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# Analysis Of Conservation Practices In The Blackland Prairie Region Of Mississippi And Construction Of A Predictor For Locating New Sites For Conservation Efforts

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# ANALYSIS OF CONSERVATION PRACTICES IN THE BLACKLAND PRAIRIE REGION OF MISSISSIPPI AND CONSTRUCTION OF A PREDICTOR FOR LOCATING NEW SITES FOR CONSERVATION EFFORTS

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ANALYSIS OF CONSERVATION PRACTICES IN THE BLACKLAND PRAIRIE REGION OF MISSISSIPPI

AND CONSTRUCTION OF A PREDICTOR FOR LOCATING NEW SITES

FOR CONSERVATION EFFORTS

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Mississippi's Blackland Prairie has been reduced below 10% of pre-Columbian extent, with few conservation practices in place. To determine efficacy of current restoration practices, plant species at remnant sites were compared with those at restoration sites. Analyses using multivariate statistical approaches revealed no generalizable patterns among four available remnants versus two available restoration sites. Thus, the aim of this project shifted to evaluating methods of identifying Blackland Prairie remnants or potential restoration sites. Location data for Blackland Prairie plant species and potentially informative environmental variables were used to develop geographic information system (GIS)-based habitat models. The best models were selected for validation against a second set of data collected from random points on public lands across the survey region. Validation surveys also were used to explore trends in predictive success and to aid in increasing accuracy through inclusion of other variables. Models incorporating soil characteristics had the highest predictive success.

Key words: Blackland, restoration, geographic information system, GIS

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# CHAPTER I

# INTRODUCTION

Grasslands occur or have occurred as large areas on all continents save Antarctica (Walter 1979). In North America, grasslands can be found from Texas north to Manitoba, and Indiana west to the Rocky Mountains (Weaver 1954). Grasslands, or prairies, can be found on all types of topography including level land, steep bluffs, and alluvial floodplains (Weaver 1954), and they usually are species-rich systems. Steiger (1930) found 237 species of prairie plants in a single square mile of prairie in Nebraska, Weaver and Fitzpatrick (1934) found 225 species of prairie plants in the Missouri Valley Region covering over 15 million hectares, and over 600 plant species were recorded for the Flint Hills region of Nebraska, an area of 1.6 million hectares (Great Plains Flora Association 1986).

In their monograph, Weaver and Fitzpatrick (1934) address the need to study prairies and make permanent records of their flora due to the rapid rate of loss of prairie vegetation. Noss et al. (1995) found that ≥90% of the tall grass prairie has been destroyed in the Midwest and Great Plains, with the remaining 10% or less existing in only small fragments. Tall grass prairie is also found in the Southeastern United States as the Blackland Prairie, found in Alabama, Arkansas, Georgia, Louisiana, Mississippi, and Texas (Peacock and Schauwecker 2003).

In Mississippi, Blackland Prairies are located in two areas: the Jackson Prairie in the central part of the state and a crescent-shaped physiographic region extending from the northeast, through central Mississippi, and into Alabama that occupies 1,649,822 ha (Soil Survey Staff 1981). The Mississippi portion of the crescent shaped region is the focus of this study and hereafter will be referred to as “the Blackland Prairie.” These areas are underlain by Cretaceous-age clay, marl, soft limestone, or chalk of the Selma Group (Soil Survey Staff 1981). The underlying geology and soil conditions contribute to a potentially highly diverse regional prairie flora (Weiher et al. 2004, Schuster and McDaniel 1973, Jones and Patton 1966). However, a USGS report listed the Blackland Prairie as an endangered ecosystem covering less than 1% of its historic range (Noss et al. 1995).

Rostland (1957) provides one of the earliest assessments of the Blackland Prairie’s vegetative history, concluding that no distinct community existed in the area and that there is no evidence to support the region having been covered totally by prairie vegetation. Through a re-analysis of data used by Rostland (1957), Barone (2005) came to the conclusion that a distinct region of vegetation existed in the Blackland area of Mississippi and Alabama, but as patches across the landscape, rather than a single contiguous unit. Blackland Prairie subsequently has been greatly degraded by human activity (Peacock and Schauwecker 2003). Because the existence of these prairies is linked to soil quality, fire, and grazing by native ungulates, severe losses in area have resulted from fire suppression practices and conversion to agriculture (Weiher et al. 2004). Remnant prairie patches can be found in old pastures, along roadsides, on utility rights-of-way, and in natural areas (Schauwecker 1996). Woody species encroachment, stock grazing, and erosion are presently degrading the few remaining prairie habitats (Barone and Hill 2007).

Although human impacts can degrade native prairies, these natural areas also will degrade naturally over time without some level of management to preserve historic disturbance processes (Wiygul et al. 2003). As recently as 2007, the flora of the Blackland Prairie remnants was assessed and found to include 168 species of native plants (Barone and Hill 2007). A majority of the sites used in Mississippi to conduct the Barone and Hill (2007) floristic survey experience no management, and thus, no regular disturbance typical of historic prairie communities (Barone and Hill 2007).

Conservation of remaining prairies and restoration of prairie lands in the region are ways that the Blackland Prairie system can be preserved. The federal government, through the US Department of Agriculture (USDA) Natural Resource Conservation Service (NRCS) created various programs to help offset costs associated with conservation practices on private land. These efforts include creating or restoring prairie fragments within the Blackland Prairie, and some of the relevant programs include the Conservation Reserve Program (CRP). The CRP was created and authorized by the Food Security Act of 1985, otherwise known as the farm bill. Conservation Practice 33 (CP33), habitat buffers for upland birds, has the main goal of creation or restoration of suitable habitat for the bobwhite quail (*Colinus* virginianus). Habitat is restored or created as buffers around farm fields. These buffers are allowed to become vegetated by natural succession or they are planted using a prescription developed for each individual enrolled site. Despite the CRP specifying the use of native vegetation to restore sites, practitioners regularly use non-native plant species such as *Festuca* spp. (fescue; Wes Burger, pers com). Many of the native prairie plant restoration efforts that have been implemented in Mississippi are the result of landowners working with Non-profit wildlife organizations as well as some state agencies to carry out prescriptions for wildlife management developed by authorities in the field of prairie restoration (Wes Burger, pers com). Studies quantifying success of these programs with regard to natural systems are very few.

This study aimed to analyze federal and state-subsidized conservation practices on private lands and their success in restoring plant communities in the direction of prairie plant assemblages typical of those found in the Blackland Prairie region. Comparing plant species composition on sites undergoing restoration practices to that of the native remnant prairies would provide some indication of the effectiveness of the practices currently being employed to restore Blackland Prairie habitat. Similarity of plant species composition between the restored and native sites would indicate current practices of the government programs are successful. If comparisons result in large dissimilarities, then current practices may be insufficient in restoring degraded areas to natural conditions. This study also will provide a basis from which candidate locations of both remnant prairie sites and potentially successful restoration attempts can be predicted.

CHAPTER II

# ANALYSIS OF CONSERVATION PRACTICES IN THE BLACKLAND PRAIRIE REGION OF MISSISSIPPI

## Introduction

Restoration and conservation practices commonly focus on site species composition and abundance (Palmer et al. 1997), with a major goal being re-creation of a sites' former pattern of species richness (Polley et al. 2005). Restoration practices are assessed by comparing species assemblage characteristics of remnant habitat to those of restored sites (Martin et al. 2005 and Polley et al. 2005). To date there have been few assessments of restoration practices in the Blackland Prairie region of Mississippi (Schauwecker and McDonald in Peacock and Schauwecker 2003). In this study, I analyzed restoration practices in the Blackland Prairie region of Mississippi based on plant species assemblages (plant species presence and abundance) and compared them with plant species assemblages of remnant prairie patches in the same region. Previous evaluations of restoration practices whose main goals were to re-establish natural vegetation have found differences between plant species assemblages in restored versus remnant prairie patches. For example, in the Blackland Prairie Region of Texas, significantly greater species richness was reported from remnant patches when compared to restoration patches ranging in age from nine to 20 years prior to sampling (Polley et al. 2005). Similar results were reported from southern Iowa where plant species richness found in remnant prairie patches was significantly higher than plant species richness in restoration patches (Martin et al. 2005). Thus, it was expected that Blackland Prairie remnant sites would have different plant species assemblages than restored sites in the same region.

## Methods

### Sample Sites

Remnant and restored prairie patches were chosen based on known accessible locations (JoVonn Hill, Tim Schauwecker, Wes Burger, and Sam Riffell pers. comm.) within the Mississippi portion of the major land resource area designating Blackland Prairie (Soil Survey Staff 1981). This research was focused in Mississippi to maximize research resources and to aid in the amount of information available to locate existing prairie patches and potential restoration sites. Information regarding extant prairie patches and current restoration efforts was obtained through collaboration with scientists and land managers employed by Mississippi State University and the Mississippi Department of Wildlife Fisheries and Parks. The six surveyed prairie sites were mapped using a Global Positioning System (GPS) (Table 1, Figures 1 and 2). All geographic data were collected, projected and analyzed using World Geodetic System (WGS) 1984 Universal Transverse Mercator (UTM) zone 16N. The extent of each site was determined by plotting points around its perimeter, as delimited by the surrounding tree line. Polygons were created using a Geographic Information System (GIS) to spatially represent each prairie patch. A 10m buffer was created inside each patch as a way to ensure sample plots would fall wholly inside the sample area. Sample locations for each patch were generated by placing random points inside the buffered interior of each prairie patch. Prairie patches more than 100m apart were considered separate and mapped as such. If patches were within a distance of 100m they were considered one patch and sampled as such. One sample plot was surveyed in May 2009 and a different plot in each patch surveyed in August 2009. Distance between these two sample points within a site ranged from 140m to 1902m.

**Site Descriptions**

Burnt Oak Lodge is located in southwest Lowndes Co., Mississippi (E 345193, N 3690655). The site was established in 2004 and has undergone restoration to convert pasture and row crop land into prairie. Herbicide applications followed by direct seeding were used to establish desired plant species on site (Jack Robertson pers. comm.). Species used, rates at which planted, and source of seed were unavailable. Converted patches are maintained by fire. For this survey, the oldest restoration area at this site was used, and it covered 10.8 hectares (ha) (Figure 2).

Bryan Farm is located in northeast Clay Co., Mississippi (E 354626, N 3723166). Row crop agriculture consisting of corn, soybeans, and Bermuda grass sod production dominate the site. In 2007, the site was enrolled in a conservation reserve program (CRP) conservation practice 33 (CP33) that established vegetated buffers around each field. Buffers of three widths (9.1, 27.4, and 36.6 m) were established. Each buffer was planted with a native warm season grass seed mixture (Sam Riffell, pers comm.). Species in the seed mix included *Andropogon gerardii, Sorghastrum nutans, Schizachyrium scoparium,* and *Chamaechrista fasciculata;* however, rates at which the site was planted were unavailable. Sample sites were located in the widest buffer treatment (36.6m), and all buffers of this width covered a combined 9.1 ha at the farm (Figure 2).

Table 1. Study sites for vegetation sampling. Sizes and specific locations were mapped prior to carrying out sampling.

| Site | Location | Ownership | Status |
|---:|---:|---:|---:|
| Burnt Oak Lodge | West of Crawford, MS | Private | Restoration |
| Bryan Farms | Northeast of West Point, MS | Private | Restoration |
| Davis Lake | Northwest of Okalona, MS | National Forest | Remnant |
| Tombigbee | North of Trebloc, MS | National Forest | Remnant |
| Dairy Farm | South of Starkville, MS | Mississippi State University | Remnant |
| $16^{th}$ Section | North of Starkville, MS | Private | Remnant |

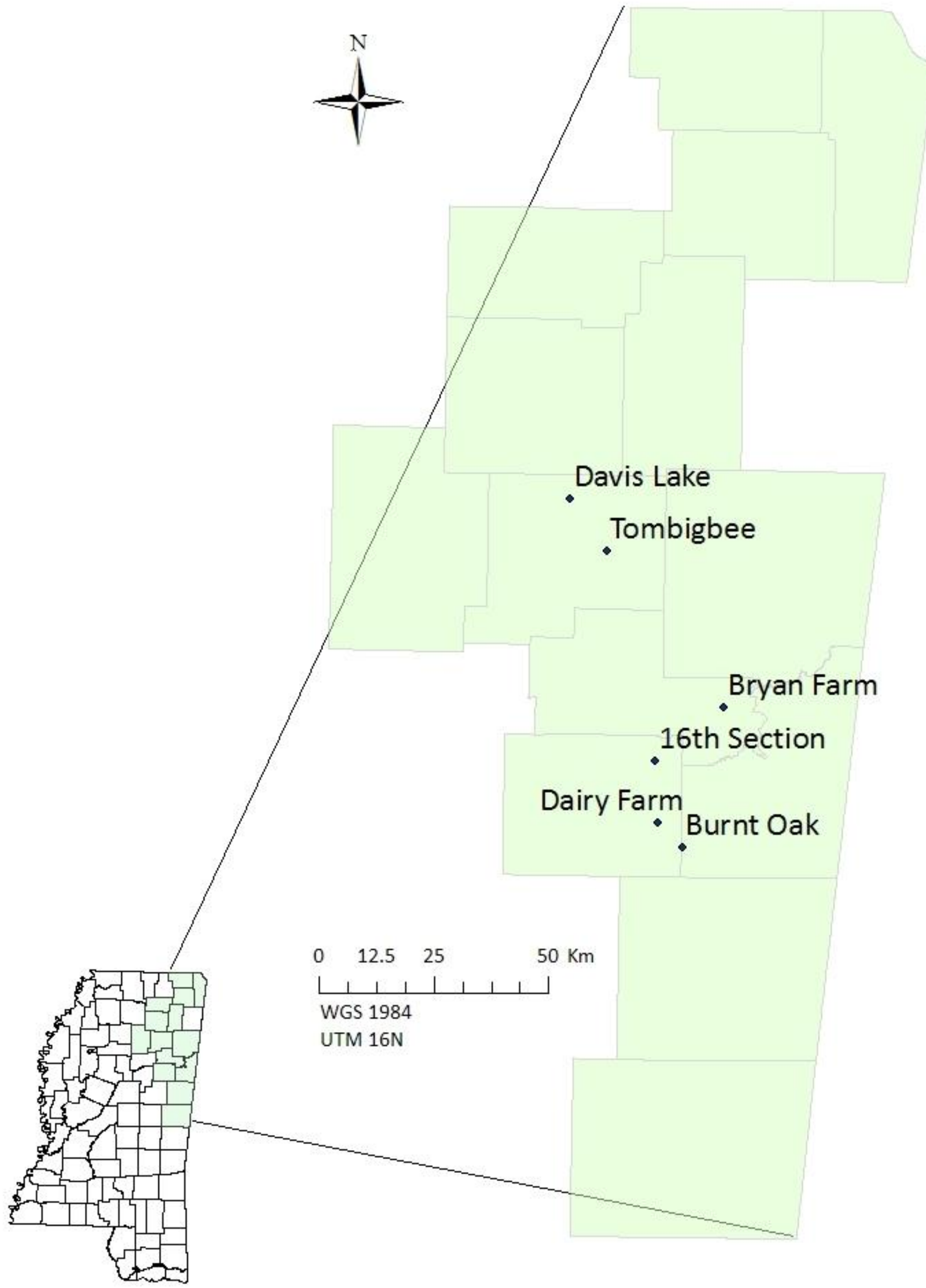


Figure1. Location of study region in Mississippi (green counties) and study sites surveyed in Chapter II.

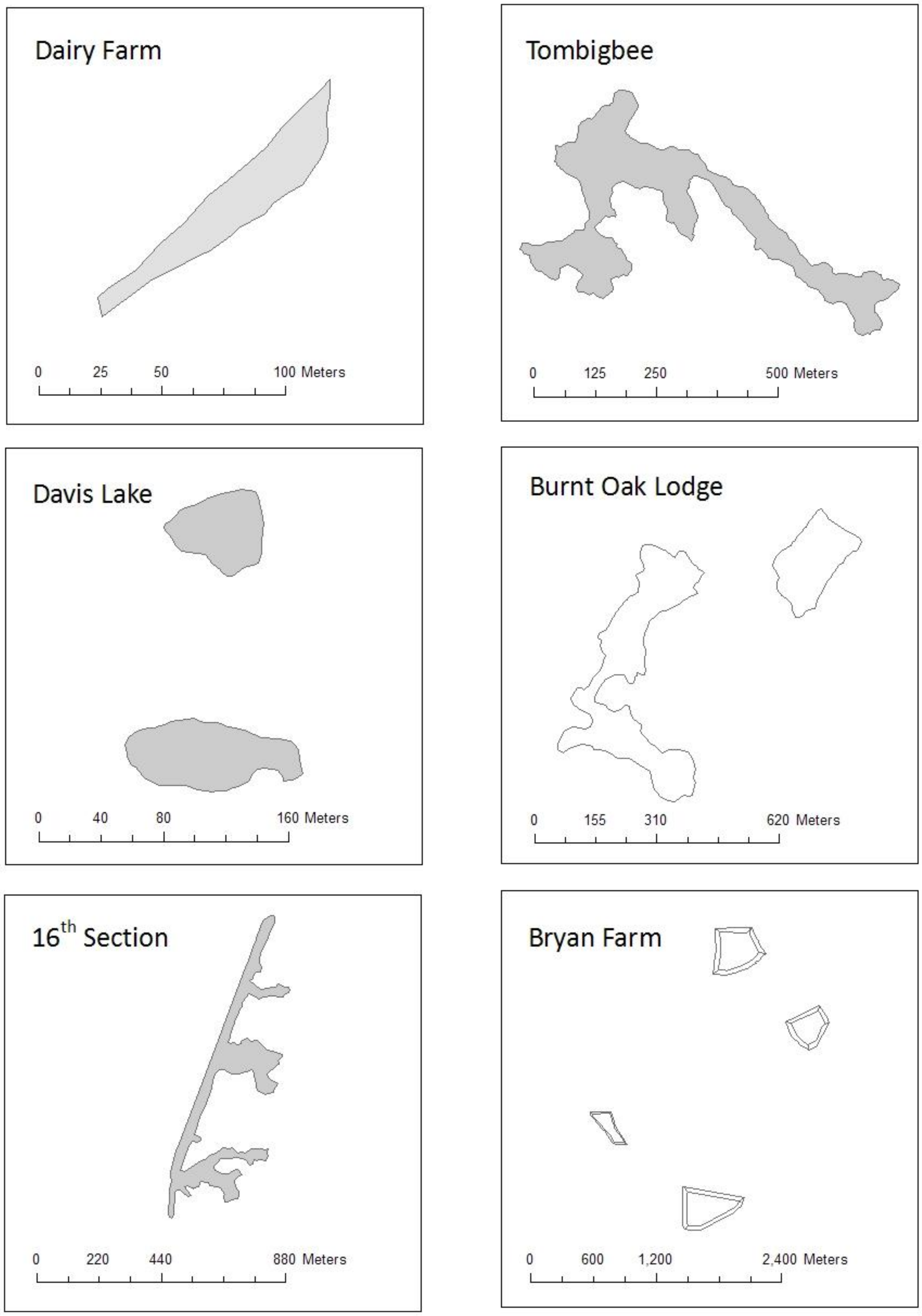


Figure 2. Maps of each study site. Remnant sites are in grey and restoration sites are in white.

Two study sites were in the Tombigbee National Forest. The Tombigbee site was located in east central Chickasaw County Mississippi (E 328593, N 3755647) and covered 8.6 ha. Another site located in north central Chickasaw County Mississippi (E 320374, N 3766723) was Davis Lake. The Davis Lake site consisted of two small patches less than 100m apart, and they covered a total of 0.6 ha. Both sites experienced controlled fires as part of overall forest maintenance (Figure 2).

The Dairy Farm site is located in southeastern Oktibbeha Co Mississippi (E 339521, N 3696257). The sampling site was adjacent to farmland that belongs to Mississippi State University Mississippi Agricultural and Forestry Experiment Station (MAFES). Periodic mowing maintained the site, which cannot be planted due to its small size and topography. The Dairy Farm site covered 1.9 ha (Figure 2).

The $16^{th}$ section site is located in northeastern Oktibbeha Co Mississippi (E 338819, N 3709628) along a power line right-of-way. A lease is maintained on the site by Friends of the Blackbelt. Periodic removal of *Juniperus virginiana* (Eastern red cedar) was the only known disturbance to the site. The $16^{th}$ section site covered 9.1 ha (Figure 2).

**Site Survey**

Site surveys were carried out using a modified nested plot design (Figure 3). The overall sample plot was 50m by 20m. Four nested plots of $1m^2$ were distributed around the inside edge of the overall plot. In each nested plot, plant species percent cover was visually estimated and recorded along with ground cover characteristics. The four subplot coverages were averaged together to give the percent cover of each species in the sample plot and represents species richness by cover. In the overall $100m^2$ plot, plant species not encountered in the subplots were

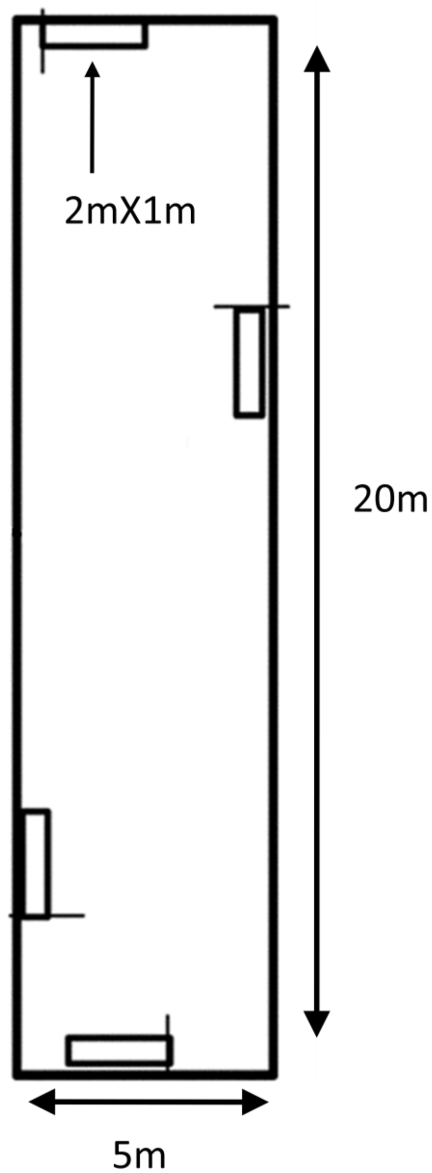


Figure 3. Sampling design used for assessing plant assemblage at prairie sites.

recorded as being present. Plant species recorded from the subplot sampling along with those from the overall plot gave the species richness for the sample plot and represents species richness by presence. Plants were identified to the species level when possible, and taxonomic nomenclature followed Weakley (2008).

**Site Comparison**

Species richness at each site was determined as a count of the species observed at each site by abundance or presence. Shannon's index was calculated using equation 1, where S is the number of species in a sample, $p_i$ is the proportion of individuals that belong to species i (McCune & Grace 2002). Evenness was calculated by equation 2 where H' is the Shannon index value and S is the species richness (McCune & Grace 2002).

$$H' = -\sum_{i}^{S} p_i \log p_i \qquad \text{Equation 1}$$

$$Evenness = \frac{e^{H'}}{S} \qquad \text{Equation 2}$$

Non-metric multidimensional scaling (NMS) was used to analyze the species assemblages. NMS is a technique used to ordinate sample sites based on species assemblages and is recommended for use in community ecology (McCune and Grace 2002). NMS has been used to analyze, for example: species composition in remnant and restored grasslands (Sulis 2002), the distribution and community structure of biological soil crusts (Bowker et al. 2005), the differences of stream macro-invertebrate and fish communities in natural streams and streams that are being restored (Lepori et al. 2005), and many others. The NMS procedure was carried out using PC-ord 5.0 with the autopilot setting using the Sorensen distance measure. A maximum of 400 iterations with an instability criterion of 0.00001 stepping down from 6 axes to

1 axis with 40 runs done with the real data set and 50 runs with randomized data (McCune &Grace 2002). Stress values per dimension were conducted using 250 runs with the real data and a Monte Carlo test with 250 runs with randomized data to determine the optimum number of axes in the solution (McCune & Grace 2002). Dimensionality and recommended starting configuration from this initial exploratory run were used to ordinate the data.

## Results

More than 100 vascular plant species were observed in total (Appendix). Site species assemblage comparison carried out using NMS resulted in a one axis solution ($r^2$=0.78), indicating Bryan Farm differed markedly from the other sites. Species assemblage characteristics including richness in both cover and presence plots, evenness, and each site's Shannon Index further supported this separation of sites (Table 2). Analysis of the Sorensen distance matrix shows that Bryan Farm is less than 30% similar to each of the remaining sites (Table 3). Pair wise comparisons between the remaining sites show a range of similarities from 37% to 54%.

## Discussion

Sixty-four of the approximately 120 species identified in this survey were also present in a recent examination of the flora of the Blackland Prairie region of Mississippi (Barone & Hill 2007). The ten most abundant species and the ten most recorded species from these surveys share 8 species (Table 4). Eleven of the twelve most common species from this survey were also reported as common in remnant Blackland Prairie patches (Barone & Hill 2007). *Cornus drummundii* was the only abundant species from this survey not listed in Barone and Hill (2007),

Table 2. Site species assemblage characteristics.

| Site | Species Richness (Cover/Presence) | Evenness | Shannon Index |
|---|---|---|---|
| **Bryan Farm** | 11/13 | 0.67 | 1.6 |
| **Burnt Oak Lodge** | 35/38 | 0.89 | 3.1 |
| **Davis Lake** | 51/66 | 0.75 | 2.9 |
| **Tombigbee** | 47/56 | 0.77 | 3.0 |
| **Dairy Farm** | 47/60 | 0.85 | 3.3 |
| **16$^{th}$ Section** | 40/47 | 0.73 | 2.7 |

Table 3. Sorensen distance matrix from NMS. Values indicate proportion similarity pair wise comparison of plant species assemblages.

| | Bryan Farm | 16th Section | Tombigbee | Davis Lake | Burnt Oak Lodge |
|---|---|---|---|---|---|
| **16th Section** | 0.23 | | | | |
| **Tombigbee** | 0.23 | 0.45 | | | |
| **Davis Lake** | 0.17 | 0.37 | 0.51 | | |
| **Burnt Oak** | 0.27 | 0.47 | 0.49 | 0.42 | |
| **Dairy Farm** | 0.22 | 0.54 | 0.53 | 0.44 | 0.53 |

but they only reported herbaceous flora of the region, reasoning that non-woody species are the focus of prairie restoration and conservation efforts.

This analysis of community composition of remnant and restored prairie sites in the Blackland Prairie of Mississippi showed that one restoration site, Bryan Farm, was dissimilar to all the remnant patches. Burnt Oak Lodge, the other restoration site, was grouped similarly to the remnant patches, suggesting a successful restoration. Sorensen distance values indicated 37% to 54% similarity among all sites, except the Bryan farm site, suggesting that the species planted on site were too few and not shared with other extant prairie patches in the Blackland Prairie region of Mississippi (Tables 4 & 5). Although Bryan Farm was the most unlike all other sites in species assemblage, comparison of the remaining sites shows a maximum of 54% similarity suggesting that species assemblages vary across the Blackland Prairie region of Mississippi.

One factor that complicated this project was the limited number of restoration sites that exist or are publicly accessible in the Blackland Prairie region of Mississippi, despite a great need for such projects, given the status of the habitat type (Noss et al. 1995). Conservation easements through the NRCS, representing restoration or conservation sites in the Blackland Prairie Region, are on private lands and information regarding these practices and access to sites are confidential (NRCS directive H_180_600_A_11-600.11). There is also a need to further locate remnant prairie patches in the region before they are lost (Barone and Hill 2007). One potential tool to aid in finding remnants is the development of a habitat suitability model, and this is addressed in the next chapter.

Table 4. Most common or abundant plant species from surveys of remnant and restoration prairie sites in the Blackland Prairie region of Mississippi in May and August 2009.Species are given in decreasing order of prevalence or abundance across sites, and underlined species are shared by both lists. All these except *Aristida purpurascens and Salvia lyrata* are vouchered in the Mississippi State University herbarium (MISSA). Identification of these other species was referenced against MISSA specimens as follows: *Aristidia purpurascens* (MISSA accession 36480) and *Salvia lyrata* (MISSA accession 15752)

| **Presence** | **Cover** |
|---|---|
| *Salvia lyrata* | *Schizachyrium scoparium* |
| *Schizachyrium scoparium* | *Sorghastrum nutans* |
| *Andropogon virginicus* | *Andropogon virginicus* |
| *Chamaecrista fasciuclata* | *Ratibida pinnata* |
| *Dalea candida* | *Aristida purpurascens* |
| *Desmanthus illinoensis* | *Ambrosia artimesifolia* |
| *Ratibida pinnata* | *Salvia lyrata* |
| *Solidago nemoralis* | *Solidago nemoralis* |
| *Ambrosia artimesifolia* | *Desmanthus illinoensis* |
| *Cornus drummundii* | *Dalea candida* |

Table 5. Plant species average abundance per site.

| | Bryan Farm | 16th Section | Tombigbee | Davis Lake | Burnt Oak | Dairy Farm |
|---|---|---|---|---|---|---|
| ***Agalinis gattingeri*** | - | - | - | 0.1 | - | - |
| ***Agalinis heterophylla*** | - | - | - | 3.8 | - | - |
| ***Ambrosia artimesifolia*** | - | - | 1.3 | 1.6 | 8.3 | 1.1 |
| ***Ambrosia sp.*** | - | 1.9 | - | - | - | - |
| ***Ambrosia trifida*** | 22.5 | - | - | - | - | - |
| ***Andropogon gerardii*** | - | - | - | 1.3 | - | - |
| ***Andropogon glomeratus*** | - | 0.6 | - | - | - | - |
| ***Andropogon virginicus*** | - | 9.4 | 0.6 | - | 16.3 | 8.8 |
| ***Aristida purpurascens*** | - | 28.8 | - | 0.1 | - | - |
| ***Asclepias lanceolata*** | - | - | - | - | - | 1.9 |
| ***Asclepias viridiflora*** | - | - | - | 0.1 | - | - |
| ***Asclepias virdis*** | - | - | - | - | - | 0.6 |
| ***Asteraceae unk.*** | - | - | - | - | 2.5 | - |
| ***Berchemia scandens*** | - | 1.3 | - | - | - | 3.9 |
| ***Blephilia ciliata*** | - | - | 1.4 | 2.6 | - | 0.1 |
| ***Bouteloua curtipendula*** | - | 0.1 | - | - | - | - |
| ***Campsis radicans*** | - | - | - | - | 1.4 | - |
| ***Carex cherokeensis*** | - | 4.4 | - | - | - | 4.4 |
| ***Carex sp*** | - | - | - | 3.3 | 3.9 | 0.3 |
| ***Celtis occidentalis*** | - | 0.1 | - | - | - | 0.3 |
| ***Chamaecrista fasciuclata*** | - | - | 1.6 | 0.3 | 2.6 | - |
| ***Chamaecrista nictitans*** | - | - | 0.1 | - | - | - |
| ***Chamaesyce maculata*** | - | 0.1 | - | - | 0.6 | - |
| ***Cirsium horridulum*** | - | - | - | 0.8 | - | - |
| ***Coculus caroliniana*** | - | - | - | - | - | 0.1 |
| ***Cornus drumundii*** | - | - | 0.4 | - | - | - |
| ***Crotalaria sagatalis*** | - | - | 0.3 | 0.8 | - | - |
| ***Dacus carota*** | - | - | - | - | 1.4 | 0.8 |
| ***Dalea candida*** | 1.9 | 0.8 | 5.0 | 7.1 | - | - |
| ***Dalea pinnata*** | - | - | - | - | 3.8 | - |
| ***Dalea purpurea*** | - | - | - | 3.9 | - | - |
| ***Dalea sp*** | - | - | 2.8 | - | - | - |
| ***Desmanthus illinoensis*** | 0.1 | 3.8 | 3.9 | - | 4.4 | 2.8 |
| ***Desmodium sp*** | - | 0.8 | 2.8 | 5.0 | 3.8 | - |
| ***Dicanthelium sp*** | - | 0.4 | 0.9 | 2.3 | 1.4 | 1.3 |
| ***Diodea sp.*** | - | 0.1 | - | - | - | - |

Table 5. Plant species average abundance per site, continued.

| | Bryan Farm | 16th Section | Tombigbee | Davis Lake | Burnt Oak | Dairy Farm |
|---|---|---|---|---|---|---|
| ***Diospyrus virginia*** | - | - | - | - | 3.8 | 0.6 |
| ***Eleocharis sp.*** | - | - | - | 0.6 | - | - |
| ***Eragrostis spectabilis*** | - | - | - | 1.4 | 1.3 | - |
| ***Erigerion sp*** | - | 1.6 | 1.9 | - | - | 1.5 |
| ***Erigerion strigosus*** | - | - | - | 0.8 | - | - |
| ***Euphorbia corolata*** | - | - | - | 0.6 | - | - |
| ***Fraxinus pennsylvanica*** | - | - | - | - | 0.8 | 0.4 |
| ***Galactia regularis*** | - | - | - | - | - | 2.5 |
| ***Galactia sp*** | - | 5.1 | 5.6 | 1.9 | 7.1 | 3.8 |
| ***Hedyotis nigricans*** | - | - | 0.9 | - | - | - |
| ***Helianthus sp*** | - | - | 0.6 | - | - | - |
| ***Houstonia purpurea*** | - | 0.1 | - | 0.1 | - | 1.4 |
| ***Houstonia tenuifolia*** | - | - | - | - | 3.1 | - |
| ***Hypericum sp*** | - | - | 0.6 | - | - | - |
| ***Hypericum spherocarpum*** | - | 0.8 | - | - | - | - |
| ***Ipomea sp*** | 0.1 | - | - | - | - | 0.9 |
| ***Iva annua*** | - | - | - | - | 2.5 | - |
| ***Juncus sp.*** | - | 0.4 | - | - | - | 4.4 |
| ***Juniperius virginia*** | - | 1.4 | 0.3 | - | - | 0.6 |
| ***Lactuca sp.*** | - | - | - | 0.1 | - | - |
| ***Lespidiza cuneata*** | - | - | - | 0.1 | - | - |
| ***Lespidiza repens*** | - | - | - | 0.1 | - | - |
| ***Lespidiza sp*** | - | - | 3.1 | - | - | - |
| ***Lespidiza virginica*** | - | - | - | 0.6 | - | - |
| ***Liatris sp*** | - | 1.4 | 2.0 | - | - | 2.5 |
| ***Liatris aspera*** | - | 1.5 | - | 1.6 | - | 0.6 |
| ***Liatris spicata*** | - | 0.6 | - | 0.1 | 1.9 | - |
| ***Liatris squarrosa*** | - | - | - | 0.1 | - | - |
| ***Lithospermum canescens*** | - | - | - | 0.1 | - | - |
| ***Lithospermum sp*** | - | - | 0.8 | - | - | - |
| ***Lobelia inflata*** | - | 0.3 | - | - | - | - |
| ***Manfreda virginica*** | - | 0.6 | - | 6.3 | - | 3.8 |
| ***Medicago lupilina*** | - | - | - | - | - | 0.9 |
| ***Melilotus sp*** | - | - | 2.5 | - | - | - |
| ***Melilotus officinalis*** | - | - | - | 1.0 | - | - |
| ***Monarda fistulosa*** | - | - | - | 0.6 | - | 4.0 |
| ***Neptunia leuta*** | - | 5.6 | - | - | - | - |

Table 5. Plant species average abundance per site, continued.

| | Bryan Farm | 16th Section | Tombigbee | Davis Lake | Burnt Oak | Dairy Farm |
|---|---|---|---|---|---|---|
| ***Oneothera sp*** | - | 0.3 | - | - | - | 0.8 |
| ***Oxalis stricta*** | - | - | 0.1 | 0.3 | 0.1 | 0.3 |
| ***Oxalis violacea*** | - | - | 0.1 | - | - | - |
| ***Panicum anceps*** | - | - | 2.5 | - | - | 0.1 |
| ***Paspalum sp.*** | - | - | - | 0.1 | - | - |
| ***Poaceae unk.*** | - | - | 13.1 | - | 10.5 | - |
| ***Physostegia angustifolia*** | - | - | - | 0.1 | - | - |
| ***Pinus teada*** | - | 0.1 | - | 0.3 | - | - |
| ***Polygalla verticillata*** | - | - | 0.1 | - | - | - |
| ***Prunella vulgaris*** | - | 0.8 | - | 2.9 | 1.3 | 1.0 |
| ***Ratibida pinnata*** | - | 0.6 | 3.8 | 19.1 | 2.0 | 7.6 |
| ***Rubus trivialis*** | - | - | - | - | 1.9 | 0.8 |
| ***Rudbeckia hirta*** | - | - | 1.9 | 0.3 | 5.1 | 0.3 |
| ***Ruellia humilis*** | - | - | - | 0.1 | - | - |
| ***Ruellia sp*** | - | - | 1.3 | 0.1 | - | - |
| ***Sabatia angularis*** | - | 0.1 | 1.5 | - | 2.0 | 2.0 |
| ***Salvia lyrata*** | 0.3 | 0.8 | 5.3 | 9.5 | 2.5 | 4.1 |
| ***Schedonorus phoenix*** | - | - | 0.1 | - | - | 16.9 |
| ***Scirpus sp.*** | - | 3.1 | - | - | - | - |
| ***Schizachyrium scoparium*** | 8.1 | 21.3 | 20.0 | 27.8 | 11.3 | 11.3 |
| ***Scleria triglomerata*** | - | - | - | 0.3 | - | - |
| ***Setaria italica*** | - | - | - | - | 5.0 | - |
| ***Silphium integrifolium*** | - | - | - | 0.6 | - | 1.9 |
| ***Siliphium laciniatum*** | - | - | 0.6 | - | - | 0.1 |
| ***Silphium radula*** | - | - | - | - | - | 0.8 |
| ***Silphium terebinthinaceum*** | - | 2.8 | 1.9 | - | 0.1 | - |
| ***Sisyrinchium albidum*** | - | 5.6 | 0.1 | 1.4 | - | - |
| ***Smilax bona-nox*** | - | - | - | - | - | 3.9 |
| ***Solanum carolinense*** | - | - | 0.6 | - | - | - |
| ***Solidago canadensis*** | - | - | - | 0.8 | - | - |
| ***Solidago gigantea*** | - | - | - | - | 0.6 | - |
| ***Solidago nemoralis*** | - | 2.0 | 9.6 | 6.3 | 0.6 | 2.3 |
| ***Solidago sp.*** | 21.9 | 0.1 | - | - | 5.3 | - |
| ***Sorghastrum nutans*** | 13.8 | - | 25.0 | - | - | - |
| ***Sorghum halpense*** | 1.3 | - | - | - | - | - |
| ***Spiranthes magnicamporum*** | - | - | 0.1 | - | - | - |
| ***Symphyotrichum patens*** | - | 3.4 | 2.8 | 1.3 | - | 1.3 |

Table 5. Plant species average abundance per site, concluded.

| | Bryan Farm | 16th Section | Tombigbee | Davis Lake | Burnt Oak | Dairy Farm |
|---|---|---|---|---|---|---|
| ***Symphyotrichum sp*** | 1.4 | - | 1.3 | 1.3 | 1.5 | 2.6 |
| ***Trifolium caroliniana*** | - | - | - | - | - | 7.5 |
| ***Toxicodendron radicans*** | - | - | 0.1 | - | - | 1.3 |
| ***Ulums alata*** | - | - | 0.1 | - | - | - |
| ***Ukn.*** | - | - | 0.1 | 4.4 | 0.6 | - |
| ***Verbena brasiliensis*** | 0.6 | - | - | - | - | - |
| ***Verbena simplex*** | - | 0.1 | - | - | - | - |
| ***Verbesina sp.*** | - | - | 0.6 | - | - | - |

# CHAPTER III

# CONSTRUCTION OF A PREDICTOR MODEL FOR LOCATING REMNANT BLACKLAND PRAIRIE PATCHES AND POTENTIAL SUCCESSFUL RESTORATION SITES

## Introduction

Predicting occurrence of species based on habitat characteristics has been used with *Ursus americanus* (Clark et al. 1993), forest breeding songbirds (Dettmers and Bart 1999), rare plants in Texas (Wu and Smeins 2000), alpine plant species (Dirnbock and Dullinger 2004), and many others. Methods to create these predictions have all used information derived from Geographic Information Systems (GIS) and publicly accessible GIS databases (Clark et al. 1993, Dettmers and Bart 1999, Wu and Smeins 2000, and Dirnbock and Dullinger 2004). A common method used to generate predictive models is logistic regression (Fielding and Bell 1997 and Manel et al. 2001). Logistic regression uses presence-absence information concerning the dependent variable and generates a model based on environmental characteristics of the locations of each presence-absence point (Bonn and Schroder 2001). Prediction models have also been generated using an integration of statistics into GIS. An example of this is the add-in of a Mahalanobis distance statistic with a GIS to generate a predictive surface based on correlations of environmental variables at points where the entity being predicted is present (Clark et al. 1993). Using information about prairie habitat from in the work described in Chapter II, along with environmental data from publicly accessible GIS databases, models using logistic regression and the Mahalanobis distance statistic were created to test  the expectation that the presence of prairie indicator species would be correlated with soil attributes, topography, and/or canopy cover.

## Methods

### Sample Sites

Prairie presence points were gathered from three sources: Chapter II sample sites, the Mississippi Museum of Natural Science herbarium (MMNS), and a statewide invasive plant survey. These sites were assembled two ways, the first being based on their having at least one of the twelve most abundant/most common plant species at the sample sites used for initial assessments of the restoration sites (Chapter II); hereafter, those species will be referred to as indicator species (Table 2). A more conservative approach for determining prairie presence was assembled using sites where at least three indicator species were present. Indicator species presence at sample sites ranged from one or three to ten respective to the method used for analysis. For MMNS data, I requested location information where records of indicator species in the study region (Figure 1) were found. For data from the statewide invasive plant survey, sampling points for the Invasive Plant Atlas of the Mid-South (IPAMS) were queried for the presence of those same twelve species. Absence points were obtained from the IPAMS database by locating sites in the study region (Figure 1) where none of the indicator species were found. Sample presence points from Chapter II, MMNS, and IPAMS totaled 40 for sites where at least one indicator species was present and 31 where at least three indicator species were present, and absence points from IPAMS totaled 30; thus, the total sample set used to generate the models was 70 points for sites with at least one indicator species present and 61 using sites with at least three indicator species present. All points were projected in ARCMap 9.3 using WGS 1984 UTM 16N.

**Environmental Factors**

The calcareous clay soils of the Blackland Prairie are responsible for the diverse flora found in the region (Jones and Patton 1966). Blackland Prairie plant community characteristics vary along soil moisture and erosion gradients ranging from nearly bare chalk outcrops to open prairie and into closed canopy woodlands (Schauwecker 1996 and Leidolf and McDaniel 1998). Open prairie, the community being modeled, is found in areas with open canopy and low to high slope, and where soil erosion often acts as a disturbance factor in maintaining prairie plant communities (Schauwecker 1996 and Leidolf and McDaniel 1998). Environmental variables representing soil particle size composition and pH were used to describe the soils' clay content and alkalinity. Topographical position, which can influence erosion capacity, is represented by the rate of change of the slope of the study region, or topographic curvature, which will indicate whether a location is horizontal, on a slope, atop a hill, or in a depression. All these environmental characteristics can be accessed from public GIS databases. A 10m Digital Elevation Model (DEM) and soil survey data layers were accessed through the Mississippi Automated Resource Information Service (MARIS; http://www.maris.state.ms.us/). Soil particle composition and pH of the soil surface data layers were created using Soil Data Viewer (USGS NRCS SSURGO), an ARCMap extension that allows for the generation of data layers based on soil survey information. A data layer representing topographic curvature of the study region was generated from the DEM using the curvature tool in spatial analyst tools of the ArcToolbox in ARCMap 9.3. USGS Southeast Gap Analysis Project data were used to generate a data layer representing percent canopy cover in the study region. All data layers were converted to properly aligned 10m-grain raster files projected in WGS 1984 UTM 16N. Values for each environmental variable were extracted to each sample point.

**Model Building**

Logistic regression using SPSS v16.0 was used to determine environmental variables' importance in determination of prairie presence, using the presence-absence data along with each site's environmental characteristics (Fielding and Bell 1997, Manel et al. 2001, Menard 2001). Forward stepwise regression was used to add in one variable at a time and generate models, and only variables resulting in significant models were retained. Significant models were used to generate probability values representing the probability that each point was predicted to have environmental characteristics suitable to the indicator species.

In ArcView 3.3, using the Mahalanobis Distance add-in from Jenness Enterprises (Jenness 2003; http://www.jennessent.com/), two sets of models were constructed from environmental variables. Combinations of uncorrelated variables were used to construct predictive surfaces. Mahalanobis distance modeling uses presence data only and calculates the relationship of examined variable values at each data point (Clark et al. 1993). One set of models were generated using points where any of the twelve indicator species were present, a second set of models was generated using points where three or more indicator species were present. Output from each modeling procedure was transformed into a GIS grid surface with values representing the probability that each grid cell has environmental characteristics of suitable habitat to find the indicator species based on a $\chi^2$ distribution (Jennes 2003; http://www.jennessent.com). Probability values were then converted to presence (1) or absence (0) predictions with presence predictions being those cells with probability values greater than 0.5 (Fielding and Bell 1997, Manel et al. 2001).

**Model Evaluation and Validation**

Models were evaluated using assessment metrics including receiver operator characteristic curves (ROC) and the respective area under the curve (AUC), overall prediction success, specificity and, sensitivity (Fielding and Bell 1997, Manel et al. 2001). Models with AUC values of greater than 0.8 were considered for further evaluation; higher AUC values represent a high positive presence prediction rate and a low false presence prediction rate. Other model characteristics including the overall prediction success, specificity and, sensitivity were in agreement with model selection for further evaluation based on AUC.  Overall prediction success measures a model's rate of correct classification of presence and absence points. Specificity represents the proportion of correctly identified presence points. Sensitivity represents the proportion of correctly identified absence points. Grid layers representing predicted presence were generated from each model selected for further evaluation with 10m cells projected in WGS 1984 UTM 16N.

Model validation was carried out on public land in the Blackland Prairie Region of Mississippi (Figure 1). Public land was determined by using MARIS to acquire GIS layers representing National Forests, National Parks, National Wildlife Refuges, Mississippi State Parks, and Mississippi State Wildlife Management Areas in the study region. Each predictor model was then extracted to the extent of public land in the region. Grid cells were then converted to points. A random subset of points was selected using the create random points function in the arctoolbox of ArcView 9.3.

Models selected for validation then were re-evaluated using data collected from this set of validation points. Validation points were surveyed in May 2010 for the occurrence of prairie indicator species. Each point was assigned a value of 0 (zero), 1 (one), or 2 (two). A value of 0 (zero) indicates that the point did not have any indicator species or characteristics of prairie habitat, open canopy with low tree density. Points that were found to have prairie indicator species present and habitat characteristics of prairie, open canopy and low tree density, were assigned a value of 1. Survey points where no indicator species were present due to agriculture or maintenance of pasture, but where indicator species were found along the border in less disturbed areas were assigned a value of 2. All models were then re-evaluated using the data from the validation surveys. The point set was projected onto each model surface and the respective prediction value extracted in order to use validation survey points to evaluate each model.

Each model was evaluated on its ability to correctly predict the presence of prairie patches and on the ability to correctly predict the presence of potential successful restoration sites based on the occurrence of prairie indicator species. To evaluate correct prediction of remnant prairie patches survey points assigned 1 were used as correctly predicted presence points and sites assigned 0 and 2 were incorrectly predicted presence points. To evaluate correct prediction of potential successful restoration sites survey points assigned 1 and 2 were used as correctly predicted points and sites assigned 0 represent incorrectly predicted points. The best model for each of these two analyses was selected based on the AUC from the ROC.

**Results**

Logistic regression yielded two models, the intercept-only model and a model incorporating percent clay. Eighteen model surfaces were generated using the Mahalanobis distance method in ArcView 3.3. All models were evaluated using ROCs and respective AUCs along with the overall prediction success, sensitivity, and specificity(Table 6). Models with AUC values of greater than 0.8 were selected for validation. All of the selected models were generated from the Mahalanobis method where sites with at least one indicator species present represented suitable habitat (Figures 4,5,6,7, and 8). Models generated by the Mahalanobis method where sites with at least three indicator species present representing suitable habitat had similar overall prediction success, sensitivity, and specificity as the one species models but the AUC values did not meet the threshold requirement of greater than 0.8 for indicating a model suitable for validation (Table 6).

In May 2010, 113 validation points were surveyed. Model performance was assessed using the validation points (Tables 7 and 8). Models performed poorly in identifying existing prairie patches, AUC 0.49-0.53 (Table 7). The Clay and Canopy model was the best at correctly identifying potential successful restoration sites, AUC 0.78 (Table 8). Areas where percent clay was between 19%-34% and canopy cover ranged 1%-47% are predicted to be potential successful restoration sites based on the Clay and Canopy model.

**Discussion**

GIS model building using the Mahalanobis method produced the best results based on AUC (Table 5). Logistic regression failed to generate a suitable model, this was possibly due to all absence points used being clustered in one part of the study region. Models selected for further evaluation had high predicted probabilities of suitable habitat that followed, spatially, the historic extent of prairie patches in the study region (Barone 2005; Figure 9); however, public land in the survey region lies mostly outside of the historic range of prairie (Figure 10). Using a survey of points of predicted suitable habitat to find indicator species to test each models’ prediction performance showed that all models were poor (AUC less than 0.6) to fair (AUC 0.6 to 0.8), according to AUCs generated from ROC curves. Higher AUC values represent better ability to correctly identify true presence points while minimizing false positive

Table 6. Model performance assessments for GIS models using 1 and 3 indicator species presence to indicate suitable prairie habitat and logistic regression models.

| Model | Prediction Success | | Sensitivity | | Specificity | | AUC | |
|---|---|---|---|---|---|---|---|---|
| | 1 Species | 3 Species | 1 Species | 3 Species | 1 Species | 3 Species | 1 Species | 3 Species |
| Clay, Canopy, and Curvature | 0.59 | 0.61 | 0.28 | 0.23 | 1.00 | 1.00 | 0.86 | 0.61 |
| Clay and Canopy | 0.49 | 0.56 | 0.10 | 0.13 | 1.00 | 1.00 | 0.92 | 0.57 |
| Silt, Canopy, and Curvature | 0.70 | 0.72 | 0.53 | 0.45 | 0.94 | 1.00 | 0.89 | 0.73 |
| Canopy and Curvature | 0.51 | 0.57 | 0.13 | 0.16 | 1.00 | 1.00 | 0.86 | 0.58 |
| Silt and Canopy | 0.48 | 0.52 | 0.08 | 0.06 | 1.00 | 1.00 | 0.91 | 0.53 |
| Clay and Curvature | 0.48 | 0.54 | 0.18 | 0.23 | 0.87 | 0.87 | 0.66 | 0.55 |
| Sand and Curvature | 0.35 | 0.46 | 0.23 | 0.23 | 0.52 | 0.70 | 0.49 | 0.46 |
| Silt and Curvature | 0.61 | 0.59 | 0.43 | 0.23 | 0.84 | 0.97 | 0.74 | 0.60 |
| Logistic Regression Intercept | 0.56 | | 1.00 | | 0.00 | | 0.50 | |
| Logistic Regression Intercept and Clay | 0.56 | | 1.00 | | 0.00 | | 0.09 | |

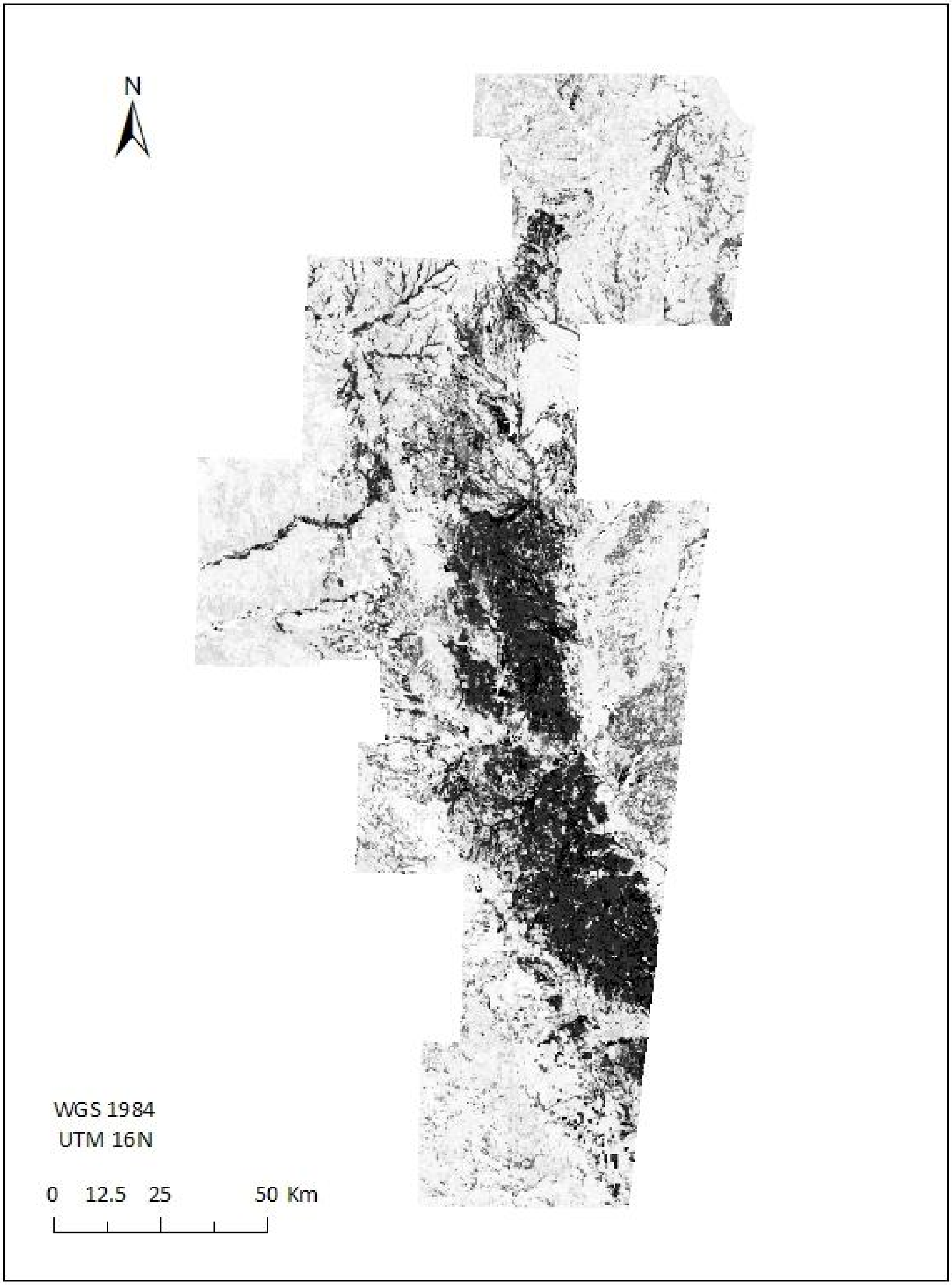


Figure 4. Map of the region highlighted in Figure 1, showing predicted suitable habitat based on canopy and percent silt. Darker color represents higher probability of suitable habitat.


Figure 5. Map of the region highlighted in Figure 1, showing predicted suitable habitat based on canopy and curvature. Darker color represents higher probability of suitable habitat

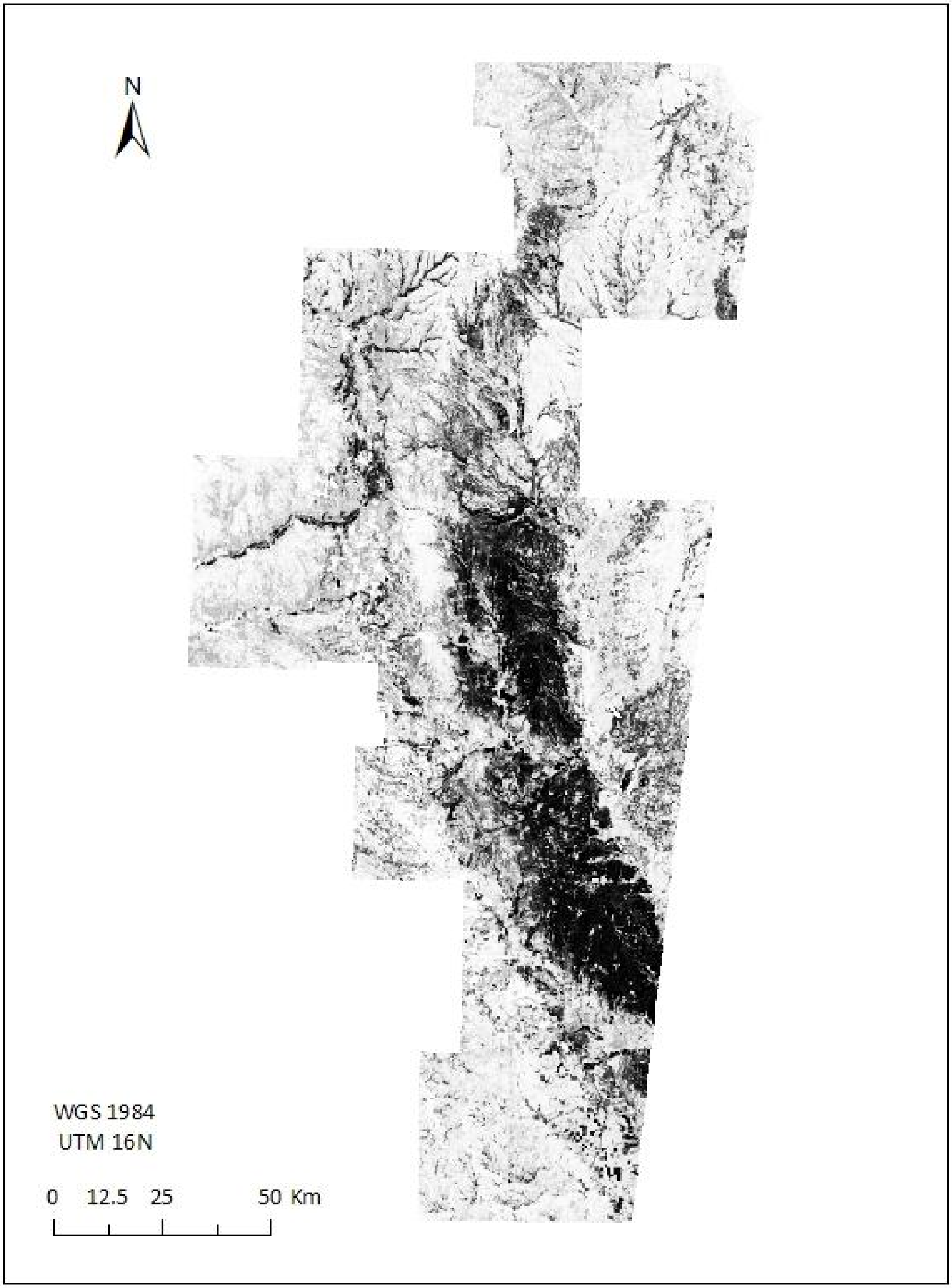


Figure 6. Map of the region highlighted in Figure 1, showing predicted suitable habitat based on canopy, curvature, and percent silt. Darker color represents higher probability of suitable habitat.


Figure 7. Map of the region highlighted in Figure 1, showing predicted suitable habitat based on canopy and percent clay. Darker color represents higher probability of suitable habitat.


Figure 8. Map of the region highlighted in Figure 1, showing predicted suitable habitat based on canopy, curvature, and percent clay. Darker color represents higher probability of suitable habitat**.**

Table 7. Model validation where points assigned a value of 2 were treated as incorrectly predicted presence of habitat suitable for finding prairie patches based on models generated using presence of at least one indicator species .

| 2=0 | Prediction success | Sensitivity | Specificity | AUC |
|---|---|---|---|---|
| Clay, Canopy, and Curvature | 0.74 | 0.50 | 0.75 | 0.51 |
| Clay and Canopy | 0.88 | 0.50 | 0.88 | 0.53 |
| Silt, Canopy, and Curvature | 0.57 | 1.00 | 0.56 | 0.52 |
| Silt and Canopy | 0.02 | 0.50 | 0.82 | 0.52 |
| Canopy and Curvature | 0.71 | 0.00 | 0.72 | 0.49 |

Table 8. Model validation where points assigned a value of 2 were treated as correctly predicted potentially successful restoration sites based on models generated using presence of at least one indicator species.

| **2=1** | **Prediction success** | **Sensitivity** | **Specificity** | **AUC** |
|---|---|---|---|---|
| Clay, Canopy and Curvature | 0.60 | 0.36 | 0.85 | 0.64 |
| Clay and Canopy | 0.61 | 0.24 | 1.00 | 0.78 |
| Silt, Canopy, and Curvature | 0.64 | 0.59 | 0.69 | 0.64 |
| Silt and Canopy | 0.57 | 0.26 | 0.89 | 0.62 |
| Canopy and Curvature | 0.55 | 0.33 | 0.78 | 0.57 |

predictions. Fielding and Bell (1997) suggest that for conservation purposes models with low false positive rates are favored due to the cost associated with investigating unsuitable sites.

Soil pH is said to be one of the most important factors responsible for the existence of the unique flora found in the Blackland Prairie Region of Mississippi (Jones and Patton 1966). The GIS surface for pH generated from the soil survey data in the study region was uninformative, given the large expanse of no data values, and models generated using pH as a factor were not usable due to that lack of information. I attempted to use cation exchange capacity (CEC) across the region to assess the acidity of the region, but that information was unavailable for a majority of the study region. Characteristics of the taxonomy of the soil series in the region might be informative regarding alkalinity or other informative soil attributes.

This study found very few remnant Blackland Prairie patches on public lands in Mississippi, supporting the designation of Blackland Prairie as an endangered ecosystem (Noss et al. 1995). Failure to locate many remnants supports the findings of Barone (2005) that the Blackland Prairie likely existed as a patches scattered throughout the region. Potential successful restoration sites (sites coded as 1 or 2 in the validation surveys) were found on land where loss of prairie vegetation has occurred, due to agriculture or cattle grazing. This aspect of the results supports previous assertions regarding reasons for prairie habitat loss (Schuawecker 1996, Barone and Hill 2007). Findings from this study have the potential to be used to aid in development of models for the location of other prairie patches in similar habitats found in Alabama (Barone 2005), central Mississippi (Barone 2005), Louisiana (MacRoberts et al. 2003), and Arkansas (Schauwecker 1996).

A state Wildlife Management Area (WMA) is the only public land found in the area historically covered by prairie (Figures 9 and 10). Only 12 percent of the surveyed validation points fell on the Black Prairie WMA. *Schedonorus phoenix* (tall fescue) was the dominant plant species found at all of the points surveyed in the WMA. This small percentage of survey points from areas that were historically prairie could have contributed the low correct presence prediction rate of the models.

Inclusion of soil characteristics improved a model's ability to correctly predict the presence of remnant prairie patches and their absence (Table 7). Correct prediction rates concerning the presence of potential successful restoration sites were low; however, models using canopy cover and either silt or clay percentages had higher specificity, or low false positive prediction rates, which are favored in conservation planning(Table 8) (Fielding & Bell 1997).

Correct prediction of absence points was high for all models using both conditions of validation sites given a value of 2. Predictions from the model generated using percent clay and canopy cover could be used to eliminate areas from receiving restoration consideration based on its high rate of correctly predicting absence points.

Correct prediction of presence points could possibly be improved using soil series information to develop GIS surface(s) representing soil characteristics such as permeability, depth, slope, pH, and particle make-up. Cropping or other land-use history could also be used in conjunction with model predictions or added to the prediction process to improve model performance.

Few attempts to use GIS to aid in determination of grassland restoration sites or areas where extant grassland patches may be found have been published. One example of GIS modeling to aid in determination of suitable sites for restoration of grasslands was carried out in the United Kingdom. It was found that suitable habitat for an increase of 50% of the coverage of calcareous grassland in the Southdowns study region could be easily achieved based on GIS model predictions (Burnside et al. 2001).

Site selection for conservation efforts is an important factor determining the success of the practices implemented. A conservation effort through the NRCS called State Acres For wildlife Enhancement (SAFE) or Conservation Practice 38 (CP-38) has an initial program allotment in the Blackland Prairie Region of Mississippi of over 1100 ha aimed at restoration of former prairie sites converted to agriculture in order to increase Bobwhite quail (*Colinus virginianus*) habitat. This study provides a tool that could be used, in conjunction with current scoring methods and requirements, to aid in determining a potential site's suitability for restoration, thereby increasing the success of project practices.

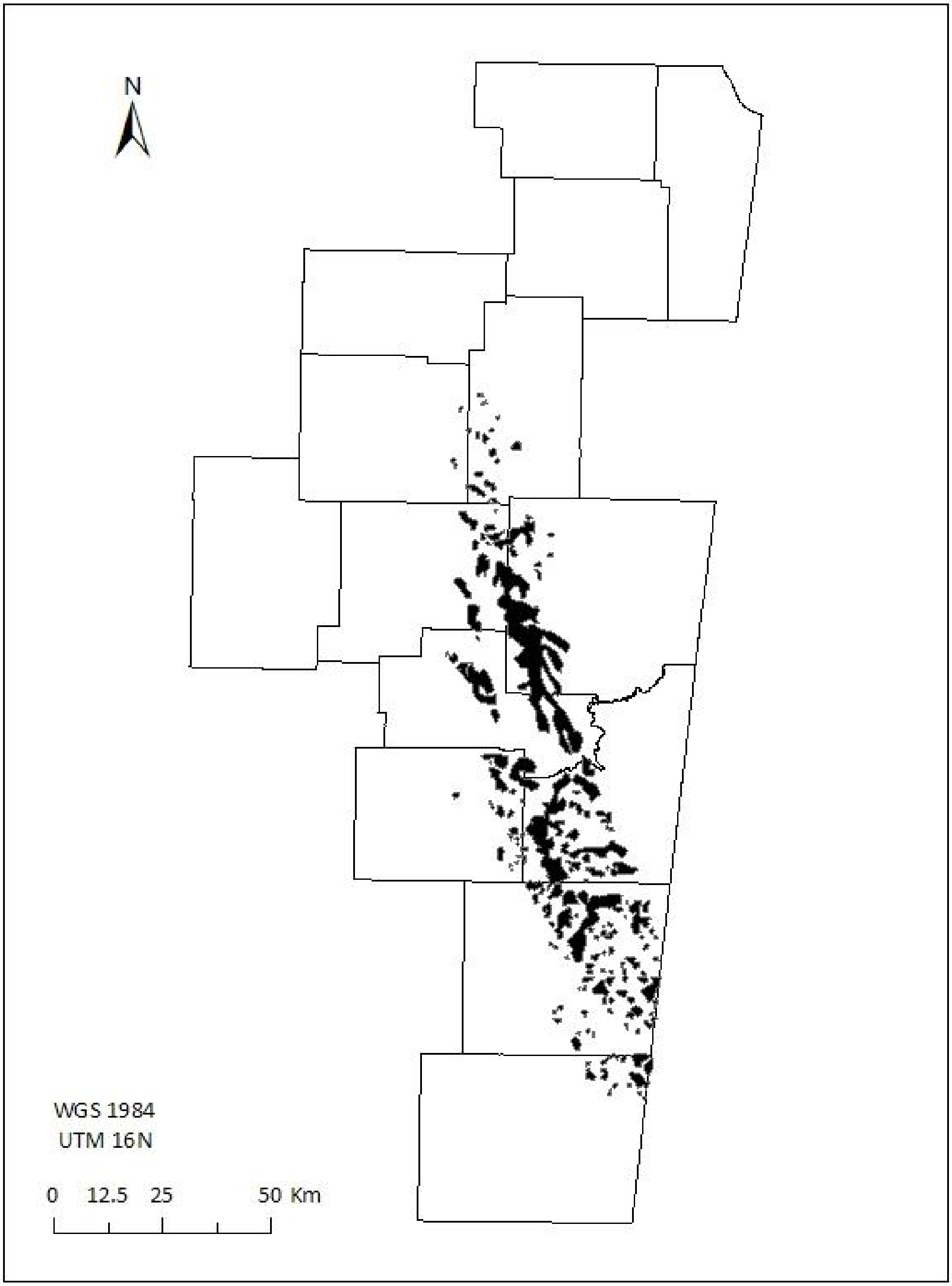


Figure 9. Map of historic extent of prairie patches in the Blackland Prairie Region of Mississippi, from Barone (2005).

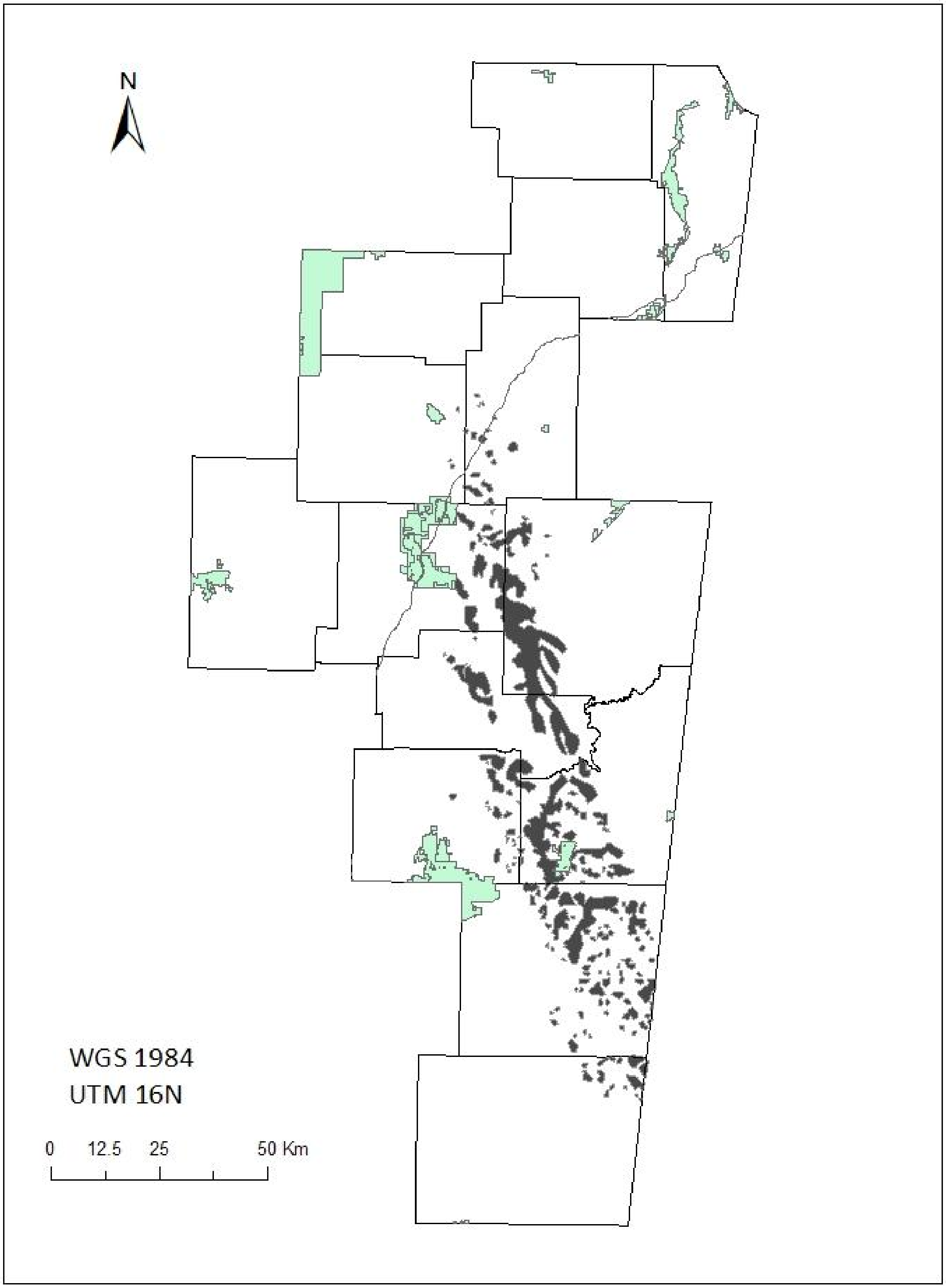


Figure 10. Map of public land (green) in the region highlighted in Figure 1, and historic extent of prairie patches in the Blackland Prairie Region of Mississippi (black), from Barone (2005).

# CHAPTER IV

# CONCLUSION

The Blackland Prairie of Mississippi is a floristically diverse area, the survey conducted for this study of remnant and restoration sites located throughout the region found over 100 plant species, many of which were also encountered in a recent published flora for the Blackland Prairie (Barone & Hill 2007). Common and abundant species found in this study (Table 4) were also reported as being common and abundant in other investigations of Blackland Prairie patches (Barone & Hill 2007, Schauwecker 1996, and Schuster & McDaniel 1973) and were present throughout the Blackland Prairie region in collections of the Mississippi Museum of Natural Science.

Documentation regarding the location and management practices of current conservation efforts being administered by federal government programs are not readily accessible to the public. Only two restoration efforts were accessible for the study presented in this document. The main goals of the surveyed restoration areas are to restore or establish habitat for game birds namely the bobwhite quail (*Colinus virginianus* ). Surveys of the restoration areas found that one restoration site, Bryan Farm, had relatively low plant species richness and low similarity to the other sites surveyed for this study (Tables 2 and 3). Burnt Oak Lodge, the other restoration site, had similar species assemblage characteristics to remnant sites, suggesting a successful restoration (Table 2).  Investigation of site species similarities showed that species assemblages vary across the surveyed areas with up to half of the species being unique in most site comparisons (Tables 3 & 5).

With the information from the survey of known accessible remnant and restoration sites, habitat suitability modeling techniques were employed to predict the location of other extant prairie patches as well as sites that may serve as suitable locations for future prairie restoration efforts. Two approaches were used; logistic regression and a Geographic Information System (GIS) based application of the Mahalanobis distance statistic. Both presence and absence data were required for logistic regression, where only presence information was needed for the Mahalanobis method. Presence points were represented by survey sites from Chapter I along with information from the Mississippi Museum of Natural Science. Absence points were extracted from a statewide floristic study. Environmental variables including soil particle composition, canopy cover, and topography were compiled for the study region. Two sets of models were generated using the Mahalanobis method. The first used presence of suitable habitat represented by sites where at least one of the indicator species was found. The second used presence of suitable habitat represented by sites where at least three of the indicator species was found. Models developed were analyzed using the Area Under the Curve (AUC) from a Receiver Operator Characteristic curve (ROC). The best models were generated by the GIS-based Mahalanobis method using sites with any of the most common and abundant species as suitable habitat (Table 7). Validation of the models was carried out using an independent data set of points throughout the region on public land. Analysis of the models' predictive power using the validation points showed poor to fair performance based on AUC values (Tables 8 & 9). Specificity (true presence prediction rate) was high for the models tested which also means a low rate of false positives (1-specificity). The best models developed used tree canopy cover and either soil percent silt or clay composition. These models could be used to help guide conservation efforts in the Blackland Prairie region of Mississippi as well as similar habitats found in Alabama, Arkansas, and Texas since they have a low likelihood of predicting suitable habitat where none exists.

This study provides support for the assertion that the Blackland Prairie is on the decline and is an endangered ecosystem (Barone & Hill 2007, Noss et al. 1995). Conservation efforts underway have been shown to restore some characteristics of the plant assemblages of extant prairies. Location of remaining prairie patches along with sites suitable for future conservation efforts can be aided by using GIS- based habitat modeling techniques.

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# APPENDIX

# PLANT SPECIES LIST FROM SURVEY OF REMNANT AND RESTORATION SITES IN THE BLACKLAND PRAIRIE REGION OF MISSISSIPPI

**Acanthaceae**

*Ruellia humilis* Nutt.

**Agavaceae**

*Manfreda virginica* (L.) Salisb. ex Rose

**Anacardiaceae**

*Rhus copallinum* L.
*Toxicodendron radicans* (L.) Kuntze

**Apiaceae**

*Daucus carota* L.
*Eryngium yuccifolium* Michx.

**Asclepiadaceae**

*Asclepias lanceolata* Walter
*Asclepias tuberosa* L.
*Asclepias viridiflora* Raf.
*Asclepias virdis* Walter

**Asteraceae**

*Ambrosia artimesifolia L.*
*Ambrosia trifida L.*
*Cirsium horridulum* Michx.
*Conoclinium coelestinum* (L.) DC.
*Echinacea purpurea* (L.) Moench
*Erigeron* sp.
*Erigerion strigosus* Muhl. ex Willd.
*Eupatorium rotundifolium* L.
*Helianthus* sp.
*Lactuca* sp.
*Liatris aspera* Michx.
*Liatris* sp.
*Liatris spicata* (L.) Willd.
*Liatris squarrosa* (L.) Michx.
*Ratibida pinnata* (Vent.) Barnhart
*Rudbeckia hirta* L.

*Silphium integrifolium* (Michx.)
*Siliphium laciniatum* (L.)
*Silphium radula* Nutt.
Silphium terebinthinaceum Jacq.
*Solidago canadensis* L.
*Solidago gigantea* Aiton
*Solidago nemoralis* Aiton
*Solidago rugosa* Mill.
*Solidago* sp
*Symphyotrichum patens* (Aiton) G.L. Nesom
*Symphyotrichum* sp

**Bignoniaceae**

*Campsis radicans* (L.) Seem. ex Bureau

**Boraginaceae**

*Lithospermum canescens* (Michx.) Lehm.

**Campanulaceae**

*Lobelia inflata* L.

**Clusiaceae**

*Hypericum* sp.
*Hypericum spherocarpum* Michx.

**Convolvulaceae**

*Ipomoea* sp

**Cornaceae**

*Cornus drummundii* C.A. Mey.

**Cupressaceae**

*Juniperus virginia* L.

**Cyperaceae**

*Carex cherokeensis* Schwein.

**Cyperaceae**

*Carex* sp.
*Eleocharis* sp.
*Scirpus* sp.
*Scleria triglomerata* Michx.

**Ebenaceae**

*Diospyros virginia* L.

**Euphorbiaceae**

*Chamaesyce maculata* (L.) Small
*Euphorbia corolata* L.
Euphorbiacae unk

**Fabaceae**

*Cercis canadensis* L.
*Chamaecrista fasciculata* (Michx.) Greene
*Chamaecrista nictitans* (L.) Moench
*Crotalaria sagatalis* L.
*Dalea candida* Michx. Ex Willd.
*Dalea pinnata* (J.F. Gmel.) Barneby
*Dalea purpurea* Vent.
*Desmanthus illinoensis* (Michx.) MacMill. ex B.L. Rob. & Fernald
*Desmodium* sp.
*Galactia* sp.
*Lespedeza cuneata* (Dum. Cours.) G. Don
*Lespedeza repens* (L.) W. Bartram
*Lespedeza* sp.
*Lespedeza virginica* (L.) Britton
*Medicago lupilina* L.
*Melilotus officinalis* (L.) Lam.
*Neptunia leuta* (Leavenworth) Benth.
*Trifolium caroliniana* (Michx.)

**Fagaceae**

*Quercus muehlenbergii* Engelm.

**Gentianaceae**

*Sabatia angularis (L.) Pursh*

**Hippocastanaceae**

*Aesculus pavia* L.

**Iridaceae**

*Sisyrinchium albidum* Raf.

**Jucaceae**

*Juncus* sp.

**Lamiaceae**

*Blephilia ciliata (L.) Benth*
*Monarda fistulosa* L.
*Physostegia angustifolia* Fernald
*Prunella vulgaris* L.
*Salvia lyrata L.*

**Oleaceae**

*Fraxinus qudrangulata* Michx.
*Fraxinus pennsylvanica* Marsh
*Ligustrum sinense* Lour.

**Onagraceae**

*Oenothera* sp.

**Orchidaceae**

*Spiranthes magnicamporum* Sheviak

**Oxalidaceae**

*Oxalis stricta* L.
*Oxalis violacea* L.

**Pinaceae**

*Pinus teada* L.

**Poaceae**

*Andropogon gerardii* Vitman
*Andropogon glomeratus* (Walter) Britton, Sterns & Poggenb.
*Andropogon virginicus* L.
*Aristida purpurascens* Poir.
*Bouteloua curtipendula* (Michx.) Torr.
*Bromus* sp.
*Dichanthelium acuminatum* (Sw.) Gould & C.A. Clark
*Dicanthelium* sp.
*Eragrostis spectabilis* (Pursh) Steud.
*Panicum anceps* Michx.
Poaceae
*Schedonorus phoenix* (Scop.) Holub
*Schizachyrium scoparium* (Michx.) Nash
*Setaria* sp.
*Sorghum halpense* (L.) Pers.
*Sorghastrum nutans* (L.) Nash
*Tridens flavus* (L.) Hitchc.

**Polygalaceae**

*Polygala verticillata* L.

**Rhamnaceae**

*Berchemia scandens* (Hill) K. Koch
*Ceanothus americanus* L.

**Rosaceae**

*Prunus angustifolia* Marsh.
*Rubus trivialis* Michx.

## Rubiaceae

*Stenaria nigricans* (Lam.) Terrell
*Houstonia purpurea* L.
*Houstonia longifolia* Gaertn.

## Scrophulariaceae

*Agalinis gattingeri* (Small) Small
*Agalinis heterophylla* (Nutt.) Small ex Britton
*Agalinis* sp.

## Smilacaeae

*Smilax bona-nox* L.

## Solanaceae

*Solanum carolinense* L.

## Ulmaceae

*Celtis occidentalis* L.
*Ulmus alata* Michx.

## Verbenaceae

*Verbena brasiliensis* Vell.
*Verbena simplex* Lehm.
*Verbesina* sp.

## Vitaceae

*Vitis aestavalis* Michx.