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in West Gulf Coast Longleaf Pine (*Pinus palustris*) Savannas

By

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Characterization of Sites for Native Herbaceous Understory Restoration in West Gulf Coast Longleaf Pine (*Pinus palustris*) Savannas

By

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ABSTRACT

Longleaf pine (*Pinus palustris*) savannas were once dominant in East Texas and parts of western and central Louisiana. Native understory species have since been removed or reduced by exotic plants that were introduced and from the reduction in the frequency of both wild and prescribed fires. A diverse layer of understory species can still be seen today, but not often in the historical savanna setting that is desirable in longleaf pine ecosystems. This project aimed to identify site characteristics associated with longleaf ecosystems that support a dense, herbaceous understory with little to no midstory cover.

A total of 65 plots were established within the Boykin Springs Area to evaluate the influence of overstory cover, basal area, aspect, elevation, and slope on the number of plant genera. The study area was divided into three sites (A, B, and C) which had differing vegetative parameters and site characteristics such as elevation and slope. Site A had been recently burned as it has and is currently being managed for Red-cockaded Woodpecker habitat. The vegetative parameters and site characteristics had significant effects on the number of plant genera found in those sites.

Six of the plots were confirmed to be on Letney soils and were evaluated for their general soil parameters (sand, silt, and clay content). Equipment used to

define understory and overstory parameters were the spherical densiometer for measuring overstory canopy cover, 1 m^2 pvc pipe frame for percent cover by growth form, and vinyl measuring tape for little bluestem cover. Due to the small sample size, these plots were not included in the data analysis for the three study sites. These plots were only utilized for their general soil parameters and vegetative composition. Soil texture and series did not have any significant effects on the number of genera on those plots.

Based on the Pearson Correlation method, the number of genera per plot increased with elevation and slope (P=0.0044 and 0.0212, R=0.372 and 0.30207, respectively). This can also be explained by the negative correlation between elevation and both the overstory cover and the basal area (P=0.0918 and 0.0983, R= -0.225 and -0.221, respectively). As elevation increased, there was a decline in basal area and overstory cover which leads to a more diverse, understory layer. Results from this study suggest that in order to promote or restore a diverse, herbaceous understory in historical longleaf pine savannas, efforts to plant specific understory species that are important in restoration efforts should be aimed at areas with open canopy conditions and on slopes with greater solar exposure.

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INTRODUCTION

Longleaf pine (*Pinus palustris*) forests were once dominant in East Texas and parts of western and central Louisiana as practically pure stands (Bray 1904), and these ecosystems still play an important role in both timber production and wildlife habitat. Historically, longleaf pine ecosystems had a dense, diverse herbaceous understory, relatively low midstory cover, and tall, mature longleaf pine trees dominating the overstory. Native understory species have since been replaced, or reduced, by the introduction of exotic plants and human population expansion, which led to fire suppression, logging, and land conversion. Native understory species still exist today, but not always in the historical savanna setting that is desirable in longleaf pine ecosystems.

The historical range of longleaf pine belt extended from the Atlantic Coast to East Texas (Mohr and Roth 1897) and contained over 37 million hectares of longleaf pine forest (Frost 1993), with just over 526,000 hectares of longleaf pine ecosystems remaining (Kelly and Bechtold 1989) (Figure 1). Today, many longleaf pine ecosystems resemble many East Texas forests characterized by dense stands of woody vegetation. With fire suppression beginning with human settlement, the once easily navigable longleaf pine forests have succeeded into a mixed pine-hardwood forest with a dense woody midstory with a relatively low, if non-existent, herbaceous understory. Tree-farming and over-harvesting of old-growth longleaf pine trees have led to a patchy, scattered range across the southeast (Bray 1904).

Understory vegetation in longleaf pine ecosystems was historically lush with diverse herbaceous vegetation of grasses and forbs. With a historic fire interval of 2-3 years, the density of woody midstory plants was reduced, leaving native, herbaceous, pyrophytic plants such as little bluestem (*Schizachyrium scoparium*), wiregrass (*Aristida* spp.*),* and eastern gammagrass (*Tripsacum dactyloides*). These plants, once well-established, provide the necessary fine fuel source to support fires that longleaf pine needs in order to thrive. Without an abundant fuel source, fire may not limit competitors such as sweetgum (*Liquidambar styraciflua*). This project aimed to develop more information on the site conditions that affect the herbaceous genera of longleaf pine savannas. This project will also help to provide further information on how to restore diverse, herbaceous understories in longleaf pine, which is also favorable to many species of wildlife.

OBJECTIVES

The overall goal of this project was to examine sites that have been identified as historically supported longleaf pine ecosystems for understory vegetation associations based on site factors, and to identify potential restoration efforts to be implemented to improve or restore native understory cover.

Specific objectives of this study were to:

1. Determine what understory plant species exist in the seedbank of sites previously supporting longleaf pine forests.
2. Correlate vegetation structure and abundance with overstory cover, basal area, soil texture, and soil series as identified by Svehla (2017).
3. Identify what site conditions currently support desired herbaceous vegetation in longleaf pine ecosystems in East Texas.

LITERATURE REVIEW

History of Longleaf Pine

Pre-settlement longleaf pine ecosystems once spanned over 37 million hectares along the Atlantic coast and Gulf of Mexico (Figure 1); 30 million hectares consisted of longleaf dominant woodlands, while the other 7 million hectares consisted of mixed tree species (other species of pines and hardwood trees) with dispersed longleaf pine (Frost 1993). This range consisted of forests, savannas, and mixed woodlands on many different sites such as dry sandhills that we see in East Texas, Appalachian Mountain ridges, and wet flatwoods (Brockway et al. 2005). Within a 30-year period from 1955 to 1985, the range of longleaf pine in the Southeastern region of the United States rapidly declined from 4.9 to 1.5 million hectares (Kelly and Bechtold 1989).

The reduction in the range of longleaf pine has been attributed to human population expansion and intervention (Table 1). Human population expansion led to increased fire suppression efforts that allowed competitor species such as loblolly pine to become more abundant (Stambaugh et al. 2011). With a decrease between 1955 and 1985 of 69 percent, Texas had only 14,973 hectares of longleaf pine remaining in 1985 (Kelly and Bechtold 1989). Almost 75% of the longleaf pine forest remaining today is privately owned and is used for recreation and production of natural resources (Dale et al. 2001).

Longleaf pine ecosystems require periodic prescribed fires in the absence of wildfires to sustain an understory that will not compete with the longleaf pine overstory, and to support the historic savanna ecotype. An increase in fire frequency will also produce a graminoid layer capable of providing the necessary fuel source to spread fire across the current range of longleaf pine.

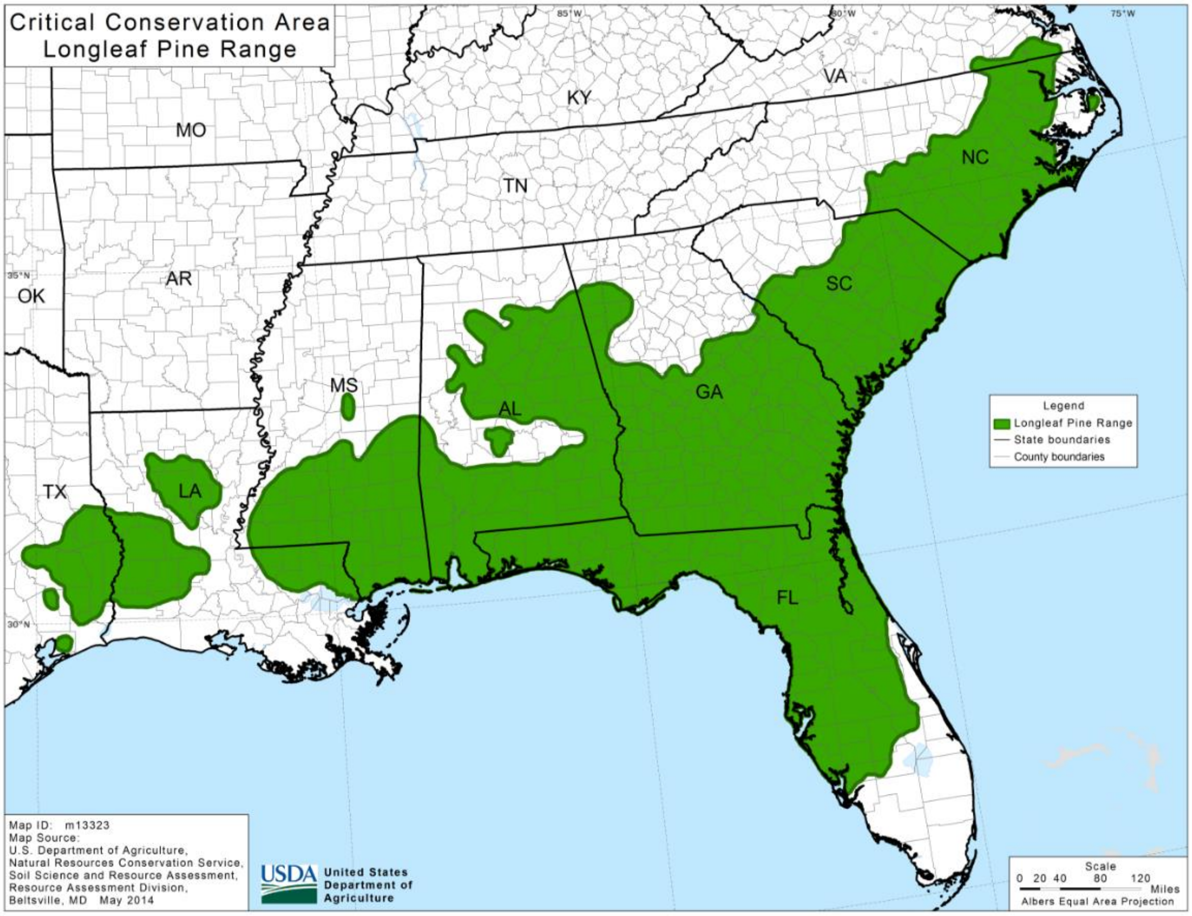

Figure 1.The longleaf pine range in 2014 across the southeast. Map taken on June 24, 2018 from the USDA website (Natural Resource Conservation Service).

Table 1.The residual area occupied by longleaf pine in thousands of hectares by state from the year 1955 to 1985 (1 = 1,000 hectares). From Kelly and Bechtold (1989).

	Year			
State	1955	1965	1975	1985
Alabama	555	400	303	275
Florida	1776	930	555	419
Georgia	1006	551	315	256
Louisiana	512	276	156	123
Mississippi	409	259	144	119
North Carolina	269	212	184	155
South Carolina	331	231	195	164
Texas	81	54	24	15
All States	4939	2914	1875	1526

Importance of Fire in Longleaf Pine Savannas

Fire was the most important ecological process that shaped and determined the range of the longleaf pine-grassland ecosystem (Van Lear et al. 2005). The historic park-like savanna setting that is most desired with longleaf pine was maintained before European settlement by very frequent, lightning induced wildfires (Chapman 1932; Heyward 1939; Platt et al. 1988). William Bartram in the late 1920s mentioned Native Americans hunting parties burning to corral game. Woody species such as American beautyberry (*Callicarpa americana)*, sweetgum (*Liquidambar styraciflua*), as well as various oaks (*Quercus* spp.), increased in number with the absence of fire (Heyward 1939; Komarek 1964; Gilliam et al. 1993).

The rapid loss in coverage of the longleaf pine ecosystem began around 1920 when logging and human population expansion led to fire suppression as fire was considered as a threat to human resources and life (Frost 1993). Fire suppression in longleaf pine ecosystems lead to a dense, woody midstory that out-competed longleaf pine regeneration (Barnett 1999). Fire is a useful tool in suppressing the midstory layer, which can both catch fallen debris and carry flames up into the longleaf canopy, which can kill overstory longleaf pine if fires become too intense (Outcalt 2006). Fire is also effective in nutrient cycling and reducing the organic matter layer that builds up from the shedding of the longleaf pine needles which suppresses the growth of the native grasses (Duvall and Whitaker 1964). Increases in shrubs and hardwoods create too much competition for longleaf pine to reproduce effectively (Chapman 1926), while burning when shrubs are young and small will suppress woody resprouting by depleting the underground carbon reserves (Olson and Platt 1995). Native Americans not only burned for hunting game, but they also burned in order to keep fuels away from their settlements (Williams 1989), to increase the quality of wildlife habitat, and also to protect them from their enemies or predators (Hudson 1976; Williams 1989).

Understory Importance

Longleaf pine ecosystems often contain some of the most important plant species for many different species of wildlife as well as maintaining the pyrophytic savanna type. Longleaf pine ecosystems contain 187 rare plant species, including 27 federally listed species that are threatened or endangered that have specific, narrow habitat requirements (Van Lear et al. 2005). Graminoid species such as little bluestem (*Schizachyrium scoparium*), wiregrass (*Aristida* spp.), and pineywoods dropseed (*Sporobolus junceus*) are just a few in the longleaf pine ecosystem identified as important by restoration ecologists. They provide an important fuel source for carrying the fire across the landscape and help maintain the frequent fire regime (Stambaugh et al. 2011).

Selected Understory Species of Importance

Little bluestem (*Schizachyrium scoparium*) is a warm season, native, perennial bunch grass that is very important to longleaf pine ecosystems, not only because it is a valuable fuel source, but it also provides necessary habitat and food for various wildlife species (Tober and Jensen 2013). Numerous song birds (e.g., cardinals (*Cardinalis cardinalis*), painted buntings (*Passerina crisis*), house finches (*Haemorhous mexicanus*), blue grosbeaks (*Passerina caerulea*), Bachman’s sparrows (*Peucaea aestivalis*), and eastern towhees (*Pipilo erythrophthalmus*) feed on the abundance of feather-like seeds, and large mammals such as white-tailed deer (*Odocoileus virginianus*) use the basal bunch for bedding (Uchytil 1989). Longleaf pine forests with lush herbaceous understory layers also provide a bounty of insects and arachnids that are important food sources to wildlife species such as the Red-cockaded Woodpecker (*Leuconotopicus borealis*). To increase the abundance of little bluestem in a longleaf pine savanna, the use of prescribed fire during a wet-year or after a wet season is encouraged (Wright 1974).

Longleaf pine plant communities in which pineland threeawn (*Aristida stricta*) is one of the dominant species include xeric, dry-mesic, and wet-mesic sites (Drew et al. 1998). Longleaf-wiregrass ecosystems rely on a very short fire return interval (1 to 5 years) in order to maintain their historic park-like conditions of having the diverse, herbaceous understory with tall, old growth longleaf pines that can rarely be seen today (Wilson et al. 1999). In addition, applications of the broad-spectrum herbicide hexazinone can suppress hardwood species that compete with wiregrass, thus increasing its abundance on the landscape (Brockway et al. 1997; Brockway and Outcalt 1999). In East Texas, this species is not common and not a species of concern in restoration efforts. Its range extends through Florida and eastward along the Atlantic Gulf Coast (Brockway and Lewis 1997). For this reason, pineland threeawn is not discussed further in this thesis.

Pineywoods dropseed (*Sporobolus junceus*) is a native, warm season, perennial bunchgrass that provides the longleaf ecosystem with a similar function as wiregrass in terms of fuel for fire and wildlife forage (Pfaff et al. 2002). This species is commonly used in longleaf pine ecosystem restoration and prefers a seedbed that is free from other vegetation, which can be accomplished using prescribed fire and/or the use of herbicidal treatment of the midstory (Brakie 2013).

Soil Texture Impacts on Understory Vegetation

Difference in soil texture occur along a gradient, which impacts the distribution of species (Knox et al. 1995). Plant type (grass, forb, shrub, tree, etc.), presence and/or dominance, and the number of genera can be correlated with parameters such as soil sand content, texture, and water retention (Fan 1993). Soil texture is directly related to water retention, which greatly affects understory vegetation, because herbaceous vegetation, such as rhizomatous grasses, have shallow root systems, unlike woody vegetation that can reach water sources deep in the soil (Walter 1979). Longleaf pine forests historically occurred on different soil types ranging from well-drained, xeric sandhills and rocky mountainous regions to poorly drained flatwoods (Boyer 1990).

METHODS

Study Area

This study was conducted within the Boykin Springs area of the Angelina National Forest (31.05186°N, -94.26804°W) near Zavalla, Texas. The climate is described as humid and subtropical (McWhorter 2005). Boykin Springs is located on the Catahoula geologic formation, and the area is characterized by hot summers (mean daily high of 34 ˚C in July) with mild winters (mean daily low of 2 ˚C in January). Mean annual rainfall for the study area is 134 cm with December and May being the wettest with both months having a mean monthly rainfall of 14.2 cm. The drier months, August and October, have a mean monthly rainfall of approximately 9.1 cm (Oswald et al. 2014). Study plots included those established by Svehla (2017) (Svehla plots hereafter) with specific soil series currently supporting longleaf pine stands and randomly established plots (study plots hereafter) located within what was historically known to be longleaf pine ecosystems. Only the plot center from Svehla's plots was evaluated for vegetative composition for this study. Most study plots were chosen "subjectively but without preconceived bias" (Mueller-Dombois and Ellenberg 1974) by establishing plots in suitable understory chosen based on visual affirmation of a diverse herbaceous understory with few midstory trees or shrubs. Some plots were located within longleaf pine ecosystems with more midstory cover.

Plot Layout

This study had 65 total plots which were divided into two categories: 59 randomly established plots (study plots), and a subset of six plots established by Svehla (2017) (Svehla plots). Study plots were located across three study sites (A, B, and C) within the Boykin Springs area (Figure 2). The three sites differed in soil series, elevation, basal area, and overstory cover which effected the understory plant species composition (Table 2). Site A (Figure 2) was in an area that had been burned a few months prior to sampling with nesting colonies of Red-cockaded Woodpeckers, indicating suitable understory habitat conditions for the purposes of this project. Plots located in sites B and C were selected to account for potential suitable areas that are not currently in the desired forest condition and could be potential target areas for understory restoration depending upon differences in site characteristics. These plots were located in a more densely vegetated area that had not been burned prior to field measurement and had standing water. Inundation in these areas could result in unsuccessful herbaceous understory restoration in these sites as species composition, elevation, and soil parameters in these two sites were different from site A.

Table 2. Study sites A, B, and C with their respective mean vegetative parameters, elevation, and slope.

Study Site	Number of Species per Plot	Grass Cover (%)	Tree Seedling Cover (%)	Shrub/Forb Cover (%)	Basal Area (ft²/acre)	Overstory Cover (%)	Elevation (m)	Slope (°)
A	20	35	38	34	86	81	36.1	4.1
B	20	44	38	31	115	86	31.1	3.4
C	14	48	15	36	102	89	22.8	1.6

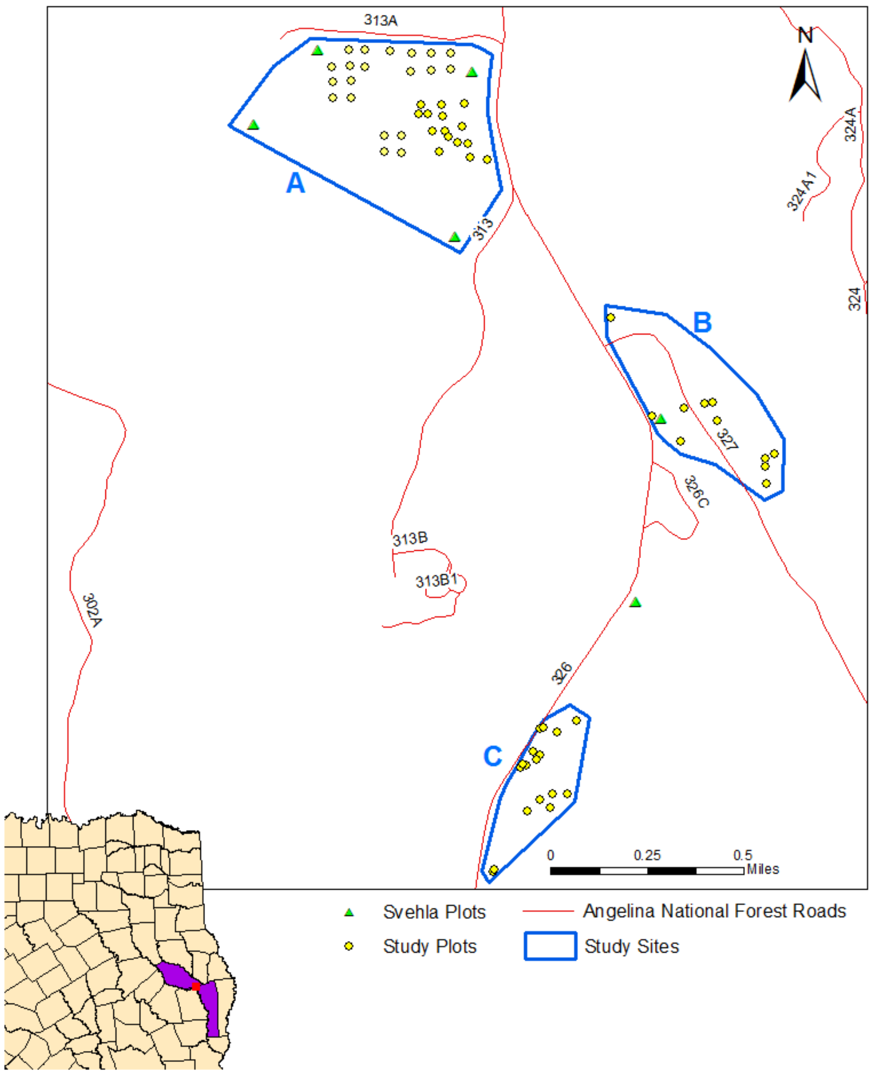

Figure 2. Location of plots within designated study sites that were grouped in order to determine if any spatial similarities or differences exist. Data acquired from the ArcGIS Database at Stephen F. Austin State University and TNRIS. June 28, 2018.

Study Plots

Once plot locations were selected with a plot radius of 5 m, and the distance between the plots was at least 50 m to reduce potential spatial autocorrelation. This 50 m spacing was based on the plot design by Svehla (2017) (Figure 4). Once a plot was established, data were recorded for that plot, and then the next plot was established by walking in an arbitrary direction that was at least 50 m away from roads and 50 m from other plots.

Svehla Plots

Svehla plots (Figure 4) were utilized to identify the effects of soil series and texture on the understory species diversity, using only the center 5 m subplot in this study of a 50 m radius plot (0.008 ha) that was used in Svehla's study, for a total area of approximately 78.5 m^2. Plot centers locations were recorded with a GPS unit.

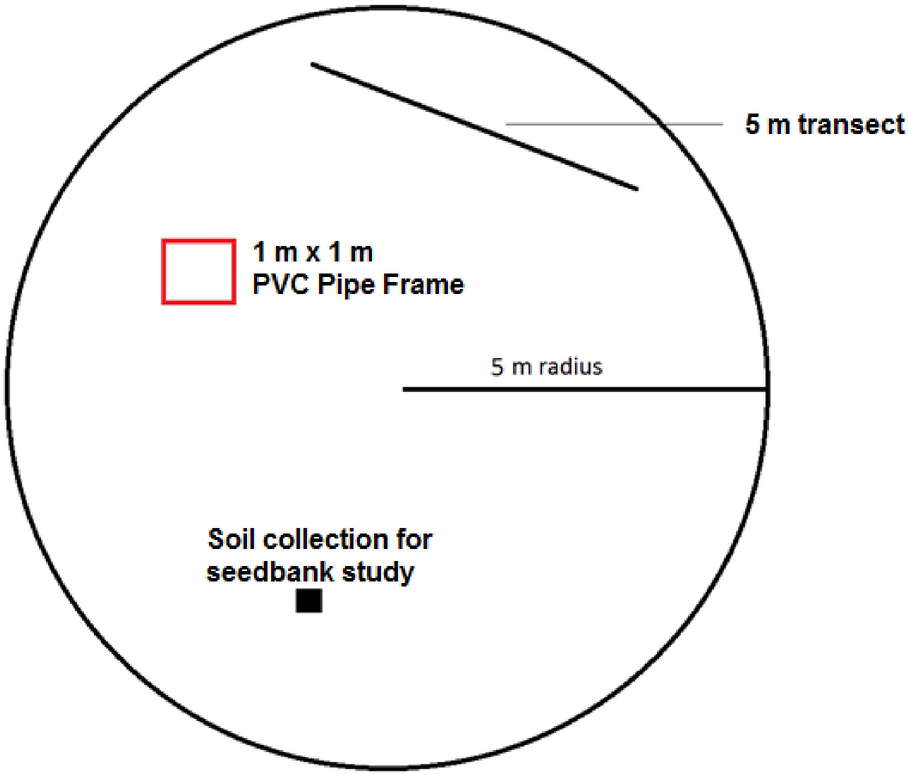

Figure 3. Plot design for all plots located within the Boykin Springs area. Basal area was also measured at the center of each plot.

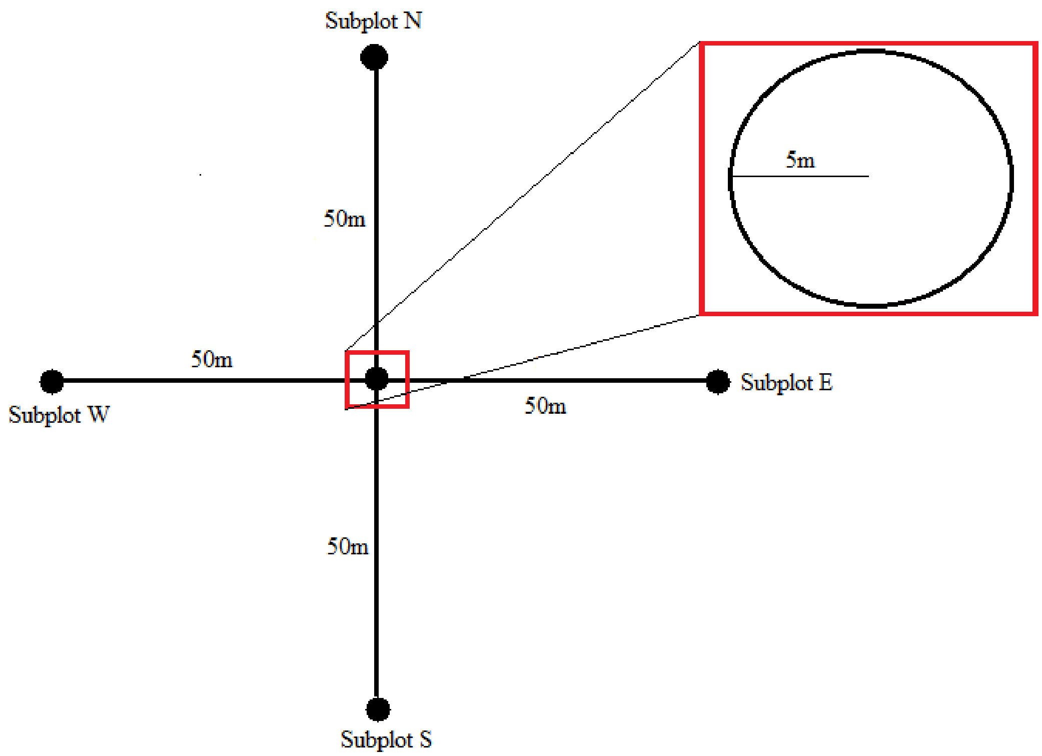

Figure 4. Plot design by Svehla (2017). Only the center plot was used in this study.

Field Methods

Seedbank Study

O and A horizon surface soil samples were collected at each study plot and the center subplot in Svehla plots for the seedbank study (Figure 4). Samples were collected using a hand shovel to extract surface material within a 0.3 m x 0.3 m area to a depth of about 15 cm, and placed into labeled brown paper bags, then transferred into perforated bins. The plastic bins were perforated by drilling five holes into the bottom of each container for the percolation of water. The bins were placed into a growth chambers set at approximately 20-25˚C and 40% relative humidity with twelve hours of light per day and watered with a hose every other day over a period of four weeks and any growth assessed. The amount of water for each bin was enough to saturate the soil, but not enough to oversaturate or leave water on the surface. The process continued for another four weeks, eight weeks in total. Any sprouting vegetation was identified and recorded for the respective plots or subplots.

Understory Percent Cover

Within each subplot, a 1 m^2 PVC pipe frame was randomly placed to visually estimate the percent cover of understory species by grass, forb, shrub, and tree growth forms (Figure 6). Data for each placement were recorded in Daubenmire

(1959) classifications (1: 0 - 5%, 2.5%; 2: 5 - 25%, 15.0%; 3: 25 - 50%, 37.5%; 4: 50 - 75%, 62.5%; 5: 75 - 100%, 87.5%) for percent grass, forb/shrub, and tree coverage. In the field, the ordinal, classified data (1, 2, 3, 4, 5) was used and then put into an excel spreadsheet at the average for that respective class (2.5, 15, 37.5, 62.5, 87.5). The shrub/forb coverage included other herbaceous vegetation as well as those species that may become part of the midstory (e.g. American beautyberry and poison oak). The shrub/forb category included both herbaceous and woody vegetation to further restrict the grasses to the grass category. The shrubs and forbs were combined into one category, while the grasses were a separate category to emphasize the importance of grasses in restoration efforts. Tree classifications included woody species that have the potential to become part of the overstory (e.g. sweetgum and longleaf pine).

In addition, any plant within the 5m radius circular subplot or study plot was identified to genus and species when possible and classified as either native or exotic (Table A1). Not all the plants within a plot were identified to species, so the number of genera was used to determine richness at each plot. To determine understory richness, a genus was recorded if it was present within the plot or if it was dominant in the surrounding areas around the subplot. If the plant could not be identified in the field, a sample was collected and pressed for identification. In addition, photographs were taken of unidentifiable plants to be viewed and identified if possible.

A 5m transect was randomly established on each plot to account for percent cover by little bluestem. Each time a blade of grass was next to or crossing the vinyl tape at a cm mark, a value of 1 recorded. A percentage of little bluestem was calculated by taking the ratio of total values recorded over the total transect length. For example, in plot BS30 little bluestem covered 27 cm of 500 cm or approximately 5.4%.

Beta Diversity Index

The three sites (Figure 2) were analyzed to assess any spatial autocorrelation or differences in areas of Boykin Springs. Since the three sites differed in mean elevation, slope, basal area, and overstory cover, a beta diversity index calculation was performed to determine differences in richness. Beta diversity between two of the sites was calculated by using the equation $\beta=(c*2)/(S1+S2)$ where β is equal to the beta diversity index, c is equal to the genera the two areas have in common, S1 is equal to the total number of genera in site 1, and S2 is equal to the total number of genera in site 2. A beta diversity index of 1 indicates exact genera composition between the sites. The sites would have complete similarity if both sites contained the same number of the same species where c would be equal to both S1 and S2. Beta diversity was calculated between all sites with S3 added to the denominator to represent the total number of genera present in site 3, and the value of c is multiplied by three instead of two.

Overstory Cover and Basal Area

Percent overstory cover was determined using a spherical densiometer at each plot center. The densiometer was held at a forearm's length from the body and held at the same angle to have consistent readings, with readings facing each cardinal direction and read the densiometer. A reading was taken from each cardinal direction and was recorded to calculate percent overstory cover (Lemmon 1956). Basal area was estimated using a 20 BAF wedge prism. At the center of each plot, the observer stood with the prism over an item or plant of choice and rotated around said plant while looking at the prism. If a tree trunk was offset from the base completely, the tree was not counted. If the tree's base and trunk were aligned even slightly, the tree was counted. Every other tree was counted if the tree was "borderline". Basal area was recorded in m^2 per ha.

Aspect, Elevation, and Slope

Aspect, elevation, and slope were determined using ArcMap version 10.5.1 in ArcGIS for desktop. Topographic maps obtained from TNRIS.org were used to determine aspect by determining which way the slope was facing for each plot. A Digital Elevation Model (DEM) of the site was used to determine the slope in degrees by downloading the DEM file for Boykin Springs and inputting it into ArcMap. Elevation was determined by using the data provided by a Garmin GPS unit and converted to meters to determine the necessary habitat requirements and needs of the associated plants in the plots.

Soil Physical Properties

Soil chemical, physical, and morphological properties from a subset of six plots from Svehla (2017), were measured. Standing in the plot center, four auger borings were made at each subplot in each cardinal direction (N, S, E, W) to determine that the entire plot is within the same soil series. Once the soil samples from each subplot, including the center, had been assured to be similar, the plots were accepted for use.

Samples derived from the plot center were taken from the first three horizons, if applicable, including the A, E, and Bt1 horizons (Svehla 2017). A brief description of the soil characteristics was conducted in order to determine profile depths up to 150 cm below the surface. These characteristics, along with the soil textures, particle size, and composition were analyzed for correlations with the vegetative composition data. Vegetative composition of the understory was also analyzed to show correlations associated soil series and textures. Soil orders were identified on these sites were Alfisols and Ultisols. Vegetative composition was recorded, and the soil parameters were used to determine the site conditions for the desired vegetation associated with soil series, texture, and depth. Study plots were not assessed for soil parameters but only accounted for vegetative composition and correlated with basal area and overstory cover.

Soil texture was obtained from Svehla (2017), who used the Bouyoucos (1951) method to determine soil texture. For the Svehla plots, vegetative composition of the understory was compared to soil texture in order to further analyze which soil parameters the vegetation requires. A soil series map (Figure 5) for the Boykin Springs area was used to determine the potential soil series for the remaining 59 plots, but soil texture and series were not confirmed in the field. The subset of six plots were confirmed by Svehla to be on Letney (Arenic Paleudults) and Tehran (Grossarenic Paleudults) soils. Five of the six plots were Letney, and one was confirmed to be Tehran, shown to be on Letney soil in site A (Figure 5). Two of the six plots were located on the Doucette-Boykin series according to soil mapping but were confirmed to be Letney in the field.

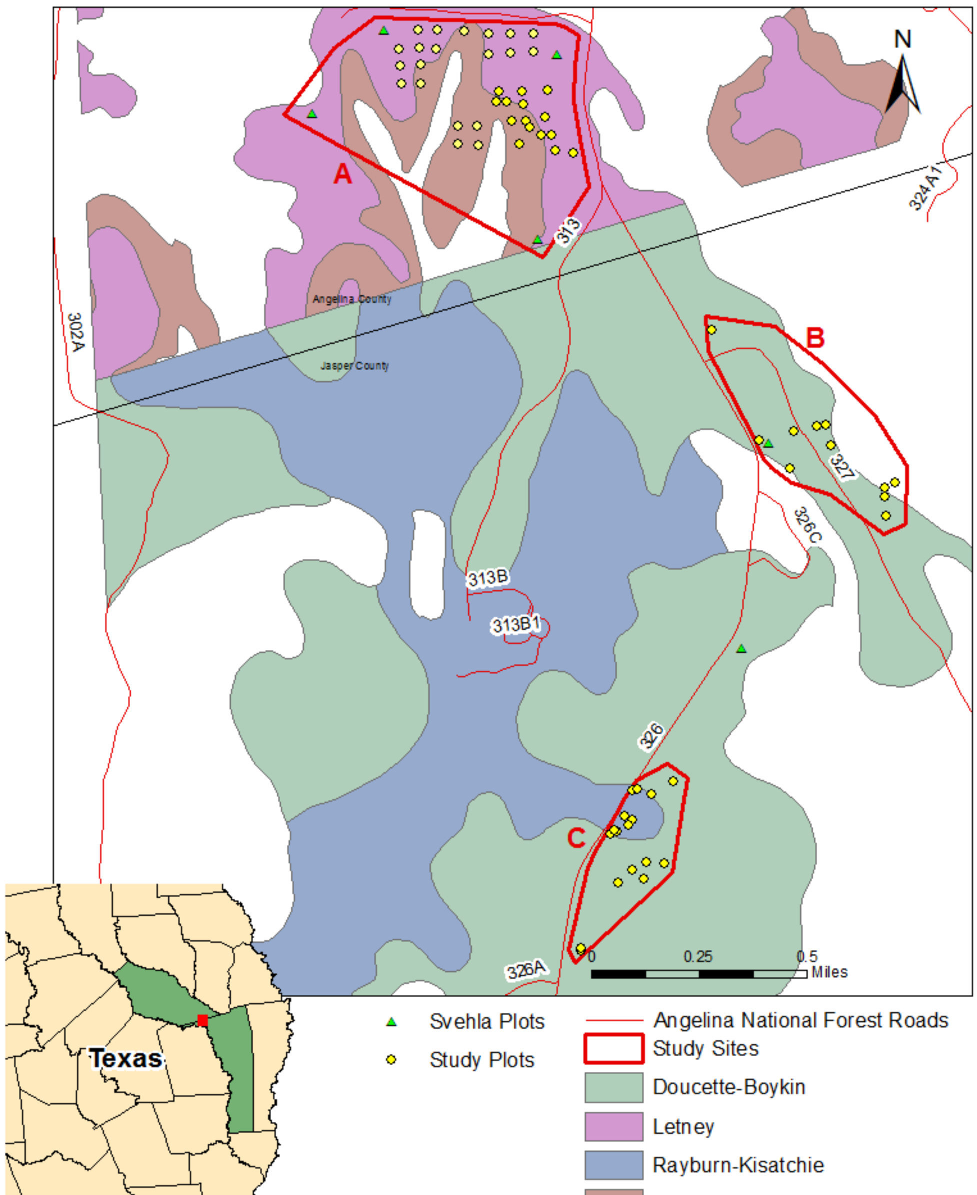

Figure 5. Soil series map for the Boykin Springs area. Soil series data obtained from NRCS website.

Data Analysis

The Pearson correlation method was used to identify correlations among the independent variables (basal area, overstory cover, elevation, slope, study site, and aspect) and their correlations with the dependent variable (number of genera). Analyses of variance were carried out to test the impact of independent variables (basal area, overstory cover, elevation, aspect, study site, and slope) on dependent variables (percent bluestem cover, percent grass cover, percent tree seedling cover, and percent shrub/forb cover). Since all dependent variables were expressed as percent, generalized linear models were used to test the effects of the independent variables on dependent variables for the fifty-nine study plots. Since species abundance was recorded as count data, for this dependent variable a generalized linear model paired with POISSON distribution was used to test the effects of the independent variables. SAS package (SAS Institute Inc. 2011) was used for all analyses. Due to small sample size, except where otherwise indicated, the term significant refers to $P \leq 0.1$ to account for biological significance. A Generalized Linear Model (GLM) that assumed the POISSON distribution was estimated to determine the influence of soil parameters and site characteristics (soil series, percent sand, percent silt, percent clay, elevation, aspect, and slope) in predicting the dependent variable 'number of genera' in the Svehla plots.

RESULTS

The seedbank study did not produce any vegetation results other than a few sprouts that died before growing large enough to identify to a genus or species level. One container began to grow a grass that was covered in trichomes which was unidentifiable but thought to be little bluestem.

Beta diversity was calculated for the three sites and expressed low similarity between each of the sites when comparing only two of the sites (Figure 6) due to the low number of genera the sites had in common with each other in comparison to their total number of genera (Table 3). When all three sites were compared to one another, the beta diversity index increased.

Table 3. Total number of genera found in each site, the number of genera specific to that site or between sites, and the total found within the Boykin Springs area.

Site	Number of Genera
A	15
B	1
C	6
A & B	9
A & C	2
B & C	5
All Sites	29
Total	**67**

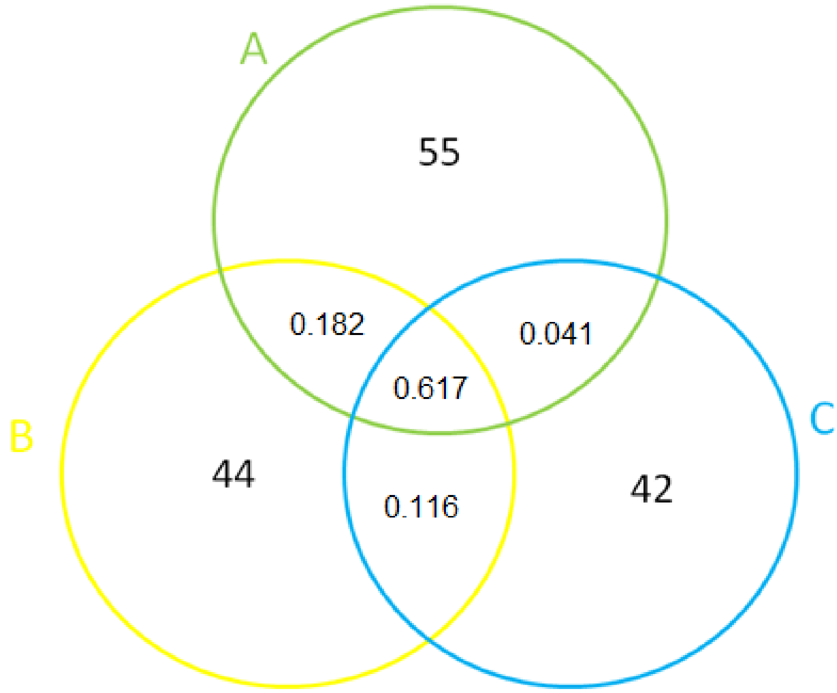

Figure 6. The total number of genera found in each site along with the beta diversity index between the three sites.

The Pearson correlation coefficient method found significant correlations between many of the variables (Table 4). Positive correlations existed between the number of genera and both elevation and slope, and between basal area and overstory cover. In addition, elevation had a significant correlation with basal area, overstory cover, and slope. Figures 7 - 13 show the correlations as scatterplots: in Figures 11 and 13, the correlation is weak. Study site showed a significant negative correlation with the number of genera, percent slope and elevation, and a positive correlation between overstory cover. The effects of aspect are shown in the GLMs due to the data being categorical. The data for aspect can be converted to numbers, but this did skew the results, and therefore was analyzed using the GLMs further discussed in this section. The plots are shown in the figures as the colors blue (A), red (B), and yellow (C) and

Table 4. Pearson correlation coefficients along with their respective p-values. “Prob > |r| under H0: Rho=0” refers to the p-value and indicates the probability of observing the correlation.

Correlation Variables	Prob > |r| under H0: Rho=0	Pearson Correlation Coefficient (R)
Number of Genera * Elevation	0.0044	0.372
Number of Genera * Slope	0.0212	0.302
Number of Genera * Study Site	<.0001	-0.625
Basal Area * Overstory Cover	0.0350	0.277
Elevation * Slope	0.0003	0.465
Elevation * Basal Area	0.0918	-0.225
Elevation * Overstory Cover	0.0983	-0.221
Basal Area * Slope	0.0622	-0.246
Study Site * Overstory Cover	0.0269	0.291
Study Site * Elevation	<.0001	-0.713
Study Site * Slope	<.0001	-0.500

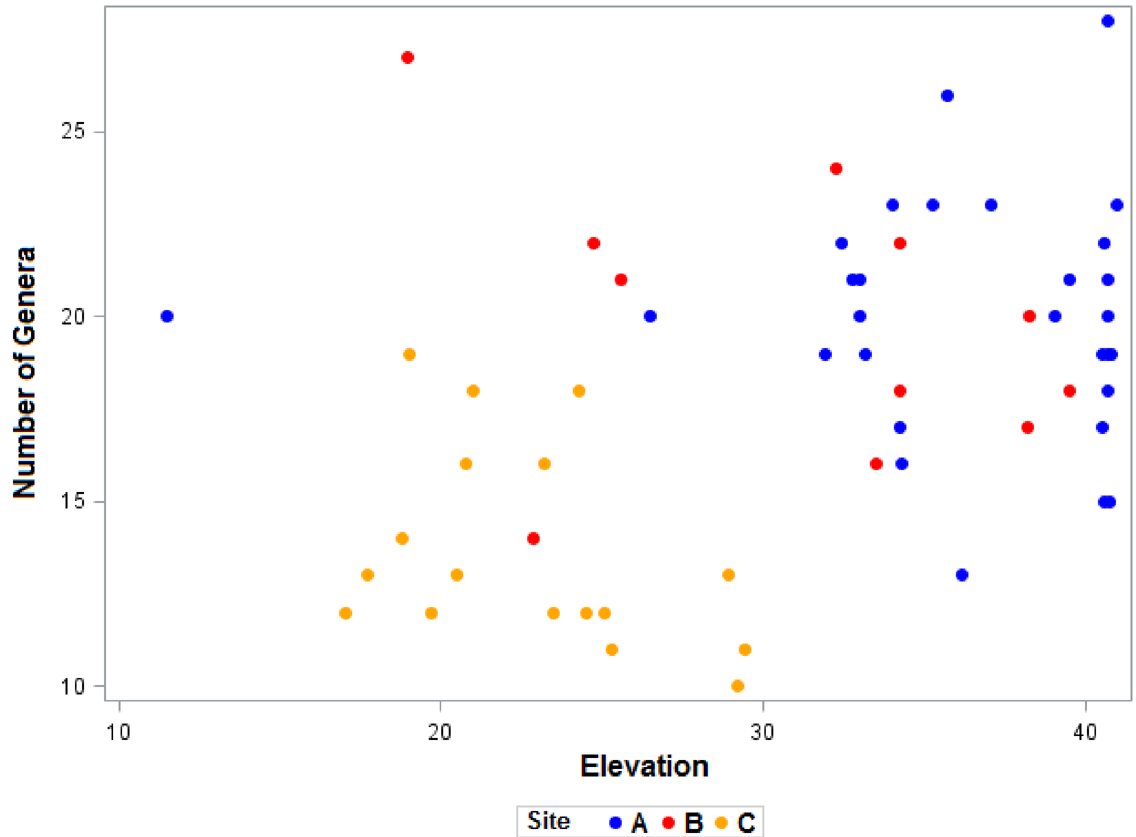

Figure 7. Scatter plot showing a positive correlation between the number of genera (y) and elevation (x) (*R*=0.372).

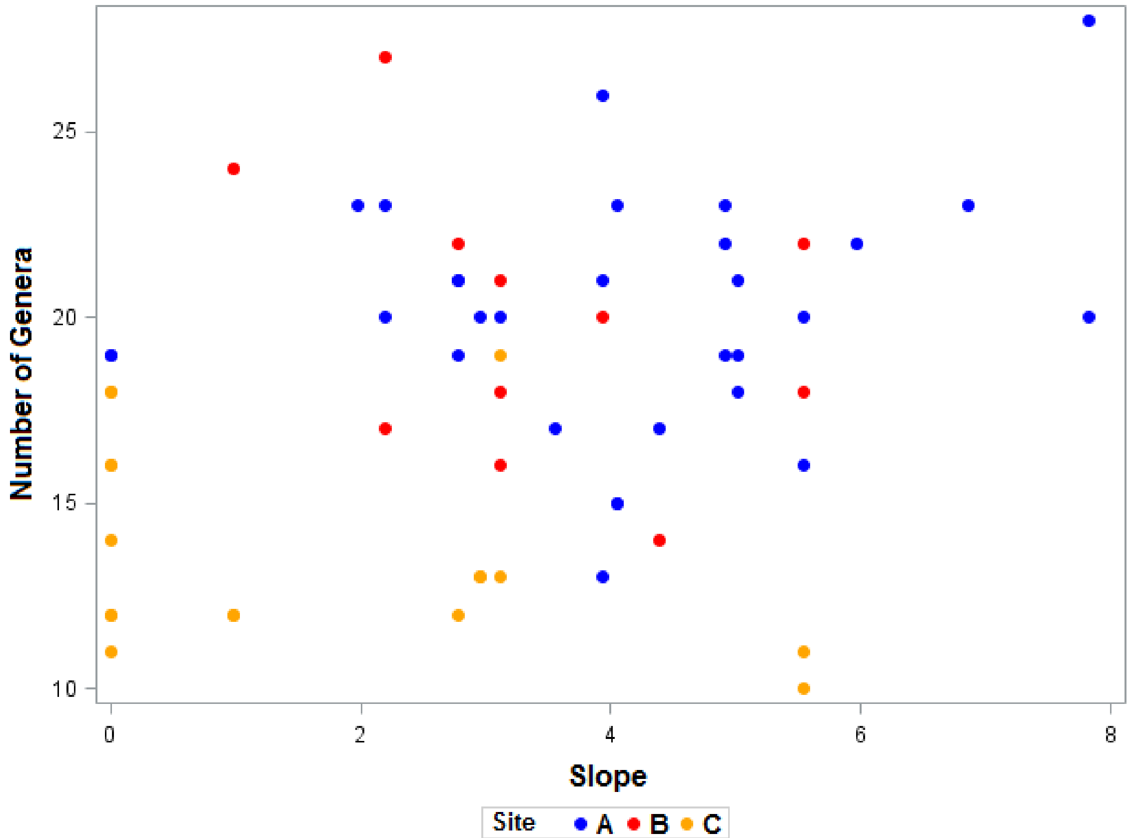

Figure 8. Scatter plot showing a positive correlation between number of genera (y), and slope (x) (R=0.302).

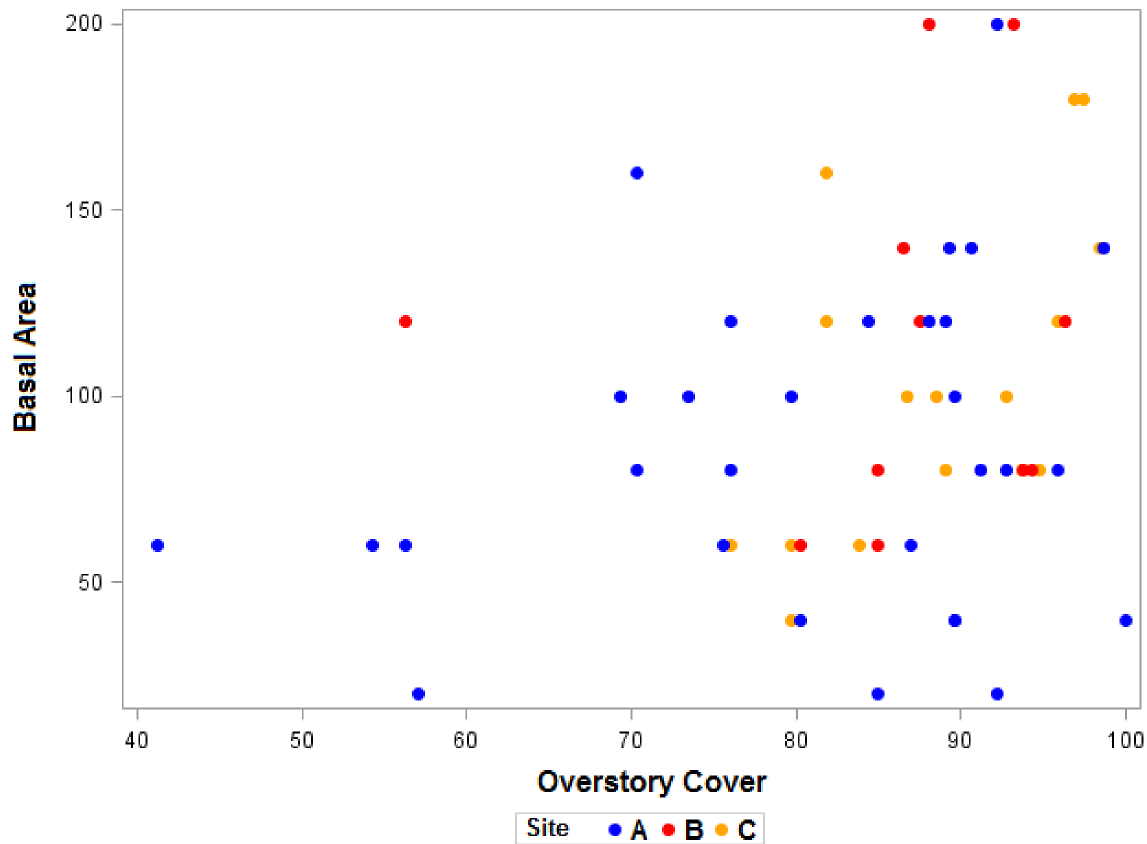

Figure 9. Scatter plot showing a positive correlation between basal area (y), and overstory cover (x) (*R*=0.277).

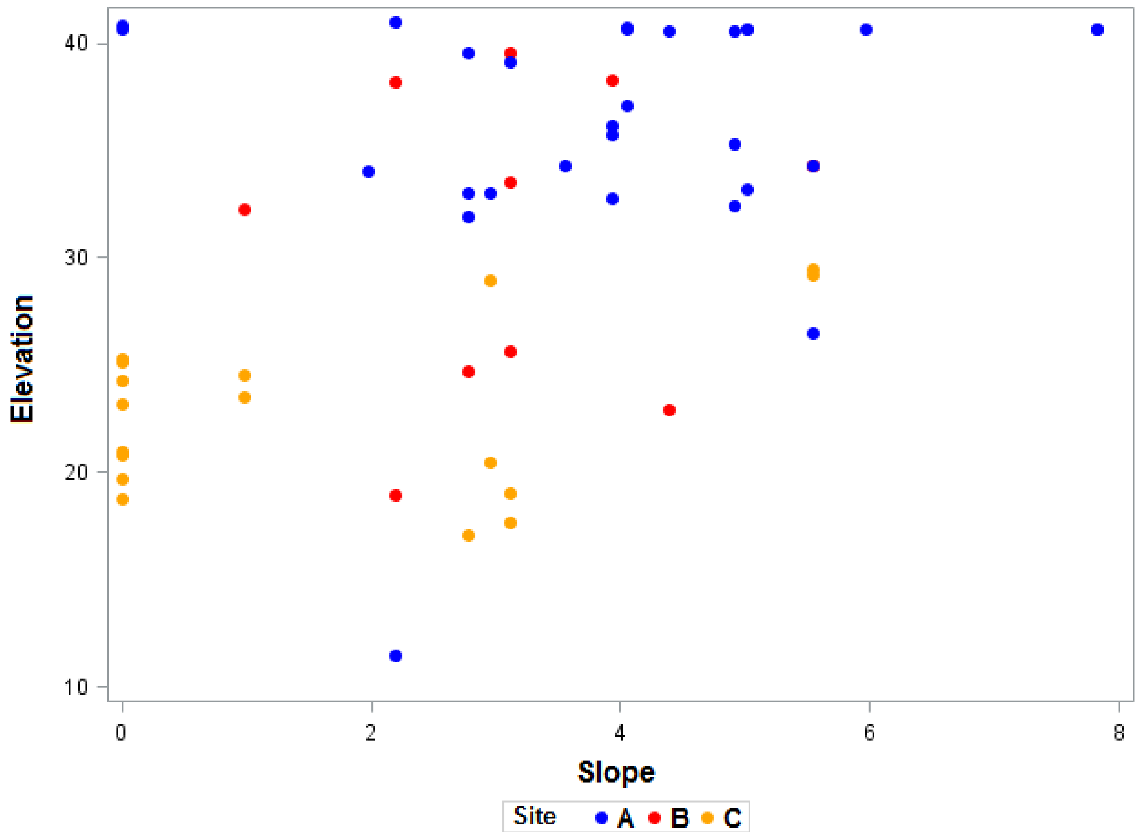

Figure 10. Scatter plot showing a positive correlation between elevation (y), and slope (x) (*R*=0.465).

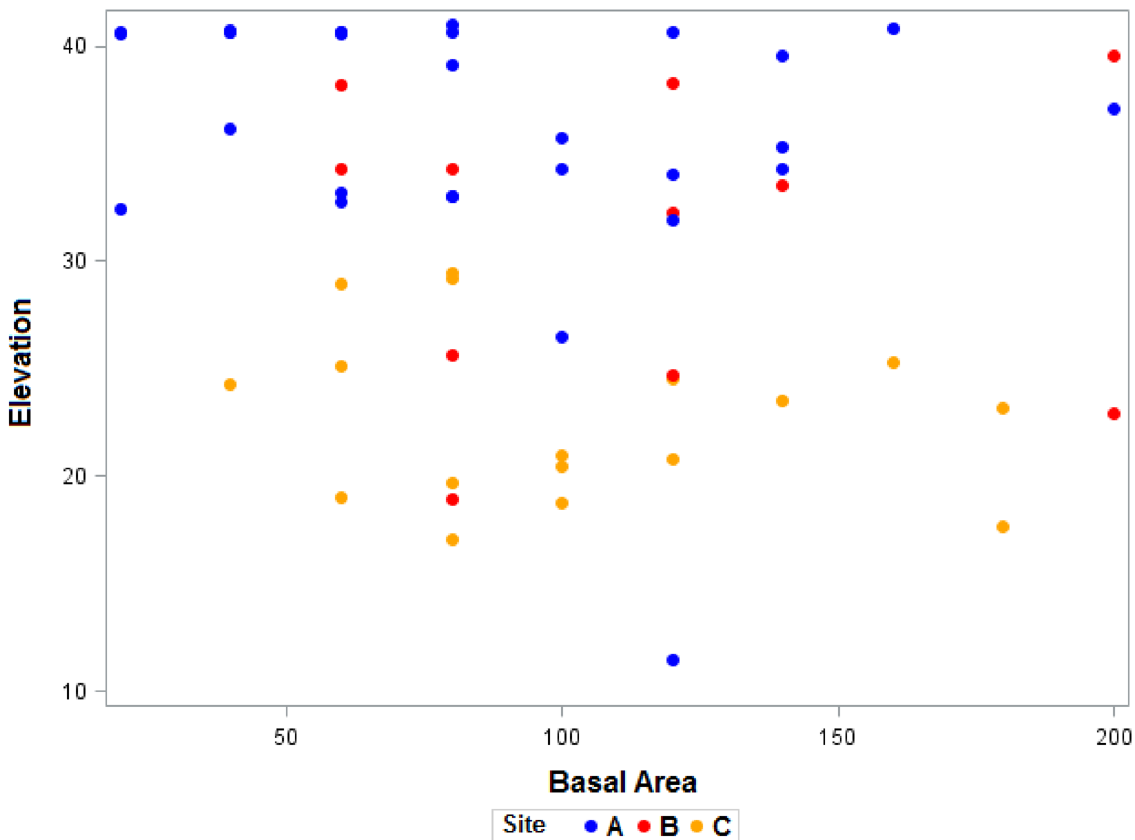

Figure 11. Scatter plot showing a negative correlation between elevation (y), and basal area (x) (*R*= -0.225).

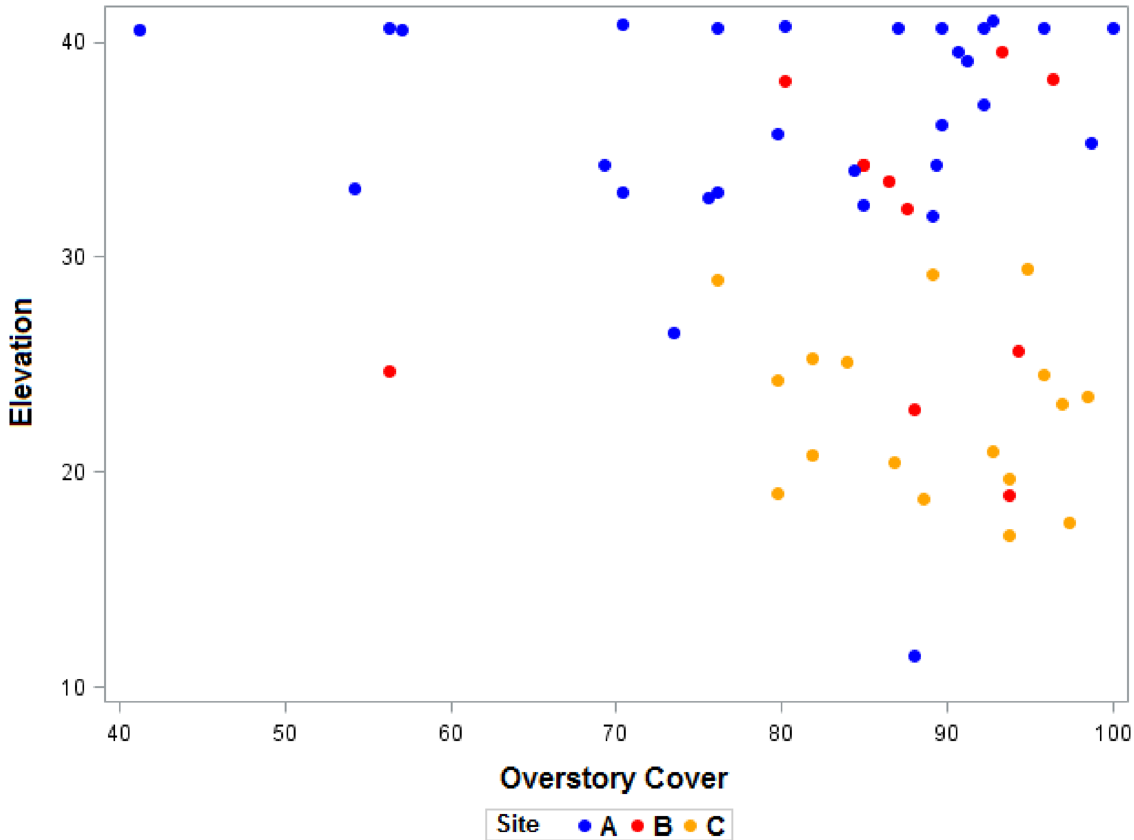

Figure 12. Scatter plot showing a negative correlation between elevation (y), and overstory cover (x) (*R*= -0.221).

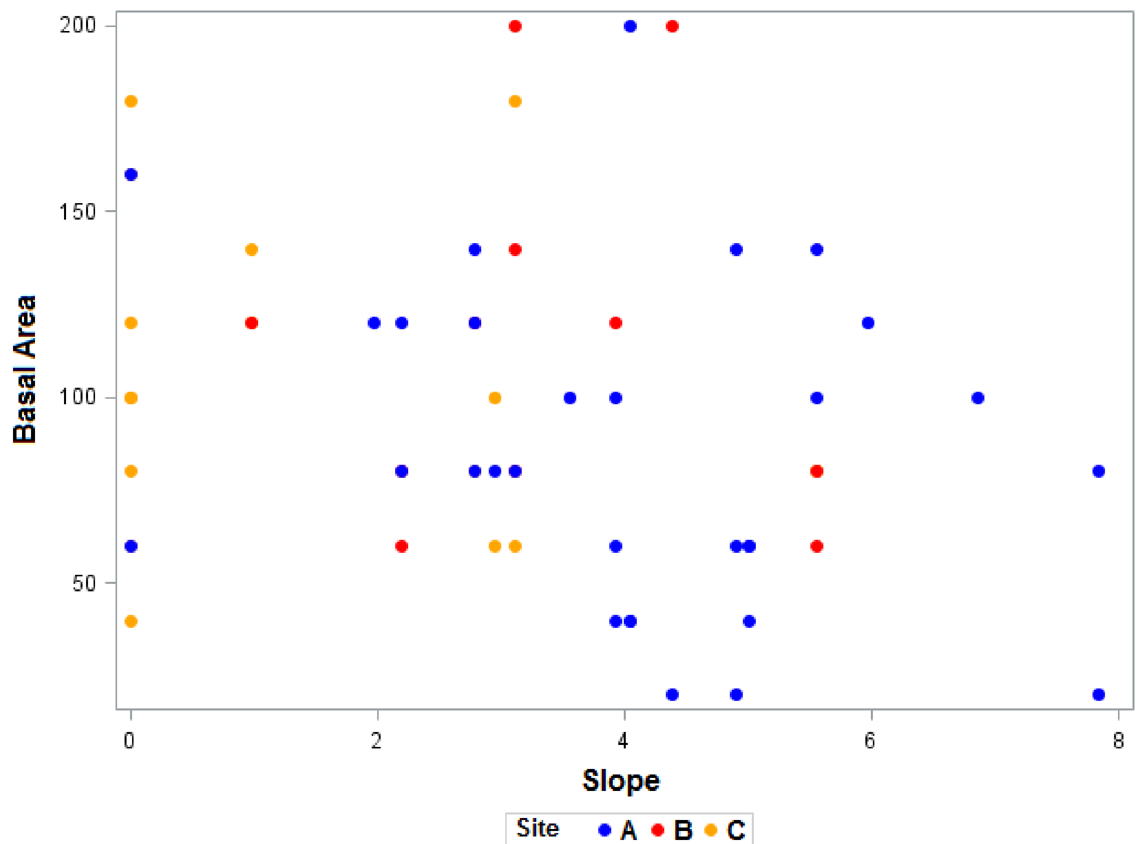

Figure 13. Scatter plot showing a negative correlation between basal area (y), and slope (x) (*R*= -0.246).

In GLM the dependent variable 'number of species' was used in order to test if the independent variables have significant impacts on the number of genera (Table 5). Elevation and study site had significant impacts on the number of genera (Table 5). Tables 6-9 are the results that used the dependent variables of percent grass cover, percent tree seedling cover, percent shrub cover, and percent bluestem cover. Significant results are shown in red. The independent variables did not have significant impacts on the percent grass cover (Table 6). Basal area, elevation, and study site had significant impacts on the percent tree seedling cover (Table 7). Elevation had significant impacts on the percent forb/shrub cover (Table 8). Overstory cover had significant impacts on the percent bluestem cover (Table 9). The GLM of the soil parameters yielded no significant results (Table 10).

Table 5. Results from GLM with the dependent variable of number of genera and the independent variables of basal area, overstory cover, elevation, slope, and study site.

LR Statistics for Type 3 Analysis						
Source	Num DF	Den DF	F Value	Pr > F	Chi-Square	Pr > ChiSq
Basal Area	1	41	0.15	0.7022	0.15	0.7002
Overstory Cover	1	41	0.51	0.4795	0.51	0.4754
Elevation	1	41	3.57	0.0660	3.57	0.0589
Aspect	7	41	0.68	0.6906	4.74	0.6921
Slope	1	41	0.19	0.6653	0.19	0.6630
Study Site	2	41	14.22	<.0001	28.45	<.0001

Table 6. Result from GLM with the dependent variable of percent grass cover and independent variables of basal area, overstory cover, elevation, aspect, slope, and study site.

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Basal Area	1	0.0742	0.0742	0.00	0.9920
Overstory Cover	1	95.0111	95.0111	0.13	0.7193
Elevation	1	40.8431	40.8431	0.06	0.8136
Aspect	7	1513.9058	216.2723	0.30	0.9506
Slope	1	10.6994	10.6994	0.01	0.9039
Study Site	2	372.4524	186.2262	0.26	0.7748

Table 7. Result from GLM with the dependent variable of percent tree seedling and the independent variables of basal area, overstory cover, elevation, aspect, slope, and study site.

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Basal Area	1	428.7461	428.7461	6.52	0.0145
Overstory Cover	1	85.9690	85.9690	1.31	0.2595
Elevation	1	350.6653	350.6653	5.33	0.0261
Aspect	7	235.7083	33.6726	0.51	0.8201
Slope	1	80.0371	80.0371	1.22	0.2764
Study Site	2	460.7686	230.3843	3.50	0.0394

Table 8. Result from GLM with the dependent variable of percent shrub/forb cover and the independent variables of basal area, overstory cover, elevation, aspect, slope, and study site.

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Basal Area	1	123.5104	123.5104	0.35	0.5557
Ovestory Cover	1	2.0014	2.0014	0.01	0.9401
Elevation	1	1355.2320	1355.2320	3.87	0.0559
Aspect	7	2993.3419	427.6203	1.22	0.3131
Slope	1	0.4924	0.4924	0.00	0.9703
Study Site	2	238.7985	119.3992	0.34	0.7129

Table 9. Result from GLM with the dependent variable of percent bluestem from the 5m transect and the independent variables of basal area, overstory cover, elevation, aspect, slope, and study site.

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Basal Area	1	18.1531	18.1531	0.08	0.7729
Overstory Cover	1	1015.2624	1015.2624	4.73	0.0365
Elevation	1	27.5355	27.5355	0.13	0.7224
Aspect	7	624.4102	89.2015	0.42	0.8860
Slope	1	15.1199	15.1199	0.07	0.7923
Study Site	2	288.3691	144.1846	0.67	0.5173

Table 10. Result from GLM with the dependent variable of understory species diversity was put into a general linear model that assumes the POISSON distribution to test for soil parameter effects.

Analysis of Maximum Likelihood Parameter Estimates							
Parameter	DF	Estimate	Standard Error	Wald 95% Confidence Limits		Wald Chi-Square	Pr > ChiSq
Soil Series	1	-0.4519	0.3713	-1.1796	0.2758	1.48	0.2236
Percent Sand	1	-0.0192	0.0865	-0.1888	0.1503	0.05	0.8242
Percent Silt	1	-0.0319	0.1053	-0.2383	0.1745	0.09	0.7621
Elevation	1	0.0058	0.0200	-0.0334	0.0449	0.08	0.7726
No Aspect (Flat)	1	-0.0666	0.5001	-1.0467	0.9136	0.02	0.8941

DISCUSSION

In order for a future the seedbank study to be successful, one suggestion is for the O and A horizons to be collected in the field and then sifted in order to reveal any seeds. The seeds can then be placed in the perforated bins with a mixture of a ratio of 1:3 sand to fertilized soil with a thickness of 4-5 cm before placing into the growth chambers. The bins should be watered every day instead of every other day as performed in this study since the bins were dry by the end of the four weeks.

The correlation that existed between the number of genera and the elevation suggests a relationship where an increase in elevation led to an increase in the number of genera (Figure 7), which also increased with an increase in slope (Figure 8). In mountainous zones, increases with elevation have led to peaks in species diversity accompanied by a decline in overall species richness (Lomolino 2001). Although East Texas is not a mountainous region, the relatively small changes in elevation had an effect on the understory vegetation. An increase in elevation also was reflected in a decrease in overstory cover and basal area (Table 4, Figures 11 and 12), which contributed to the increase in the number of genera due to the greater availability of light reaching the forest floor. (Barbier et al. 2008). Slope was not significantly correlated with overstory cover. The increase in elevation was also positively correlated with slope that also produced this effect (Figure 10). However, slope was negatively correlated with basal area; as the degree of slope increased, the basal area decreased (Figure 13). Herbaceous species respond to soil moisture and can indicate water table conditions which is often associated with elevation and slope (Stromberg et al. 1996). Not surprisingly, the significant correlation between basal area and overstory cover indicates where the higher the basal area the higher the overstory cover (Figure 9). This could be either due to few, larger overstory trees with either larger canopies or a higher number of smaller overstory trees with smaller canopies. Overstory cover and basal area are positively correlated with each other, and one can be used to predict the other (Mitchell and Popovich 1996).

The study sites (Figures 7-13) were correlated with the number of genera, overstory cover, elevation, and slope (Table 4). The site location of the plots (Figure 3) or 'study site' had significant effects on the percent cover by tree seedlings, the number of genera, and percent shrub/forb cover (Table 4). This most likely was due to the prescribed burning of site A a few months before data collection, and areas B and C were not burned prior to field collection but had higher amounts of midstory cover. Site A was higher in elevation than sites B and C which also directly influenced the number of genera and overstory cover. Site A had a denser herbaceous understory cover with more longleaf pine regeneration. Prescribed burning is not only effective in removing or reducing competitive midstory species, in this case it increased the vigor of herbaceous understory species by allowing more sunlight to reach the forest floor as well as the potential increase in soil nutrients (Olson and Platt 1995). The grouping along the x axis with elevation and grouping along the y axis with the number of genera (Figure 7) shows that site A had the highest elevation and the highest number of genera. Figure 12 also shows the grouping along the y-axis as elevation with site A having higher elevation, and site C had the lowest. The grouping along the y-axis indicates the number of genera was highest in site A. Site B had lower elevation than site A, but was higher than site C, and resulted in a similar number of genera for sites A and B. All study sites were also correlated with slope (Figures 8 and 10) with grouping along the x-axis as slope. Slope affects drainage properties in soil, and the herbaceous vegetation in this area are located on well-drained soils. Higher genera richness was in site A where the elevation and slope was the greatest. While unconfirmed, it is possible that higher slopes, even of this degree, might have influenced soil texture to the degree that slope was acting as a surrogate of soil drainage differences (Brady and Weil 2017). The more plots in lower overstory cover in site A compared to sites B and C could be a contributing factor to site A having the most understory cover.

Using a GLM that assumed the POISSON distribution identified significant impacts of independent variables on the number of genera, as the number of genera was affected by the elevation and site (Table 5). Site C had the lowest mean elevation and therefore had the lowest number of genera. The POISSON distribution suggests that in all cases except for the understory species diversity, aspect had a significant impact upon the dependent variable. The direction (aspect) and degree of the slope influences sunlight exposure, and in turn influences vegetative cover.

Generalized linear models (GLMs) were used to determine the site characteristics that influenced the percent cover of vegetation by growth form (grass, tree seedling, and shrub/forb). The percent grass cover was not influenced by basal area, overstory cover, elevation, aspect, slope, and study site (Table 6). Although the results showed no significant affects, visual observations showed significant effects of overstory cover on the coverage of grasses. From field observations, less overstory cover did have an effect of more coverage of grasses. Basal area, elevation, and study site had significant effects on the percent coverage of tree seedlings (Table 7), possibly contributing to the increase in the number of plant genera present (Figure 7) further explaining the effect of elevation on the percent cover of tree seedlings. More tree seedlings were present with lower overstory cover which as well is explained by an increase in available sunlight reaching the forest floor.

Svehla confirmed six of plots within the Boykin Springs area to be on Letney soils, which have a high sand content, and therefore low water retention capabilities that support an herbaceous understory layer (Brady and Weil 2017). The sample size for the soil impacts was too small to observe any significant effects on the understory vegetation. To assess the impacts of the soil characteristics on the vegetative composition, all plots would need to be sampled for soil series and texture.

CONCLUSIONS AND MANAGEMENT IMPLICATIONS

The main environmental factors driving species abundance and presence were elevation and overstory cover. From field observations, less overstory cover led to more coverage of grasses, and from data analysis, an increase in elevation led to a decrease in basal area and overstory, which leads to more solar radiation that reaches the forest floor. This in turn creates a more desirable, diverse herbaceous understory (Jameson 1967). Planting projects would need to focus primarily on areas with less overstory cover and lower basal area where there will be adequate light reaching the forest floor. This would also mean that with an overabundance of midstory, thinning would allow for increased viability of understory species plantings, either from fire, mechanical, or chemical methods.

Little bluestem was present on all 65 plots and is therefore not a species of concern for restoration efforts in the Boykin Springs area. Pineywoods dropseed was not present on all plots, nor as abundant as little bluestem. This species would need to be prioritized for restoration projects in East Texas. It was present in all three study sites and would therefore be successful in plantings in more well-drained, open canopy areas within the three sites.

Prescribed burning is not only effective in removing or reducing competitive midstory species, in this case it increased the vigor of herbaceous understory genera by allowing more sunlight to reach the forest floor as well as the increase in soil nutrients (Olson and Platt 1995). Area A had been burned prior to data collection and had significantly more amounts of little bluestem and pineywoods dropseed. Longleaf pine needs these fine fuel species to carry fire across its range and eliminate woody species that would compete with the overstory trees as well as the herbaceous understory. Important understory species such as little bluestem and pineywoods dropseed are necessary in longleaf pine savannas to maintain the fine fuel source for periodic fires to reduce midstory competition. Periodic prescribed burning will not only reduce competition, but also expose a nutrient enriched soil bed that these important understory species need to grow. Longleaf pine ecosystems with a two to eight-year fire return interval are most effective at producing a dense, diverse herbaceous understory with increases in fire dependent species of grasses such as little bluestem and Pineywoods dropseed (Brockway and Lewis 1997).

Soil characteristics such as soil series and soil texture did not show significant effects on understory species diversity in this study, but with a larger sample size, further research would need to be performed in order to test for soil parameter effects on plant species diversity. In this study, a small sample size of six plots was used to determine soil parameter effects on the understory vegetation. It would be beneficial to research the soil parameter effects on the vegetative composition by confirming soil series and soil texture on a larger sample size while determining the vegetative composition. This would also be beneficial in analyzing the effects of elevation and slope on the soil drainage properties. Overall, to restore longleaf pine ecosystems in Texas, management practices of periodic prescribed fire along with plantings of important understory species in areas with open canopy cover on slopes with the most solar exposure will provide a denser and more diverse herbaceous understory.

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APPENDIX

Table A1. Sixty-seven genera found in the Boykin Springs area near Zavalla, Texas with the respective native status, the number of plots that contained each respective species, the study sites where the species occurred, and their growth form category.

Genus	Number of Plots	Native Status	Study Site	Growth Form
Alophia	3	N	A	Shrub/Forb
Ambrosia	36	N	A,B,C	Shrub/Forb
Ampelopsis	2	N	A	Shrub/Forb
Andropogon	1	N	A	Grass
Aristolochia	15	N	A	Shrub/Forb
Asimina	4	N	C	Tree
Berlandiera	16	N	A,B,C	Shrub/Forb
Callicarpa	52	N	A,B,C	Shrub
Campsis	2	N	B,C	Shrub/Forb
Carex	14	N	A,B	Grass
Carya	5	N	A,B,C	Tree
Ceanothus	4	N	A	Shrub/Forb
Centrosema	3	N	A,C	Shrub/Forb
Chamaecrista	3	N	A	Shrub/Forb
Chasmanthium	2	N	C	Grass
Cichorium	1	E	A	Shrub/Forb
Cirsium	1	N	C	Shrub/Forb
Clitoria	14	N	A	Shrub/Forb
Cnidoscolus	22	N	A,B,C	Shrub/Forb
Commelina	19	E	A,B,C	Shrub/Forb
Conyza	20	N	A,B	Shrub/Forb
Croton	50	N	A,B,C	Shrub/Forb
Cyperus	17	N	A,B	Grass
Desmodium	52	N	A,B,C	Shrub/Forb
Dichanthelium	46	N	A,B,C	Grass
Echinacea	14	N	A,B	Shrub/Forb
Eleocharis	1	N	C	Grass

Eragrostis	5	N	B,C	Grass
Eryngium	1	N	B	Shrub/Forb
Fragaria	1	N	A	Shrub/Forb
Galactia	16	N	A,B,C	Shrub/Forb
Gelsemium	5	N	A,B,C	Shrub/Forb
Helianthus	18	N	A,B	Shrub/Forb
Hypericum	10	N	A,B	Shrub/Forb
Ilex	18	N	A,B,C	Shrub/Forb
Ipomoea	6	N	A,C	Shrub/Forb
Liatris	4	N	A	Shrub/Forb
Liquidambar	29	N	A,B,C	Tree
Mimosa	45	N	A,B,C	Shrub/Forb
Morella	7	N	B,C	Shrub/Forb
Osmunda	2	N	C	Shrub/Forb
Oxalis	5	N	B,C	Shrub/Forb
Parthenocissus	9	N	B,C	Shrub/Forb
Paspalum	12	N	A,B,C	Grass
Pinus	33	N	A,B,C	Tree
Pityopsis	41	N	A,B,C	Shrub/Forb
Pteridium	49	N	A,B,C	Shrub/Forb
Quercus	21	N	A,B	Tree
Rhus	18	N	A,B,C	Shrub
Rubus	9	N	A,B,C	Shrub/Forb
Sassafras	37	N	A,B,C	Tree
Schizachyrium	65	N	A,B,C	Grass
Setaria	2	N	C	Grass
Smilax	8	N	A,B,C	Shrub/Forb
Sporobolus	16	N	A,B	Grass
Stillingia	14	N	A	Shrub/Forb
Strophostyles	17	N	A,B,C	Shrub/Forb
Stylisma	1	N	A	Shrub/Forb
Stylosanthes	29	N	A,B,C	Shrub/Forb
Taraxacum	1	E	A	Shrub/Forb
Tephrosia	33	N	A,B,C	Shrub/Forb
Toxicodendron	61	N	A,B,C	Shrub/Forb
Tradescantia	5	N	A,B	Shrub/Forb
Tragia	10	N	A	Shrub/Forb
Tripsacum	33	N	A,B,C	Grass

Vitis	24	N	A,B,C	Shrub/Forb
Yucca	3	N	A	Shrub/Forb

VITA

After receiving her diploma from New Diana High School, Diana, Texas, in 2011, Brooke McCalip entered Stephen F. Austin State University in Nacogdoches, Texas. During the summer of 2012, she attended Kilgore College to obtain more credit hours, and in the summer of 2013, she completed an internship working for the National Park Service, helping with the rescue and conservation of loggerhead sea turtles. She received the degree of Bachelor of Science in Ecology and Evolutionary Biology with a minor in Forest Wildlife Management in May 2015. The summer of 2015, she pursued a temporary position of Biological Technician for the USDA Forest Service in Silverthorne, CO. In June 2016, she entered the Graduate School of Stephen F. Austin State University and received a Master of Science degree in August 2018. Brooke currently works as an Environmental Scientist for Hydrex Environmental in Nacogdoches, Texas.

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