# ABSTRACT

## SOIL SEED BANK GERMINATION AND UNDERSTORY DIVERSITY IN OAK SAVANNA RESTORATIONS

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The cumulative effect of widespread conversion of natural areas to agricultural land use, invasion of non-native species and 20$^{th}$ century fire suppression has increased habitat fragmentation and has led to the overall decline of species diversity and ecosystem functionality of oak savannas across the North American prairie-forest ecotone region. This research was conducted in a 30ha oak savanna restoration project in north central Illinois, USA. We analyzed differences in restoration management history and practices by comparing a five-year-old restoration effort against a degraded unmanaged unit. We use multivariate analyses to determine the influence of variation in understory light levels using hemispherical lens photography and variation in soil N, C, pH, and percent sand/silt/clay on herbaceous species diversity in random sampling plots. Results indicate a significant difference in species richness, cover and stem counts between the managed and unmanaged units. Additionally, we collected soil samples from both units and germinated the soil seed banks using three different treatment methods: watering with aqueous smoke extract, heating samples to 100 °C, and watering samples with distilled water. Significant differences were found in species per tray and germinants per tray between treatments.

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# CHAPTER 1

# INTRODUCTION

## Oak Savanna

Typified by fluid and shifting boundaries resulting from interactions between climate, topography, and fire, Midwestern savannas formed a unique ecotone between the eastern deciduous forests and the tall grass prairies of the Plains states (Nuzzo 1986; Anderson and Bowles 1999). Savanna ecosystems are characterized as having a generally scattered, open-grown oak-dominated overstory structure with a dense herbaceous layer of forbs and grasses whose distribution pattern is heavily influenced by disturbance events such as wildfires and droughts (Anderson 1998; Karnitz 2006). Savannas are exceedingly species diverse due in part to the highly varied mosaic of soil and light gradients caused by their broken canopy and spatially distinct structure (Leach and Givnish 1999).

## Ecosystem Origin

The genesis of what is considered the oak savanna ecotone dates back to a warming period nearly 8,000 – 3,000 years before present during the late Pleistocene period, an era marked by glaciations, inter-glacial periods, and species migration, both flora and fauna, due to changes in global climate (Anderson 2006). This warming period is frequently referred to as the Hypsithermal period, characterized by a generally warmer and drier climate that was very conducive to frequent and intense fires (Camill et al. 2003). The millennia following the end of the Wisconsin Glaciation saw a constantly changing boundary between woodlands and prairie. This transitional zone is known as an ecotone where the spatial extent of either ecotype is directly controlled by disturbance factors such as fire and grazing pressure and also by climatic factors such as precipitation rates and droughts (Harrington 1991).

Prairie forbs and grasses are evolved to withstand drought conditions more successfully than most tree species. This adaption, coupled with tree's inability to withstand frequent intense fire, allowed prairies to expand their range after the last glaciation. Additionally, Native American populations increased substantially during this time period, which in turn had a dramatic effect on ecosystem function and species compositions. Native Americans were the primary source of ignition in most regions. By managing their surroundings with fire for thousands of years, Native Americans were essentially "keystone species" (Nowacki 2008). The indigenous populations were using fire as a tool to herd game species including elk and bison, to clear land for agricultural purposes, to promote vegetation growth, and to maintain a relatively open space free from thickets and trees (Pyne 1982).

Climate, fire and topography were major driving forces behind the patchy mosaic characteristic of savannas. Fires played a pivotal role in defining vegetation types and tree distribution across the oak savanna ecotone. Fires, driven by the prevailing west-to-east winds, would race across flat prairies and up dry south-facing slopes. The lee sides of hills, however, were protected from fires and thus maintained trees and thickets (Abrams 1992). Rivers, streams, wetlands, and sandy uplands worked as fire breaks which helped to maintain a patchy mosaic of burned and unburned areas.

The rain shadow created by the Rocky Mountains, in conjunction with changing air current patterns of the Hypsithermal period (Clark et al. 2001), had a direct effect on precipitation rates across the Great Plains. This in turn caused a west-to-east gradient of short grass prairies, mixed grass prairies, tallgrass prairies, and savannas progressing into the Eastern deciduous forest, each with its own suite of flora and fauna. At the heart of the tallgrass prairie region are two of the longest rivers in the world; the Missouri and the Mississippi. This interconnected network of waterways created a matrix of fire breaks, wetlands, floodplains, and riparian areas that contributed immensely to the overall heterogeneity of the tallgrass prairie and oak savanna ecotone region.



## Anthropocene

Prior to European settlement in the 1840s, oak savanna covered 11-13 million hectares of the Midwest extending over an eight-state region. By 1985, however, approximately only 0.02% of high-quality oak savanna remained intact due to the cumulative effect of widespread conversion of natural areas to agricultural land use, invasion of non-native species and 20$^{th}$-century fire suppression (Nuzzo 1986). Today, these anthropocentric factors have resulted in increased habitat fragmentation and have led to the overall decline of species diversity and ecosystem functionality of oak savannas across the region (McCune and Cottam 1985).

Fires, frequently ignited by Native Americans as a tool to clear land for agriculture and drive bison herds, were prevalent in the pre-settlement Midwest and played a vital role in the formation and maintenance of oak savanna ecosystems (Abrams 1992; Whitney 1994; Nowacki and Abrams 2008). Compared to many fire-intolerant species such as elm (*Ulmus sp*.), walnut (*Juglans sp*.), and cherry (*Prunus sp*.), oaks (*Quercus sp*.) thrived in this frequent fire environment due in part to their thick, fire-resistant bark and their ability to re-sprout after being top-killed by fire (Stearns 1991; Abrams 1992). Typically, oak savannas burned on a 4.5-year interval cycle which maintained oak dominance by keeping fire-intolerant tree species populations in check (Wolf 2004). The sparse spatial distribution of oaks created a patchy mosaic of available resources which enabled tallgrass prairie species and more shade-tolerant herbs to thrive in the transitional savanna community (Leach and Givnish 1999).

Anthropogenic processes, namely fire suppression associated with the onset of European settlement of the Midwest in the early part of the 19$^{th}$ century, pushed natural systems beyond ecological thresholds and along trajectories bound for radically different ecosystem composition, form, and structure (Rayburn and Major 2008). What little oak savanna that remained after the initial logging and agricultural conversion was further degraded by cessation of wildfire. Many of these small oak savanna remnants transitioned into closed canopy woodlands with increased proportions of mesophytic, fire-tolerant tree species (Apfelbaum and Haney 1991; Anderson 1998; Anderson et al. 2000). In addition, the greater stand density caused a marked increase in humidity, decrease in solar radiation and wind speeds, and a cooler and moister forest floor which drove down species diversity and favored more shade-tolerant herbs (Nowacki and