had a single application in May, compared to the lowest yield from the plots whose litter application took place in Aug/Sep/Oct.<sup>16</sup> In addition, the pastures have a slight slope downwards from pasture 1 towards pasture 3, which could also have contributed toward the larger biomass values of pasture 3.

### Conclusion

The commercial fertilizer treatment significantly increased Bermudagrass biomass and cover, even when the growing conditions for the bermudagrass were not ideal, with a lower-than-average precipitation in the 60-day growing period. However, unless the pastureland has irrigation or a watering method established, the less-than-ideal environmental constraints are not unusual.

In East Texas, a good establishment method for improved bermudagrass may be to establish the pasture using a commercial fertilizer and maintain

the pastures using organic fertilizers, such as broiler poultry litter or horse manure. While commercial fertilizer was effective in establishing bermudagrass, the use of organic fertilizers such as poultry litter or horse manure for long-term pasture maintenance may be a more cost-effective and sustainable method. If pasture establishment is done correctly, the establishment should be the most expensive and labor-intensive part. Once a pasture is established, pasture management and upkeep are done yearly or every several years. Management practices such as fertilization and re-seeding are done yearly, while practices such as liming, tilling, herbicide application, re-establishment, etc., are done every few years. By integrating scientific research into practical pasture management practices, land managers can improve the land while maintaining an economically friendly operation that can produce profits or, at minimum, break even. Pasture management can be done in many ways, but the main goal is to have a healthy pasture that can handle grazing pressure for many years and remain healthy for future generations.

### Acknowledgement

The authors are grateful to the Arthur Temple College of Forestry and Agriculture at Stephen F. Austin State University for providing access to the SFASU Equine Center and for funding the project.

### Funding Sources

The Arthur Temple College of Forestry and Agriculture at Stephen F. Austin State University providing funding in the form of a research assistantship, access to facilities and resources. Funding for authorship or publication was not provided. As such there is no grant no.

### Conflict of Interest

The authors do not have any conflict of interest.

### Data Availability Statement

Data is available from the corresponding author upon request. The manuscript incorporates all datasets produced or examined throughout this research study.

### Ethics Statement

This research did not involve human participants, animal subjects, or any material that requires ethical approval.

**Informed Consent Statement**

This study did not involve human participants, and therefore, informed consent was not required.

**Permission to Reproduce Material from other Sources**

Not Applicable.

**Author Contributions**

- **Carolina De Leon:** Conducted the field study, performed the data analysis, and prepared the initial draft of this manuscript.

- **Brian Oswald:** Supervised the field study and analysis, and reviewed the manuscript.
- **Candis Scallan:** Review the manuscript and provided valuable insights and suggestions to improve the field study and the manuscript.
- **Leland Thompson:** Review the manuscript and provided valuable insights and suggestions to improve it.

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