

just six soundbites of 'review', which appear to have been selected purely for publicity. Personally, I would prefer to see some attempt at balance here; the book is good enough to stand constructive criticism on its website.

Overall, despite its faults, this book contains many fascinating, informative and sometimes insightful articles, which together make both a useful reference and a fine addition to a coffee table. Most readers should, like me, happily spend hours flicking from one article to another, learning something while celebrating the wonderful diversity that is the world's islands. If you are thinking of treating yourself to something a little indulgent, you could do a lot worse than the *Encyclopedia of Islands*.

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thesis abstract

## In search of the forest primeval: data-driven approaches to mapping historic vegetation

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### Introduction

The current biogeographic patterns in a given area are not only the product of contemporary environmental factors, such as climate, topography, and edaphic conditions, but historical factors as well, including anthropogenic disturbance regimes. In North America, for instance, much of the native temperate forest and grassland has been modified in the time since European settlement as a result of intensive human activity (e.g. Forman 1998). Since past human activities can influence biotic patterns for many years (Dupouey et al. 2002), interpretation of biogeographic phenomena without explicit consideration of human influence may lead to erroneous conclusions.

To better understand the influence of these disturbance regimes on ecosystem structure and function, researchers are increasingly using historical data to construct baselines from which subsequent changes in biogeographic patterns can be measured (e.g. Shutler and Hoagland 2004;

Fritschle 2008). Among the datasets that have been extensively used in such reconstructions are the Public Land Survey (PLS) field notes, witness tree records, and plat maps (i.e. survey map of tracts of land) (Wang 2005). Public Land Survey records provide one of the few quantitative records of pre- and early-European vegetation in much of the western United States. These data have been used to evaluate vegetation dynamics (DeWeese et al. 2007), composition and structure of historical forest and woodland communities (Anderson and Anderson 1975), species-environment interactions (Wang 2007), and distribution and abundance of individual species (Wang & Larsen 2006).

Despite their widespread adoption, PLS data are fraught with limitations, among them bias in tree selection (Bourdo 1956), taxonomic uncertainty (Mladenoff et al. 2002), and the coarse sampling methods employed by surveyors (He et al. 2007). Nonetheless, the data of the PLS

have richly contributed to our understanding of past ecological conditions and use of these and similar datasets in biogeographic reconstructions is likely to continue. The challenge for current researchers, then, is to develop novel approaches to overcome some of the limitations and improve the robustness of these data for use in ecological analysis (e.g. Mladenoff et al. 2002, Wang and Larsen 2006; He et al. 2007).

### **Aims and methods**

My PhD research is built upon the broad supposition that evaluation of current biogeographic patterns must be predicated on antecedent conditions, typically prior to widespread anthropogenic disturbance regimes. In a narrow sense, my dissertation focuses on land use, land cover, and woody plant compositional changes in the Arbuckle Mountains of south-central Oklahoma during a period of rapid demographic change (circa 1870 to 1898). In this regard, the research seeks to provide insight into the ecological processes of habitat fragmentation, woody plant encroachment, and so-called mesophication that are believed to have occurred subsequent to the historical period under investigation.

In a broader context, this research is an evaluation of how anthropogenic alterations in landscape patterns and processes may affect the distributions of individual woody plant taxa. Though the datasets utilized in this research are unique to the region, the methods employed in this study should be transferable to other areas of interest. Additionally, the patterns and processes under investigation are not unique to the region under investigation. The results, therefore, should be placed within the context of anthropogenic change that has occurred throughout the eastern deciduous forests of North America, particularly in the western cross timbers, in the period following European settlement.

In order to accomplish these goals, my dissertation is divided into two broad research themes. The first employs repeat PLS data from the 1870s and 1890s, respectively, to quantify changes in landscape structure, woody taxa assemblages, and anthropogenic markers in the

study area during this period of rapid demographic transition. The present-day state of Oklahoma, U.S.A., is unique in that the U.S. General Land Office (GLO) conducted two separate Public Land Surveys in a portion of the state during a relatively short time span (Hoagland 2006). Beginning in the early 1870s, the GLO surveyed all lands of the Chickasaw Nation in what was then Indian Territory (Gibson 1981). In 1895, the United States Congress appropriated funds for the survey of all tribal lands in Indian territory, including those lands that had been previously surveyed in the 1870s (Gibson 1981).

Part of the resurveyed area includes a portion of the state that is characterized by a mosaic of forest, woodland, and grassland vegetation known collectively as the cross timbers (Hoagland et al. 1999). During the past century, a combination of land use practices and fire suppression is believed to have contributed to increased woody plant abundance in former grasslands in the region (Hoagland and Johnson 2001) and may have led to increases woody plant densities in woodlands and forests (i.e. so-called mesophication) (Engle et al. 2006). Moreover, there is evidence of widespread habitat fragmentation in the area resulting from various land use practices (Hoagland and Johnson 2001; Shutler and Hoagland 2004).

The goal of this portion of the research was to utilize the repeat PLS data to evaluate the biological consequences of various anthropogenic activities. Specifically, I quantified landscape structure and associated woody plant assemblages at two discrete points in time, one corresponding to pre-European settlement, the other following European settlement. The analyses involved the quantification of habitat fragmentation, analysis of changes in the distribution and composition of woody plant species, and comparisons of structural differences in arborescent habitats between the two survey periods.

I databased all PLS witness tree records in the study area for the two survey periods and plotted the location of individual witness tree records using conventional GIS techniques. Additionally, I digitized all PLS plat map data for the study area, creating GIS layers for land cover types

and anthropogenic markers, such as structures and transportation networks (see Fagin and Hoagland 2002 for a discussion of GLO survey methods). I calculated the spatial association between individual tree taxa and environmental covariates to test the null hypothesis of no differences in species composition in the different environmental units between the two survey periods. A rejection of the null hypothesis would indicate that other factors (e.g. anthropogenic) contributed to distributional differences. I calculated average distance to recorded trees, density, and basal area at each survey point for each survey period and tested for significant differences between the survey years. I also used calculated stem density values and universal kriging to create continuous density surfaces for each survey period to characterize the differences in dominant arborescent community types.

The second broad research theme utilizes a Bayesian method known as weights-of-evidence (WofE) to address the problem of coarse sampling structure of PLS records (tree data were only collected along section lines at 0.8 km (0.5 mi) intervals). Several attempts have been made to convert discrete PLS point data into continuous surfaces using kriging and other interpolation methods (e.g. Wang and Larsen 2006; Wang 2007). While these methods may adequately represent the spatial patterns of individual species over large areas (Wang and Larsen 2006), these methods typically fail to consider the numerous environmental covariates, such as edaphic conditions and topographic position, which can influence the distribution of individual species at finer scales. A more statistically rigorous method calls for combining species–environment relationships to estimate the areal extent of individual species from point data (He et al. 2007).

Weights-of-evidence is a discrete, data-driven multivariate method based on a log-linear form of Bayes' rule. Weights-of-evidence is used to measure the spatial association between maps of independent environmental variables and dependent variable point data (Bonham-Carter et al. 1989). Weights-of evidence modeling proceeds in several phases: development of a spatial data-

base, extracting predictive evidence for the phenomena under investigation, calculating weights for each predictive map (evidential layer), combining weights for each evidential layer, and model validation (Kemp et al. 1999). In my models, the dependent variables were individual woody taxon occurrences estimated from PLS witness tree records. I selected six wood plant taxa (*Quercus stellata*, *Q. marilandica*, *Q. velutina*, *Carya texana*, *C. illinoensis*, and *Juniperus* spp.) to model, based on their historical or subsequent importance within the study area. For the independent variables, I selected five environmental factors known to influence the distribution of the selected taxa and that were available at both the spatial and temporal scale under investigation. The covariates selected were substrate (parent material), soil type, elevation, moisture availability (derived from slope and aspect), and historical land cover. I ran six different models, one for each of the taxa under investigation, to estimate the historical posterior probability of occurrence of each taxon under investigation. I validated each model using a split-sample approach, in which the occurrences of each taxon were divided into two randomly generated sets, a model building set and a validation set (Carranza and Hale 2000). For a complete discussion of the WofE method, see Bonham-Carter et al. (1989).

## Results

The main results of my dissertation will be presented in several forthcoming publications. The first paper, currently under review, focuses on the use of WofE modeling of PLS data. A second paper, currently in preparation, will compare the land cover and woody plant compositional changes in the Arbuckle Mountains between the two survey periods. Additional papers will compare the present-day Arbuckle landscape to historic conditions and explore alternative methods to WofE to model PLS data to finer resolutions. Finally, this research belongs to a larger body of past and ongoing research on the historic vegetation of Oklahoma (e.g. Shutler and Hoagland 2004; Hoagland 2006).

The core findings of this research are: 1. The landscape of the Arbuckle Mountains became increasingly fragmented during the 27 years between the two surveys as large scale agriculture became ubiquitous in the region; 2. Changes in stand composition between the two survey are concurrent with anthropogenic disturbance regimes; 3. Analyses of changes in density between the two surveys indicate that the cross timbers of the Arbuckle Mountains were denser immediately prior to European settlement than in the period following settlement, while data from both survey periods tend to confirm that the present-day cross timbers are denser than historic times; and 4. The WoFE method adequately estimated the posterior probabilities of *Q. stellata*, *Q. marilandica*, *C. texana*, and *Juniperus* spp., but underpredicted posterior probabilities for *C. illinoensis* and *Q. velutina*.

### Discussion

The land cover change documented in the study area between the two surveys corresponds to a period of rapid demographic shift and is primarily due to land clearance for agriculture, transportation networks, and anthropogenic structures. The changes in stand composition between the two surveys imply that these anthropogenic disturbance regimes may be responsible for shifts in biogeographic patterns. However, these changes may also be related to taxonomic uncertainties in the historical datasets rather than actual changes in community dominance.

Despite several inherent limitations, the weights-of-evidence method proved to be a statistically valid method to map individual taxon distributions at finer resolutions than afforded from traditional methods of mapping PLS data. Weights-of-evidence belongs to a growing body of research techniques that can be used to predict species distribution from point occurrence data (see Elith et al. 2006 for reviews of similar methods). While my results indicate that WoFE may also be used to create probabilistic maps of the historic distribution of certain woody plant taxa from PLS data, several other methods, such as weighted logistic regression (Agterberg et al.

1993) or the Dempster-Shaefer (Yager and Liu 2008) may better handle issues arising from uncertainty in historical datasets and missing data.

### Conclusion

Within the last decade, there has been an increase in the use of PLS data in ecological analysis (Fagin and Hoagland 2002; Wang 2005). As use of these data becomes more commonplace, the need to properly place the significance of historical biogeographic patterns in the context of the contemporary landscape becomes essential. Moreover, the need to map these data to finer resolutions to truly elucidate changes in biogeographic patterns increases. My research analyzed the degree and direction of changes in woody plant abundance since historic times in the Arbuckle Mountains, Oklahoma. However, the methods utilized and the findings thereof are applicable to a wide range of biogeographic studies.

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