Nachusa Grasslands

West Holland Savanna Restoration Plan

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Background

Once a widespread ecosystem in Illinois and elsewhere, only 0.02% of midwestern oak savannas remain. Aside from rarity, the impetus for savanna restoration is their exceptional biodiversity. Savannas, with 10-30% canopy cover, share species with both prairie and more shaded woodlands (30-80% canopy cover), in addition to species unique to oak savanna. Accordingly they have more biodiversity, with 300-500 species across a site, than prairies, woodlands, or forests. The canopy cover of trees provides heterogeneity of light, moisture, and nutrients. Oak savannas require regular fire to outcompete faster growing and more shade-tolerant mesophytic trees, which are fire-sensitive. Decades (perhaps centuries) of fire exclusion in addition to losses to agriculture and development have led to the near extinction of this ecosystem.

I propose two small restoration sites (site map Appendix A) to serve as pilot restorations to guide restoration of the remaining woodlands with savanna potential. Site A is 2.24 acres near the center of West Holland Savanna, also known as Brant 2. Site B is approximately 0.7 acres at the north end and bordering the 30-acre Senger prairie planting to the north. Site A is an opportunity to release existing oaks while providing open grassland and to provide an anchor point for extending restoration (including establishing oaks) to the recently de-mesophicated section to the east, as well as for any future thinning in the surrounding woodlands. Site B is currently a mesophytic barrier between the interior oak woodland and the prairie to the North. The goal is to provide habitat and ecosystem connectivity throughout the Stone Barn Savanna tract from Senger Prairie to the north to Tell Labs to the south.

The proposed restoration is small but these small restorations provide knowledge of the local response to restoration as well as habitat heterogeneity, propagule pools for surrounding restoration, connectivity to the prairie to the north, and an incremental approach to restoration to not overwhelm our resources. The studies that I read leave several unanswered questions and, aside from the need to thin and burn, there are no established best practices to follow. The optimal fire regime, timing of thinning, approach to seeding, strategies to recruit oaks, etc. all remain elusive. Here I have compiled the available evidence and try to offer logical suggestions to assist the restorationist in making decisions.

Site Description

Location:

Site A

Central West Holland Savanna/ Brant 2
Roughly circular 2.24 acre area surrounding open-grown bur oak at N41° 53.810' W89° 22.298'
Two large open-grown burr oaks exterior to NW corner, six 3-8 inch diameter oak interior to South central edge, four mature white oaks interior to NE corner.

Site B

Northern edge of West Holland/ Brant 2
North Boundary (approximate): N41° 53.940' W89° 22.311'. Previously cleared (mulched) edge.
East Boundary (approximate): N41° 53.896' W89° 22.297'. Group of three white oaks.
South Boundary (approximate) N41° 53.899' W89° 22.316'. Open grown shagbark hickory.
West Boundary (approximate): N41° 53.943' W89° 22.342'. Row of white oaks.

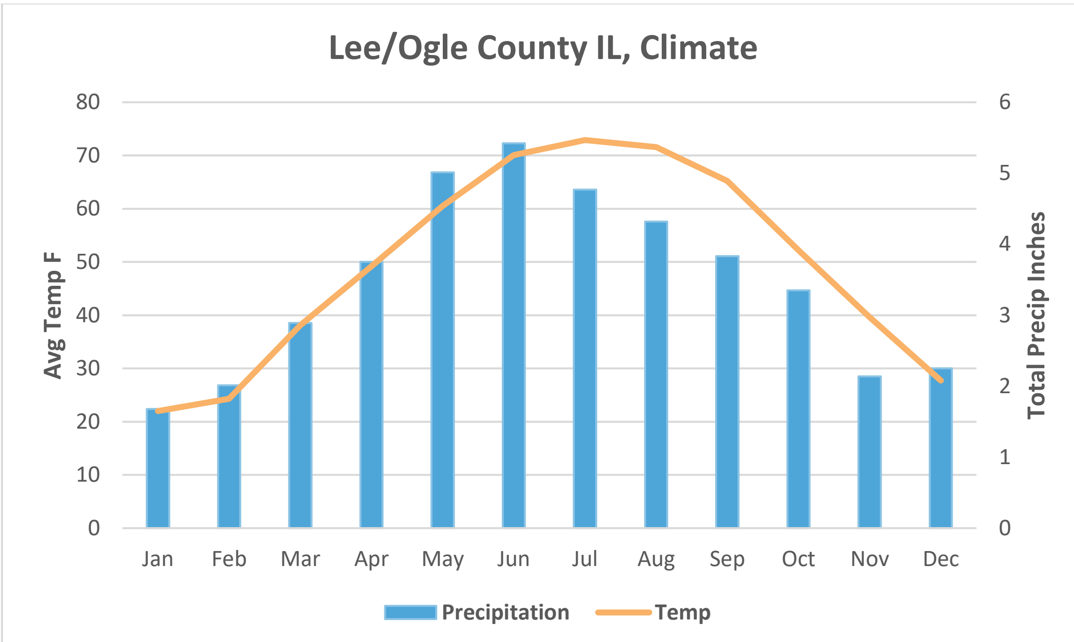
Physiography

The topography of Site A is flat while Site B is gently rolling and bisected north to south by two shallow swales without standing water. Site B slopes upwards from the northern adjoining Senger prairie at an approximately 15% slope with northerly aspect. Soils at Site B and eastern Site A are predominantly Boone Loamy Fine Sand, a Mesic, uncoated Typic Quartzipsamments residuum weathered from underlying St Peter sandstone. Drainage is excessive. Depth to restrictive paralithic bedrock is 20 – 40 inches, and depth to water table is > 80 inches. pH is 5.8 with ≤ 0.5% SOM and CEC of 2 meq/100g[1]. The western half of Site A is Whalan Loam, which is well drained and 20 to 40 inches to bedrock. The soil is glacial till over residuum weather from limestone. pH is 6.5, 1.5% SOM, and CEC of 16.5. See Appendix B for soil map.

[1] All soil data is from Web Soil Survey, not a soil test.

CLIMATE

Lee country has a hot-summer humid continental climate with average temperatures ranging from 25 (January) to 72^{o}F (July), an average 165-day frost-free period, and 41 inches of annual precipitation (NOAA U.S. Climate Normals 1991-2020).



Data Source: https://agacis.rcc-acis.org/

VEGETATION

I performed an informal wandering survey of the site on 10/27/22. Groundlayer coverage ranged from ~20% in more shaded areas to 80% in more sun. Across the site (occurring in separate areas), the groundlayer was ~20% sedge and 80% forb. Identifiable groundlayer vegetation includes greenbrier, sedges (at least two species), black raspberry, tall goldenrod, American bittersweet, black and white snakeroot, poke milkweed, pokeweed, Canadian clearweed, aster (two species), *Anemone virginiana*, horse gentian, *Agastache sp*., and silky wildrye. Only the snakeroots, hyssop, and Carex, in some isolated patches, occur in abundance. Shrubs in Site A include blackhaw viburnum, autumn olive, and most abundantly, amur honeysuckle[2]. The more closed canopy Site B lacks a shrub layer. The lack of shrub diversity (usually a component of savannas) may be due to honeysuckle competition and annual fire (Saxton 2012). Midstory trees include shagbark and bitternut hickory, slippery and Siberian elm, black cherry, quaking aspen, and Osage orange. Canopy trees include white oak, burr oak, black oak, northern red oak, and white swamp oak, Siberian elm, black cherry, shagbark hickory, and quaking aspen. See Appendix C for a 2012 plant survey of the tract and Appendix D for a tree species list with density and basal area. Open grown oaks of similar size (approximately 50 ft canopy) are common throughout Stone Barn Savanna and along the periphery of this restoration site. Figure 1 shows the current distribution of dominant trees overlayed on a 1939 aerial photograph.

White oak (Q. *alba*) disperse primarily by seed rain (below the parent tree) during mast years, which produces oak seedlings at the edge of existing canopies. This creates clusters of white oaks interspersed by prairie and this mosaic was described by early settlers (Brudvig & Asbjornsen 2005). This pattern is seen within

[2] Control is in progress

Stone Barn Savanna, but with clusters of white oaks surrounded by mesophytes and hickory. There are occasional midstory oaks, mostly white oak, black oak, and northern red oak. Oak seedlings are rare, and in many areas absent. The current basal area (measured with a forestry prism) ranges from 80 ft^2/ac where thinning has already occurred to 110 (and near 100% canopy cover) without thinning. Saxton (2012) measured the basal area at 120 ft^2/ac in the Brant tracts.

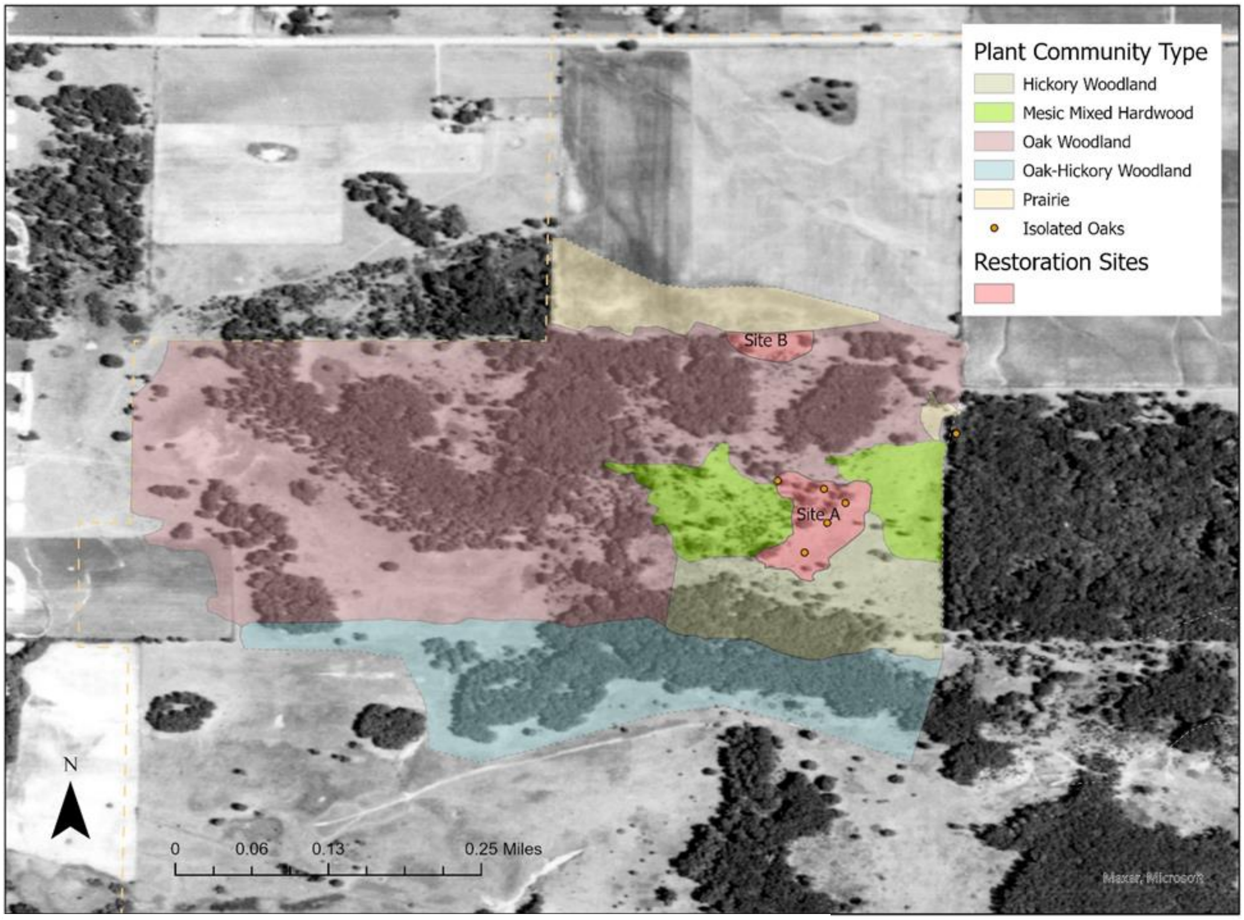


Figure 1—Current and historical vegetation cover

Site History

The Stone Barn Savanna woodlands have several large, open-grown oaks, which indicate historical savanna conditions prior to canopy closure (Brock & Brock 2004). Closed canopy results in more vertical tree structure with shorter branches and missing lower branches. Figures 1 and 2 shows about half the area surrounding the project site was treeless in 1939 and the presence of open-grown oaks throughout the forested areas in the photograph indicates even less canopy cover prior to this.

From neighbors we know that the site was long grazed (C. Considine, Nachusa Grasslands, 2022, pers. comm.), which may have kept the 1939 open areas treeless. Possibly prescribed fire was used to promote forage for grazing as described for the Kankakee Sands region in mid-1800s to early 1900s (Considine et al. 2013). Parts were also likely clearcut, and perhaps selectively harvested as well, as there are different tree communities along distinct lines. The previous owner of the neighboring Bennet tract reported a clear view through the trees when he bought the property in the 1980s, indicating invasion by amur honeysuckle and development of a dense shrub layer after this (Saxton 2012). Saxton found slippery elm and black cherry accounting for 40% of relative density but only 10% of basal area, indicating recent invasion of pole-size, even-aged mesophytes.

Figure 2—1939 Aerial Photograph (left) and current satellite image (right).

Our restoration sites are approximately above and below the "17" on the map below, taken from the 1839 Public Lands Survey. The survey indicates that there was historically bur oak savanna ("barrens") with black and white oak savanna to the south. The bur oak savanna transitioned to prairie much as the woodland does today at the Senger prairie reconstruction.

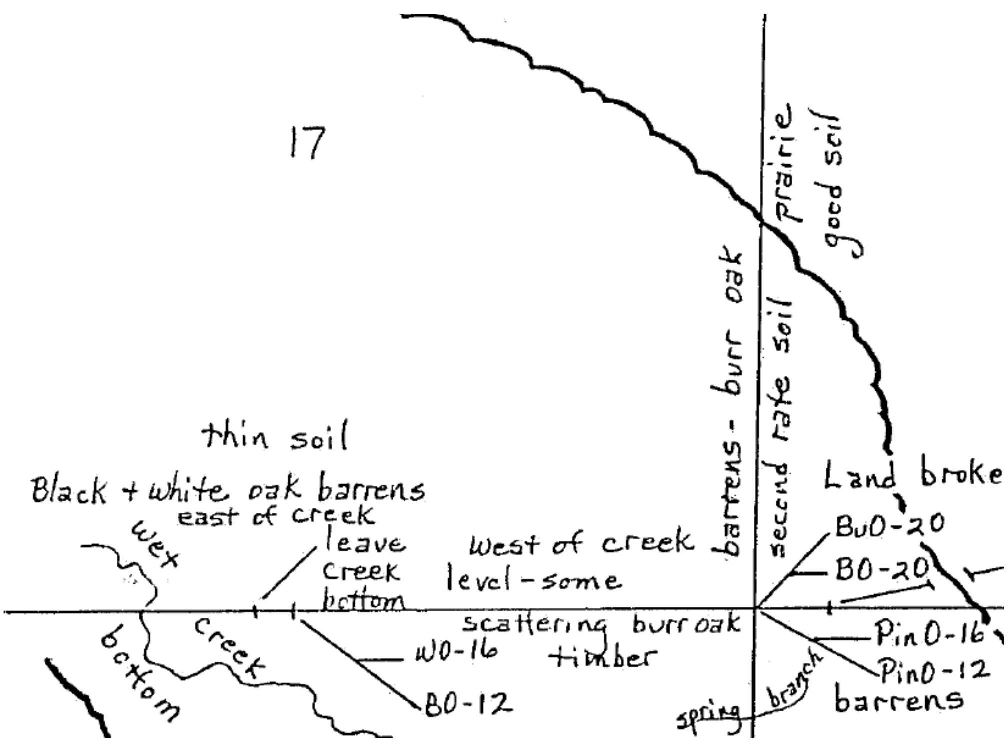


Figure 3—1839 PLSS map of site

At Site A, restoration is ongoing with annual prescribed fire, control of invasive species (primarily amur honeysuckle), removal of mesophytes, and reduction of tree density. The area was basal bark sprayed in fall 2021, spring 2022, and fall 2022. In October 2022 we forestry mulched honeysuckle (mostly dead from previous basal bark treatment), elms, and black cherry in Site A.

To the east of Site A an area with the most open canopy of the Stone Barn Savanna tract and a tree cover of almost exclusively mesophytes was basal bark sprayed in 2022 and previously and will be almost treeless. It was seeded around 2020 with a combine prairie mix. Currently diversity is low and dominated by forbs, with joe pye weed most abundant. At the SE corner of this site there is small clearing, which was a dolomite quarry and was seeded around 2019 and now has a robust, though not diverse, stand of prairie plants including Canada wildrye, little bluestem, Indiangrass, big bluestem, goldenrod, and tall boneset.

Reference State

The reference ecosystem for this site, beyond oak savanna, is unclear. Using Anderson and Fralish (1999), the sandy, relatively shallow soil and location in Northern Illinois would suggest Eastern Sand Savanna, however these are dominated by black (Quericus velutina) or blackjack oak, while the current canopy structure and dominant species—large, open-grown white and bur oak—suggests Deep Soil Savanna. Given the current oak composition and desirability of this state, the target ecosystem will be Deep Soil or White Oak Savanna, as categorized by Wilhelm & Rericha (2017). Red, black, bur, and white oak are all present and all are ecologically appropriate for Illinois savanna. Savannas have sparce tree cover and a grass-dominated but forb-rich, highly diverse groundlayers. While limited light under tree canopies decreases alpha diversity locally, the canopies provide additional niches of light, moisture (via shade and rain interception), and soil (leaf litter), thereby increasing beta diversity across the ecosystem such that savannas have more diversity than prairies or woodlands. The groundlayer is usually described as prairie-like with more C3 grasses and a greater proportion of forbs in the shadier areas. Savannas also include occasional shrubs such as hazelnut and blackhaw viburnum. A species list that includes species from four published species lists for Illinois filtered for species present at Nachusa as well as transect surveys of existing savanna/ woodland sites (not necessarily 10-30% canopy cover) are included in Appendices E and F for Illinois and Nachusa reference communities.

Of the oaks, black oak occupies the driest and sandiest sites, followed by white, with bur oak in the more mesic and fertile sites (Anderson et al. 1999). As mentioned, white oaks (Q. alba) disperse primarily by seed rain during mast years, which produces oak seedlings at the edge of existing canopies. While the shade of the oak clusters reduce alpha diversity, beta diversity can maintained by the gaps (Brudvig 2010). Gamma diversity occurs from variations in fire frequency and severity, mostly related to topography and natural fire breaks. White oak group acorns are typically not cached by squirrels while red oak acorns, which have higher tannins but also higher energy, are cached—and thus dispersed—for use later in winter (Steele & Yi 2020). White oak group acorns are eaten or if they are cached, the squirrels remove the embryo with their teeth to prevent it from germinating. This has been described for *Q. alba* and *macrocarpa* and eastern gray squirrels and fox squirrels. Squirrels also are more likely to cache larger acorns, however. Perhaps this could account for farther dispersal of burr oaks. In a variation on pyric herbivory, some authors have found that grazers reduce fuel loads and, while trampling or eating some seedlings and thus helping to maintain an open canopy, they allow others to escape top-killing by fire (Considine et al. 2013). This could explain the sparse recruitment of trees in historical savannas rather than the thicket of grubs (repeatedly top-killed oaks with large roots but stunted stems) that we commonly seed today despite fire. With oak seedlings being a preferred browse for white-tailed deer (Pendergast et al. 2015), they and elk may have contributed to this suppression. Finally, Native Americans promoted mast trees by girdling competing hardwoods (Abrams & Nowacki 2008). Could they have also selectively released individual oaks similarly to the modern "crop tree release"?

In the presence of frequent fire, oaks maintained their dominance relative to mesophytic trees through fire adaptations including thick bark, root before shoot growth, and hypogeal germination with underground root collars and meristems. Bur oak are the most fire tolerant of the oaks found at Nachusa and white oaks (group) are more fire tolerant than red due to tyloses, which compartmentalize fire injuries. Oak savannas are thought to have had a historical Fire Return Interval of 1-3 years[3] but irregular with interruptions allowing oaks to recruit into the canopy. A frequent FRI without variability favors prairie. This regime maintained the 10-30% savanna canopy cover[4]. Fire-free intervals of 10-30 years allowed maturation of oak seedlings and grubs (Dey & Kabrick 2015). Unexplained is why these long periods without fire would have occurred in a regime of annual or near-annual anthropogenic fire. Similarly, the difficulty with which fire opens canopies in mature stands (often taking decades) raises the question of why woodlands did not grow up in these fire-free intervals from the numerous grubs and seedlings often seen in oak clearings with sufficient light. The historical fire regime is less important than the regime needed currently to suppress mesophytes. Woody encroachment into grasslands is increasing in recent years despite prescribed fire. Seed rain from fragmented landscapes, increased carbon dioxide and nitrogen, and changing precipitation patterns may all contribute (Helzer 2014).

High plant diversity along with structural heterogeneity promotes increased diversity in invertebrates, small mammals, birds, and herpetofauna (Dey & Kabrick 2015). The savanna supports grassland birds, some woodland birds that do not require closed canopy, and characteristic savanna birds such as eastern kingbird, eastern bluebird, Bell's vireo, orchard oriole, and barn owl (Barrioz et al. 2013; Packard & Cornelia 1997). The savanna will also continue to support the more than 500 species associated with oaks, including leaf beetles, woodland-conservative ants, wasps, and lepidopterans (Wilhelm & Rericha 2017; Tallamy 2009). Savanna species listed by the Illinois State Wildlife Action Plan as "critical" include wood frog, blue-spotted salamander, black-billed cuckoo, red-headed woodpecker, and northern flicker (Fahey et al. 2015).

Savanna restoration is complex given the dynamic equilibrium between tree mortality and ingrowth to maintain both trees and grassland and there is a tension between needing frequent fire to maintain open conditions and longer fire intervals to allow ingrowth (Peterson & Reich 2001). This precarious equilibrium makes oak savannas inherently unstable, with Q. alba particularly prone to shift towards woodland conditions by its tendency to spread through seed rain (Brudvig & Asbjornsen 2008).

SWOT Analysis

Strengths:

The site has several open-grown white oaks. Invasive species pressure is predominantly bush honeysuckle with lesser amounts of autumn olive. These can be controlled with basal bark herbicide throughout the cooler months and suppressed with regular fire. Lower productivity (sandy) soil may limit the abundance of herbaceous invasive plants and should favor native groundlayer species better adapted to this soil. Mid and understory at the site and surrounding woodlands are predominantly mesophytes and invasives. Removing these will allow some light penetration, however this typically only increases light by about 10-15% (Bowles et al. 2007; Dey & Kabrick 2015). The small prairie planting in the clearing ESE of Site A, an abandoned dolomite quarry, has vegetated nicely after one seeding with minimal invasion, showing the potential for clearing trees and seeding.

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[3] Of the three analyses used for fire history, sedimentary charcoal, soil charcoal, and fire scar, only fire scar has the fine temporal resolution and accurate dating to be used for these short FRIs. However, fire scar analysis is limited to the age of the trees, about 400 years old, meaning most fire histories account for only the years after Native American depopulation (Hart & Buchanan 2012)

[4] This is typically roughly equivalent to a basal area of 30 ft^2/ac. This can also be seen as less than 20 trees per acre with a 20 inch dbh (a woodland has about 20-50 trees per acre this size) (Dey et al. 2017)

Finally, while low in plant species richness, the site is not a monoculture of invasive species or, as found in some degraded sites, Pennsylvania sedge (Nielsen et al. 2003).

Weaknesses:

1. Most of the canopy is shagbark hickory with occasional oaks. The canopy is excessively closed and the canopy trees are large enough that felling will produce a large quantity of logs to lay on the ground or require removal.
2. There is minimal savanna (heliophytic) herbaceous groundlayer currently at the site. Conservative savanna species are unlikely to tolerate prolonged closed canopy conditions either as mature plants or seed or bud bank (Anderson et al. 1999), meaning active restoration with seed will likely be required.
3. Site B has a north-facing aspect, creating more mesic conditions and disfavoring savanna. We are precluded from using the south-facing section of West Holland due to a mature shagbark hickory woodland there without existing oaks.
4. Advanced regeneration—existing seedlings, saplings, stump sprouts and grubs—accounts for most oak regeneration (as opposed to new seedlings) but are largely absent. Addressing this will require a complicated synchronization of thinning and burning, and perhaps planting, discussed below.

Opportunities:

De-mesophication has occurred in other parts of Nachusa, providing insight and seed sources. Nachusa Grasslands is involved in and supportive of savanna restoration in the Stone Barn tract. The site has an engaged steward and volunteers have helped with spraying on work days. We have surplus dry-mesic seed mix this year to use on the site. The Chicago area Forest Preserves also have decades of experience with savanna restoration and can be a resource. There is an annual seed exchange that could be used for additional seeds.

Threats:

1. A leading cause of oak woodland and savanna decline is mesophication due to fire exclusion (Nowacki & Abrams 2008). Mesophication occurs when fire intolerant mesic species such as elm, maple, and black cherry, overtop developing oak seedlings and keep them suppressed in the understory. These species put their energy into rapid growth as seedlings and overtop the oak seedlings, which concentrate their initial growth into their roots to survive fire. Following this shift in tree composition there is positive feedback loop that suppresses fire and promotes mesophytes (at the expense of oak regeneration). Oak leaves are well suited to carry fire—cupped shape for loose stacking, high lignin content, resistant to decay—and oaks give themselves a competitive advantage by promoting fire. The mesophytes, in contrast, suppress fire with limp, tightly packed, rapidly decomposing leaves. Additionally, the dense midstory reduces solar radiation, wind, and temperature while increasing humidity. (Nowacki & Abrams 2008) This state shift requires substantial restoration input to reverse. Simply reintroducing the lost fire regime is insufficient and instead the mesophytes must first be removed for flammable conditions to return. Of note, the Whalam loam section of site A, with less drainage, more SOM, and higher CEC, is largely mesophytic trees without oaks.
2. White-tailed deer have a major impact on groundlayer diversity (e.g. Côté et al. 2004). They also contribute to mesophication by preferentially browsing oak seedlings over mesic species or by mesic species growing above browse height more quickly (Pendergast et al. 2015). Deer also promote invasive species by spreading seeds and remove competing native plants. Loss of native plants to invasive plant competition then concentrates browsing pressure on remaining native plants (Knight et al. 2009). Mesophication also promotes invasive species, which more efficiently capitalize on nutrients and moisture. A 2010 study by Royo et al. found that herbaceous diversity only improved when canopy gaps were created (thinning), fire was introduced, *and* deer density was reduced. Native species are also more prevalent in areas with deer

hunting than without (Rooney et al. 2004). In another study, deer exclosure with canopy gaps doubled the Importance Value (a measure of tree dominance) of oaks compared to thinning alone (Thomas-Van Gundy et al. 2014).

3. Oaks (particularly red oaks) are dying across the region due to oak wilt while white oaks are being lost to Rapid White Oak Mortality (a drought-fungus interaction) (Taft 2020). Additionally, while oaks are resistant to fire, they are not immune. Davis (2021) found ~ 50% burr oak mortality (from all causes but strongly related to diameter, i.e. smaller classes more likely to die from fire) over 25 years of burning. There is a reasonable resistance to felling living oaks even when there are spaced too densely for other objectives. Perhaps once there are sufficient oak saplings, some mature oaks can be safely felled for canopy reduction. Conversely, a greater threat to oak survival (and regeneration) is canopy closure and mesophication so opening canopy ultimately promotes oak persistence.
4. Invasives include amur honeysuckle, autumn olive, garlic mustard, white sweetclover (in the cleared margin adjoining the prairie), multiflora rose (predominately in the cleared areas), ground-ivy (*Glechoma heduracea*), and oriental lady's thumb (*Persicaria longiseta*). Amur honeysuckle dominated the site until recently. It reduces native cover through competition for light and nutrients, increases native tree seedling mortality, and negatively affects animal population through dietary changes (Baker 2019). It may also be allelopathic (Dorning & Cipollini 2005), although I am skeptical of allelopathy studies using extracts and this may be more of laboratory party trick than a real-world phenomenon.

RESTORATION PLAN

GOALS

1. Convert current closed-canopy woodland to savanna with a basal area <30 sqft/acre or 30% canopy cover and grass-dominated groundlayer by three years after project start[5].
2. Achieve high-quality savanna plant community with > 90% native cover and > 100 native species.
3. Achieve oak regeneration with at least 15 oak seedlings/saplings greater than 3 ft tall in the project area by five years after project start.
4. Provide habitat connectivity from prairie to interior of the oak woodlands of Stone Barn Savanna to facilitate movement of species and propagules.

MEASURES

1. Develop indicator species list and assess site (wandering survey) for presence annually. Consider using the Revised Qualitative Rapid Assessment (Appendix H)
2. Percent native cover with species richness every three years for 12 years using existing Brant 2 transects[6]
3. Fixed photo points to assess structure and groundlayer cover over time (Kleiman 2022)
4. Presence of grassland preference birds within site.

[5] Project start will be the control of invasive species the fall prior to initial thinning, i.e. fall 2022.
[6] One of two transects is shown in Appendix G. These are available on the Nachusa shared drive.

INTERVENTIONS

The literature is consistent on the need for invasive species control, thinning (removal) of trees for canopy reduction, frequent prescribed fire, and deer control. How to accomplish this is inconsistent and poorly studied. I will therefore present several options, with current site conditions and local expertise dictating the chosen actions.

1. **Invasive species control:**

   Invasive species should be well-controlled prior to opening the canopy as increased light will promote them. Forestry mulching can be used to remove shrubs (before or after herbicide) and small mesophytic trees as necessary but should be avoided, when possible, to prevent soil disturbance and accidental damage to small oaks. Basal bark spraying of stumps and regrowth the spring after fall/winter cutting have been an effective approach at Nachusa. Basal bark spraying of shrubs followed by cutting (mastication) or burning as also been effective and is preferred when spraying of regrowth will not be accomplished. Basal barking without clearing has an advantage of providing a physical barrier to herbivory of the recovering groundlayer and oak seedlings (Baker 2019). There are not currently extensive invasive herbaceous species (such as garlic mustard) at the site but we will monitor for this and foliar spot spray or pull as needed. An Iowa study (Brudvig 2010) with high pre-treatment native cover (94-97%) had an immediate increase in exotic cover following thinning with native cover falling to 89% before trending upwards again without intervention in the three years after thinning. However, seeding with a diverse seed mix at the time of thinning should provide competition to invasive species (Millikin et al. 2016; Glennemeier et al. 2020; GRN Workshop 2022). We can use our dry-mesic prairie mix and plant in Winter 2022. This should also help ameliorate the soil disturbance caused by thinning.

2. **Tree thinning:**

   Site A is an island of open savanna centered around an existing open grown bur oak and expanded to include oaks to the north, northeast, northwest and south. Thomas-van Gundy et al. (2014) suggest that while silvicultural guidelines for oak regeneration in oak-hickory forests recommend gaps of at least 0.5 acres, 0.01 to 0.2 acres should be enough to perpetuate existing advanced regeneration. The boundary for Site A was determined by a distance from existing oaks that is equal to the canopy diameter of the bur oak (~50 ft or 25 steps) on the basis that old-growth canopy gaps provide sufficient light for oak growth while second-growth canopy gaps do not (Thomas-Van Gundy et al. 2014).

   Multiple studies failed to find a reduction in canopy cover from burning alone or only after several decades (Nielsen et al. 2003; Bowles et al. 2017; Taft 2020; Bassett et al. 2020). Dormant season fires only reliably top-kill stems less than ~5 inches (Dey & Kabrick 2015; Peterson & Reich 2001). Thinning provides light to the groundlayer which promotes floral diversity and fine fuel (grass) to maintain a fire regime, which favors oaks over mesophytes. The sunlight also increases the growth rate and survival of oak seedlings, promoting the persistence of the oak overstory as mature oaks die (Peterson & Reich 2001; Brudvig & Asbjornsen 2005). An Iowa study found dramatically increased growth and survival of Q. alba seedlings after removing all mesophytic trees and large shrubs. However our site is largely devoid of seedlings. Finally, seedlings, will not grow to saplings without thinning (Brudvig & Asbjornsen 2005).

   After the initial fire, thin all midstory trees and as many non-oak canopy trees as can be accommodated on the ground or moved offsite. As many canopy trees that can be safely left standing as snags can be killed by hack-and-squirt or basal bark herbicide the preceding fall. This initial thinning can target 50% canopy cover or a basal area of 45 ft2/acre (the lower end of woodland and well below the current basal area of 80). Prior to the site being burned the second time, two years after the first fire, basal bark treat invasive shrubs and mesophyte regrowth. Less than 50% canopy cover is needed for grass dominance and heliophytic forbs (Dey & Kabrick 2015) but some recommend incremental thinning to avoid excessive invasive species and increased risk of wind or ice damage to trees (anecdotal, citation not found). Brudvig & Asbjornsen (2005) reduced their canopy cover from forest to savanna conditions in one thinning by removing all mesophytes and large shrubs and found 3x greater Q. alba seedling survival in thinned plots than in controls. I leave this decision to Nachusa managers without a recommendation but I lean towards doing the thinning all at once if it can be accomplished.

Following the fire, thin the tree canopy to less than 30% or basal area 30 ft^2/ac. Vander Yacht et al. (2020) found a limited herbaceous groundlayer response at 70% but an exponential increase below 30%. More light will also dramatically increase the growth rate of oak seedlings/ saplings (Brudvig et al. 2011) to a fire-resistant size. Thinning from the current basal area of 110 ft^2/ac at Site B and 80 at Site A to <30 will require either a location to move them to, multiple thinnings over time (delaying development of a savanna community), or a combination of felling and killing but leaving standing. These snags are valuable habitat and at least six snags and three with dbh greater than 10 inches per acre is recommended (KY DFWR; Shaver & MacGowan 2022), however they also create a hazard from falling limbs. Thinning is time consuming, in one restoration it required 240 person-hours for 2.1 acres (Brock & Brock 2004).

If not removed initially, ultimately remove almost all hickory (a few may be retained if they do not increase the basal area above 30). Overly crowded oak removal in areas surrounding the restoration sites should be balanced against the need to retain oak to offset natural mortality from stress, windfall following thinning, injury/ disease, and age. I believe the benefits of thinning oaks outweighs the risk. Aside from improving the health of the current trees with increased light, leaving seedlings shaded we risk losing a future generation of oaks. I suggest removing diseased, damaged, or malformed (e.g. poor canopy or forks, which predispose the tree to rot) oaks, especially those that are suppressing healthier trees. I suggest targeting a mixture of age classes when thinning oaks. Select for white oak and, especially, burr oak, which have greater fire tolerance and lifespan than the red oak group (Peterson & Reich 2001).

If logs are removed from the site, do so when ground is frozen (Brock & Brock 2004; Brudvig & Asbjornsen 2008) and skid on snow or use grapple bucket on skid steer to minimize soil disturbance. Trees could be moved to a landing and offered to neighbors for free firewood.

If interseeding is deemed necessary, and I suspect it will be, Somme Preserves cautions to not thin more area than we have seed for (E. Kojima, 2022, pers. comm.). This problem can be mitigated by using prairie seed for most of the area if the canopy cover is low enough.

3. **Prescribed fire:**

Frequent (annual or biennial) prescribed fires are usually needed to prevent mesophication, suppress woody shrubs, and maintain open savanna conditions. Yander Yacht (2020) found excessive woody understory following thinning and burning in Tennessee and Kentucky and suggests burning prior to the thinning to suppress the small trees and shrubs and to burn in the late growing season (August-September) for better control. Another approach is to wait two years after thinning to allow regrowth and germination of the woody seedbank and to allow oak seedlings to develop their roots and then burn (Brose & Van Lear 1998). The two-year delay also allows mesophyte seeds to germinate and become vulnerable as seedlings to fire. Brose & van Lear suggest that waiting several years between thinning and burning may be “critical” to allow oak to develop roots and avoid “substantial”[7] mortality.

Optimum fire return interval is not clearly established. Peterson & Reich (2001) studied intervals ranging from near annually (eight fires per decade) to exclusion in Minnesota. Three fires per decade (three-year FRI) prevented development of a shrub layer and canopy encroachment. However, they found

[7] In one study 68% of one-year-old red oak seedlings were killed by a spring prescribed fire and 80% of the survivors were top-killed (Johnson & Columbia 1974).

suppressed seedlings and no oak (bur and pin) saplings with one-to-three-year FRIs. Conversely, some sites such as the eastern slope of West Henkle have abundant and crowded oak grubs, far exceeding a desirable density. This is likely due to the weedy nature of black oaks here and full sunlight. The inability to recruit under frequent fire is contradicted by Nachusa's experience of oak seedling survival to > 4" dbh despite annual fire regime (see Heinkel for example), however, this may occur due to full sunlight at these locations. The Savanna Oak Foundation near Madison WI recommends annual burning but do not discuss recruitment specifically. In a Minnesota study where it takes three growing seasons for bur oak saplings to reach a height of 1.5 m, saplings were nearly absent under an annual fire regime (Peterson & Reich 2001). Biennial fires promotes forbs (along with the dominant graminoids) and can result in higher species richness (Tester 1989) while longer FRIs result in increased woody understory. Varying the season of burn will prevent vegetation homogeneity.

I suggest burning once in late fall/ early winter following a year (or more) of herbicide treatment and forestry mulching. The goal is to consume the woody understory to facilitate further tree thinning and spraying of understory regrowth as well as achieve a low intensity fire (select appropriate weather conditions) when fuel loads are high to not damage oaks, while reducing heavy fuels. Then continue to thin in winter as described above. Wait two years to allow regrowth of invasive species and mesophytes (also allowing decomposition of logging debris during this time). If this regrowth is tolerable, however, and there are oak seedlings, I would continue to delay fire to allow seedlings to establish roots. An oak sapling with well-established roots can top-kill from fire but regrow multiple times, waiting for suitable light levels and a break in fires to pursue substantial shoot growth. Oak seedlings are rarely > 1 ft in height under an intact canopy (Dillaway & Stringer 2006) but the shoot may be decades younger than the roots (Thomas-Van Gundy et al. 2014). Brose and van Lear found that oak (species undefined) rootstocks allowed to develop for two years after thinning responded to top-kill by sending up a single vigorous sprout. This improved, single-bole form is more rot resistant and aesthetically pleasing.

Burn biennially for 3-4 fires (Vander Yacht, 2021, pers. comm.) until mesophytes and invasives are adequately controlled. Brose and van Lear (1998) found good mesophyte control with the lowest oak mortality (compared to summer and winter) by burning in spring during late leaf expansion while Burger et al. (2017), Barrioz et al. (2013) and Vander Yacht (2020) recommend late summer (mid-August to late September) for optimal suppression of woody understory, albeit with limited published evidence. Wisconsin DNR found that late August burning killed shrub honeysuckles without resprouting (as well as post oaks so this warrants caution where there are vulnerable seedlings/saplings), unlike spring burning (Meunier et al. 2021). Growing season fire requires at least one and possibly two (anecdotal) years of accumulated fuel.

If there are oak seedlings to protect at the time of fire, I would use late spring, otherwise late summer. The traditional late fall or early spring is an option too of course but I think the other times should be tried. Repeated late spring fires may (I do not know this to be the case) negatively affect cool-season plants and spring ephemerals, however, so also vary burn season. Once mesophytes and shrubs are controlled and there are only/ predominantly oak grubs left, pause fire to allow oaks to grow to 4 in dbh, at which point they should tolerate prescribed fire without top-killing (although top-killing may still occur in trees less than 8 in according to several studies). The amount of time this takes varies by author. From 3-10 years (Burger et al. 2017) to 7-10 years (Vander Yacht, 2021, pers. comm.) to or up to 20-30 years (Dey & Kabrick 2015). Bur oaks may tolerate fire at 12 years of age (Gucker 2011). I found no mention of how often these recruitment periods should be repeated for long-term (centuries) persistence of an oak community. Somme Preserve, working on a small scale, protects young oaks by raking and backburning around them (E. Kojima, 2022, pers. comm.). I support this but it may not be scalable to larger restorations.

Finally, reintroduce regular, low-moderate intensity fire. The fire-free period will result in accumulated fuel. Minimize fire intensity using weather conditions and consider clearing debris from around oaks to prevent loss of oaks (Dey & Kabrick 2015). Finally, our restoration is small and has an active steward and volunteers so control of woody encroachment with fire vs spot spraying with herbicide is less critical if they have time.

4. **Deer Control:**

Set target for deer harvest and monitor harvest with the goal of increasing it. This target can be arbitrary because we will never harvest enough deer to reach historical, sustainable levels (8-14 deer per mi^2 in the Chicago area according to Glennemeier et al. 2020). Lane County Forest Preserves used USDA Wildlife Services to cull deer and achieved a dramatic reduction in browse damage despite only reaching about 50% of their targeted reduction to 15-30 deer per mi^2 (GRN Workshop 2022). Expand the number of hunters with access to the preserve and give preference to the hunters harvesting the highest number of does. *Hunters Feeding Illinois* accepts donated deer, incentivizing taking more deer than the hunter needs or wants to process. Donation also improves the public perception of deer culling. Illinois does not have an Earn-a-Buck permit program to incentivize killing of does (though Nachusa could implement its own rules). INDR does offer Deer Population Control Permits, which could be a good option outside of hunting season. Consider a bounty or contest to incentivize harvest. Somme preserve protects small oaks by caging them (Kojima, 2022, pers. comm.), again desirable but may not be scalable. If this were to be done, I would pre-assemble 5 ft by 6 in hardware cloth tree tubes with a fragile or degradable seam to avoid constricting the tree.

5. **Planting of savanna species:**

A key question is vegetation response to thinning with bare soil and low-diversity shade-tolerant woodland forbs currently predominant. Some authors have had success without seeding or recommend seeding only for severely degraded sites (e.g. Vander Yacht et al. 2020 and Dey & Kabrick 2015 respectively). Vander Yacht et al (2020) found a 21-fold increase in herbaceous diversity attributed to nearby propagules, dormant buds, and present but infrequent species. They also reported the appearance of conservative species at the end of the study period despite 80 years of canopy closure. In contrast, Nielsen et al. (2003) found minimal groundlayer response with no significant increase in C4 grasses and legumes absent or failing to respond[8] and notes that the studies showing a spontaneous response were done in the 1960s and 1980s, whereas this study was conducted after 70 years of fire exclusion. Fire exclusion was widespread by the 1930s, and probably at the time of Native American genocide, and by now a century or more without fire has passed[9]. Barrioz et al. (2013) also found a depauperate legume response. Glennemeier et al. (2020) seeded annually for “several” years and then as needed (when trees were removed) for a highly successful and persistent restoration. This approach is standard in the Chicago area (Kojima 2022, pers. comm. and Anonymous, Lane Country Forest Preserves, GRN Workshop, 2022, pers. comm.). Whether the site should be seeding and when can be based on species present in existing clearings and roadsides near the site (do these resemble a savanna or prairie community?) (GRN Workshop 2022), seed/bud bank response to previous thinnings on the preserve, and coordination with other management actions. Saxton (2012) studied germination of the seed bank in Brant and germinated 21 species. 64% of the germinants were white snakeroot, sedges, or black medic. While native seeds,

[8] Legumes are an indicator of intact nutrient cycling and a precursor, along with C4 grasses, for establishment of certain other species as well as for multiple ecosystem functions (E. Bach, Nachusa, 2022, pers. comm.)

[9] The bud bank currently seems to be thought to contribute more to ongterm persistence of plants than the seed bank but little is known about the longevity of buds (Ott et al. 2019).

especially woodland seeds, have inconsistent germination, these results are not encouraging. Given the lack of diversity on site currently and invasive pressure. It would be prudent to seed after thinning with 5 lbs/acre dry-mesic prairie mix. This will provide a native groundlayer matrix to which savanna species can be added later.

Removal of leaf litter, which inhibits germination, with fire should be done prior to seeding. Seeding with equipment will be difficult if there are downed logs on site while seeding before thinning will result in seeds being buried or moved by logging debris. Seeding at the time of thinning (vs waiting a year or two for seed/bud bank response) to inhibit invasive species is highly recommended by the Poplar Creek Prairie Stewards/ Cook County Forest Preserves (GRN Workshop 2022) if the desired species are not already present around the site. Brock & Brock (2004) report “excellent” establishment of seeded species in newly cleared areas in Wisconsin. Glennemeir seeded an 129 species mix annually followed by lower diversity seedings in small areas as needed. Some shrubs, especially hazelnut, were natural in fire-protected areas of savannas. These should be planted. Presently rare savanna species with limited seed sources, such as purple milkweed, can be planted as plugs. Appendix E is a seed mix of species present at Nachusa and included in lists of typical species or surveyed remnants in Illinois. Most of these species are shade-tolerant and have scarce seeds so I would plant these under the tree canopies and slightly north (i.e. shaded). Spring ephemerals should be planted immediately after harvest. The unshaded areas can be planted with a mesic or dry-mesic prairie mix. While the savanna grassland understory is a distinct community from prairie (Packard 1983), I believe there is enough overlap that this will provide a suitable matrix. If seeds are limited, priority can be given to seeds that are under-represented in degraded savannas. These include heliophytes (i.e. prairie species), conservative species, and dispersal-limited species, i.e. those with passive dispersal, ant dispersal, or heavy wind-dispersed seed (Brudvig & Mabry 2008).

White oak seed rain will serve to fill in the empty space of Site B and add oaks to the NE corner of Site A. However, the excessive amount of oak woodlands with the expansion of white oak into the open space limits our landscape diversity and should be managed against. I therefore recommend planting bur oaks throughout the empty areas. Either in the first year after planting or after invasive shrubs have been adequately controlled such that fire can be paused for a couple years. Somme Preserves sometimes plants acorns (Kojima 2022, pers. comm.). One of our volunteers inadvertently but successfully established a stand of bur oaks by leaving a bucket of acorns on his porch where the squirrels found them and planted them[10]. Oak seedlings were successfully established at Nachusa in Hook Larson by planting acorns with a dibble bar. Plant every few steps as few acorns will establish. Start planting further from the mature oaks to have adequate acorns where they are needed. If appropriate ecotype is available, bare root seedlings are a more reliable approach and if the roots are short enough a dibble bar does this quickly. Growth of seedlings under parent trees can be minimal and one study suggested transplanting seedlings to inter-canopy gaps (Brudvig & Asbjornsen 2005). One final consideration for oak regeneration is avoiding fire during mast years after acorn drop as the fire kills the acorns (Nation et al. 2021).

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[10] Presumably they neglected to excise the embryos when presented with such a time-sensitive bounty. Does caching without embryo removal occur during mast years? Does the squirrel population in Stone Barn Savanna affect oak regeneration? Would hunting them during mast years have an effect?

Timeline[11]

	Fall Year 0	Winter Year 1	Spring Year 1	Fall Year 1	Spring Year 2	Fall Year 2	Winter Year 2	Spring Year 3	Fall Year 3	Late Spring Year 4	Late Spring Year 6	Fall Year 7	Spring Year 17
Activities	**Planned Date**	Dec. 2022	Apr. 2023	Nov. 2023	Apr. 2024	Nov. 2024	Jan. 2025	May 2025	Nov. 2025	May 2026	May 2028	Nov. 2029	Mar. 2039
Delineate project area	11/1/2022												
Basal bark	11/26/2022												
Hack-and-Squirt	11/1/2022												
Forestry mulch	10/21/2022												
Fire													
Tree Felling													
Seeding													
Plugs													
Deer Harvest (annual)													

Add date completed in cells

Peri-Restoration Adverse Ecological States

There is less experience with savanna restoration than prairie restoration and modifying vegetation composition, light (and moisture) levels, and invasive species abundance within an existing ecosystem entails more dynamism and complexity, and accordingly less predictability, than prairie reconstruction on row crop fields. Therefore, I include several possible adverse community states that may occur in response to restoration, with corresponding interventions (in no particular order).

State 1—Invasive Plants/ Woody Understory Uncontrolled after Initial Herbicide and Fire

Description: Honeysuckle may persist or new waves of invasive species (such as autumn olive seen in adjacent restoration) continues to outcompete native herbaceous groundlayer species. Increased light may dramatically increase invasive species and *Rubus spp.*

> Intervention 1.1: Retreat with basal bark herbicide followed by cutting and fire as needed. Cost of fire is delayed oak recruitment with repeated top-killing.
>
> Intervention 1.2: Interseed native species after fire.
>
> Intervention 1.3: If using dormant season fire, switch to growing season.

State 2—Lack of Native Plant Cover or Diversity

Description: A depauperate seed/ bud bank from decades of invasive shrub dominance and canopy closure and lack of nearby savanna propagule source may result in minimal groundlayer response to thinning or response only by ruderal species (which has a longer persisting seed bank (Ma et al. 2021)).

> Intervention 2.1: Interseed following fire using prairie mix and savanna mix in Appendix E.

[11] Adjust according to observed conditions.

State 3—Failure to Restore Heliophytic Groundlayer

Description: The site has been heavily shaded and dominated by woodland forbs (and invasive shrubs) for decades. The savanna seed and bud bank is likely depauperate. Opening canopy and increased light may be insufficient for restoring the savanna groundlayer.

Intervention 3.1: Interseed annually with prairie mix after prescribed fire

Intervention 3.2: Reduce canopy cover.

State 4—Insufficient grass or oak leaf litter to carry fire

Description: Groundlayer is not yet established and oaks are too far apart for adequate litter and fire is needed for woody control.

Intervention 4.1: Thin canopy further (ensure <50% for grass)

Intervention 4.2: Mow standing vegetation to create fuel

Intervention 4.2: Consider oat (fall) or millet (summer) nurse crop while native grasses establish.

State 5—Limited Oak Recruitment

Description: Lack of oak germination or recruitment into larger size classes may result from existing oaks being over-mature with decreased acorn production, browsing of seedlings by white-tailed deer, or top-killing by frequent fire.

Intervention 5.1: Pause prescribed fires for as long as system will tolerate, ideally up to ~10 years, without mesophication or reinvasion, until oak saplings are > 4-inch dbh.

Intervention 5.2: If fire rest is not possible extend Fire Return Interval as tolerated.

Intervention 5.3: Protect oaks < 4-inch dbh from fire by some combination of clearing fuels around them, wetting around them, low intensity fire, or steel culvert pipe.

Intervention 5.4: Drought stress has been found to increase fire mortality for Ponderosa Pine saplings, (another fire-adapted tree) (Partelli-Feltrin et al. 2020). Consider burning soon after precipitation.

Intervention 5.4: Ensure gaps of at least 0.1 to 0.2 acres are present for sufficient sunlight for oaks to recruit into overstory.

Intervention 5.5: Plant acorns or bare root seedlings.

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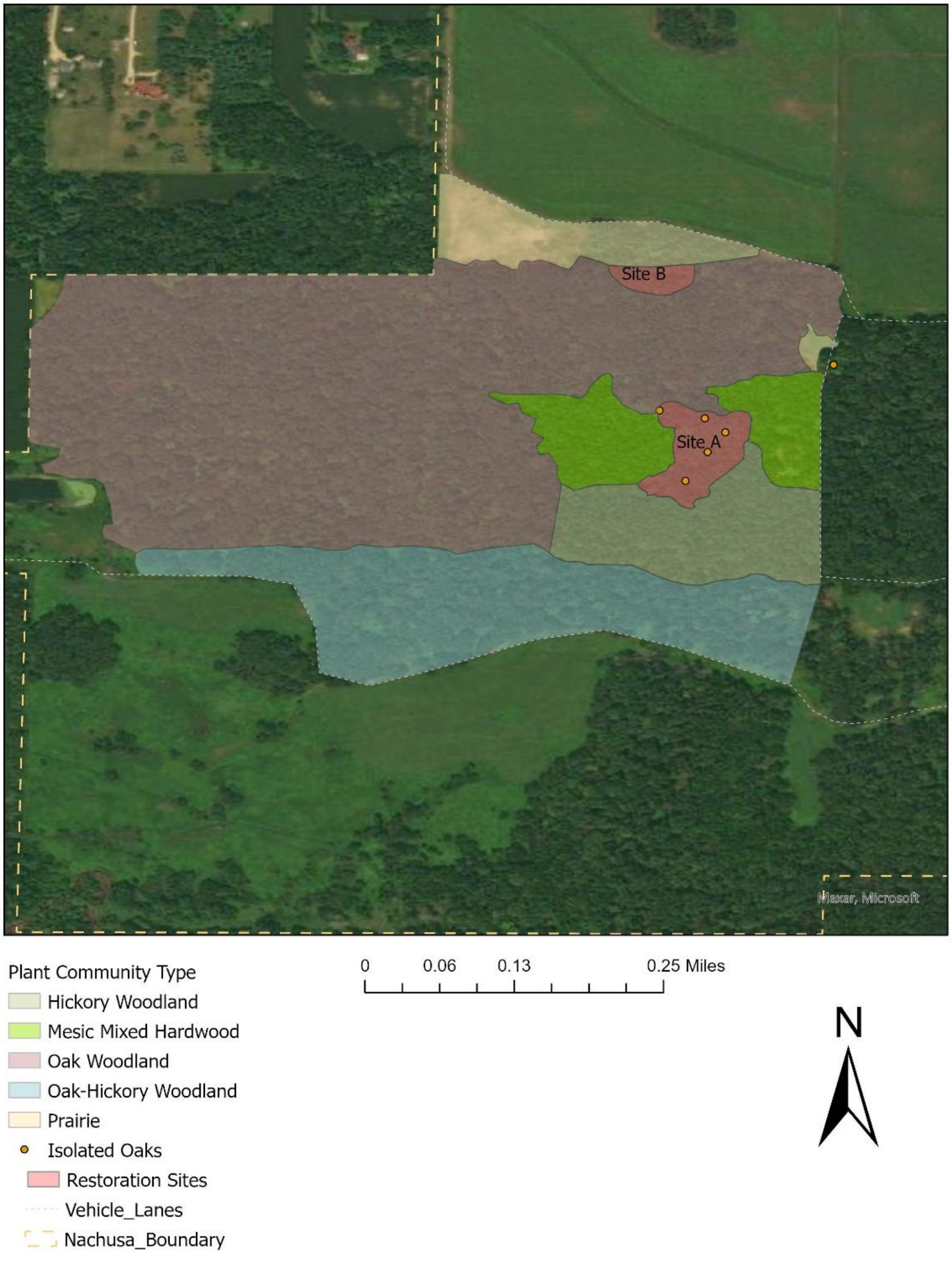
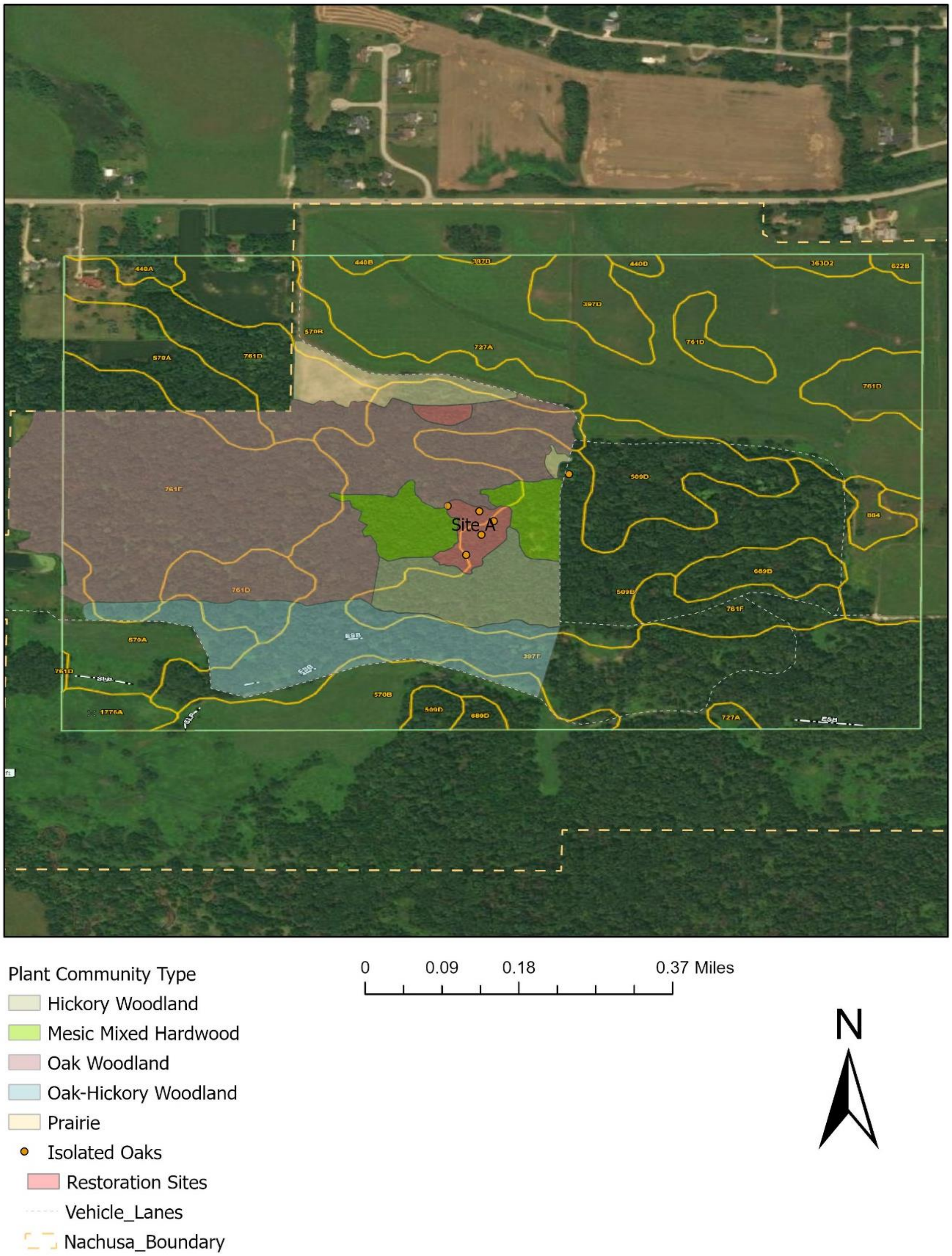
APPENDICES

Appendix A—Site Map



Appendix B—Soil Map (Data Source: Web Soil Survey)



Appendix D—Sampling of Woody Species and Basal Area (Saxton 2012)

Table 1 – Point Centered Quarter sampling results from Brandt. Asterisks denote species not found in Bennett. ^ Denotes introduced species.

Species	Species Density	Relative Density stems/ha	Basal Area per Hectare	Relative Basal Area	Dominance
Carya ovata	319.47	37.41	12.47	45.39	82.80
Ulmus rubra	238.50	27.93	2.35	8.55	36.48
Quercus alba	42.69	5.00	6.67	24.27	29.27
Prunus serotina	103.05	12.07	0.59	2.14	14.21
Maclura pomifera^	48.58	5.69	1.80	6.55	12.24
Quercus rubra	16.19	1.90	1.83	6.65	8.54
Quercus macrocarpa	2.94	0.34	1.09	3.98	4.32
Celtis occidentalis	23.56	2.76	0.19	0.68	3.44
Carya cordiformis	17.67	2.07	0.12	0.42	2.49
Rhamnus carthartica^	13.25	1.55	0.06	0.21	1.76
*Lonicera maackii**^	8.83	1.03	0.02	0.07	1.11
*Butula pendula**	2.94	0.34	0.15	0.53	0.87
*Populus grandidentata**	2.94	0.34	0.09	0.34	0.68
*Ptelea trifoliata**	4.42	0.52	0.02	0.06	0.58
*Morus alba**^	1.47	0.17	0.02	0.09	0.26
Fraxinus americana	1.47	0.17	0.01	0.03	0.20
*Crataegus mollis**	1.47	0.17	0.00	0.02	0.19
*Fraxinus pennsylvanica**	1.47	0.17	0.00	0.02	0.19
Viburnum prunifolium	1.47	0.17	0.00	0.01	0.18
*Gleditisia triacanthose**	1.47	0.17	0.00	0.01	0.18
Total	**853.88**	**100.00**	**27.48**	**100.00**	**200.00**

Appendix E—Vegetation Sampling Species List (Saxton 2012)

Agastache nepetoides	*Menispermum canadense*
Agrimonia gryposepala	*Osmorhiza longistylis*
Agrimonia parviflora	*Oxalis stricta*
Alliaria petiolata	*Parthenocissus quinquefolia*
Amphicarpa bracteata	*Pilea pumila*
Arisaema triphyllum	*Phalaris arundinacea*
Aster shortii	*Phryma leptostachya*
Botrychium virginianum	*Plantago rugelii*
Carex sp.	*Poa sp.*
Carex blanda	*Podophyllum peltatum*
Carex grisea	*Polygonum sp.*
Carex jamesii	*Polygonum virginianum*
Carex rosea	*Potentilla simplex*
Carex sparganoides	*Prunus serotina*
Carya cordiformis	*Quercus alba*
Carya ovata	*Quercus rubra*
Celtis occidentalis	*Ranunculus recurvatus*
Circaea lutetiana	*Rhamnus cathardica*
Cryptotaenia canadensis	*Rhus radicans*

Ellisia nyctelea *Elymus villosus* *Eupatorium purpureaum* *Eupatorium rugosum* *Festuca obtusa* *Galium aparine* *Galium circaezans* *Galium concinnum* *Galium triflorum* *Geranium maculatum* *Geum canadense* *Glechoma hederacea* *Gleditsia triacanthos* *Hackelia virginiana* *Hydrophyllum virginianum* *Lonicera maackii* *Maclura pomifera*	*Ribes missouriense* *Rosa multiflora* *Rubus allegheniensis* *Sanicula gregaria* *Smilax lasioneura* *Smilax tamnoides* *Solidago canadense* *Solidago ulmifolia* *Stachys tenuifolia* *Taraxacum offininale* *Trillium recurvatum* *Triosteum aurantiacum* *Ulmus rubra* *Viburnum prunifolium* *Viola pubescens* *Viola sororia* *Vitis ripara*

Appendix E—Nachusa Savanna Seed Mix[12]		
Scientific Name	**Common Name**	**CC**
Actaea pachypoda	white baneberry	8
Agalinis tenuifolia	slender false foxglove	3
Agastache nepetoides	yellow giant hyssop	5
Agastache scrophulariifolia	purple giant hyssop	5
Ageratina altissima	white snakeroot	3
Allium canadense	wild onion	3
Ambrosia artemisiifolia	common ragweed	0
Amorpha canescens	lead plant	10
Amphicarpaea bracteata	upland hog peanut	5
Andropogon gerardii	big bluestem	5
Anemone quinquefolia	wood anemone	7
Anemone virginiana	eastern tall anemone	5
Antennaria neglecta	woolly cats foot	3
Antennaria plantaginifolia	pussytoes	4
Apocynum androsaemifolium	spreading dogbane	5
Apocynum sibiricum	smooth indian hemp	2
Aralia nudicaulis	wild sarsaparilla	8
Arisaema dracontium	green dragon	6
Arisaema triphyllum	jack-in-the-pulpit	5
Arnoglossum atriplicifolium	pale indian plantain	8
Asclepias exaltata	poke milkweed	10
Asclepias purpurascens	purple milkweed	8
Asclepias tuberosa	butterfly weed	8
Asclepias verticillata	whorled milkweed	1

[12] From (Wilhelm & Rericha 2017; Packard & Cornelia 1997; Anderson et al. 1999)

Astragalus canadensis	canadian milkvetch	8
Aureolaria grandiflora var. pulchra	yellow false foxglove	10
Aureolaria pedicularia	clammy false foxglove	7
Baptisia lactea	white wild indigo	8
Besseya bullii	kitten tails	10
Botrypus virginianus	rattlesnake fern	5
Brachyelytrum erectum	short-awned wood grass	9
Bromus kalmii	prairie brome	10
Bromus pubescens	woodland brome	10
Camassia scilloides	wild hyacinth	7
Campanulastrum americanum	tall bellflower	4
Carex blanda	common wood sedge	1
Carex cephalophora	short-headed bracted sedge	5
Carex cristatella	crested oval sedge	4
Carex festucacea	fescue oval sedge	9
Carex hirtifolia	hairy wood sedge	5
Carex jamesii	grass sedge	5
Carex normalis	spreading oval sedge	5
Carex pensylvanica	common oak sedge	5
Carex rosea	curly-styled wood sedge	5
Ceanothus americanus	new jersey tea	8
Celastrus scandens	climbing bittersweet	4
Chenopodium standleyanum	woodland goosefoot	5
Circaea canadensis	enchanters nightshade	3
Cirsium discolor	pasture thistle	3
Claytonia virginica	spring beauty	4
Comandra umbellata	false toadflax	9
Coreopsis palmata	prairie coreopsis	10
Crataegus coccinea	scarlet hawthorn	5
Crocanthemum bicknellii	pinweed rockrose	8
Danthonia spicata	poverty oat grass	3
Dasistoma macrophylla	mullein foxglove	8
Desmodium canadense	showy ticktrefoil	4
Desmodium illinoense	illinois ticktrefoil	9
Desmodium paniculatum	panicled ticktrefoil	6
Dichanthelium latifolium	broad-leaved panic grass	8
Dioscorea villosa	wild yam	5
Dodecatheon meadia	shooting star	6
Echinacea purpurea	purple coneflower	10
Elymus canadensis	canada wild rye	4
Elymus riparius	riverbank wild rye	5
Elymus villosus	silky wild rye	5
Elymus virginicus	virginia wild rye	3
Erigeron pulchellus	robins plantain	8
Erigeron strigosus	daisy fleabane	5
Erythronium albidum	white trout lily	5
Eupatorium perfoliatum	common boneset	4

Euphorbia corollata	flowering spurge	4
Eutrochium purpureum	purple joe pye weed	6
Festuca subverticillata	nodding fescue	5
Fragaria virginiana	wild strawberry	0
Galium boreale	northern bedstraw	10
Galium concinnum	shining bedstraw	7
Galium triflorum	sweet-scented bedstraw	5
Gaura longiflora	common gaura	2
Gentiana alba	yellowish gentian	9
Gentianella quinquefolia subsp. occidentalis	stiff gentian	8
Geranium maculatum	wild geranium	5
Geum canadense	white avens	1
Helianthus divaricatus[13]	woodland sunflower	5
Helianthus grosseserratus	sawtooth sunflower	4
Helianthus hirsutus	hispid sunflower	7
Helianthus occidentalis	western sunflower	10
Heliopsis helianthoides	false sunflower	7
Heuchera richardsonii	prairie alum root	10
Hieracium gronovii	hairy hawkweed	8
Hieracium scabrum	rough hawkweed	7
Hydrophyllum virginianum	virginia waterleaf	5
Hylodesmum glutinosum	pointed ticktrefoil	7
Hypericum punctatum	spotted st johns wort	4
Hypoxis hirsuta	yellow star grass	8
Hystrix patula	bottlebrush grass	5
Iris virginica var. shrevei	blue flag	5
Krigia biflora	false dandelion	9
Lactuca canadensis	wild lettuce	1
Lactuca floridana	wood lettuce	8
Leersia virginica	white grass	5
Lespedeza capitata	round-headed bush clover	4
Lespedeza virginica	slender bush clover	7
Liatris scariosa var. nieuwlandii	savanna blazing star	9
Lithospermum croceum	hairy puccoon	8
Lithospermum latifolium	american gromwell	10
Lobelia siphilitica	great blue lobelia	4
Lobelia spicata	pale-spiked lobelia	4
Menispermum canadense	moonseed	5
Moehringia lateriflora	wood sandwort	8
Monarda fistulosa	wild bergamot	4
Muhlenbergia mexicana	wood satin grass	5
Napaea dioica	glade mallow	4
Osmorhiza claytonii	hairy sweet cicely	4

[13] Somme Preserves has found woodland sunflowers to be aggressive and dominant, keep seed quantity low or do not include in mix (http://woodsandprairie.blogspot.com/2022/12/the-battle-of-aggressive-sunflower.html)

Oxalis violacea	violet wood sorrel	8
Oxypolis rigidior	cowbane	8
Panicum virgatum	switch grass	3
Parthenocissus quinquefolia	virginia creeper	4
Pedicularis canadensis	wood betony	9
Phlox divaricata	woodland phlox	5
Phlox pilosa	sand prairie phlox	8
Phryma leptostachya	lopseed	6
Physostegia virginiana	obedient plant	4
Podophyllum peltatum	mayapple	4
Polemonium reptans	jacobs ladder	8
Polygonatum biflorum	smooth solomons seal	4
Potentilla simplex	common cinquefoil	3
Prenanthes alba	white lettuce	5
Pycnanthemum virginianum	common mountain mint	5
Ratibida pinnata	yellow coneflower	4
Rosa carolina	pasture rose	5
Rudbeckia hirta	black-eyed susan	1
Rudbeckia subtomentosa	sweet black-eyed susan	8
Rudbeckia triloba	brown-eyed susan	1
Sanguinaria canadensis	bloodroot	5
Sanicula canadensis	canadian black snakeroot	5
Sanicula marilandica	black snakeroot	5
Schizachyrium scoparium	little bluestem	5
Scrophularia lanceolata	early figwort	4
Scutellaria ovata	heart-leaved skullcap	9
Silene stellata	starry campion	6
Silphium integrifolium	rosinweed	5
Sisyrinchium albidum	common blue-eyed grass	6
Sisyrinchium angustifolium	stout blue-eyed grass	5
Smilacina racemosa	feathery false solomons seal	5
Smilacina stellata	starry false solomons seal	5
Smilax lasioneura	common carrion flower	5
Solidago juncea	early goldenrod	3
Solidago nemoralis	old-field goldenrod	3
Solidago speciosa	showy goldenrod	8
Solidago ulmifolia	elm-leaved goldenrod	5
Sorghastrum nutans	indian grass	5
Symphyotrichum drummondii	drummonds aster	3
Symphyotrichum ericoides	heath aster	6
Symphyotrichum lateriflorum	calico aster	4
Symphyotrichum ontarionis	ontario aster	5
Symphyotrichum shortii	shorts aster	7
Taenidia integerrima	yellow pimpernel	10
Tradescantia ohiensis	common spiderwort	3
Trillium recurvatum	prairie trillium	5
Triosteum aurantiacum	early horse gentian	5

Triosteum perfoliatum	late horse gentian	4
Uvularia grandiflora	bellwort	7
Veronicastrum virginicum	culvers root	8
Vicia americana	american vetch	4
Viola pedata var. lineariloba	birds foot violet	9
Viola pedatifida	prairie violet	9
Viola sororia	common blue violet	3
Zizia aurea	golden alexanders	5

Appendix F— Fixed transect surveys of existing savanna/woodland at Nachusa Grasslands (Bach & Kleiman 2021)
Savanna: P08
Phytolacca americana
Parthenocissus quinquefolia
Brachyelytrum aristosum
Pilea pumila
Antenoron virginianum
Brachyelytrum erectum
Solidago ulmifolia
Ulmus rubra
Rubus allegheniensis
Carex rosea
Ageratina altissima
Galium circaezans
Circaea canadensis
Sanicula odorata
Savanna: P24
Hystrix patula
Arctium minus
Ambrosia trifida
Urtica gracilis
Cryptotaenia canadensis
Leonurus cardiaca
Fallopia scandens
Chenopodium album
Verbesina alternifolia
Lactuca floridana
Viola sororia
Agastache nepetoides
Symphyotrichum shortii
Alliaria petiolata
Rubus occidentalis
Carex blanda
Geum canadense
Festuca subverticillata
Savanna P39
Lonicera maackii

Cirsium discolor
Ulmus americana
Cirsium arvense
Conyza canadensis
Campanulastrum americanum
Rubus pensilvanicus
Elymus villosus
Solidago canadensis
Eutrochium purpureum
Ratibida pinnata
Rosa multiflora
Cornus racemosa
Plantago rugelii
Phryma leptostachya
Celtis occidentalis
Poa compressa
Leersia virginica
Smilax lasioneura
Taraxacum officinale
Carya cordiformis
Savanna: P41
Carex pensylvanica
Dichanthelium oligosanthes
Carex vulpinoidea
Poa pratensis
Sorghastrum nutans
Koeleria macrantha
Schizachyrium scoparium
Tephrosia virginiana
Comandra umbellata
Echinacea pallida
Dichanthelium implicatum
Ambrosia psilostachya
Liatris aspera
Quercus velutina
Tradescantia ohiensis
Coreopsis palmata
Penstemon pallidus
Euphorbia corollata
Erigeron strigosus

Appendix G–Brant 2 Transect (1 of 2) plant survey.

Site: Brandt2 Transect #2 -- Runs E-W		GPS	
Date: September 16, 2009		Start:	N 41.89618 W 89.37193 Acc. 17ft
Samplers: Cody Considine and Brian Glaves		End:	N 41.89595 W 89.37302 Acc. 15ft

SU		1N	2S	3N	4S	5N	6S	7N	8S	9N	10S	11N	12S	13N	14S	15N	16S	17N	18S	19N
SPECIES	**Conservation Value (SW)**																			
Galium aparine	1			35	2										12	1				
Beggars Lice sp. (Stickyweed?)		17						7	5		3	2	4	5	7					7
Carex sp. #1			5		5		10	5					60	7	3		3	3		
Carex sp. #2																			12	
Prunus serotina	1							1		1			1		5	3	3	1		2
Plantago major		7			1															
Glechoma hederacea micrantha																		3	3	5
Ulmus sp.	3.5				TREE				TREE					1	1	1		2	3	
Pteridium aquilinum latiusculum	5					1														
Alliaria petiolata (officinalis)																	5			
Ribes missouriense	5		5							10		3				5		3	20	
Smilax rotundifolia	7										7									
Lonicera sp.				30	25	25			15	85	7	85	12	67			1			1
Polygonum (Tovara) virginanum	2	1	10	12		5	2	3	3				6	7	7	2	45	35		25
Trifolium campestre (procumbens)										1										
Festuca obtusa (subverticillata)	5	5					5	5	10							7				
Carex pennsylvanica	5																			
Rhus (Toxiodendrcon) radicans	2	2			1	5	15	3	2	1	3	15	5	15			2			
Xanthoxylum americanum	3																			
Daucus carota								1		1										
Eupatorium rugosum	4	35	7	50	57		35	5	10	1	45	7		7				5	7	12
Unknown grass		12																		
Unknown Propeller sp.											5	5								
Unknown Native (Picture)										2										
Unknown meadow rue				5	2					5							3		7	
Viola sororia	3		5		1		5			3		1	3			1				
Parthenocissus quinquefolia	2					7	1	3		1			1	1				3	1	
Trifolium repens											2									
Vitis riparia	2											2								
	Number of species/quadrant	7	5	5	8	5	7	9	6	11	7	8	8	8	6	7	7	8	7	6

Total C-values	50.5
Total Number of species	15
Average C-value	3.366666667
FQI value	13.03904393

Appendix C—QRA. Citizens for Conservation 2022, my revisions in blue. Original available at https://tnc.box.com/s/t1amflh005fs30yywx2ac65e6l2q9bew and use is described here: https://grasslandrestorationnetwork.org/2022/07/22/restoring-grassland-birds-and-healthy-prairie-at-galloping-hill/

Qualitative Rapid Assessment – Where are we at?

Site: ____

Date: _________________

Observer(s): ____

Please fill out the following for each QRA focus area and include a map showing the area's location within the site.

Barrier Weeds Present or Adjacent:

Characterize the area generally:

Matrix species abundance:

Conservative species abundance:

Relevant management history or site history:

Other notes such as bare soil, wildlife use, etc:

Management actions needed	When	With what urgency

QRA Value: _________

Any additional explanation for QRA Value:

QRA Guide

0 – Restoration has not yet started

Typically, these are degraded areas. However, high quality areas may fall into this category if they aren't currently under active management.

1 – Structure: The right shape

Management Focus: Controlling Invasives

1.1 Restoration has started (barrier weeds are abundant, otherwise mostly weedy species present).

1.2 Restoration in progress, heavy focus on barrier weeds (barrier weeds are abundant but not everywhere; few native species present).

1.3 Barrier weeds under control but still not many native species; may be primarily bare ground, dead weeds, or annual weeds. Ready for seeding.

2— Composition: the right species

Management Focus: Seeding

2.1 Native matrix established, forbs present but widespread, perennial weeds only scattered. Barrier Weeds may be present but are no longer the primary management focus. Annual or biennial weeds may be prevalent.

2.2 Forbs becoming more diverse and uniform across site, weeds widely dispersed.

2.3 Plant communities diverse and rich across site.

3— Process: Ecosystem integrity allows natural processes to maintain a healthy state

Management Focus: Maintaining (ideally with fire)

3.1 Only fine-tuning left, many conservative forbs and graminoids. Any invasive weeds can be controlled through fire or infrequent manual control.

3.2 Fire maintainable, only scattered weeds, species diversity nearly complete.

3.3 Fully fire maintainable, all expected species are present.

4—*Function: The right relationships (energy and nutrient cycling)*

Management Focus: De-escalation (reduce fire frequency, reintroduce missing fauna)

4.1 Some ecosystem-typical animals present.

4.2 Herbivory and predation (e.g. birds diving for insects) observed. The site is teeming with faunal sound and movement. *Annual* fire no longer needed to control woody encroachment or exotic cool-season grasses.

4.3 Multiple phyla of fauna present including rare, conservative, or dispersal-limited species.

Barrier Weeds, Matrix Species, and High-quality Indicator Species for BGI Sites

PRAIRIE	
Barrier Weeds	
Cirsium arvense	Canada thistle
Dipsacus spp.	Teasel
Lotus corniculatus	Bird's Foot Trefoil
Melilotus spp.	Sweet Clover
Pastinaca sativa	Wild Parsnip
Phalaris arundinacea	Reed Canary Grass
Securigera varia	Crown Vetch
*Solidago altissima**	Tall Goldenrod
**Seeding can begin while working to eradicate*	
Matrix Species	
Bouteloua curtipendula (dry)	Side-oats grama
Coreopsis palmata	Prairie Coreopsis
Eryngium yuccifolium	Rattlesnake Master
Heliopsis helianthoides	False sunflower
Monarda fistulosa	Wild Bergamot
Pedicularis canadensis	Wood betony
Ratibida pinnata	Yellow coneflower
Schyzicharium scoparium	Little Bluestem
Silphium spp.	Silphiums
Sporobolus heterolepis	Prairie Dropseed
High-quality Indicator Species	
Asclepias sullivantii	Prairie milkweed
Asclepias viridiflora (dry)	Short Green Milkweed
Carex meadii	Mead's Sedge
Ceanothus americanus	New Jersey tea
Comandra umbellata	Bastard Toadflax
Dichanthelium leibergii	Leiberg's Panic Grass
Dichanthelium scribnerium (dry)	Scribner's Panic Grass
Dodecatheon meadia	Shooting Star
Gentiana puberulenta	Prairie Gentian
Hesperostipa spartea	Porcupine Grass
Heuchera richardsonii	Prairie Alum Root
Hypoxis hirsuta	Yellow Star Grass
Lilium philadelphicum	Prairie Lily
Lithospermum canescens	Hoary Puccoon
Oxalis violacea	Violet Wood Sorrel
Phlox pilosa fulgida	Prairie Phlox
Polygala senega	Seneca Snakeroot
Psoralidium tenuiflorum (dry)	Scurfy Pea
Viola pedatifida	Prairie Violet

SAVANNA	
Barrier Weeds	
Alliaria petiolata	Garlic Mustard
Celastrus orbiculatus	Oriental Bittersweet
Lonicera spp.	Honeysuckle
Phalaris arundinacea	Reed Canary Grass
Rhamnus cathartica	Buckthorn
Securigera varia	Crown Vetch
*Solidago altissima**	Tall Goldenrod
**Seeding can begin while working to eradicate*	
Matrix Species	
Bromus latiglumis	Ear-leaved Brome
Carex pennsylvanica	Penn Sedge
Cinna arundinacea	Common Wood Reed
Elymus spp.	Rye grasses
Pedicularis canadensis	Wood betony
Quercus alba	White Oak
Quercus macrocarpa	Bur Oak
Silene stellata	Starry Campion
Solidago ulmifolia	Elm-leaved Goldenrod
Taenidia integerrima	Yellow Pimpernel
High-quality Indicator Species	
Asclepias purpurascens	Purple milkweed
Brachyelytrum erectum	Short-awned Wood Grass
Ceanothus americanus	New Jersey tea
Cirsium altissimum	Tall Thistle
Dodecatheon meadii	Shooting Star
Gentiana alba	Yellow gentian
Hieracium umbellatum	Canada hawkweed
Krigia biflora	False Dandelion
Lathyrus venosus	Veiny pea
Lilium michiganense	Michigan Lily
Phlox divaricata	Woodland Phlox
Thalictrum thalictroides	Rue anemone

WOODLAND	
Barrier Weeds	
Alliaria petiolata	Garlic Mustard
Celastrus orbiculatus	Oriental Bittersweet
Lonicera spp.	Honeysuckle
Phalaris arundinacea	Reed Canary Grass
Rhamnus cathartica	Buckthorn
Rosa multiflora	Multiflora rose
Matrix Species	
Arisaema triphyllum	Jack-in-the-Pulpit
Bromus pubescens	Woodland Brome
Carex pennsylvanica	Penn Sedge
Carex spp.	Sedge species
Carya ovata	Shagbark Hickory
Cinna arundinacea	Common Wood Reed
Elymus hystrix	Bottlebrush Grass
Elymus spp.	Rye species
Erythronium albidum	Trout lily
Eutrochium purpureum	Purple Joe Pye Weed
Glyceria striata	Fowl manna grass
Leersia virginica	White grass
Quercus spp.	Oaks
Solidago ulmnifolia	Elm-leaved Goldenrod
Trillium recurvatum	Red Trillium
High-quality Indicator Species	
Asclepius exaltata	Poke milkweed
Aureolaria grandiflora var. pulchra	Large flowered false foxglove
Brachyelytrum erectum	Short-awned Wood Grass
Camassia scilloides	Wild Hyacinth
Caulophyllum thalictroides	Blue Cohosh
Diarrhena americana	Beak Grass
Dioscorea villosa	Wild yam
Hepatica acutiloba	Hepatica
Lathyrus ochroleucus	Pale Vetchling
Lilium michiganense	Michigan Lily
Lithospermum latifolium	Woodland puccoon
Phlox divaricata	Woodland Phlox
Silene virginica	Fire Pink
Symphyotrichum shortii	Short's aster
Trillium grandiflorum	Large-flowered White Trillium
Uvularia grandiflora	Bellwort

OPEN WETLAND	
Barrier Weeds	
Lythrum salicaria	Purple Loosestrife
Phalaris arundinacea	Reed Canary Grass
Phragmites austrailis	Common Reed
Schoenoplectus fluviatilis	River bulrush
Typha latifolia	Cattails
Matrix Species	
Acorus calamus	Sweet Flag
Carex pellita	Prairie Wooly Sedge
Carex stricta	Common Tussock Sedge
Carex lacustris	Common Lake Sedge
Carex tribuloides	Awl-fruited oval sedge
Iris virginica var. shrevei	Blue flag
Leersia oryzoides	Rice Cut Grass
Sparganium eurycarpum	Common Bur Reed
High-quality Indicator Species	
Chelone glabra	Turtlehead
Bromus ciliatus	Fringed brome
Caltha palustris	Marsh Marigold
Campanula aparinoides	Marsh bellflower
Cardamine bulbosa	Bulbous spring cress
Gentianella crinita	Fringed Gentian
Lathyrus palustris	Marsh Vetchling
Lilium michiganense	Michigan Lily
Lysimachia quadriflora	Prairie Loosestrife
Lythrum alatum	Winged loosestrife
Mentha arvensis	Wild mint
Oxypolis rigidior	Cowbane
Pedicularis lanceolata	Swamp Betony
Phlox glaberrima interior	Marsh Phlox
Rosa palustris	Swamp rose
Scutellaria galericulata	Marsh skullcap

WOODED WETLAND/VERNAL POND	
Barrier Weeds	
Lythrum salicaria	Purple Loosestrife
Phalaris arundinacea	Reed Canary Grass
Phragmites austrailis	Common Reed
Rhamnus cathartica	Buckthorn
Typha latifolia	Cattails
Matrix Species	
Carex lupulina	Common hop sedge
Carex tribuloides	Awl-fruited oval sedge
Epilobium coloratum	Cinnamon willowherb
Glyceria striata	Fowl manna grass
Iris virginica var. shrevei	Blue flag
Lycopus americanus	Common water horehound
Mimulus ringens	Monkey flower
Penthorum sedoides	Ditch stonecrop
Scutellaria lateriflora	Mad-dog skullcap
High-quality Indicator Species	
Caltha palustris	Marsh Marigold
Chelone glabra	Turtlehead
Glyceria septentrionalis	Floating manna grass
Lilium michiganense	Michigan Lily
Lobelia cardinalis	Cardinal flower
Oxypolis rigidior	Cowbane
Proserpinaca palustris	Mermaid weed
Ranunculus flabellaris	Yellow water crowfoot
Sium suave	Tall water parsnip
Solidago patula	Swamp goldenrod