

M.L. 2016 Project Abstract

For the Period Ending June 30, 2019

PROJECT TITLE: Bluffland Restoration and Monitoring in Winona

PROJECT MANAGER: Neal Mundahl

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FUNDING SOURCE: Environment and Natural Resources Trust Fund

LEGAL CITATION: M.L. 2016, Chp. 186, Sec. 2, Subd. 08h

APPROPRIATION AMOUNT: \$99,000

AMOUNT SPENT: \$92,189

AMOUNT REMAINING: \$ 6,811

Sound bite of Project Outcomes and Results

The 40 acres of dry bluff prairies, bur oak savannahs, and mixed oak-basswood forests within Garvin Heights Natural Area were restored by removing invasive plants (MN Conservation Corps, goat grazing), replanted with native species, monitored to assess recovery, enhanced with signage for visitors, and demonstrated with workshops for regional stakeholders.

Overall Project Outcome and Results

A 40-acre bluffland park in Winona, MN, containing rare dry bluff prairies and bur oak savannahs adjacent to a heavily visited (40,000+ visitors annually) overlook, became overrun with invasive buckthorn and honeysuckle. This project planned to restore the native plant community by 1) surveying the existing plant community, 2) removing invasive plants, 3) planting and seeding native plants, 4) conducting workshops on invasive plant management for the public, and 5) surveying the recovering plant community. Pre-restoration plant surveys indicated low numbers of native plant species. Cutting, treating, and burning by the MN Conservation Corps and browsing by goats (five separate periods over 3 years) were used to help reduce and manage the invasive plants. Native plants were planted and seeded to restore the natural community. During restoration, two public workshops were held to educate area citizens on methods for managing invasive plants on their own lands and restoring native plant communities. Recent plant surveys have documented the presence of 181 species at the site to date, with 127 of those not present before restoration. A large, reproducing population (>600 plants) of a state threatened species, Great Indian Plantain, has developed after buckthorn removal from one area of a savannah. A Winona State University (WSU) graduate student completed a thesis focused on the restoration effort and the workshops, developing a basic management plan for the site moving forward. Restoration efforts will continue, with ongoing management of buckthorn emerging from the seedbank and the germination and spread of newly planted native species. WSU has funded a new graduate assistantship (tuition plus stipend) to continue the restoration and monitoring work at the site. This project, along with new educational signage for the site, will demonstrate to the public the methods and benefits of managing invasive plants on natural habitats.

Project Results Use and Dissemination

1. Throughout the project period, various information about the project was posted on the project web site maintained by Winona State University (<https://www.winona.edu/outdoored/garvin.asp>), on a project-specific Facebook page (<https://www.facebook.com/Garvin-Heights-Natural-Area-Blufflands-Restoration-Project-357534101286304/>), and on the Winona State Biology Department Facebook page (<https://www.facebook.com/biologyWSU/>). The community was informed of upcoming workshop opportunities via hard-copy postings within the community, targeted mailing, Facebook postings, group

email lists, newspaper notifications, and a radio broadcast. Workshops, community presentations, on-site signage, and presentations at regional science meetings further served to present the project and its findings to the public.

2. Prior to site restoration, plant surveys on-site were used to produce a list of species present. In addition, a list species in the WSU herbarium collected from Garvin Heights was generated. (spreadsheets included via email)
3. Presentations about the project and its results were given by the PI (Winona Master Gardeners, Mississippi River Research Consortium) and by several undergraduate students (WSU Ramaley Undergraduate Research Celebration).
4. Graduate student Ryan Walsh recently completed his thesis (Walsh, R. 2019. Garvin Heights Restoration Project. Professional Science Masters Thesis, Winona State University, Winona, MN. 56 p.) that focused on the Garvin Heights project in general, the first workshop, and the effects of goat browsing on buckthorn. Included in his thesis are a series of recommendations for future management at the project site that will form the basis for a future management plan. In the near future, we plan to develop a manuscript from his thesis, on the effects of goat browsing, for submission to a peer-reviewed scientific journal. (thesis included via email)
5. Graduate student Tamberlain Jacobs is creating an up-to-date plant inventory list for the project site. She also is developing a bloom calendar for the site, which will allow visitors to determine what plants may be in bloom at various times of the year. (spreadsheets included via email)



Environment and Natural Resources Trust Fund (ENRTF) M.L. 2016 Work Plan Final Report

Date of Report: August 15, 2019

Final Report

Date of Work Plan Approval: June 7, 2016

Project Completion Date: June 30, 2019

PROJECT TITLE: Bluffland Restoration and Monitoring in Winona

Project Manager: Neal Mundahl

Organization: Department of Biology, Winona State University

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Location: Winona, Wabasha, Olmsted, Fillmore, Houston, Goodhue

Total ENRTF Project Budget:

ENRTF Appropriation: \$99,000

Amount Spent: \$92,189

Balance: \$ 6,811

Legal Citation: M.L. 2016, Chp. 186, Sec. 2, Subd. 08h

Appropriation Language:

\$99,000 the second year is from the trust fund to the Board of Trustees of the Minnesota State Colleges and Universities system for Winona State University to inventory, restore, and monitor the 40-acre Garvin Heights Natural Area in Winona and provide related public outreach and education. Plant and seed materials must follow the Board of Water and Soil Resources' native vegetation establishment and enhancement guidelines. This appropriation is available until June 30, 2019, by which time the project must be completed and final products delivered.

I. PROJECT TITLE: Restoration/Monitoring of Winona's 40-acre Blufflands Natural Area

II. PROJECT STATEMENT:

The 40 acres of dry bluff prairie, bur oak savannah, and bordering oak-basswood forest within Garvin Heights Natural Area will be restored by removing invasive plants (via goat grazing and MN Conservation Corps) and replanting with native species, monitored to assess ecological recovery, enhanced with new and expanded environmental education signage for site visitors, and explained and demonstrated with hands-on workshops for regional landowners and other stakeholders.

This restoration site is of special significance because:

- It contains a mix of dry bluff prairies and bur oak savannahs, ecosystems becoming increasingly rare throughout southeastern Minnesota and the greater Driftless Area Ecoregion.
- It is an accessible, high-visibility location, situated in a City park that attracts 40,000 to 50,000 residents and visitors annually during all seasons.
- It can serve as a model for invasive species management and habitat restoration to a large public audience and provide opportunities for landowner education.
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This project is unique because:

- Under faculty mentorship, undergraduate and graduate students will delineate habitats and collect pre- and post-restoration community data to assess the success of the restoration effort.
- The project will blend innovative (goat grazing) and conventional invasive plant control (with significant public volunteer effort: Friends of the WSU Landscape Arboretum) in a highly visible, public location, allowing the public to observe and experience the entire process.
- It will educate regional landowners and others about invasive plant management via workshops, using the project site as the model and nearby sites for experiential learning/application of techniques.

III. OVERALL PROJECT STATUS UPDATES:

Project Status as of January 1, 2017: *Prior to the beginning of the project period, the Conservation Corps of MN and IA used the project site to train new crew members in chain saw use and safety. As a result, buckthorn and honeysuckle were removed from 0.5 hectare of bur oak savannah. After July 1, major habitat types were delineated via GPS. Plant lists were generated for 1) species currently present on savannah and prairie sites, 2) species seeded on site during various efforts since 2002, and 3) species from the site currently preserved in the Winona State University herbarium. Remaining standing trees in the cleared savannah were identified and measured, and canopy coverage was determined. A herd of 35 goats browsed on buckthorn and honeysuckle for 21 days during fall, eating leaves, shoots, and bark. Informational signage was designed and installed on-site to provide the public with information about the project. A press release to regional news outlets, and interview and photos in a local newspaper, and a presentation to the Winona County Master Gardeners provided additional information to the public. An informational web site is being developed for project postings and updates.*

Project Status as of July 1, 2017: *The Conservation Corps of MN and IA worked at the project site two times during 2017: in January to burn buckthorn brushpiles on the savannah (cut the previous winter), and in May to perform a prescribed burn on savannah and prairie sites. A herd of 70 goats browsed on buckthorn and honeysuckle for 23 days in June. An informational web site was established by Winona State University personnel (<https://www.winona.edu/outdoored/garvin.asp>). The web site now includes photos and updates on the project. Additionally, a Facebook page was created for the project for more rapid communication and posting of project activity photos. Project personnel met with ecological consultants to discuss and plan for upcoming community workshops dealing with invasive species control.*

Project Status as of January 1, 2018: *During 19 days in October, a herd of 60 goats browsed on buckthorn and honeysuckle in savannah and prairie habitats. On July 5, a local newspaper featured the earlier, summer goat browsing with a front-page photo and article that included an interview with the goats' owner. During the fall, two Winona State University biology majors conducted a small mammal survey on the savannah and prairie restoration site. Conservation Corps personnel were unable to perform additional clearing of buckthorn because they were called away to work on hurricane relief in Texas.*

Project Status as of July 1, 2018: *The Conservation Corps of MN and IA returned to Garvin Heights in April to cut and chemically treat buckthorn on the north savannah between the two bluff prairies, where goats had not been willing to penetrate the dense stand of young buckthorn. A herd of 40 goats browsed on buckthorn and honeysuckle in savannah and prairie habitats during three weeks in June. On June 9, Winona State University hosted a 1-day workshop on management of invasive plant species, with a field trip to the Garvin Heights project site.*

Project Status as of January 1, 2019: *The Conservation Corps of MN and IA used propane torches to kill seedling buckthorn and honeysuckle on the south savannah. The crew also cut and piled some dead trees on the savannah for later burning. Plant surveys on cleared savannahs found a large population of Great Indian Plantain, but few other natives. During late fall, the south savannah was seeded with a mix specifically designed for the site.*

Overall Project Outcomes and Results: *A 40-acre bluffland park in Winona, MN, containing rare dry bluff prairies and bur oak savannahs adjacent to a heavily visited (40,000+ visitors annually) overlook, became overrun with invasive buckthorn and honeysuckle. This project planned to restore the native plant community by 1) surveying the existing plant community, 2) removing invasive plants, 3) planting and seeding native plants, 4) conducting workshops on invasive plant management for the public, and 5) surveying the recovering plant community. Pre-restoration plant surveys indicated low numbers of native plant species. Cutting, treating, and burning by the MN Conservation Corps and browsing by goats (five separate periods over 3 years) were used to help reduce and manage the invasive plants. Native plants were planted and seeded to restore the natural community. During restoration, two public workshops were held to educate area citizens on methods for managing invasive plants on their own lands and restoring native plant communities. Recent plant surveys have documented the presence of 181 species at the site to date, with 127 of those not present before restoration. A large, reproducing population (>600 plants) of a state threatened species, Great Indian Plantain, has developed after buckthorn removal from one area of a savannah. A Winona State University (WSU) graduate student completed a thesis focused on the restoration effort and the workshops, developing a basic management plan for the site moving forward. Restoration efforts will continue, with ongoing management of buckthorn emerging from the seedbank and the germination and spread of newly planted native species. WSU has funded a new graduate assistantship (tuition plus stipend) to continue the restoration and monitoring work at the site. This project, along with new educational signage for the site, will demonstrate to the public the methods and benefits of managing invasive plants on natural habitats.*

IV. PROJECT ACTIVITIES AND OUTCOMES:

ACTIVITY 1: Habitat delineation via GPS/GIS, pre- and post-restoration inventory and monitoring of invasive, native, and rare/indicator species, and educational signage development and placement

Description: Dry bluff prairies, bur oak savannahs, and oak-basswood woodlands will be delineated and mapped (GPS/GIS) throughout the project site. The project site includes three separate dry bluff prairies, two separate bur oak savannahs, and oak-basswood forests on east-facing, west-facing, and north-facing slopes. Habitats will

be delineated and mapped to document the locations and acreages of each habitat type within the project site, producing a digital GIS database that will be used to guide the current project and future management efforts.

All habitats will be monitored to inventory existing plant communities prior to and after restoration and to determine the abundance of rare, threatened, and/or indicator species (plants, birds, pollinators), to assess the success of the restoration. Local herbarium and county biological survey records also will be used to document past flora and fauna within the project site. Plot, transect, and random stratified sampling will be used to assess plant communities, point counts will be used to document breeding bird populations, and a combination of active netting, light traps, and pit traps will be employed to survey the abundances or pollinators and other invertebrates.

New and expanded educational signage will be developed and installed within each habitat. Existing signage is limited to historical photographs and general information and photographs describing invasive species, prairies, and savannahs, all in a single location. New, habitat-specific signage will be developed and placed in each habitat type to highlight the restoration process and flora and fauna within the various habitats. Signage will emphasize the roles of the CC of MN and goat grazing in the restoration process. Temporary signage will be developed and placed during various stages of the project to keep the general public informed of ongoing activities.

Summary Budget Information for Activity 1:

ENRTF Budget: \$ 46,984
Amount Spent: \$ 44,667
Balance: \$ 2,317

Outcome	Completion Date
1. Habitat delineation via GPS/GIS	May 31, 2017
2. Pre-restoration inventory of existing plant communities	May 31, 2017
3. Pre-restoration assessments of rare, threatened, and/or indicator species	May 31, 2017
4. Post-restoration inventories of recovering plant communities	June 30, 2019
5. Post-restoration assessments of restored rare, threatened, and/or indicator species	June 30, 2019
6. Development and placement of educational signage	June 30, 2019

Activity Status as of January 1, 2017: *We began the process of delineating the various habitats within the project area. We used a GPS unit to mark the approximate boundaries of bur oak savannah, dry bluff prairie, and mixed oak/hickory/basswood/maple woodland. Our GPS unit produced files that have proven difficult to transfer and incorporate as a layer in GIS, so we will be repeating the process with a different system.*

We have conducted some initial surveys of the plant communities at the project site, specifically within savannah and prairie habitats. Our working list currently contains 18 species of trees, 9 species of shrubs, 8 species of grasses, and 42 species of forbs. Of these, 2 species are listed as State Special Concern (Plains Wild Indigo, White Wild Indigo) and 1 species is a State Threatened Species (Great Indian Plantain, 3 plants). In addition, we noted the presence of an orchid, Great Plains Ladies'-Tresses. Many species characteristic of regional savannahs and dry bluff prairies were observed, as were several nonnative and/or invasive species. During the next growing season, we will attempt to locate those species on a WSU Herbarium list of species collected from Garvin Heights, plus species that were listed as seeded on the site during past projects.

Informational signage was developed and erected on-site to inform the public of the various aspects of the project. Included on a large sign is acknowledgement of funding by ENRTF (including a logo) and a list of all collaborators and subcontractors (plus logos).

Activity Status as of July 1, 2017: *The prescribed burn in May and goat browsing in June prevented any additional plant surveys from being conducted during spring.*

Activity Status as of January 1, 2018: *Summer examinations of savannah and prairie habitats suggested that the combination of spring burn and goat browsing suppressed the growth of many species on both habitats during the 2017 growing season. Most species observed in 2016 were found during 2017, although abundances and vigor appeared to be reduced. Most grasses also were reduced in abundance compared to 2016. Further examinations will be needed during 2018 to determine if additional species from the herbarium list can be located on the project site. Any native species present historically, but still missing from the current species list, will be included in the list of plants to be seeded (or transplanted) later during 2018. Post-restoration inventories will begin after a final goat browsing in early summer 2018.*

Activity Status as of July 1, 2018: *Due to the late arrival of spring, prairie and savannah plants were slow to emerge during 2018. Post-restoration inventories will begin in July (after the final goat browsing) to aid in development of a list of seeds needed to restore native diversity to both savannah and prairie habitats.*

Activity Status of January 1, 2019: *Plant inventories on the dry bluff prairies generally found the same species as during 2016 and 2017. Although common on the prairie below the undeveloped overlook, leadplant was very rare on the prairie below the developed overlook. We will work with our nursery consultants to determine if this and a few additional species should be selected for seeding and/or planting on this habitat. Plant surveys of the cleared, south savannah were plagued by a thick ground cover of seedling buckthorn and older honeysuckle—few other plants were observed, and they were uncommon. Surveys found buckthorn densities of 120 plants/m² on the savannah. On the north savannah, which was cleared of buckthorn in April 2018, we located >600 plants of Great Indian Plantain, a state threatened species. These plants were found in 18 groupings, and contained 48 plants that flowered during summer 2018. Previously, we had located only 3 clusters of this species, all on the dry bluff prairie near the developed overlook.*

Final Report Summary: *Habitat delineation at the project site resulted in a mosaic of varying habitats, including multiple dry bluff prairies, bur oak savannahs, and mixed oak/hickory/basswood/maple woodlands. New graduate student Tamberlain Jacobs repeated delineations performed earlier in the project and is confirming agreements and rectifying differences. Pre-restoration plant inventories were created by repeated seasonal surveys, seed lists from previous restoration efforts, and herbarium collection records. During 2019, post-restoration plant surveys have confirmed the presence of 181 species to date, making note of rare, threatened, and/or indicator species (e.g., Great Indian Plantain). We are still working to confirm the presence of 50 additional species (e.g., several species of trees, prairie/savannah species still being examined for proper identification [awaiting blooms or seeds]). This year, 127 species have been added to the project site species list. To date, we also have produced a project site bloom calendar comprised of 148 species, with more species to be added as late-summer and fall-blooming plants come into season. Plant communities are slowly recovering after project disturbances (goat grazing, fire, cutting) and seeding/planting activities, with recovery expected to continue for the next several years. Efforts to suppress buckthorn in the prairies and savannahs will continue (cutting, treating, burning), allowing for better establishment of seeded/planted native plants. As plant communities take hold, informational project signage will be replaced by more permanent signage using a small, endowed funding source for site restoration.*

Activity 2: Invasive plant removal by goats and CC of MN, and reseeding/replanting of 40 acres of bluff prairies, savannahs, and bordering woodlands

Description: Buckthorn, honeysuckle, oriental bittersweet, and red cedar will be removed from dry bluff prairies, bur oak savannahs, and oak-basswood forests by grazing goats, the Conservation Corps of Minnesota, and community volunteers. CC of MN will begin by removing large buckthorn from oak savannah habitat and conducting prescribed burns on savannah and prairie sites. Some non-buckthorn trees also may be thinned from savannahs to restore the native, open condition. Goat grazing (twice per year, each year) will remove woody vegetation (small or re-sprouted buckthorn and honeysuckle) on savannah habitats and severely invaded sections of prairie. CC of MN personnel and volunteers will remove buckthorn, honeysuckle, bittersweet, and

red cedar from sensitive, less-invaded bluff prairie and forest habitats.

Prairies and savannahs will be restored by seeding and planting with native forbs (emphasizing flowering species to enhance pollinator populations) and grasses, and savannahs and forests will be restored by planting bur oak saplings and other tree species as needed to enhance natural reproduction. Appropriate seed mixes for southeastern Minnesota dry bluff prairie and bur oak savannah will be prepared by a regional seed source company. Inter-seeding of prairie and savannah habitats will occur during fall, winter (over snow), and/or spring to maximize effectiveness. Young trees will be hand-planted on savannah and forest habitats as needed to restore native species that are absent, low in abundance, or lacking in successful recent recruitment.

Summary Budget Information for Activity 2:

ENRTF Budget: \$ 44,573
Amount Spent: \$ 41,104
Balance: \$ 3,469

Outcome	Completion Date
1. Invasive plants removed by goats, CC of MN, volunteers	June 30, 2018
2. Bluff prairies and savannahs reseeded and planted	June 30, 2019
3. Bur oak saplings, other species planted in savannahs and woodlands	June 30, 2019

Activity Status as of January 1, 2017: *Prior to the beginning of the project period, the Conservation Corps of MN and IA used the project site to train their 2016 crew members in proper chain saw use and safety. They limited their activities to a 0.5-hectare area of bur oak savannah immediately adjacent to the parking area. This land is owned by the City of Winona, which granted them special permission for this activity. During a single day in late February, the Corps cut and piled buckthorn and honeysuckle on-site. The now dried piles will be burned by a Corps crew this winter. The Corps also will decide this winter when to perform further cutting of buckthorn and honeysuckle, and examine the possibilities for prescribed burns on both savannah and prairie habitats.*

We encountered a problem between lawyers for the City of Winona and those for one of our subcontractors, relating to wording of contracts concerning liability. Because the City required that the entire project “package” of agreements be approved by the City Council prior to beginning of work, we faced many weeks of delays in getting Activity 2 underway. Appropriate language was eventually worked out, allowing work to commence.

For 21 days during November, 35 goats owned by Diversity Landworks LLC were used to browse on invasive plants. The goats were confined by solar-powered electrified fencing to 3 different paddocks (1.5 to 2.7 acres) during the period: 11 days in Paddock 1, consisting of unmanaged savannah; 3 days in Paddock 2, consisting of the Corps-cleared savannah; and 7 days in Paddock 3, a mixed dry bluff prairie and oak savannah where invasive plants had been “managed” several times over the past 15 years. The public enjoyed the opportunity to see goats at work on the invasive plants at this high-visibility site. Diversity Landworks personnel indicate that this was the “most public” location in which their goats have been used, and they answered many questions from curious people about the goats, the project, what can be expected on-site in the future.

Activity Status as of July 1, 2017: *Crews from the Conservation Corps of MN and IA burned brush piles on the cleared savannah during January 2017. These brush piles were the results of clearing of buckthorn and honeysuckle by the Corps the previous year. In total, 47 brush piles containing >350 m³ of brush were burned. Despite burning brush on frozen ground with snow, burning sterilized the ground beneath piles, preventing plant regrowth during spring. However, as the ground surrounding the burn sites was largely covered in seedling buckthorn plants, sterilization was likely beneficial.*

The Corps crew conducted a prescribed burn of savannah and prairie habitats at the project site on May 12. Fuel for the fire on the savannah was mostly oak leaves, which produced a spotty, but hot fire that killed seedling and older buckthorn. However, because fuel was not evenly distributed, many areas did not burn. Fuel was much more abundant on the prairie, and the burn was more effective for most areas. However, two areas dominated by young buckthorn did not contain much fuel for the fire, so buckthorn survived.

For 23 days in June 2017, 70 goats browsed on buckthorn and honeysuckle in savannah and prairie habitats. They spent 7 days in Paddock 1 (unmanaged savannah), 6 days in Paddock 2 (cleared savannah), and 10 days in Paddock 3 (prairie). Browsing was effective on non-seedling buckthorn, with goats eating leaves, branch tips, and girdling older plants by eating bark. Plants girdled by goats during fall 2016 resprouted from their bases, and goats browsed those sprouts. A local newspaper, the Winona Post, took photographs of the goats while they were browsing on Garvin Heights, and interviewed one of the co-owners of the goat-browsing business, Diversity Landworks LLC, for an article/photo that appeared on the front page of the paper a few days after the goats finished their summer browsing (article appeared in the 5 July 2017 edition).

Activity Status as of January 1, 2018: *Goats (60 head) returned to the project site for 19 days of browsing during October 2017. Since the June browsing, young buckthorn and honeysuckle on the cleared savannah had sprouted and/or grown vigorously. The seedbank for buckthorn appears to be rich in the soils of the cleared buckthorn. Even after the October browsing, buckthorn seedling densities were high (dozens of plants/m²), although the majority (~75%) had been browsed by goats. We may consider using a propane-fueled flame weeder, in conjunction with additional spring burns if adequate fuel is present, to kill buckthorn seedlings on the cleared savannah in coming years. Planting the cleared savannah with a grass-heavy seed mixture may provide the fuel needed to produce hot prescribed burns capable of killing young buckthorn, that likely will continue to sprout for several years.*

We had planned for the Corps to continue with additional buckthorn clearing on the project site during summer or fall 2017, particularly in the uncleared savannah, along the edges of the prairie, and in the woodland along the public walkway. However, those plans were canceled when many Corps crews responded to the national call for workers to assist with storm damage clean-up in Texas following the hurricane. A few individual citizen volunteers cut and chemically treated some buckthorn within the project site, but their efforts were minimal.

Activity Status as of July 1, 2018: *The Conservation Corps worked at the project site during April, hampered by late-season snowfalls, to cut and chemically treat buckthorn on a strip of savannah habitat separating the two dry bluff prairies. Young buckthorn in this habitat were very dense (~9 saplings/m²), and goats have appeared unwilling to penetrate this growth to eat the brush. Instead, goats browsed only the peripheral plants. Corps personnel cut and piled buckthorn, which will be burned later this fall when the Corps will attempt to perform a prescribed burn on the savannah habitats.*

Goats browsed buckthorn and honeysuckle on the project site for 3 weeks in June. For this period, 40 does (all with nursing young) were used to create a more significant impact on buckthorn. Nursing does eat more browse than wethers (castrated males, which comprised the majority of the herd used on the project site previously), and it was hoped that they would browse and kill shoots from buckthorn girdled last year. Goats had browsed at the project site three times previously without incident. However, during June the goats were targeted with paintballs, driving the entire herd from their enclosure into an off-site field. They were returned to their enclosure by their owners after a nearby resident reported the escapement and vandalism. Only days later, Winona police officers captured four juveniles with a stolen goat in their car at the project site after park closure. These same juveniles also were in possession of a paintball gun. The juveniles have been charged with vandalism and theft.

Activity Status of January 1, 2019: *The Conservation Corps had hoped to perform a prescribed burn on the cleared savannahs during fall to kill young invasive plants, but again were hampered by a lack of fuel (mostly a ground cover of seedling buckthorn and young honeysuckle with scattered oak leaves). Consequently, Corps personnel used propane torches to kill the invasives on the cleared south savannah, leaving two small "control" patches unburned to examine the effects of their efforts. Plant counts in both burned and unburned areas found that nearly 90% of buckthorn seedlings had been killed by the propane torches.*

On the south savannah, Winona State University's BIOL 418 Plant Ecology class spread a seed mix containing 36 species of forbs, sedges, and grasses during late fall/early winter. The seed mix was specially prepared for this site by Bill Carter from Prairie Moon Nursery. We hope that these plants can become established over the

next few years as the buckthorn seedbank diminishes. In the interim, we expect to maintain the savannah by periodic mowing or browsing, using propane torches to control young buckthorn and honeysuckle, until growth of the seeded plants provides adequate fuel to support periodic prescribed burns.

Final Report Summary: Goats were browsed on the project site a total of five different periods, with their final visit during June 2019, a year later than expected completion. The extended use of goats resulted from a strong seed bank of buckthorn within the savannah habitats, and an apparent inability of goats to access dense patches of buckthorn within the prairie. In general, goat browsing in this very public area was well received. Site visitors were intrigued by the goats, enjoyed photographing them, and asked numerous questions about the restoration project.

The Conservation Corps of MN and IA cut and treated buckthorn, thinned the bur oak savannah, conducted controlled burns, burned brush piles, and used weed torches to control seedling and yearling buckthorn during multiple visits throughout the project period. Even with these efforts, canopy coverage within the savannahs remains on the high end for quality savannah habitat. Corps personnel have recommended a long-term, gradual thinning of young bur oaks to either maintain or reduce canopy coverage.

Multiple seedings of native vegetation have taken place within the savannahs as the buckthorn population was reduced by browsing, cutting, treating, and burning. Because these seedings took place during the final year of the project period, the effects of these likely will not be observed for a few years. Consequently, we planted >400 plugs of grasses and forbs in the savannah to accelerate the process. We also will consider planting a cover crop of Canada rye to provide more fuel for future prescribed fire to further suppress buckthorn seedlings.

Activity 3: Invasive management workshop development and initial delivery to regional landowners, interested public

Description: One-day and two-day, hands-on workshops will be developed for and presented to regional landowners and other stakeholders to explain and demonstrate the process and methodology of invasive plant management and habitat restoration. Workshops will use 1) the project site as a model and 2) nearby City-owned (Bluffside Park) and University-leased (Krueger Woods) lands for hands-on, experiential learning and experimentation.

The WSU Arboretum and Land Stewardship Committee will develop a series of workshops, grounded in Aldo Leopold’s Land Ethic, to provide participants with practical approaches for developing and maintaining environmentally sustainable landscapes. With the Garvin Heights project site as a model, and using a learning-by-doing approach, workshops will demonstrate the principles and best practices (e.g., methods, skills, and techniques) of invasive plant control. A hands-on approach will educate participants in the safe use of tools, equipment, and materials.

Summary Budget Information for Activity 3:

ENRTF Budget: \$ 7,443
Amount Spent: \$ 6,418
Balance: \$ 1,025

Outcome	Completion Date
1. One-day and two-day management/restoration workshops developed	June 30, 2017
2. Management/restoration workshops delivered to public	June 30, 2019

Activity Status as of January 1, 2017: Planning and development of workshops has been delayed slightly due to the hiring of a new Arboretum Director and the retirement of our Land Steward. A search for a new Land Steward is underway, and this person will work with our new Arboretum Director and a new University Arborist to develop the workshops. They will be assisted by a new graduate student, personnel from our goat browsing contractor, and Conservation Corps personnel.

Activity Status as of July 1, 2017: *A new Arboretum Director, Lisa Pearson, was hired by Winona State University to oversee management of the University's public lands and spaces. Project personnel (PI, grad student Ryan Walsh) met with the Arboretum Director, other members of the WSU Landscape Arboretum, and representatives of a private ecological consulting firm to discuss possibilities for the development of the invasives management/restoration workshops. General workshop formats were discussed based on attendees' past experience, and budgeting was examined. With oversight from the Arboretum Director, it was planned that workshops would be developed and presented by the PI, the yet-to-be-named Land Steward, and grad student Ryan Walsh, with assistance from other project partners (goat browsing contractor, Conservation Corps personnel, additional local ecological restoration specialists).*

Activity Status as of January 1, 2018: *Winona State University appointed Dr. Amy Runck, Associate Professor of Biology, as its new Land Steward. She has been proactive at getting up to speed regarding the Garvin Heights project. She is able to assist with the development and delivery of the invasives management/restoration workshops. Grad student Ryan Walsh took a leave of absence during fall semester and will return to the project (and working on workshop content) in January 2018.*

Activity Status as of July 1, 2018: *Winona State University hosted a 1-day workshop on the management of invasive plants, using the Garvin Heights project site for a field trip. Grad student Ryan Walsh, working with WSU Camps and Conferences staff, planned and organized the workshop. The workshop was designed to provide information to area residents interested in invasive plant management, and to connect them with various public agencies and private contractors that could assist them with managing invasives on their lands. The workshop attracted 27 citizens from the region. During the morning session, participants had the opportunity to connect with and ask questions of public agencies (e.g., Conservation Corps of MN and IA, MN Department of Agriculture, City of Winona), NGOs (e.g., The Nature Conservancy), and private contractors (e.g., Diversity Landworks, Landspirit Design, Prairie Restorations Inc., Prairie Moon Nursery, Acer Forestry). Participants also heard speakers talk about identifying invasive plants, where to find assistance, how to develop a management plan, and how to restore a site after invasive eradication.*

During the afternoon session, workshop participants were transported to the Garvin Heights project site, where they learned to identify various invasive plant species and heard presentations from project participants: WSU staff (basic project plan and goals), the Conservation Corps (demonstration of the tools and techniques used on-site), and Diversity Landworks (goat browsing). Goats had been brought on-site 6 days prior to the workshop, allowing participants to see the impact of goat browsing on both young and older buckthorn and honeysuckle.

***Although the workshop took place in early June, bills for the various services associated with the workshop have yet to cycle through the WSU Business Office. Therefore, funds have been encumbered, but not spent, as of this report.*

Activity Status as of January 1, 2019: *Unsolicited feedback from workshop participants indicated that several landowners used information gained during the workshop to initiate invasive plant control activities on their properties. One participant sent a series of workshop photos, and made the decision to control invasive plants on her dry bluff prairie. She previously had been reluctant to do so, afraid that the use of chemical controls would have an adverse effect on the native plant community. We view this as a major accomplishment, as her property is enrolled in the Minnesota Land Trust, but habitat quality continued to decline due to lack of invasive control actions. Several other participants have connected directly with our workshop presenters and vendors for assistance with their property.*

After the June workshop, participants were contacted to determine if they were interested in a workshop sequel—a more applied, hands-on field activity at Garvin Heights and nearby University and City lands. The response level was poor, so a potential fall workshop was not conducted. However, we continue to field questions from local residents who did not attend the workshop, connecting them to our workshop participants and vendors. During spring, we plan to again explore the possibility of offering a hands-on workshop.

Final Report Summary: *Winona State University hosted two workshops centered on invasive species management and habitat restoration. The first workshop attracted 27 people to learn about various methods for dealing with invasive plant species in the Winona area. Representatives of public agencies, NGOs, and private businesses gave presentations and interacted with participants to provide methodology and guidance for handling invasive species on private lands. The Garvin Heights project site served as demonstration area, where workshop participants learned to identify various invasive species and observed various methods for their control (cut and treat, burning, goat browsing).*

Immediately after the final goat browsing at the Garvin Heights project site in June 2019, a second workshop provided 12 participants with hands-on experience in restoring a bur oak savannah. Planned by graduate student Tamberlain Jacobs and led by Gabe Ericksen of Landspirit Design, participants planted 8 species of grasses and forbs to help jumpstart the new plant community. Mr. Ericksen demonstrated various techniques for planting, showed participants how to group and/or space different species for maximum growth, and instructed how to select the proper locations for planting (e.g., soil depth, sun exposure, expected plant height). Among the participants were two families, the City of Winona's sustainability director, and a local city council member. Because this planting workshop took place during a very warm period of summer, the City of Winona delivered water daily to fill on-site rain barrels, and all plants were watered each day for two weeks by volunteers.

V. DISSEMINATION:

Description:

Products resulting from this project will be disseminated via a web site, news releases, workshops, community presentations, on-site signage, and presentations at regional science meetings. These diverse methods are intended to reach a variety of audiences, allowing us to share information with site visitors, local residents, and the broader regional citizenry.

The web site for the Winona State University Landscape Arboretum will provide a key link between the project and its benefactors (<https://www.winona.edu/outdoored/arboretum.asp>). The web site will provide a source for all information about the project, from schedules of proposed activities to photos, videos, and reports of on-site happenings. Links will be provided for workshop registration, to access news releases, and to volunteer as a Friend of the Landscape Arboretum.

News releases will be produced and disseminated through the Winona State University Communications and Marketing office. This office prepares and distributes information and news items to regional newspapers, radio, and television, as well as preparing web content and a periodic news magazine.

Project workshops (Activity 3) and community presentations will be prepared and delivered by project leadership and affiliated members of the WSU Landscape Arboretum throughout the project cycle and beyond. On-site signage will be produced and updated throughout the project period to keep site visitors apprised of current activities, with placement of permanent signs planned for the end of the 3-year project period.

Finally, the scientific findings of the project (before/after surveys of invasive plants, success of various management techniques, habitat recovery, SGCN surveys) will be presented at regional science meetings by project leadership and graduate and undergraduate students. Potential venues may include state meetings of the Society of American Foresters and The Wildlife Society, the Mississippi River Research Consortium, the Upper Midwest Invasive Species Conference, the North American Prairie Conference, and undergraduate science symposia hosted by Winona State University, Saint Mary's University of Minnesota, and Viterbo University.

Status as of January 1, 2017: *A variety of approaches have been used to date to inform the general public about the project and its activities. The WSU Communications and Marketing Office produced a press release for regional news outlets at describing the project and its major goals. We received significant, positive feedback from friends and alumni who heard about the project through the press release.*

We are developing several different platforms for use on digital media. The web site for the Winona State University Landscape Arboretum will be used as a major link for the project, but management of that web site is restricted to a particular webmaster. To allow for more frequent and detailed postings about the project, we are developing a separate web site that will be linked directly to the Arboretum website. The Arboretum website still

will be used for major posting and workshop details, whereas the additional site will be available for day-to-day updates, photos, and related communications. We also will take advantage of a dedicated Facebook page for the project for similar project updates and postings. This latter also will provide the opportunity for immediate feedback about the project from the public.

We were invited to give a presentation about the project to the Winona County Master Gardeners group in late October. During that presentation, we informed the group about the project goals and major activities, provided them with a photographic survey of the project site and the various plants identified in our species inventory, and solicited volunteers from the group to help with various project activities.

A large sign was developed and erected on the project site to inform the public about the project and its major activities, provide contact info for questions, and to give credit to the projects supporters (especially ENRTF) and collaborators. We also included logos from all of these groups/organizations. The sign framework was designed to allow for placement of additional information as needed. Vandals pulled the empty sign framework from the ground shortly after it was placed, requiring us to make the signposts more secure (with cement).

Two undergraduate students and one graduate student have been collecting species inventory data (plants, birds) at the project site, and have been documenting the effects of the goats on the invasive plants during the first grazing session. The undergraduates will present their findings at undergraduate science symposia this coming spring at WSU and/or Saint Mary's University of MN. We also are providing data on buckthorn damage from goat grazing to our goat grazing contractors to use in a presentation about goat grazing that they will be making at a regional sustainable farming conference this winter. They also have asked to post this information on their business website to inform the public about the impacts of goats on invasive plants.

Status as of July 1, 2017: We continue to inform the community about the project and its activities in a variety of ways. In addition to the project web site maintained by Winona State University (<https://www.winona.edu/outdoored/garvin.asp>), with content provided by the PI, we maintain a project-specific Facebook page (<https://www.facebook.com/Garvin-Heights-Natural-Area-Blufflands-Restoration-Project-357534101286304/>) for more immediate communication with the community. We have used this to quickly highlight the arrival of goats at the project site, as well as showing photographically the results of prescribed burns and goat browsing. We also make postings about the project on the Winona State Biology Department Facebook page (<https://www.facebook.com/biologyWSU/>) to reach a larger audience.

Status as of January 1, 2018: During the 2017 fall semester, two Winona State Biology students have been conducting small mammal surveys via live-traps on savannahs and prairies at the Garvin Heights project site. To date, only two species (deer mouse, short-tailed shrew) have been collected in the project site, with deer mice dominating catches. Students will be presenting their findings at the annual meeting of the Minnesota Chapter of The Wildlife Society in February 2018.

Two students who either conducted surveys on birds or monitored the effects of goat browsing on buckthorn last fall graduated after fall semester 2017. Each student was honored as the top graduate in their respective major (Ecology or Environment Science) at a University-sponsored ceremony on December 7. One of these students presented her research findings at a University-sponsored research symposium in April 2017, whereas the other provided her data to the goat-browsing business in support of their statements that browsing severely injures buckthorn.

Status as of July 1, 2018: Two undergraduate students presented the results of their small mammal survey of the Garvin Heights project site at a University-sponsored research symposium in April 2018. Deer mice dominated collections, especially in prairie habitats. Similar surveys will be conducted in future years to determine if small mammal diversity changes with invasive species management.

During April, the PI gave a presentation about goat browsing impacts on buckthorn at the Annual Meeting of the Mississippi River Research Consortium in La Crosse, WI. Specifically, selective girdling of buckthorn by goats

(avoidance of large- and small-diameter stems) and reductions in density of young buckthorn after goat browsing were highlighted.

During May and June, the invasive plant management workshop was advertised via hard-copy postings within the community, targeted mailing, Facebook postings, group email lists, newspaper notifications, and a radio broadcast (by grad student Ryan Walsh). We were successful in reaching a diverse group of local residents, from city dwellers to farmers. Some were simply curious about the Garvin Heights project and wanted to learn more about it, whereas others owned property enrolled in the Minnesota Land Trust and wanted to learn how to better manage invasive plants.

The invasive plant management workshop provided participants with an up-close introduction to the project, as well as an in-person examination of the results of the project to date. Participants saw how Conservation Corps personnel removed invasive plants from savannah and prairie habitats, and also how bad the problem was before work began by examining an untreated plot nearby. They also had the opportunity to view goat browsing in person, observing exactly how goats browsed leaves and branch tips and nibbled bark.

Status as of January 1, 2019: We continued to highlight project activities on a timely basis on the Winona State Biology Department Facebook page (<https://www.facebook.com/biologyWSU/>). This enables us to reach a larger audience than either the specific project Facebook page or the project web site. In fact, some of our posts have been re-posted by a City of Winona council member to highlight important activities within Garvin Heights Park. Recent photos and videos of WSU students working on the project have had several thousand views on the Winona State Biology Department Facebook page.

We met with two City of Winona council members prior to the council taking action on a new City Parks improvement funding initiative. The City council passed the initiative, proposing to spend between \$27 million and \$42 million on parks and trail improvements and expansions. Specifically, the initiative proposes a new, \$3.2 million Bluffland Traverse Trail that will pass through Garvin Heights Park, connecting with and expanding trails east and west of the park. This trail would increase visitor use of the park, making it one of several hubs for hiking and biking trails throughout the City. Hopefully these activities will bring additional funding for continued invasive species management activity within Garvin Heights Park and on other properties along the trail system.

Final Report Summary: Throughout the project period, various information about the project was posted on the project web site maintained by Winona State University (<https://www.winona.edu/outdoored/garvin.asp>), on a project-specific Facebook page (<https://www.facebook.com/Garvin-Heights-Natural-Area-Blufflands-Restoration-Project-357534101286304/>), and on the Winona State Biology Department Facebook page (<https://www.facebook.com/biologyWSU/>). The community was informed of upcoming workshop opportunities via hard-copy postings within the community, targeted mailing, Facebook postings, group email lists, newspaper notifications, and a radio broadcast. Workshops, community presentations, on-site signage, and presentations at regional science meetings further served to present the project and its findings to the public.

Graduate student Ryan Walsh recently completed his thesis (Walsh, R. 2019. Garvin Heights Restoration Project. Professional Science Masters Thesis, Winona State University, Winona, MN. 56 p) that focused on the Garvin Heights project in general, the first workshop, and the effects of goat browsing on buckthorn. Included in his thesis are a series of recommendations for future management at the project site that will form the basis for a future management plan. In the near future, we plan to develop a manuscript from his thesis, on the effects of goat browsing, for submission to a peer-reviewed scientific journal.

Graduate student Tamberlain Jacobs continues to identify more plants within the project area, using her plant taxonomy expertise acquired while working at previous natural resources jobs in various locations in MN and elsewhere. She is developing a more complete, up-to-date plant inventory list for the project site. She also is developing a bloom calendar for the site, which will allow visitors to determine what plants may be in bloom at various times of the year. **Winona State University has funded a graduate assistantship for work at Garvin Heights for the next 2 years**, with Tamberlain Jacobs filling that role for the upcoming academic year. As part of her assistantship, she will work to update the WSU herbarium collection for Garvin Heights, work more closely with the WSU Landscape Arboretum Committee and Friends of the Arboretum to develop a citizen stewardship

group and a series of volunteer work projects (additional invasive plant management, seed collecting), and develop updated signage for the various habitats at the restoration site.

VI. PROJECT BUDGET SUMMARY:

A. ENRTF Budget Overview:

Budget Category	\$ Amount	Overview Explanation
Personnel:	\$ 49,427	1 project manager at 84% salary, 16% benefits, for 2 weeks in the summer, for 1 year (\$6,484); Land Steward at 84% salary, 16% benefits, for 2 weeks in the summer, for 1 year (\$5,443); 1 graduate student at GA stipend for 2 years (\$37,500).
Professional/Technical/Service Contracts:	\$ 33,000	1 contract with Diversity Landworks LLC for grazing goats to control invasive plants (\$ 20,000); 1 contract with Conservation Corps of Minnesota for removal of invasive plants (\$ 13,000)
Equipment/Tools/Supplies:	\$ 15,573	GPS units, cameras, inventory supplies (\$ 2,000); workshop materials and supplies (\$ 2,000); prairie/savannah seed (\$ 8,573); native trees (\$ 3,000).
Printing:	\$ 1,000	Educational signage
TOTAL ENRTF BUDGET:	\$ 99,000	

Explanation of Use of Classified Staff: N/A

Explanation of Capital Expenditures Greater Than \$5,000: N/A

Number of Full-time Equivalents (FTE) Directly Funded with this ENRTF Appropriation: 1.1 FTE

Number of Full-time Equivalents (FTE) Estimated to Be Funded through Contracts with this ENRTF Appropriation: 0.4 FTE

B. Other Funds:

Source of Funds	\$ Amount Proposed	\$ Amount Spent	Use of Other Funds
Non-state			
Private donations (cash)	\$ 11,000	\$ 3,212	Undergraduate student salary
City of Winona (in-kind)	\$ 24,000	\$ 24,000	Park maintenance, security
State			
Conservation Corps of MN (in-kind)	\$ 13,000	\$ 13,000	Invasive plant removal
WSU Arboretum Director (in-kind)	\$ 29,209	\$ 29,209	Facility coordination, oversight (10% annual)
WSU Land Steward (in-kind)	\$ 31,262	\$ 31,262	Workshop development, delivery (10% academic year)
Project Manager (in-kind)	\$ 77,378	\$ 77,378	Student supervision (20% academic year)
TOTAL OTHER FUNDS:	\$ 185,849	\$ 178,061	

VII. PROJECT STRATEGY:

A. Project Partners:

Project Team/Partners Receiving Funds

- Neal Mundahl** (WSU Department of Biology, Ecologist, project manager, student mentoring; \$6,484)
- Bruno Borsari** (WSU Land Steward, workshop and interpretive signage development; \$5,443)
- Graduate and Undergraduate students** (WSU Department of Biology, habitat delineation, plant inventories, SGCN surveys: graduate student, \$37,500; undergraduate salaries from private donations)
- Pure Prairie Vision LLC** (Goat grazing management; \$20,000)
- Dustin Looman**, MN DNR and Conservation Corps of Minnesota (Invasive plant removal, consultation; \$13,000)
- Prairie Moon Nursery** (Seed, plant source, consultation; \$11,573)

Project Team/Partners Not Receiving Funds

- City of Winona** (Park maintenance)
- New Hire TBD** (WSU Landscape Services and Arboretum Director)
- Carol Jefferson** (Plant Ecologist, Department of Biology emerita: historical site consultant, past species inventories, MN DNR contacts)
- William Beatty** (WSU Department of Geosciences: GIS)
- WSU Arboretum and Land Stewardship Committee** (WSU institutional facilitation)

B. Project Impact and Long-term Strategy: The Garvin Heights Natural Area project site is located in the central part of the Blufflands Subsection of the Paleozoic Plateau. The Blufflands has the most Species in Greatest Conservation Need (SGCN) of any subsection in Minnesota, including 82 species that are federal or state endangered, threatened, or of special concern. Oak savannahs and prairies are key habitats for SGCN within the Blufflands, but most (97% and 99%, respectively) have been lost since the 1890s. The proposed project will restore and enhance bur oak savannahs and dry bluff prairies, protect additional cliff and bluff habitats, and enhance pollinator populations by managing invasive plants and replanting with native species. The high-visibility project site will showcase invasive species management and habitat restoration to a large public audience, inventory/monitor for SGCN, encourage public participation in the restoration, and provide additional and continuing opportunities for landowner education in invasive plant management and habitat restoration.

Winona State University and the City of Winona are committed to retaining project lands in a restored state for continuing education of students, the public, and regional stakeholders. Friends of the WSU Landscape Arboretum will be actively involved in the restoration, and will be instrumental in long-term maintenance through continued monitoring and removal of invasive plants and the initiation and conduct of regular, prescribed burns on prairie and savannah habitats. The WSU Environmental Club and WSU classes (e.g., General Ecology, Plant Ecology) will continue their modest monitoring and management efforts on a regular schedule. The City of Winona will continue to maintain access infrastructure (e.g., road, parking lot, paved walkways, overlooks), provide visitor services (restrooms, trash removal), and other services as needed (security, fire supervision).

C. Funding History:

Funding Source and Use of Funds	Funding Timeframe	\$ Amount
Xcel Energy (trail construction, invasive plant removal)	2013-2014	\$ 10,000
Private donations (trail maintenance, tree removal)	2011-2013	\$ 2,000
Winona State University (sign replacement, repair)	2013	\$ 800

VIII. FEE TITLE ACQUISITION/CONSERVATION EASEMENT/RESTORATION REQUIREMENTS:

A. Parcel List: See attached Parcel List

B. Acquisition/Restoration Information: N/A

Restoration

- 1. Provide a statement confirming that all restoration activities completed with these funds will occur on land permanently protected by a conservation easement or public ownership.**

All lands involved in this project currently are in public ownership: State of Minnesota, City of Winona, and City of Winona Park Board.

- 2. Summarize the components and expected outcomes of restoration and management plans for the parcels to be restored by your organization, how these plans are kept on file by your organization, and overall strategies for long-term plan implementation.**

We expect that our restoration plans for the Garvin Height Natural Area will lead to improved condition of the dry bluff prairies, bur oak savannahs, and oak-basswood forests that comprise the project site. We anticipate a dramatic reduction in the abundance of buckthorn and honeysuckle after their removal by goats and the CC of MN personnel, and continuing reduction/suppression through efforts of the Friends of the WSU Arboretum. In addition, we anticipate an increase in the diversity of flowering forbs in prairie and savannah habitats.

Management plans for the restoration of the Garvin Heights Natural Area will be filed and maintained by the grant author, by the WSU Arboretum and Land Stewardship Committee, the office of the V.P. of Facilities and Finance, and office of the Provost and V.P. for Academic Affairs. Management plans for the site will become a continuing part of the mission of the WSU Arboretum and Land Stewardship Committee.

The WSU Arboretum and Land Stewardship Committee will be tasked with managing the site in its restored state, working with the City of Winona and other community partners to maintain the restored site by suppressing invasive plants, conducting prescribed burns, and monitoring and encouraging a diverse community of flowering forbs for pollinators. The WSU Arboretum and Land Stewardship Committee will explore funding sources, following the expiration of the LCCMR grant, to enable continued monitoring and maintenance efforts on the restored parcels. Sources of funding include University-budgeted landscape funds, privately donated funds available through the WSU Foundation, and external grant sources (e.g., Winona County, MN, Department of Agriculture, U.S. Department of Agriculture, and others). Additionally, long-term maintenance and restoration will enable WSU undergraduate and graduate students (classes, small group projects, senior capstone research, and graduate projects), as well as interested community members to learn-by-doing through engaging in the long-term maintenance of this property.

- 3. Describe how restoration efforts will utilize and follow the Board of Water and Soil Resources “Native Vegetation Establishment and Enhancement Guidelines” in order to ensure ecological integrity and pollinator enhancement.**

Restoration activities will follow the guidelines as established in the 2015 Board of Water and Soil Resources publication, “Native Vegetation Establishment and Enhancement Guidelines”. Specific habitats (dry bluff prairie, bur oak savannah, oak-basswood forest) will be delineated to quantify the acreage of each habitat type within the project area. After removal of invasive plants, habitats will be inter-seeded/planted with seeds/plants obtained from a regional supplier (Prairie Moon Nursery) within 30 miles of the project site. Seed mixes for dry bluff prairies and bur oak savannahs will incorporate a high diversity of forbs to stimulate development of rich flowering communities, to provide habitat for pollinators during all seasons.

- 4. Describe how the long-term maintenance and management needs of the parcel being restored with these funds will be met and financed into the future.**

Following restoration, the Garvin Heights Natural Area will need regular maintenance and management to sustain the restored condition. These maintenance and management activities will include removal of re-sprouting or new invasive woody and herbaceous vegetation, regular prescribed burns on prairie and savannah habitats, and possible inter-seeding and/or replanting to maintain high plant diversity in all habitats. These activities will occur under the direction and guidance of the WSU Arboretum and Land Stewardship Committee, the WSU Arboretum Director, and the WSU Land Steward. University funds are allocated for maintenance and management of the WSU Arboretum on an annual basis. In addition, a private endowment for Garvin Heights has been established within the WSU Foundation. Funds generated from this endowment are to be used exclusively to pay for supplies, materials, and student salaries associated with maintaining the Garvin Heights Natural Area. Additional funding will be sought from other sources for any large projects that may develop in future years.

5. Describe how consideration will be given to contracting with Conservation Corps of Minnesota for any restoration activities.

The Conservation Corps of Minnesota has been contracted (contact Dustin Looman) for this project to remove invasive plants on habitats that are too sensitive (e.g., dry bluff prairie) and/or too steep for goat browsing. In addition, CC of MN personnel will be needed to remove buckthorn and other invasive woody vegetation too tall for goats to browse effectively. CC of MN will provide 50% of their services as in-kind contributions for this project, to help advertise and promote their activities within southeastern Minnesota at a highly visible, public location.

6. Provide a statement indicating that evaluations will be completed on parcels where activities were implemented both 1) initially after activity completion and 2) three years later as a follow-up. Evaluations should analyze improvements to the parcel and whether goals have been met, identify any problems with the implementation, and identify any findings that can be used to improve implementation of future restoration efforts at the site or elsewhere.

Activity 1 will involve both pre- and post-restoration surveys and inventories of plant communities and SGCN. These surveys and inventories will be used to evaluate the effects of the prescribed treatments in reducing the abundance of invasive vegetation and improving the diversity of native plants within the dry bluff prairies, bur oak savannahs, and oak-basswood forests that comprise the Garvin Heights Natural Lands project site. This before/after assessment will provide feedback on the immediate success of restoration efforts and/or problems with those efforts within the 3-year project period, allowing for management course corrections prior to beginning long-term site management.

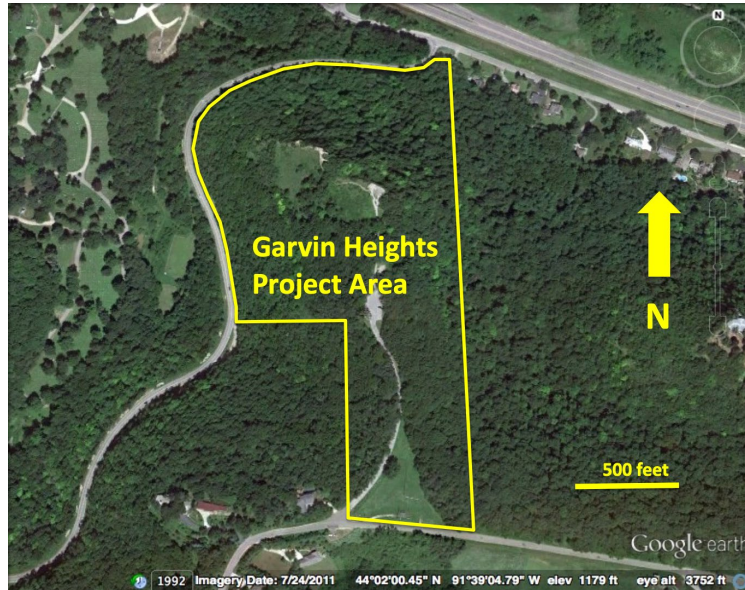
Follow-up evaluation of the habitat restoration efforts will be undertaken by WSU students and faculty, after expiration of the LCCMR grant (2019-2022 and beyond), based upon the availability of needed funds from the University, private donations, and external grant sources. Long-term maintenance and continued restoration of these parcels, as a public demonstration site within the southeastern Minnesota region, and as a resource for teaching and research for undergraduate and graduate education, is a high priority of the WSU Landscape Arboretum.

IX. VISUAL COMPONENT or MAP(S): See attached map

X. RESEARCH ADDENDUM: N/A

XI. REPORTING REQUIREMENTS:

Periodic work plan status update reports will be submitted no later than January 1, 2017, July 1, 2017, January 1, 2018, July 1, 2018, and January 1, 2019. A final report and associated products will be submitted between June 30 and August 15, 2019.



Location of the Garvin Heights project area in Winona, MN.



Goats browsing on a cleared bur oak savannah at Garvin Heights, Winona, MN.



Contrast between a section of woodland invaded by buckthorn browsed by goats (left) and an unbrowsed section (right) at Garvin Heights, Winona, MN.



Minnesota Conservation Corps workers clearing buckthorn from a dry bluff prairie at Garvin Heights, Winona, MN.



Winona State University Plant Ecology students surveying the population of Great Indian Plantain, a state threatened species, on a bur oak savannah at Garvin Heights, Winona, MN.



Workshop participants watching a demonstration of how to manage invasive plant species by Minnesota Conservation Corps personnel.



WSU students hand-seeding a bur oak savannah after the first snowfall at Garvin Heights, Winona, MN.



Workshop participants planting grass and forb plugs in a bur oak savannah at Garvin Heights, Winona, MN.



Workshop participants learning about the role of goat browsing in habitat restoration at a bur oak savannah at Garvin Heights, Winona, MN.

Environment and Natural Resources Trust Fund
Final M.L. 2016 Project Budget



Project Title: Bluffland Restoration and Monitoring in Winona

Legal Citation: M.L. 2016, Chp. 186, Sec. 2, Subd. 08h

Project Manager: Neal Mundahl

Organization: Winona State University

M.L. 2016 ENRTF Appropriation: \$ 99,000

Project Length and Completion Date: 3 Years, June 30, 2019

Date of Report: August 15, 2019

ENVIRONMENT AND NATURAL RESOURCES TRUST FUND BUDGET	Activity 1 Budget	Amount Spent	Activity 1 Balance	Activity 2 Budget	Amount Spent	Activity 2 Balance	Activity 3 Budget	Amount Spent	Activity 3 Balance	TOTAL BUDGET	TOTAL BALANCE
BUDGET ITEM	Habitat Delineation, Monitoring, Signage			Invasive Plant Removal, Replanting			Workshop Development, Delivery				
Personnel (Wages and Benefits)	\$43,984	\$41,754	\$2,230				\$5,443	\$5,000	\$443	\$49,427	\$2,673
Neal Mundahl, Project Manager: \$6,484 (84% salary, 16% benefits); 7% FTE for 1 year											
Bruno Borsari, Land Steward: \$5,443 (84% salary, 16% benefits); 7% FTE for 1 year											
1 Graduate Student: \$37,500 (90% salary, 10% benefits); 50% FTE each year for 2 years											
Professional/Technical/Service Contracts											
Diversity Landworks, LLC (goat grazing of invasives)				\$20,000	\$20,000	\$0				\$20,000	\$0
Conservation Corps of Minnesota (invasive plant removal)				\$13,000	\$10,710	\$2,290				\$13,000	\$2,290
Equipment/Tools/Supplies											
Field equipment (GPS units, cameras, inventory supplies)	\$2,000	\$1,917	\$83							\$2,000	\$83
Workshop materials/supplies							\$2,000	\$1,418	\$582	\$2,000	\$582
Prairie/savannah seeds				\$8,573	\$8,454	\$119				\$8,573	\$119
Native trees				\$3,000	\$1,940	\$1,060				\$3,000	\$1,060
Printing											
Educational signage	\$1,000	\$996	\$4							\$1,000	\$4
COLUMN TOTAL	\$46,984	\$44,667	\$2,317	\$44,573	\$41,104	\$3,469	\$7,443	\$6,418	\$1,025	\$99,000	\$6,811



GARVIN HEIGHTS RESTORATION PROJECT

A THESIS PRESENTED TO THE FACULTY OF
WINONA STATE BIOLOGY DEPARTMENT

In partial Fulfillment of the Professional Science
Masters Program

Ryan Walsh

June 2019

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Chapter 1: Introduction

Currently Garvin Heights is facing an over-abundance of European buckthorn *Rhamnus cathartica*, that it is altering the natural bur oak savannah and dry bluff prairie habitats that have existed there for thousands of years. In past years, occasional efforts attempted to remove buckthorn from prairies, but the invasives quickly returned when control activities lagged. The purpose of the current project and the focus of this thesis is to use disturbances such as cutting, chemical treatment, prescribed grazing, and burning to reduce buckthorn abundance and allow native species to recover. Both the habitats and species within are extremely rare, adding to the importance of this research and the restoration efforts.

For this project, there were two hypotheses. First, goats are facultative eaters that will start by browsing on buckthorn yearlings and as those populations decrease will move on to taller(adolescent) and shorter(seedlings) buckthorn plants. Second, goats will selectively browse on buckthorn with intermediate stem diameters, while avoiding those that are too large or too small for them to browse on. These hypotheses will be explored further in later chapters. In addition to these hypotheses, this project will also cover habitat delineation of the Garvin Heights area, an educational workshop on invasive species, and recommendations for future management activities.

Chapter 2: Background

Dry Bluff Prairie and Bur Oak Savannah

Dry bluff prairies or dry-mesic prairies are unique to the Midwestern United States, specifically the Driftless area, and are uncommon because of the conditions needed for them to occur (Wisconsin DNR, 2018), although they once occupied large portions of the tallgrass region (Ladd, 1995). Dry-mesic prairies usually grow in steep, bedrock-cored bluffs created from glacial till along river valleys and, because of space limitations, grow in patches rather than large running prairies like one might see with traditional lowland prairies (Fred Harris and Robert Dana , 2014). To have a dry bluff prairie, generally a south- or west-facing slope is required to provide ample sunlight for evaporation. A slope with a north- or east-facing slope will usually have forest or savannah, due to higher moisture levels present in these habitats. Traditionally, dry bluff prairies are found on top of bedrock with steeper slopes where water is excessively drained, within areas that experience extreme moisture deficits throughout the growing season (Fred Harris and Robert Dana , 2014). The amount of canopy coverage is generally very low, with around 10% being the cut-off. Conversely the amount of ground coverage is usually very high, reaching around 100% with very few sparsely populated plots (Fred Harris and Robert Dana , 2014). The soil content can range from loams to loess and residuum, the latter being found on steeper slopes (Fred Harris and Robert Dana , 2014). These xeric conditions favor plants that are adapted to surviving with little moisture and poor soil fertility, like medium

grasses and forbs with trichomes, little biomass above ground, and smaller leaves (Fred Harris and Robert Dana , 2014).

The following grasses are all found on the dry bluff prairie: little bluestem (*Schizachyrium scoparium*), side-oats grama (*Bouteloua curtipendula*), hairy grama (*Bouteloua hirsuta*), and prairie dropseed (*Sporobolus heterolepis*) (Wisconsin DNR, 2018). The following are all common shrubs found on dry bluff prairies: Lead plant (*Amorpha canescens*), silky aster (*Symphotrichum sericeum*), flowering spurge (*Euphorbia corollata*), purple prairie-clover (*Dalea purpureum*), cylindrical blazing-star (*Liatris cylindracea*), and gray goldenrod (*Solidago nemoralis*) (Wisconsin DNR, 2018). A majority of the plant species found in a dry bluff prairie are grasses and forbs, with only a few shrubs (Fred Harris and Robert Dana , 2014). The exact composition of a dry bluff prairie varies greatly, but usually is dominated by little bluestem. Regular wildfires are required to maintain dry-mesic prairies, but the required frequency is much lower than mesic or wet prairies due to its xeric nature (Fred Harris and Robert Dana , 2014). If fire does not occur on a regular basis, these prairies will start to transition to savannah or woodland, although the dry conditions and poor soil make this very difficult. Before large populations of humans were present, these biomes also saw heavy grazing from large ungulates. Since then, most of these species have been hunted to extinction or are endangered. This lack of herbivory has also had a strong impact on the makeup of these natural area.

There are several classes of dry bluff prairie, including dry barrens prairie, dry sand/gravel prairie, dry hill prairie, and dry bedrock prairie. Garvin Heights is the latter of these classes. These classes are created by landscape present, but also by the flora that exists within the ecosystem. In this case, species present will include false boneset, beardless birdfoot violet,

cylindric blazing star, and gray-headed coneflower, all of which are uncommon in the other three classes (Fred Harris and Robert Dana , 2014). Due to the unique plant species present in these areas, there also is a unique set of animals that exist in these areas, including rare species like timber rattlesnakes, skinks, loggerhead shrikes, prairie voles and prairie pocket mice.

The other area of interest to this project is the bur oak savannah or oak opening. A savannah is defined by its lack of coverage, specifically its ability to allow grasses to be the dominant species in the area, and generally has one tree species at higher concentration than any other (Curtis 1959). Additionally, canopy coverage in a savannah typically ranges from 10% to 50% (Curtis 1959). The coverage is kept low or open via regular fire and/or grazing by herbivores (USDA, 2003). Without disturbances to keep the coverage low, the amount of trees increases in the understory and we see a transition to a woodland or forest. This fact is abundantly clear for the savannahs found at Garvin Heights, which have a canopy coverage >75% (N. Mundahl, unpublished data).

Savannahs in the Midwest typically exist in what are called border zones between prairies and woodlands. Bur oak savannahs typically develop on well-drained, south- or southwest-facing slopes (Curtis 1959). The soil typically is deep with a high level of calcium carbonate or calcareous in nature (Curtis 1959). The dominant tree species in Garvin Heights is the bur oak. This species does particularly well in the savannah due to its thick bark, which allows it to survive fire and create seedbeds (Abrams, 1992). Deep roots and xeromorphic leaves also give it an advantage in the dry conditions typically seen on the savannah (Abrams, 1992). Unfortunately, one of the weak points of the bur oak is its lack of shade tolerance

(Abrams, 1992). This is a major issue for this project, as one of the negative aspects of buckthorn is its creation of shade and ability to outcompete young oaks (Abrams, 1992).

Part of how a savannah is defined is by how the dominant trees grow on it. Because canopy coverage is low, savannah trees display an open growth pattern, with branches growing horizontally rather than vertically as traditionally seen in woodlands and forests. When walking a savannah area you will typically see what are known as street trees. This have low horizontal branches that spread out.

Much like the dry bluff prairies, the bur oak savannah has a characteristic makeup of grasses and forbs that includes little bluestem (*Schizachyrium scoparium*), white wild indigo (*Baptisia leucantha*), lead plant (*Amorpha canescens*), purple coneflower (*Echinacea purpurea*), round-headed bush clover (*Lespedeza capitata*), and blue aster (*Aster anomalis*) (USDA, 2003). Shrubs typical to this ecosystem include New Jersey tea (*Ceanothus americanus*), hazelnut (*Corylus americana*), and pasture rose (*Rosa carolina*) (USDA, 2003). The bur oak savannah at Garvin Heights can be defined by its increased canopy coverage (>75%) predominantly of fire-tolerant bur oak trees, with grasses and forbs scattered throughout. Bur oak savannahs are one of the most threatened ecosystems in the Midwest and are among the most threatened in the world, with less than 0.01% of the original savannah community remaining. This only increases the need for restoration research on these areas (USDA, 2003).

This project took place within the boundaries of Garvin Heights Park. Part of the project focused on the two dry bluff prairies (different strategies for each one). The upper and lower dry bluff prairies at Garvin Heights both have high diversities of grasses and forbs, with

buckthorn growing along prairie edges and in isolated patches. The upper prairie shown in figure 3 has been subjected to several prescribed fires and two buckthorn cut-and-treat activities during the past 15 years. The lower prairie shown in figure 4 has only experienced prescribed fire during the same time period. Larger buckthorn were removed (cut and treated) within the savannah by the Conservation Corps of Minnesota starting in February 2016 and continuing through 2019. The other ecosystem of interest is bur oak savannah at Garvin Heights shown in figures 1 and 2, which currently is defined by its high canopy coverage (>75%) predominantly of fire-tolerant bur oak trees, with grasses and forbs scattered throughout. Until recently this area has not seen as many treatments as the prairies have, and consequently had a much larger population of buckthorn with a greater size range. Unlike the prairies where the buckthorn was mostly restricted to the fringes, the savannah had large numbers of buckthorn throughout the habitat. This can be attributed to the greater amounts of shade found on the savannah due to lack of disturbances. As mentioned previously, disturbances help maintain the preferred level of canopy coverage for a savannah and the loss of disturbance leads to greater amounts of shade and niches for plants like buckthorn.

Habitat Restoration

When planning a restoration, it is important to have a strategy in mind. This strategy is based on several factors, including the type of ecosystem, level of degradation, intended use, and target community, to help guide actions taken (Kline 1997). For example, ecosystems like prairie tend to repair themselves over a relatively short period when compared with a boreal forest that, due to poor soil quality and a short growing season, do not rebound well after damage has occurred.

There are two general strategies to use when performing a habitat restoration, passive and active, with the level of degradation being the most important factor determining which approach to use (Muller et al. 1998). There are many factors to examine when assessing land degradation and many ways to do it. Of these factors there are six essential ones that we focus on in reference to degradation: biomass, social, economic, biodiversity, water, and soil (SOLAW: Land Degradation report 3, 2011). Biomass includes all living matter, ignoring all abiotic factors (SOLAW: Land Degradation report 3, 2011). Social factor is how the land is being used by humans for non-economic reasons; camping, picnicking and fishing are all good examples of social aspects land use. Economic is focused on what kind of financial benefits an area of land provides. This might include things like lumber, agriculture, or natural resources. This factor focuses more on overuse and deforestation. Biodiversity is the diversity of life that is present in a given area. In degradation terms, we are looking at things like loss of species and formation of monocultures. Water is the loss of usable water for organisms. This can refer to things like desertification, pollution, or eutrophication (Eswaran, 2001). The final factor is soil health, which refers to the ability of the soil to sustain life (SOLAW: Land Degradation report 3, 2011). Many different things can affect soil health, ranging from leaching, salinization, acidification, loss of nutrients, and erosion. These factors combined can all be used to help judge degradation, but a given area does not require us to look at all of them. For Garvin Heights, the focus is on social, biodiversity, and soil health, which all are negatively impacted by buckthorn and will be discussed in detail within the buckthorn section below.

If the level of degradation is minor and the environment appears that it will return to normal after removal of the stresses causing the change, then taking a passive approach is

preferred (Muller et al. 1998). The passive approach allows the environment to fix itself. For example, if humans picking flowers were causing an issue, one might simply implement rules against picking flowers, removing the stress and letting the seed bank repair the damage. If the habitat has been degraded to such an extent that the environment cannot fix itself, a more active approach may be considered. Active restoration is when heavy intervention is used to restore the habitat. When this route is chosen, there are several tools available in our toolkit, including thinning, burning, invasive species control, planting, and seeding (DellaSala et al. 2003).

Prescribed burns are the intentional burning of lands to simulate the natural fires that occurred there historically. The restoration objective of a prescribed burn includes reducing overstory tree density and basal area to levels historically reported, selecting for native tree species, eliminating/suppressing understory as well as creating a healthy herbaceous layer with grasses as the dominant species (Peterson, 2001). Once a “healthy” savannah has been established the long-term goal of prescribed burning should be the maintenance of said area. Reduction in fire frequency leads to structural changes in the prairie and savannah including increased tree density, basal area, and canopy cover (Peterson 2001; Abrams 1990). This effectively improves the habitat and native plant communities while reducing chances of the far more dangerous wild fires (Kurtz, 2013; Peterson, 2001). In fact, seedling density of bur oak is increased by prescribed burns, not damaged by it (Peterson, 2001). Bur oak is classified by Rowe (1983) as a resistor, which means it is very effective at coping with fire. They are described as shade-intolerant with the ability to survive low-severity fires with little or no damage due to their thick bark (Rowe, 1983; Peterson, 2001). Conversely buckthorn is an

avoider or a shade-tolerant and fire-sensitive species that slowly reinvades following a disturbance (Peterson, 2001). They require a long, fire-free period to become established and the juveniles are easily killed by fire (Peterson, 2001). Avoiders also have the tendency to alter the habitat to make fire less likely. This is indeed true of buckthorn, as its rapidly decaying litter and increased shading make fires less likely (Peterson, 2001). Coupling these facts with the history of fire suppression in the area makes Garvin Heights an ideal area for prescribed burns, and for that reason fire was added to the restoration plan. For the Garvin Heights restoration, prescribed burns will serve to eliminate buckthorn and reduce the amount of shade. It also will serve the purpose of pushing back the understory and reducing the overstory, bringing the canopy coverage back to a more natural state in the savannah while stopping any transitions in the prairie. For the long term it should reduce some of the future canopy coverage as well.

Grazing is the intentional release of herbivores onto a piece of land allowing them to eat the plant species present. A prescribed grazing seeks to suppress invasive plants by altering the timing, intensity, and frequency of grazing and by stocking animals based on their dietary preferences (Rinella, 2009). Well managed prescribed grazing seeks to cause significant damage to the target plant, limit damage to surrounding vegetation (especially native species), and can be integrated with other disturbances as part of a larger restoration plan (Frost, 2003).

Much preparation goes into performing a prescribed grazing. The first step in the process is to decide which animals to use, e.g., cattle, goats, sheep, geese, and horses all can be used (Tu et al., 2001). Each organism specializes on different types of plant material. Cattle and horses feed heavily on invasive grasses and roughage, although horses are more selective (Tu et al., 2001; Frost, 2003). Sheep are very effective at taking care of herbaceous flowering plants,

so they are excellent for handling invasive forbs (Frost, 2003). Goats have narrow, strong mouths which are very effective for removal of individual leaves from woody stems and for chewing branches (Frost, 2003). Additionally, they are able to push over larger wood shrubs and trees in order to girdle and damage upper parts of the plant (Tu et al., 2001). They also handle allelochemical metabolism with a greater efficiency than other organisms traditionally used in prescribed grazing (Frost, 2003). Goats have a tendency to eat large amounts of browse even when other kinds of forage are available (Nelle, 2001). Consequently, they will not focus on one type of plant and ignore all others. Goats are the best choice when the trying to remove invasive woody species from an area.

On top of choosing a type of organism, a particular species, age group(s), and sex need to be chosen (Frost, 2003). All these factors influence how an organism feeds and should be considered when making decisions on what organism to use. After deciding on an organism the next thing to consider is when to have the grazing event. The time period of the grazing should be planned to inflict the most damage on the invasive species, while limiting the impact on the native species (Tu et al., 2001). Early in the growing season is generally not a good idea, as many plants are tolerant of herbivory when competition for soil nutrients and moisture is low (Frost, 2003). As the seasons progress and plants shift to seed production, they become less tolerant of herbivores. This is the ideal time to have a prescribed grazing event as it can be extremely detrimental to the plants (Frost, 2003). Too late in the season and the risk of the herbivores becoming transporters for the seed increases (Tu, M., Hurd, C., and Randall, J., 2001).

The final step in the process is deciding how long to leave the animals on the site. Too long will lead to overgrazing and damage to the native species, while inviting new invasive species in (Tu et al., 2001). Too short and they won't have the desired impact on the area. Good management of the area requires monitoring the area to make sure the proper amount of control is achieved without damage to the desirable species (Tu et al., 2001).

There are both positives and negatives to grazing. Positives include allowing native species to make a comeback, pushing back encroaching forest, and improving both nutrient recycling and plant growth. Additionally, herbivores are very good in areas that are sometimes untreatable by other methods (e.g., too steep, too expensive for herbicides, or mechanically difficult). Another positive is that they can eat, fertilize, and spread some of the native species. There also are some negatives that come along with prescribed grazing. When not properly controlled, it can lead to overgrazing which in turn damages the system (Tu et al., 2001). Additionally, it can reduce native plant cover, disturb soil, and spread invasive species from one cut to another (Tu, M., Hurd, C., and Randall, J., 2001). The goal of using prescribed grazing at Garvin Heights is to allow goats to graze on the property, effectively eliminating many of the buckthorn saplings and adolescent trees while limiting the damage to the native species. We also hope to reduce the transitioning of prairie to savannah while reducing the understory and canopy coverage in the existing savannah.

Prescribed thinning is another tool that is used by restoration biologists to help remove invasive species, decrease basal area, and, in the long-term, decrease canopy coverage (Dey, 2017). The objective is to increase desirable plants by selectively removing plants and increasing the amount of available light (Dey, 2017). There is much debate over how to

proceed, but many believe in more holistic approach which removes both mid-story and overstory portions, creating more of an open stand and allowing ground species to flourish (Dey, 2017). The overall goal should be to reduce unnatural shade created by lack of disturbances and invasive species. The actual process starts with evaluating historical surveys and identifying pest species (Dey, 2017). Once these species are identified, healthy amounts of coverage and basal area per acre should be determined. One should keep in mind that just because a tree or plant is native does not mean that it should not be cut during a prescribed thinning, as the purpose of the thinning is not just to remove invasives, but also to make the overall area healthier. The plants and shrubs that will be cut are then identified with an emphasis on certain species. At this point, the stands can be cut and the stumps sprayed.

One of the positives to prescribed thinning is that the trees cut from the stand can then be used to fund other disturbances within the restoration area (Dey, 2017). Another positive that comes with thinning is the amount of control. Thinning allows those performing the restoration to be very specific about what species of plants they want removed and which ones they want to keep (Dey, 2017). The other disturbances discussed in this paper do not allow for this much control. The negatives to the process stem mostly from cost. If the wood that is being harvested is not being sold and the labor provided is not on a volunteer basis, then this process can be very expensive. This expense is even higher when a cut-and-spray approach is taken. As extra costs will be incurred for herbicides. Additionally it can create issues by creating space for opportunistic invasive species to move in (Kinkead, 2013). The process of thinning at its base removes shade and this creates opportunities for species that have a high tolerance for light. For Garvin Heights, the purpose of this process is to eliminate the larger individual buckthorn

that have thicker basal area and higher tolerance to fire. These also are the size buckthorn that we believe to be most resistant to prescribed grazing. The other purpose of the prescribed cutting is to “thin” the area. The savannah and prairie at Garvin Heights were very dense at the beginning of this project, so through thinning the hope is they will return to a more natural state.

To bring back the native species to the area, a system of interseeding and overseeding will be implemented. Instead of plowing and starting with turned soil, interseeding is simply seeding the existing soil as is. That provides several benefits over plowing in that it does not damage the native species that already are present, and it does not lead to unnecessary erosion (Packard 1997).

The process is started by evaluating the area and determining the seed mix. When designing the seed mix, several things should be taken into consideration, such as grass-to-forb ratio (usually 50/50 mix), seed quality, seeding rates/size, germination rates, ecological behavior, efficiency of seeding technique, season of planting, and budget (Diboll 1997). Seed quality and germination rates go hand in hand as the pure live seed (PLS) value is estimated from germination rate and purity (Diboll 1997). This will help to determine the amount of seed needed for interseeding. Ecological behavior of the different plants should also be a major concern; too many slow-to-establish or fast-to-establish plants can lead to problems, as well as plants that can exclude others from the area (Diboll 1997).

Before interseeding can occur, shading and plant density should be accounted for. A major issue with interseeding as opposed to traditional plow-in seeding is light as a limited

resource (Packard 1997). In prairies and savannahs with large numbers of densely packed grasses and forbs, it can be difficult for light to reach new seeds. To decrease this problem, interseeding can occur in early spring or immediately after burn/mowing (Packard 1997). If amount of moisture in the soil and aggressiveness of current plants can be accounted for, this can be helpful in making separate mixes for these different areas. For small areas such as Garvin Heights, hand sowing the seeds was more than adequate. We used a ratio of roughly one cup of seed to every 100 square feet. Similar strategy were used for both the savannah and prairie areas. However the seed mixes were specific to each area.

European Buckthorn

The major issue that threatens the habitats at Garvin Heights is invasive species, particularly European buckthorn (*Rhamnus cathartica*). Invasive species are those that have not faced selection pressure in that area, but can establish and grow in many areas. (USDA 1999). They grow very quickly and spread from their native habitat to other areas, much like a cancer (USDA 1999). Typically, they are introduced as ornamentals or decorative plants. Usually these plants are aesthetically pleasing or serve another purpose such as hedging for cattle. Invasive species are particularly problematic because they have not existed in that area, which means they do not have many of the natural selection pressures that other native species face, which means that they can survive and procreate without population controls keeping them in check.

Buckthorn is a flowering plant or angiosperm. It is deciduous in nature, meaning it drops its leaves and fruit annually via abscission. It grows to about 25 feet in height, but smaller plants are much more common (Hanson 2018). It produces offspring at 9-20 years of age depending

on the location and available resources. The bark is brown with oval-shaped leaves that have a pointed tip at the end, glossy coating, finely toothed, and are arranged opposite to alternate. It has a wide tolerance for both wet and dry conditions, again making it troublesome as an invasive species (Knight et al. 2007). Its light and moisture tolerances allow it to survive in a wide variety of ecosystems. It is an extremely resilient plant that is able to survive in a multitude of areas and conditions.

European buckthorn is classified as an invasive species. It was brought to Minnesota in the mid-1800s and sold as a hedging plant by many nurseries until the 1930s (Hanson 2018). Buckthorn is extremely troublesome for several reasons, chief among them being it out-competes native plants for resources, allowing it to drive these native species out (Hanson 2018). There are several different characteristics that make this possible. Like many plants that grow in the shade of savannah, buckthorn is shade tolerant. It exhibits low mortality at low light levels and higher mortality in deep shade, but many of its seedlings are still able to survive in these conditions (Knight, 2007). Conversely, it exhibits greater growth and abundance in areas with more light, but requires much more moisture (Knight, 2007).

Another feature that allows it to out-compete native plants is the length of time it retains its foliage. Buckthorn buds earlier in the year and sheds its leaves later in the year in comparison to the native species living around it (Knight, 2007). This allows it to gather resources for much longer period of time than the species it is competing against. This also is the reason for its high carbon gains along with carbon efficiency (Knight, 2007).

Buckthorn is extremely prolific and the male plants on average can fertilize 6-7 female plants, this high rate of proliferation can be problematic when try to control the organism (Knight, 2007). The drupes have a very high germination rate even without scarification or stratification, although both appear to positively influence germination rates (Knight, 2007).

Secondary compounds are chemicals found within a plant that can be both positive and negative for the plant. In the case of buckthorn, it produces a chemical called emodin which causes invertebrates to actively avoid it as well as having an allelopathic aspect (Knight, 2007). This is a huge benefit, as it allows buckthorn to avoid some of the native insect species that feed on other plants as well as facilitating growth of its offspring in the area surrounding it (Knight, 2007).

The formation of thickets by buckthorn alter the community by creating significant amounts of shade in the mid- and understory. These alterations lead to changes in the makeup of the community. Species that survive better on or in buckthorn are selected for, which opens the door for more shade tolerant species to move in, alter the base of the food chain, and change the amount and availability of certain nutrients (Knight, 2007). In essence buckthorn moves in and takes the place of a cornerstone species.

The ability of buckthorn to spread is one of the reasons that it is such a pervasive species to deal with. It produces small berries that are consumed by birds, the seeds pass through bird digestive tracts undamaged, and are dropped far from their parent plants (Bell et al. 2003). Digestive tract juices cause seed scarification, which has a positive impact on germination rates

(Knight, 2007). Using birds as a vector to spread their seeds has allowed buckthorn to cover wide swaths of the United States and Canada.

When combining buckthorns abilities to survive, procreate and spread it start to become very clear why this tenacious plant is so hard to deal with. It is alround tough plant to deal with and eliminate. Through the process of completeling my research project I have developed a very healthy respect for buckthorns adaptability to harsh circumstances.

Chapter 3: Habitat Delineation

Introduction

Degradation of ecosystems has become more and more prevalent over the past decades, leading to drastic alterations in disturbance regimes, exotic species expansion, and loss of native species (Hansen et al. 2011). Most times, an ecosystem or habitat spans a much larger area than what falls within a specific, protected area. Consequently, it has become much more common to delineate entire ecosystems. Usually these delineations are determined by the presence of a specific organism within the ecosystem that is used to define it, for example, the home range of grizzly bears were used to define the greater Yellowstone ecosystem (Hansen et al. 2011). Habitat delineation is a process in which an outline or perimeter of a given ecosystem is made. Within a restoration project, this serves a very important purpose. Each area is unique and should be treated as such. The prairies and savannahs at Garvin Heights each received different treatments, so it was very important that the borders of each area were defined.

Within Garvin Heights, three distinct habitats exist: dry bluff prairie, bur oak savannah, and oak-maple-basswood forest. The dry bluff prairie is defined by the presence of grasses and the lack of large deciduous trees. The lack of canopy coverage is the characteristic that helps identify the borders of the dry bluff prairie. The bur oak savannah is characterized by bur oak that exhibit a growth pattern indicative of “savannah conditions”, with major branches positioned more horizontally than vertically. These types of bur oak were used to define the

areas between the oak-maple-basswood forest and the bur oak savannah. The oak-maple-basswood forest is defined by its high levels of coverage from fire-tolerant oaks, maples, and basswoods, characterized by their relatively few, low branches (Kline 1997). The oak-maple-basswood forest was defined by exclusion; essentially everything that does not fall into one of the other two groups fell within the oak-maple-basswood forest.

Methods

The process of delineating the area occurred in several steps, the first of which was gathering background information on the characteristics of each of the habitats that exist at Garvin Heights. The process involved research into each of habitats and finding a focus for how to define them. In the case of the dry bluff prairie, it was a lack of canopy coverage that was used as the defining factor. Normally the canopy coverage for the prairie ranges between 0-10%, with ground coverage ranging from 50%-100% (Fred Harris and Robert Dana , 2014). The bur oak savannah has anywhere from 10-50% canopy coverage, with slightly less ground coverage (Curtis 1959). Additionally, the presences of bur oaks with lower branches growing in a horizontal manner was used as a defining factor (Curtis 1959).

After the characterizations of each area were settled upon, the next step was to identify the borders of each habitat. The first step in this process involved walking the area to get a feel for what was present. The next step used a dichotomous key called “Minnesota Trees” by David Rathke to identify basswoods and bur oaks that make up the borders between the different habitats at Garvin Heights. After identifying the borders, they were then outlined using fluorescent flagging tape to ease the process of GPS mapping. A phone application called Gaia

was used to delineate each of the habitats. The borders of the habitats were walked again, but this time using the Gaia application to track the borders and mark landmarks to better identify the edges between the areas. This information was then saved as a GPX file and transferred to Google Earth for imaging. Through Google Earth, the habitats were delineated and the images recorded for future use.

Delineated Areas

Several different stands were mapped during the course of this project, each within the confines of Garvin Heights Park. The first area was the non-cleared bur oak savannah on the west side of, and parallel to, the entrance road. This area can be seen in figure 2 and borders private property to the south and west and the second, cleared savannah to the north. This is the area that had seen no restoration efforts previous to the current project, and still has the highest level of mid- and upper-story coverage. The second savannah seen in figure 1 lies to the west of the parking lot and pedestrian walkway to the overlook. Like the other savannah, it is a bur oak-dominated savannah. Part of its southern border abuts private property, with the oak-basswood forest along its western edge. It extends to just north of the downhill walking path, with a narrow section to the northwest that splits the upper and lower prairies. This savannah runs along the southern edge of both the upper and lower prairies. This area has experienced a wide spectrum of disturbances over the last few years, transitioning from a closed stand to an open stand. The upper prairie seen in figure 4 runs along the western edge of the walking path to the overlook. It runs along the cliff edge on the northern end of Garvin Heights, with the second savannah to the south and west. This area had an abundance of buckthorn in its southwestern corner that, through disturbances, has been significantly reduced. The lower

prairie seen in figure 3 is further west than the upper prairie. It can be reached by taking a dirt walking path along the northern cliff edge below the savannah. Its northern border is the cliff edge, its eastern and southern borders abut the savannah, and the western border adjoins oak-basswood forest. This area had the lowest levels of degradation of any area within Garvin Heights, and because of its steep slope, received only prescribed thinning.

Data

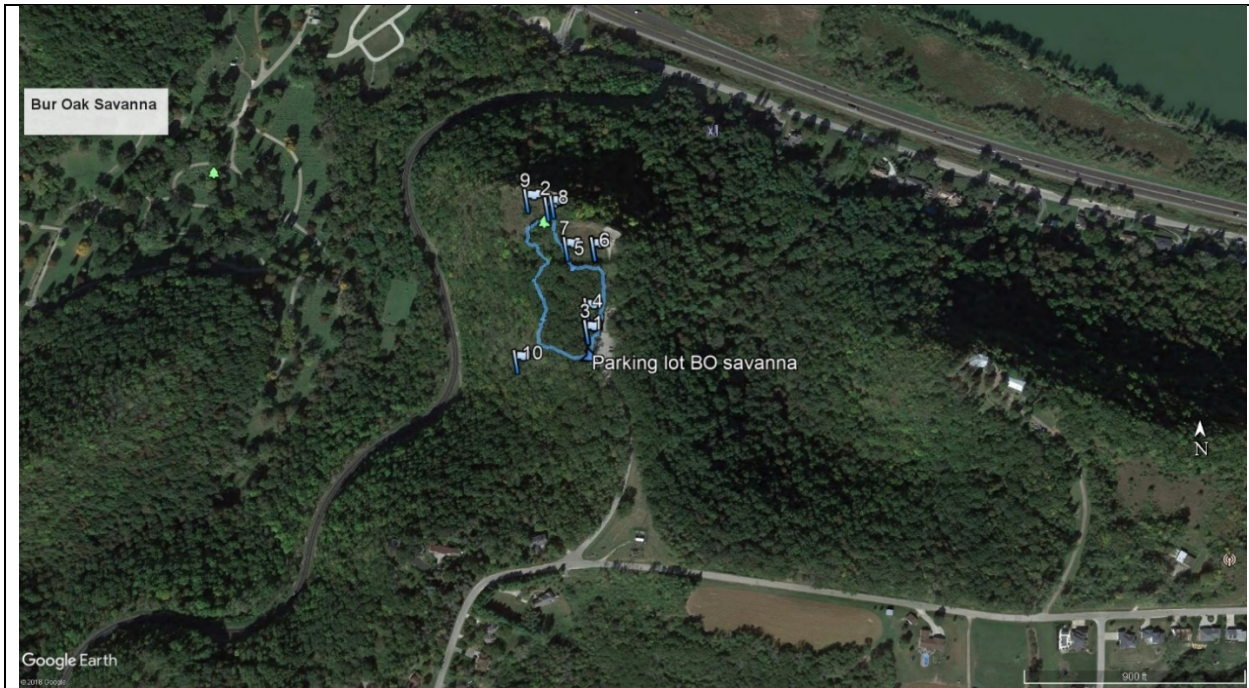


Figure 1: Bur oak savannah parallel to the parking lot on the western side. Divides the upper and lower prairie at map points 7-9.

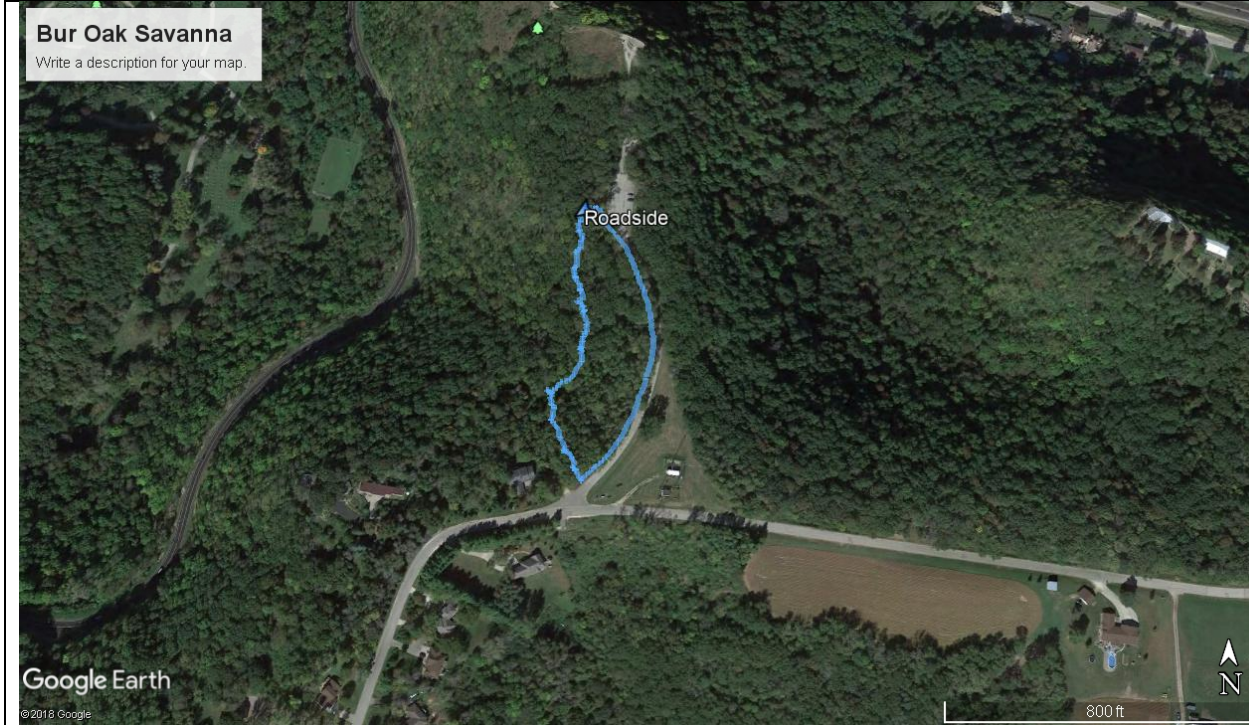


Figure 2: Roadside bur oak savannah which borders the roads, edges of the property and the second savanna on the north side.



Figure 3: Lower dry bluff prairie with the northern border being the cliff side and the other borders being the savannah and forest.

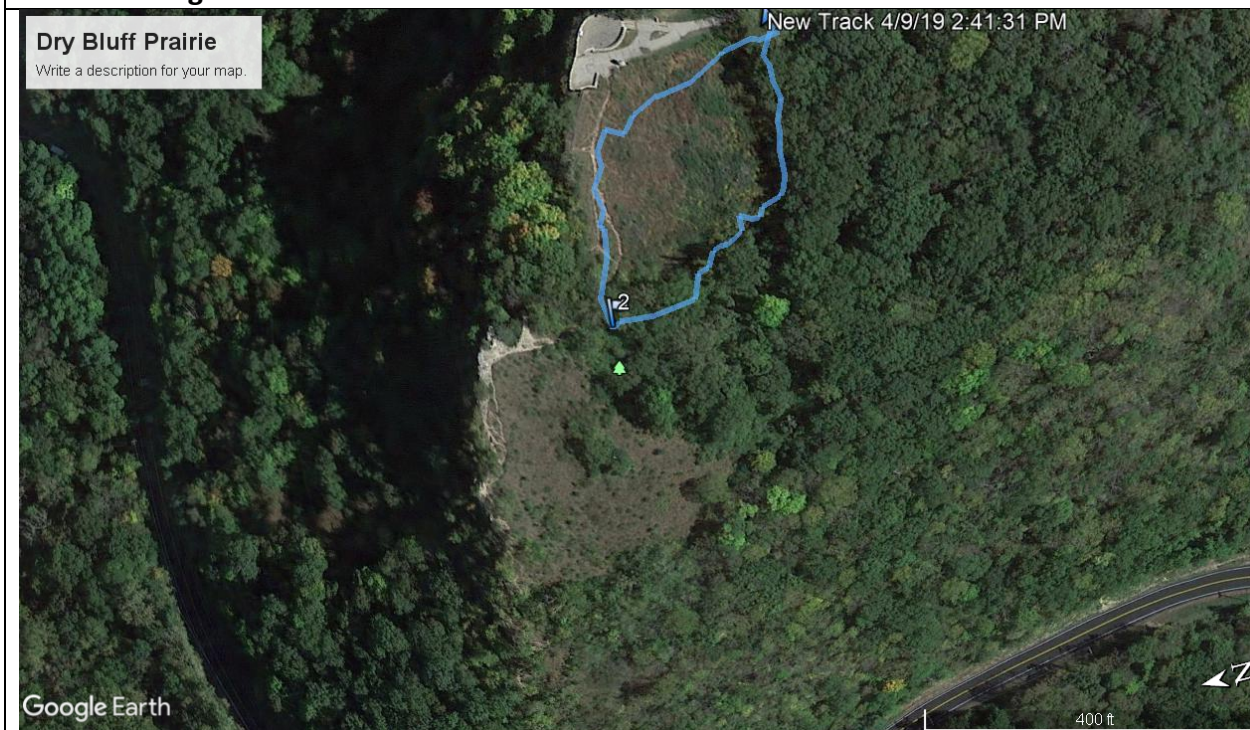


Figure 4: Upper dry bluff prairie runs next to the lookout and the path leading up to it.

Chapter 4: Grazing Surveys

Introduction

In any restoration project, multiple tools are used to decrease the level of degradation. There is no “magic bullet” that will fix all of the problems at a site by itself; rather, a mix of different disturbances is required to bring an area back to its natural state. This portion of the project focused on prescribed grazing and how to improve the outcomes so that future restoration efforts benefit. In particular, we focused on the effect of prescribed grazing on buckthorn densities on the savannah, the mindset being that absolute density of the buckthorn should decrease if the goats are being effective on the savannah. Goats are efficient eaters and so choose plants sizes that reflect that. If given a choice on the savannah, the goats will choose plants at eye level and move up and down from there (Lovreglio, 2014). Based on this, the expectation would be that they would start with yearling and seedling plants, then from there eat larger buckthorn plants. If this is correct then we should see larger amounts of grazing on yearlings initially with increased grazing of larger and smaller plants the following years.

Goats are facultative eaters, having a tendency to change their behavior depending on their environment. When allowed to roam free, they will feed very selectively on whatever they find to be most appetizing, but when penned they have a tendency to feed on what is available within the fenced-in area (Lovreglio, 2014). They become less selective and more efficient. As the seasons change and food availability changes, this also will affect their feeding habits as they have a tendency to move up and down their height range, something many other grazers

will not do (Plessis, 2004). Seasonal changes can be compared to resource availability in a penned-in area; as the feed becomes more scarce in the penned-in area, they move up and down their feed height range.

Methods

To test the first hypothesis, during year 2 we used random quadrant surveys to examine the density of buckthorn and how it changed over the course of the project. To take surveys accurately, a folding, 1-m² quadrant was used to define the perimeter of each plot site. Sample sites were assigned randomly using a line and compass to determine direction. Walking from east to west, every 15 paces a plot was taken with the placement rotating to a different compass heading at each plot site. At each site, the number of buckthorn was recorded and categorized into ranges based on their height. Seedlings were classified as 12" or less, yearling as 12"- 54" and adults as greater than 54". After traveling to the edge of the section, the surveyor moved 10 paces north and repeated the process going west to east. Upon reaching the northern boundary of the section the survey was completed. These data were transferred to a spreadsheet for data analysis and interpretation. Counts were made prior to and shortly after goat browsing.

Additional density data were collected by an undergraduate student during year 1 using a smaller quadrant (0.1 m²). For her collections, the area was divided up into the uncut area (Fig 2) and the cut areas (Fig 1), the difference being that one area (cut) received a prescribed thinning whereas the other did not. Within both cut and uncut areas, plant counts were made by placing a quadrant every 10 paces along a weaving transect, with plants <12" in height

categorized as seedling and plants >12" categorized as yearlings. Buckthorn >36" in height were not tallied. Again, counts were made prior to and shortly after goat browsing.

Goats were provided by Diversity Landworks for a fee. They were penned into each habitat at Garvin Heights for approximately five days, then moved to the next paddock where the procedure was repeated. They were not provided with any supplementary food, only water, so as to force them to feed on the woody browse within the area. They did have regular human interaction, as Garvin Heights sees many guests who frequent the grounds.

Study Site

The savannah next to the parking lot at Garvin Heights was used for this portion of the project. This savannah is west of the parking lot and walking path that leads out to the overlook. It shares a border with the roadside savannah and private property to the south and runs along the oak-basswood forest on its western boundary. It extends over the steps and divides the upper and lower prairies running all the way to the bluff edge. It can be found above in figure 1. This section was historically dominated by bur oaks, but has seen a lot of change over the past several decades as buckthorn moved in and took over. Recently it has seen controlled burns, prescribed thinning, and prescribed grazing. The thinning in particular removed a lot of the adult buckthorn from the area and eliminated much of the mid-story coverage. The second area used in this experiment can be found in figure 2 and is the bur oak savannah found alongside the entry road on the west side of it. It runs along the border of the property on the south and west sides with the northern siding butting up against the other savannah used. This savannah had not received any treatment prior to this grazing.

Table 1: Buckthorn surveys pre- and post-grazing for year 1. Also includes browsing percentages and browsing by paddock.

Pre-Goat Cut				Post-Goat Cut area				Totals		%browsed		Uncut area				Totals		%browsed				
seedlings	yearlings	seedlings	yearlings	eaten seedlings	not eaten seedlings	eaten yearlings	not eaten yearlings			eaten seedlings	not eaten seedlings	eaten yearlings	not eaten yearlings									
49	0	2	0	0	4	1	1	6	16.6666667	1	0	0	0	1	100							
60	1	0	0	0	7	3	0	10	30	0	1	0	0	1	0							
36	0	3	0	0	5	4	0	9	44.4444444	0	5	0	0	5	0							
10	2	0	0	1	2	3	1	7	57.14285714	0	2	0	3	3	100							
29	5	0	0	1	4	0	2	7	14.28571429	0	1	1	0	2	50							
24	2	4	0	0	8	0	0	8	0	0	3	3	0	6	50							
8	3	9	1	1	3	2	0	6	50	1	1	1	0	3	66.6666667							
9	1	12	0	0	6	0	3	9	0	0	4	0	0	4	0							
25	1	20	1	0	2	3	0	5	60	0	2	4	2	6	33.3333333							
8	4	29	1	0	0	2	1	3	66.6666667	0	3	2	0	5	40							
36	2	15	0	2	6	2	1	11	36.36363636	2	2	0	0	4	50							
26	2	29	0	1	23	1	0	25	8	2	0	3	0	5	100							
11	0	29	2	0	0	1	2	3	33.3333333	0	0	2	0	2	100							
55	1	35	3	0	2	0	0	2	0	0	6	0	0	6	0							
71	0	19	0	0	3	0	0	3	0	0	13	3	1	17	17.64705882							
49	0	16	0	0	0	1	0	1	100	0	10	0	1	11	0							
6	1	17	1	0	0	0	0	0	0	2	10	0	0	12	16.6666667							
12	2	6	1	0	2	3	0	5	60	0	2	6	0	6	0							
17	1	18	1	0	0	0	0	0	0	0	6	0	0	6	0							
9	0	6	0	3	6	0	0	9	33.3333333	0	2	0	0	2	0							
10	3	3	0	5	5	0	0	10	50	0	4	0	0	4	0							
4	0	8	1	3	5	0	0	8	37.5	0	0	4	0	4	100							
4	1	21	1	1	39	1	0	41	4.87804878	1	0	2	0	3	100							
6	0	16	3	1	17	0	0	18	5.555555556	2	1	3	0	6	83.3333333							
4	2	9	0	0	2	0	2	4	0	1	0	5	0	6	100							
5	0	3	2	0	0	2	0	2	100	0	0	2	0	2	100							
15	0	38	1	0	0	0	0	0	0	0	0	0	0	0	0							
3	4	5	0	0	1	0	0	1	0	1	0	0	0	1	100							
10	2	46	0	0	2	0	0	2	0	1	0	0	0	1	100							
2	1	17	1	0	0	1	0	1	100	0	1	0	0	1	0							
1	0	8	0	0	0	2	1	3	66.6666667	0	0	3	0	3	100							
13	0	6	0	0	0	1	0	1	100	0	2	4	0	6	66.6666667							
55	1	18	2	4	5	2	0	11	54.54545455	0	2	4	0	6	66.6666667							
18	4	7	1	0	1	3	0	4	75	1	13	1	0	15	13.3333333							
3	1	5	0	0	0	2	1	3	66.6666667	0	2	1	0	3	33.3333333							
6	0	11	1	0	0	3	0	3	100	1	0	7	0	8	100							
4	2	2	0	0	0	2	0	2	100	1	4	0	0	5	20							
5	5	5	0	1	5	1	1	8	25	0	4	3	0	7	42.85714286							
24	0	9	0	0	6	1	1	8	12.5	5	7	0	0	12	41.6666667							
24	0	0	1	2	3	0	0	5	40	0	6	0	2	8	0							
Sum	766	54	506	25	Sum	26	174	47	17	Mean	6.6	40.75129064	Sum	22	123	59	4	Mean	5.2	47.30427171		
Mean	19.15	1.35	12.65	0.625	Mean	0.65	4.35	1.205128205	0.425	SD	7.475773	34.91353713	Mean	0.55	3.075	1.475	0.1	SD	3.831047	41.39616456		
SD	18.5314	1.477177	11.31269	0.837808	SD	1.21000106	7.248518858	1.196034834	0.747217059	SD	0.985796567	3.583348241	1.768492042	0.378932373	SD	0.985796567	3.583348241	1.768492042	0.378932373	SD	3.831047	41.39616456
					Sum total seedlings	200	Sum total yearlings	64			Sum total seedlings	145	Sum total yearlings	63								

Table 2: T/P values for the densities before and after goat grazing for year 1. Also included is the uncut vs. cut (not directly compared)

T value	Seedling	Yearling
Cut	21.75294846	2.168924929
Uncut	18.40445794	-0.688382979
P value	Seedling	Yearling
Cut	1.22925E-35	0.01652899
Uncut	8.69539E-31	0.246721

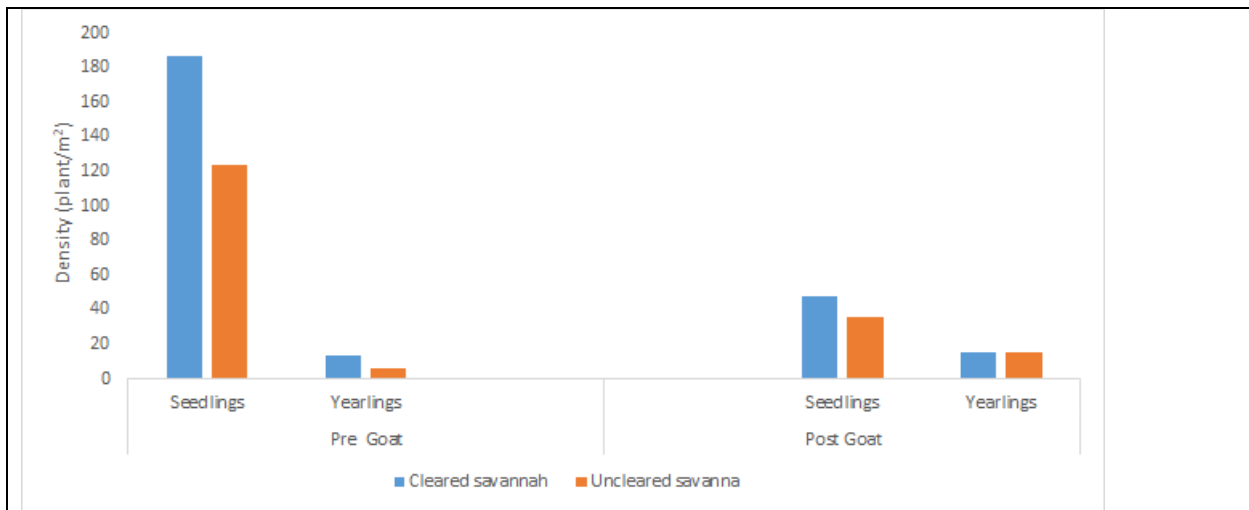


Figure 5: Densities for year one for pre- and post-goat grazing by cut/uncut areas.

Table 3: Buckthorn Surveys pre- and post-grazing on the savannah for year 2.

	Pre Goat Savannah		Post Goat Savannah	
	Seedlings (<12")	Yearlings (12"-54")	Seedlings (<12")	Yearlings (12"-54")
6	3		18	0
16	1		0	6
64	0		2	0
24	6		0	0
8	3		22	0
20	2		1	0
34	1		4	3
13	0		1	0
6	0		6	0
12	10		0	0
44	11		6	4
27	2		0	1
21	2		0	3
96	1		0	0
36	1		0	0
23	5		13	5
58	0		0	0
68	2		7	8
31	0		10	0
0	0		0	4
44	3		2	0
61	8		0	0
8	5		0	0
32	8		0	0
0	1		6	0
78	7		3	5
7	1		4	0
47	0		1	2
6	2		16	0
14	10		11	2
Total	904	95	17	0
Mean	30.13333333	3.16666667	2	2
SD	24.98790512	3.404695878	9	1
Density	30.13333333	3.16666667	12	0
			10	1
			3	0
			86	5
			69	1
			31	0
			37	0
			30	0
			Total	439
			Mean	10.70731707
			SD	18.01144623
			Density	10.70731707
				53
				1.292682927
				2.076582558
				1.292682927

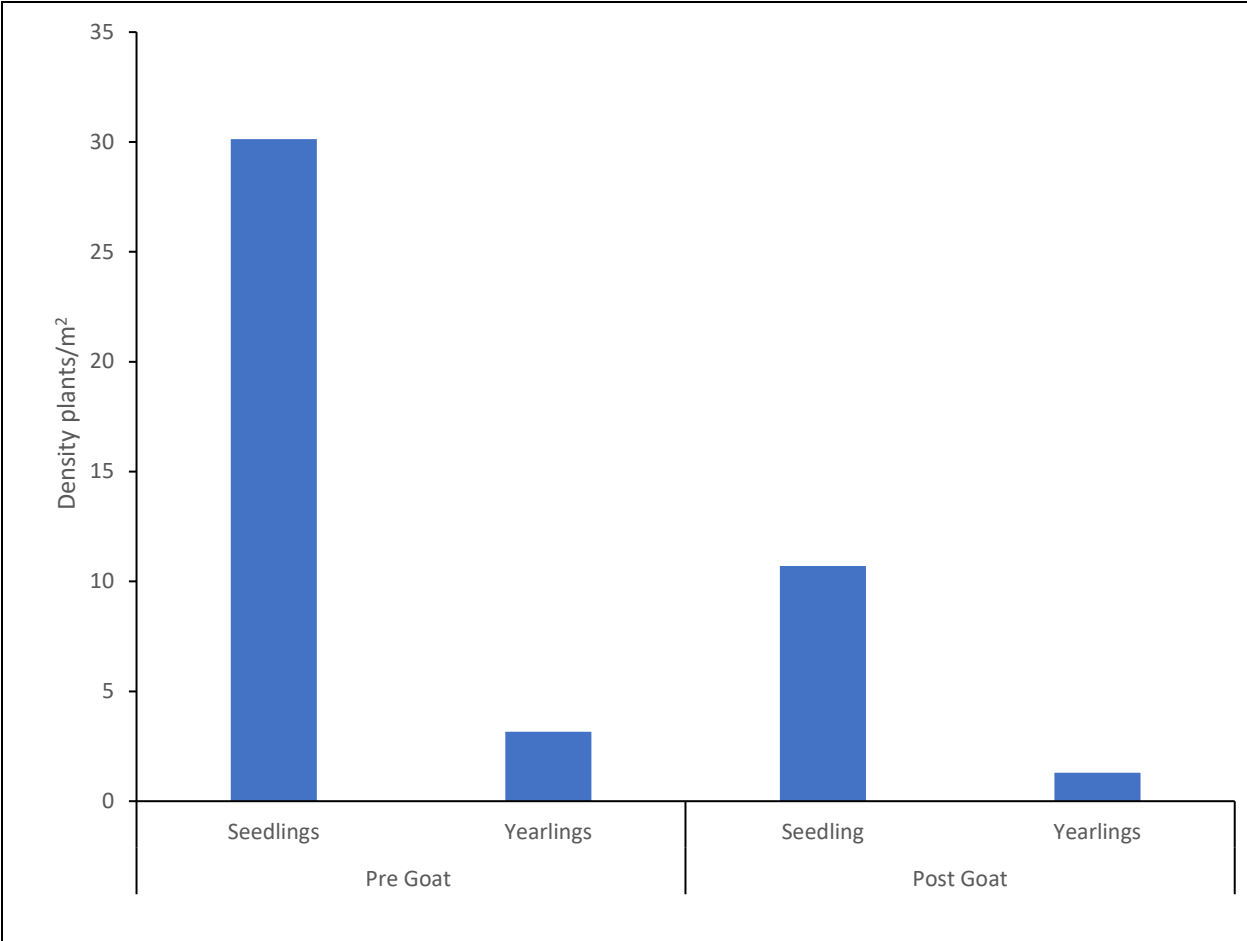


Figure 6: Mean densities for plots on the savannah pre- and post-goat grazing, year 2.

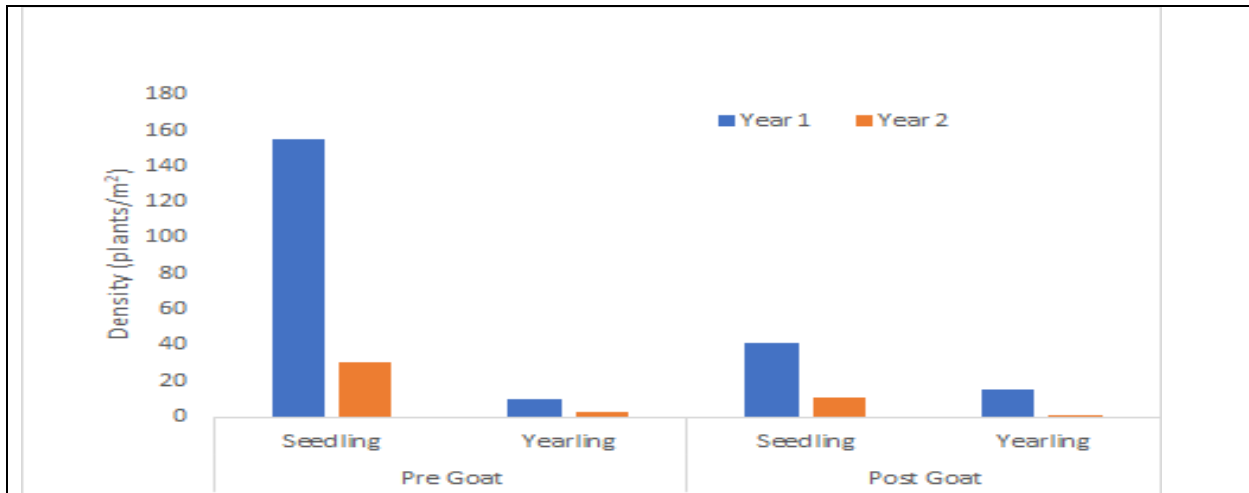


Figure 7: Mean densities from year 1 and year 2 combined.

Table 4: T and P values comparing densities before and after goat grazing for seedlings and yearlings year 2.

	Seedlings	Yearlings
T value	3.624505	2.67283
P value	0.000275	0.004689

Data Analysis

The data was collected and analyzed to determine if there was a significant difference between the densities of buckthorn before and after prescribed grazing occurred. Means and standard deviation/error were calculated using Excel. Densities pre- and post-browsing were compared using simple, two-sample t tests.

Results

Table 1 contains year 1 data collected by Bonnie Hammack. The general trend shows a decrease in average amounts of buckthorn, both seedling and yearling, the one exception being yearlings in the uncut area (Figure 5). Although not the focus of this paper, results did not show a significant difference between the cut and uncut areas for browsing.

Table 2 focuses on the P and t values comparing the densities from year 1. Seedling buckthorn densities were significantly lower after goat browsing than before, in both cut and uncut portions of the savannah. Yearling densities in the cut area also were significantly lower after browsing, but yearling densities in the uncut area were slightly (but not significantly) higher after browsing than before.

Table 3 and Fig 6 contain buckthorn density data from year 2. Both seedling and yearling densities declined after browsing to levels approximately one-third of their pre-browsing levels. These post-browsing declines in density were statistically significant for both age groups (Table 4). Overall, goat browsing produced significant declines in densities of both seedling and yearling buckthorn during both years. Densities of both seedling and yearling buckthorn also were much lower during year 2 than during year 1, both pre- and post-browsing (Figure 7), suggesting a year-to-year decline in buckthorn densities following repeated browsing events.

Discussion

Browsing data support the use of goats within the savannah habitat, as they show a significant decrease in the number of buckthorn yearlings and seedlings from the beginning of the project to the completion of grazing. Goats had a significant impact on the buckthorn population. This agrees with the concept of goats as facultative eaters, as suggested by the trend seen across the 2-year period. It seems the goats start with plants at eye level and move upward and downward from there, which explains the high browsing observed in yearlings the first year, but as these plants became less available, the focus changed to the shorter seedlings. These results support the experiments hypothesis as well as the hypothesis created by Plessis in South Africa (Rinella, 2009).

The results of this experiment support the use of goats to reduce the number of seedlings and yearlings during a restoration. However, there are some additional confounding variables that have to be considered. First was the use of multiple disturbances (browsing, cutting, fire) within each of the areas. These different disturbances cannot be accounted for, so it may be hard to tell what, if any impact, they had on the experiment. Second is the natural mortality of the seedling buckthorn. Again, it is difficult to tell if reduction of mean density is due to goats or natural mortality. An obvious experiment to solve this issue would be a control using two areas that did not see grazing and measuring density over a period of time.

Chapter 5: Girdling Survey

Introduction

In addition to browsing on young buckthorn, goats also strip bark from older buckthorn, with some plants being completely girdled. Girdling kills the aboveground portion of the plant, but the plant resprouts from its base. These resprouts are then consumed by goats during their next grazing period. For this portion of the project, the hypothesis was that goats would selectively browse on buckthorn with intermediate stem diameters, while avoiding those that are too large and less palatable. The purpose of this study was to improve how goats are used during restoration efforts. When doing prescribed thinning, girdling is a method that is sometimes implemented, but goats are much more efficient at it than we are. It is extremely effective at eliminating mid-size to larger plants that due to the thickness of their bark, do not always respond well to prescribed burning.

When a generalist is allowed onto a piece of land so it can graze on all plant species that are present it is known as prescribed grazing. The hope is that they will only damage the plants species invasive to the area therefore not tolerant of herbivory, while leaving the native species alone (Rinella, 2009). Prescribed grazing can take the form of eating leaves, whole plants or girdling plants as is the case in this portion of the project. Grazing can be used to treat both the symptoms and the overall problem(s) leading to them. At Garvin Heights, the buckthorn is the symptom of too much coverage in the savannah and prairie leading to transitioning to different habitats. Prescribed grazing can be used to eliminate the buckthorn as well as reducing the amount of coverage and opening up the areas so shade tolerant plants cannot take root.

Goats have very interesting feeding habits. They have very strong jaws with nimble lips and tongues that allow them to graze on short grasses and other foliage not normally eaten by domestic livestock (Lovreglio, 2014). They are very efficient eaters choosing to go after foods that can be found at eye level (Lovreglio, 2014). They tend to move around a lot and browse from plant to plant. Goats do not focus on any specific plant, but it is thought that they have an easier time handling shrubs rather than grasses and forbs (Nelle, 2001; Frost, 2003). They will often feed on shrubs and herbaceous weeds that other domestic herbivores avoid, and their preference for leaves as well as terminal twigs makes them an excellent alternative for handling invasive shrub species (Lovreglio, 2014). In addition to these abnormal feeding behaviors, they also will eat plants such as poison ivy and oak that are poisonous to other grazers (Kauakou, 1992; Duarte, 2012). It is believed this is due to their ability to dilute the poisonous compounds by browsing on other plants, as well as passing some of it into their milk (Lovreglio, 2014). Their ability to reach high into trees also is a factor in goat feeding. Despite their height, they are able to control plants until they reach a height of 1.5 meters (Plessis, 2004). The range of browsing heights appears at least in part to be controlled by season and availability of food. It should also be noted that goats traditionally graze over a large area, allowing them to be more selective when confined and tending to feed more on woody plants and trees (Lovreglio, 2014).

The use of goats was a good choice for Garvin Heights for many reasons. Goats' body design makes them perfect for handling buckthorn, as they have no issues with leaves, woody stems, or branches (Frost, 2003). They also are large and strong enough to push over larger buckthorn to reach the branches higher up on the plant (Tu, M., Hurd, C., and Randall, J., 2001). As mentioned previously in the buckthorn section, there are some allelochemicals produced by

buckthorn that can be detrimental to other plants and herbivores, but goats are able to metabolizing these chemicals (Frost, 2003). Combining these factors made goats the obvious choice for prescribed grazing.

Study Site

Two areas within Garvin Heights were surveyed. The first area was the non-cleared bur oak savannah on the west side of, and parallel to, the entrance road as seen in Figure 2 in the habitat delineation section. This area borders private property to the south and west and the second, cleared savannah to the north. This area had seen no restoration efforts previous to the current project, and still has the highest level of mid- and upper-story coverage. The second area was a portion of the second savannah that runs between the upper and lower prairies as seen in Figure 1 (points 5-2). During the prescribed grazing, this area was grazed at the same time as the upper prairie so as not to cause problems with the trail system. Its southern side runs along the stairs, with the northern side ending at the bluff. The western and eastern borders of this area are the upper and lower prairies.

Methods

To collect data on the amount of girdling that occurred, a belt transect girdling survey was performed. The tape was laid down at random intervals within the roadside savannah. A 10-meter length was used for the survey, with buckthorn within a meter of the transect being recorded. Buckthorn were recorded as browsed or not browsed in the context of girdling (if part of the bark was removed it was browsed). Additionally, the size of the buckthorn plants

were recorded by diameter and put within ranges. The percent of the girdling also was recorded (0-100%).

Goats were provided by Diversity Landworks for a fee. They were penned into each habitat at Garvin Heights for approximately 5 days, then moved to the next paddock where the procedure was repeated. They were not provided with any supplementary food, only water, to force them to feed on the food within the area. They did have regular human interaction, as many guests frequent Garvin Heights.

Data

Table 5: Diameter of buckthorn girdled/not girdled. Percent of buckthorn browsed or not browsed by the goats within paddock 1 and 3. Selection is shown to the far right. Chi square analysis was performed and showed significant results.					
Paddock 1			Paddock 3		
Diameter	Browsed	%	Not Browsed	%	Selection
<10	0	0	8	3.2	-3.2
10 to 19	18	7.758621	87	34.8	-27.0414
20 to 29	79	34.05172	64	25.6	8.451724
30 to 39	81	34.91379	42	16.8	18.11379
40 to 49	35	15.08621	20	8	7.086207
50 to 59	15	6.465517	15	6	0.465517
60 to 69	4	1.724138	9	3.6	-1.87586
70 to 79	0	0	3	1.2	-1.2
80 to 89	0	0	2	0.8	-0.8
Totals	232			250	
chi-square = 77.7					
degrees of freedom = 8					
P (Chi square) = 0.000					
Diameter	Browsed	%	Not Browsed	%	Selection
<10	0	0	19	12.92517	-12.9252
10 to 19	91	51.41243	122	82.9932	-31.5808
20 to 29	81	45.76271	6	4.081633	41.68108
30 to 39	5	2.824859	0	0	2.824859
40 to 49					
50 to 59					
60 to 69					
70 to 79					
80 to 89					
Totals	177		147		
chi-square = 91.2					
degrees of freedom = 3					
P (Chi Square) = 0.000					

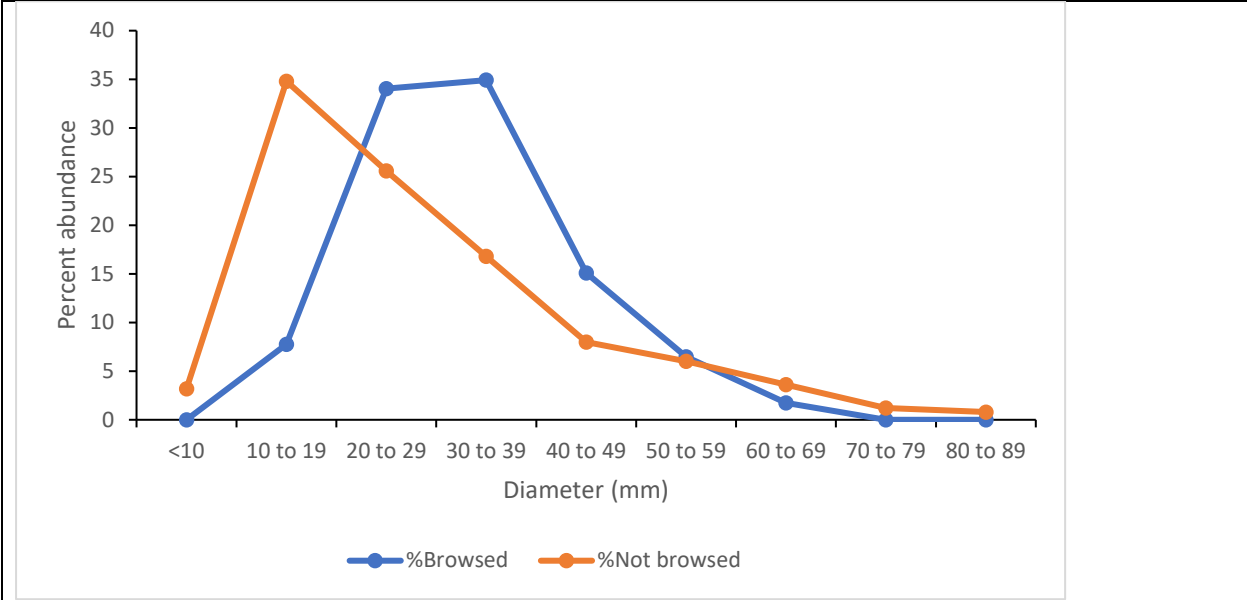


Figure 8: Diameter vs. percent grazed by goats/not grazed by goats. Graph depicts the trend in browsing behavior by the goats in paddock 1.

Table 6: Range of girdling on individual plants within each paddock. The amount that the individuals plants were girdled was measured and a percent of the total calculated.

Paddock 1			Paddock 2		
Range girdled	Number	%	Range girdled	Number	%
1 to 25%	8	3.162055	1 to 25%	10	4.291845
26 to 50%	19	7.509881	26 to 50%	20	8.583691
51 to 75%	24	9.486166	51 to 75%	23	9.871245
76 to 99%	34	13.43874	76 to 99%	30	12.87554
100%	168	66.40316	100%	150	64.37768
Total	253		Total	233	

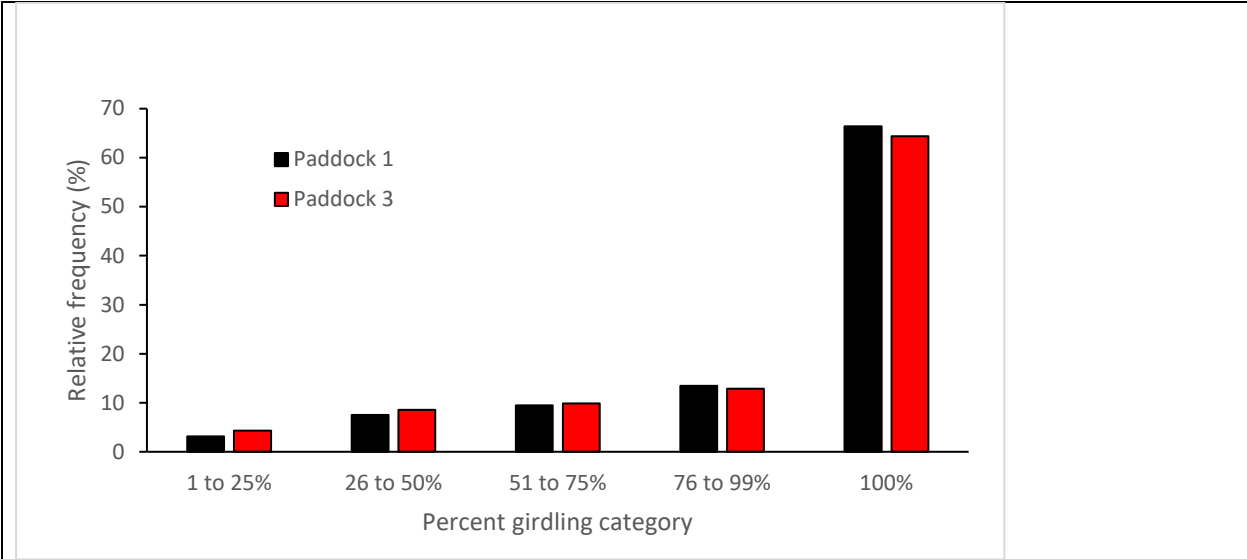


Figure 9: Range of girdling vs relative frequency.

Data analysis

Girdling data were analyzed to see if there was a relationship between girdling and plant diameter and, if so, what diameters goats preferred. Chi-square contingency table analyses were performed to assess whether the distributions of diameters of browsed and unbrowsed buckthorn differed from one another in each of two different parts of the savannah, indicative of possible size-selective browsing by goats. Positive or negative selection by goats was also calculated for each 10-mm diameter size category in each of the two different parts of the savannah by using the following equation:

$$\text{percent}_{\text{browsed}} - \text{percent}_{\text{not browsed}} = \text{Positive or Negative selection}$$

Data also were gathered to determine how completely goats girdled buckthorn stems, i.e., if goats were completely girdling the plant (100%) or only a certain percentage of the plant stem circumference was stripped of bark. To make this easier, the amount of girdling on a given plant was estimated to be in one of five categories: 1-25% of the plant circumference girdled, 26-50%, 51-75%, 76-99%, or 100%. Chi-square analyses were performed to determine whether each girdling category was represented by equal numbers of plants (separate analysis for each area of the savannah). A chi-square contingency table analysis was used to compare the distribution of plants among girdling categories between the two different parts of the savannah.

Results

In both paddock 1 and 2, buckthorn that goats girdled or partially girdled had larger stem diameters than buckthorn that had no stripped bark (Table 5, Figure 8), and the stem size distributions of buckthorn girdled or partially girdled versus not stripped differed significantly both in paddock 1 ($X^2 = 77.7$, $df = 8$, $P < 0.0001$) and paddock 3 ($X^2 = 91.2$, $df = 3$, $P < 0.0001$). Goats displayed positive selection for buckthorn with stem diameters from 20 to 59 mm in paddock 1 and from 20 to 39 mm in paddock 3 (Table 4), selecting against plants with stem diameters <20 mm. Due to the more limited stem size distribution of buckthorn in paddock 3 (5 to 39 mm) compared to paddock 1 (5 to 89 mm; Table 5), the stem size distribution of buckthorn girdled in paddock 3 was significantly skewed ($X^2 = 166$, $df = 3$, $P < 0.0001$) toward smaller plants than in paddock 1.

Goats stripped bark off 48-55% of the buckthorn stems 5 to 89 mm in diameter within the two paddocks. Of the buckthorn stems that experienced bark stripping by goats, >60% were completely girdled in both of the paddocks examined (Table 6, Figure 9), with complete girdling significantly more common (paddock 1: $\chi^2 = 347$, $df = 4$, $P < 0.0001$; paddock 2: $\chi^2 = 291$, $df = 4$, $P < 0.0001$) than lesser degrees of bark browsing. The pattern of partial to complete girdling did not differ significantly ($\chi^2 = 0.72$, $df = 4$, $P = 0.949$) between the two paddocks.

Discussion

Several different conclusions can be drawn based on the data gathered on girdling behaviors. First, there is a preference towards stem diameters of 20-59 mm. This would suggest that goats prefer to feed on plants within this range of diameters while avoiding those outside of this range. Because the data suggest that goats girdle primarily in the 20-59 mm range, I would suggest altering a restoration for prescribed thinning so that those individuals who are mechanically removing plants should aim for any plants greater than 59 mm while leaving plants below that diameter to be handled by a mix of prescribed grazing and burning. This, in turn, will allow the prescribed thinning to be more focused and efficient. It should also be noted that this supports the hypothesis that goats will selectively browse on buckthorn with intermediate stem diameters, while avoiding those that are too large or too small for them to browse on.

The second conclusion that can be drawn is that goats have a tendency to fully girdle buckthorn when they start browsing on a plant. This supports the use of goats as a restoration tool, as plants can survive if not completely girdled. The fact that the goats girdle all the way

around the plant suggests that those plants they choose to girdle will more than likely die. This should alter restoration strategies slightly, as those performing other types of disturbances can avoid girdled plants with the expectation that they have been girdled to extent that they will not survive. It should also be noted that fully girdled plants can still resprout and it should not be assumed that just because a plant is fully girdled, it is done causing problems. In such cases, additional disturbances such as additional goat browsing on resprouts or prescribed burning are advised.

Goats are effective at dealing with plants below 60 mm in diameter, and when they browse on them, they will likely do so to such an extent that the plant will die. This should alter how a restorationist approach uses goats so that they get the most out of their prescribed grazing. Again, the issue of resprouts should be noted and dealt with accordingly.

Chapter 6: Workshops

Introduction

Based on information that was gathered during this project, it became abundantly clear that the problems facing Garvin Heights cannot be corrected without buy-in from the stakeholders living in the nearby area. With this in mind, the Garvin Heights restoration project also included an outreach portion, to provide the general public with information about invasive plant management and specific information about the Garvin Heights project. This was part of the grant provided for the project by Minnesota's Environmental and Natural Resources Trust Fund. The project has completed one of the two required workshops, with the second one to occur in summer 2019.

Planning

To prepare for the first program, a 4- to 5-hour workshop proposed to connect citizens with experts in invasive plant control and management, a meeting was initiated with a third-party contractor to organize and plan the workshop. However, it was determined that the contractor's fees were beyond the budget for the project, so in-house resources were used instead. Blandine Berthelot with WSU Camps and Conference Services was contacted to help plan the event. Blandine's role was to schedule the venue, set up an online RSVP registration form, order box lunches for attendees, and contract bus transportation for attendees to visit Garvin Heights. The workshop agenda was discussed and included a speaking/booth session in the morning and on-site demonstrations at the Garvin Heights project site in the afternoon. As part of the planning process, many public and private institutions were contacted to see if they

wanted to participate in the symposium and at what level. Several private companies agreed to participate and present information, including Diversity Landworks, Prairie Restorations Inc., Landspirit Design, Acer Forest LLC, and Prairie Moon Nursery, and others. From the government sector, the Department of Natural Resources, Conservation Corps of MN and IA, and the City of Winona Office of Sustainability all participated in the workshop.

Several approaches were used to advertise the planned workshop. Fliers and a postcard campaign were started to garner interest, with many of the local businesses and landholders receiving information. Postcards were designed by the WSU graphics art department and went through a couple of iterations before they were acceptable. Additionally, a public service announcement was placed into the local newspaper to help gather participants. A website was designed and connected to the project's website. In an effort to gather some of the school faculty to participate, an email announcement was sent out to let them know about the workshop. Finally, a radio interview on KWNO radio station was used to inform the public and to gather more attendees.

In the weeks leading up to the workshop some of the finer detail were determined. Blandine scheduled food and transportation for 50 participants. After some discussion, Haake Hall was decided as the location for the indoor portion of the workshop. Three individuals agreed to speaking engagements: Dustin Looman from DNR/Conservation Corps, Kaitlyn O'Conner from Prairie Moon Nursery, and Zach Reusch from Acer LLC. After discussions with each one, it was decided that Dustin would speak about his experiences doing restorations with the Conservation Corps, Kaitlyn would speak about the process of creating a prairie, and Zach would talk about the restoration process itself.

Agenda

The following is the full agenda for the workshop

- 9 am - Table set-up for open forum
 - Arrive at Haake Hall and set up your booth
 - This included Gabe, Kyle, Dustin, Kaitlyn, Eric, and John
- 10am - 10:15 am - Welcoming and intro statements
 - Neal and I will get everyone organized for the speaking portion of the symposium and provide opening remarks.
 - Dustin, Zach, and Kaitlyn will speak in that order
 - Dustin Intro: I graduated from Winona State University in 2004 with a Recreation and Tourism degree. While doing my internship at Frontenac State Park I was informed about the Minnesota Conservation Corps. Once done with the internship I started with MCC in the fall of 2004. I worked as a crew member for 6 months and a crew leader for another 2 years. In 2006 I took the Assistant Manager position with the Corps “now CCM” and have not looked back. During the last 12-ish years I have lead and managed many projects for different Federal, State, County and City organizations. Some of the projects include Rx fire, exotics species removal, hazard tree removal, wildfire details, trail construction/restoration just to name a few. I have also had to opportunity to train over 200 crew members in chainsaw and fire related trainings with many folks moving on to DNR, Federal, or County positions.
 - Zach Intro: After graduating from Michigan Technological University in 2007 with a Bachelor of Science in Forestry, Zach started his forestry career in Western Montana. He has spent the past 10 years working in the forests of Minnesota, Wisconsin, Iowa, and Illinois. Since starting his own forestry business in 2011, he’s been able to focus on maintaining and enhancing forested and other wild lands while balancing landowner’s interests. Acer Forest and Tree is a family owned natural resource consulting business specializing in forest management planning and implementation, ecological surveys, restoration and also urban tree care. An effort to help a few friends on a few acres in 2011 quickly developed into professional services that currently manage more than 8500 acres of forestland in southeast Minnesota. Every good tree produces fine fruit; strive to keep the good trees.
 - Kaitlyn intro: Kaitlyn O’Connor was born and raised in the Southeast Minnesota Driftless Region, a place she still calls home. Along with being the Education and Outreach Specialist at Prairie Moon Nursery, she also acts as a consultant to the Winona State University Arboretum. Before working in the private sector, Kaitlyn worked with the Minnesota DNR as a park naturalist and local non-profit organization Land Stewardship Project as a political organizer. Her educational background includes

Environmental Science, Geoscience, and Sustainability. She now homesteads in rural Winona County at Wiscoy Valley land co-op where she spends her free time foraging, gardening, cooking, playing frisbee with her dog Indigo, and tending to a small flock of backyard chickens.

- 10:15 - 11:45 Speakers will give 10-20 min presentations (questions will be saved for table session)
 - Each speaker will present information
- 11:45am – 12:30 pm Lunch
 - Lunch will be provided but feel free to talk and interact with the participants
- 12:30 – 1:00 Open forum/table session
- 1:00 – 1:15 Travel to Garvin Heights
- 1:15 – 3:00 Station Exercise (30 mins per station + 10 mins for rotation)
 - Neal and I will break the bigger group up into three groups and send one to each of you. The demo will last 30 mins with a 10-minute transition period in between. Expect about 10 per group.
 - Goat talk/anatomy demo (from goats groups will go to the tour)
 - Goat guys will focus on prescribed grazing, set up, care etc.
 - Tell them about what it is you do and how you go about doing it
 - definitely use the goats during your presentation; if you are comfortable let them touch the goats (completely up to your discretion)
 - Tour of the grounds (from the Tour to the Conservation Corp/eliminating buckthorn)
 - Walk the grounds show participants different invasive species and how to ID them. Try to stick more to the prairie. Neal and I will help out with this one as much as possible. Essentially I want them to be able to ID things like Buckthorn and Honeysuckle but we can also focus on some other interesting plants.
 - Identifying and eliminating buckthorn (From the CC to the goats)
 - Demonstrate cutting, spraying techniques for eliminating buckthorn, honeysuckle etc. Talk a little about the prescribe burning process but emphasize that it not something a land owner should undertake without professional help.
 - Run through the process start to finish of ID, assessing, and eliminating invasive species from an area. Talk about previous project and let them know that it is ongoing, not something that is done once. Compare treated sections to untreated sections.
 - Don't be afraid to let them get a little dirty.
- 3:00 – 4:00 Regroup and answer any lingering questions/sign up for more comprehensive workshop
 - At the end please send your groups back to the parking lot. We will wrap up and head back.

Workshop

The workshop occurred on Saturday June 9, 2018, with 26 attendees and approximately 20 presenters and their assistants. The process was facilitated by Neal Mundahl and Ryan Walsh, with the latter keeping track of the schedule. The speakers presented their information in the morning, and then time was given so that the attendees could eat lunch and talk to the presenters. In the afternoon a chartered bus was taken up to Garvin Heights, where demonstrations occurred. The demonstrations started with how to identify some of the more prevalent invasive species (Garlic Mustard and Buckthorn), which was done by the Conservation Corps and Acer LLC. The Conservation Corps went on to demonstrate each of the tools they used on a daily basis, including weed torchs, hand saws, chainsaws, and herbicides. Also included was a demonstration of the invasive species management app, which is being used currently to track the movements of invasive species across the state. The final demonstration was of the goats and some Q/A on their care. The participants were bussed back to campus, where the workshop ended.

The second outreach program will be a day-long, hands-on opportunity for a smaller number of attendees to learn about invasive plant control efforts. The set-up for invitation will be much the same as the previous workshop, but with more of an emphasis on using the mailing list to garner participants. Blandine will be asked to help set up lunches for the event, as well as advertising. The instructors will consist of private contractors and the Conservation Corps. Attendees will have a more interactive experience focusing on hands-on activities. These will include learning to cut and spray invasive species, using a dichotomous key to identify different species, and working on action plans for their own properties.

The goal of the second workshop will be for the participants to be able to go home with an actionable plan for their own property, and to act as ambassadors for a healthier ecosystem in their community. The purpose is to improve the overall health of plant community within the Garvin Heights area.

Chapter 7: Maintenance, Recommendations and Future experiments

Before going into the issue of maintenance, it is important to establish that the actual issue at Garvin Heights is not the presence of buckthorn, but the lack of disturbances. The lack of natural wild fire and grazing created an ideal environment for buckthorn to move into. With this in mind, buckthorn will be treated as a symptom of a larger problem rather than the problem itself. This segues into the issue of how to maintain the three habitats at Garvin Heights Park. Maintaining the current environment will require a long-term, adaptive pest management plan coupled with multiple types of disturbances, including prescribed grazing, prescribed burning, and prescribed thinning. Having a plan in place and these disturbances are key to keeping the habitats at the appropriate coverage levels and buckthorn densities low.

Before trying to perform future disturbances it is important to have a plan in place to determine at what point these disturbances should occur. The adaptive approach focuses on flexible decision-making when it is not certain what impact disturbances will have on the environment. It focuses more on the causal relationship and monitoring the effects to adjust management policies (Williams, B.k., R.C. Szaro and C.D. Shapiro, 2009). In more simple terms, it is learning how to solve the problem by trying to solve it (doing). The basis for this approach was established in the early part of the 20th century and combined ideas from business, experimental science, systems theory and industrial ecology (Williams, B.k., R.C. Szaro and C.D. Shapiro, 2009). The adaptive management system moves in a cycle and starts by assessing the problem. The next phase is design; in this phase a solution to the problem is created. Implementation is where the plan is set in motion. After the plan is put in motion, it is then monitored via regular assessment and then evaluated. After being evaluated, the plan is then

adjusted and the problem reassessed (Williams, B.k., R.C. Szaro and C.D. Shapiro, 2009). The only real drawback to an adaptive plan is that they are hard to implement for a long period of time, as they require continual work.

Although it was not strictly stated, adaptive management is essentially what has occurred at Garvin Heights. The problem was assessed and it was determined that changes were necessary. A plan was created by Dr. Neal Mundahl, which included hiring a graduate student, habitat delineation, multiple disturbances, and stakeholder education. Ryan Walsh was assigned as the graduate assistant on the project and the plan was implemented, starting with delineation and moving into disturbances as well as education. The monitoring/evaluation was performed in the form of buckthorn densities and data analysis, determining that the disturbances are effective for reducing coverage and lowering density of buckthorn. At this point in the project the management plan needs to be adjusted and reassessed. For an adaptive management plan to work into the future, it will have to be maintained continuously for a long period of time. Otherwise the Garvin Heights area will simply return to the state it was in prior to the disturbances. For this to work, regular monitoring will have to occur at the site with an action threshold for buckthorn density. What this means is that after the site is stabilized, someone will have to go out on a yearly basis and perform surveys. The surveys will be used to assess the problem. Once a certain threshold for buckthorn or coverage is reached, a disturbance should be implemented. This will allow Garvin Heights to be maintained using a system rather than guess work.

Beyond having an adaptive plan in place, a regular set of disturbances should occur on a normal basis. As mentioned above, it is important to keep the coverage at the correct level to

maintain the savannah and prairie. These disturbances will help maintain a healthy community of native plants and keep the invasives from invading. Prescribed burns should occur at a minimum of once every 2.5 years to keep densities and coverage at an acceptable level. This will prevent the development of canopy ingrowth and sapling thickets (Peterson, 2001). When burned at this rate, there is a 6-8% density decline with a 4-7% decline in basal coverage (Peterson, 2001). This also significantly reduces the overstory density, while having a very low impact on the native bur oaks (Peterson, 2001). There should not necessarily be an action threshold for prescribed burning; it should simply occur at regular intervals regardless of the absolute density and coverage. This will decrease the reliance on other disturbances, while keeping the chances of naturally occurring wild fires down.

Prescribed grazing and thinning should be done in tandem on a regular basis to keep the densities of buckthorn seedlings/yearlings at around 10 plants/m² and 1 plants/m² respectively. An increase above 15 plants/m² for seedlings and/or 5 plants/m² for yearlings should signal the use of prescribed grazing and thinning. Coverage should be kept around 20-35% for the savannah. If the coverage rises above this range, action should be taken so it does not exceed 75%. The prairie should be kept below 10% coverage, but any buckthorn thickets should signal a need for disturbances. As mentioned, above regular surveys should occur to make sure the levels are staying around these ranges. This recommendation calls for an adaptive plan; if these ranges do not work, then the action threshold should be altered. It should also be noted that the generalists should be expected to handle plants below 59 mm in diameter and for efficiency sake the workers should handle plants larger than that. Again, if this does not appear to work in the future, the plan should be altered.

There are several experiments that should be considered for the Garvin Heights area in the future. Most are related to soil content and buckthorn's impact on it. Based on how buckthorn spreads, it would be interesting to study the impact of buckthorn on nutrient levels, specifically nitrogen, as buckthorn adds a lot to the soil over a very short period of time. This may act as facilitation, but more research would be needed to really know. Additionally, work on allochemicals produced by buckthorn and left in the soil might produce some interesting results. Another set of experiments relates to scarification and buckthorn. This could examine the movement of buckthorn seeds through the digestive tract of goats and birds. There previously have been bird studies in this area, but it might be interesting to look at the native species to see if they impact the seeds in a different way. It would be very novel to study the impact on buckthorn seeds from moving through the digestive track of goats as there does not currently appear to be any studies done in this area. Another avenue of study would be seed choice and birds. This study would be used to see if birds would choose buckthorn fruit when given other choices, and if so, what kinds of birds. Off of this experiment one might study the impact of buckthorn on the diversity of bird species in the Garvin Heights area to see if there is a correlation between species diversity and buckthorn moving in. Finally, a study examining buckthorn's impact on the community might improve our understanding of the plant. In this study, one would look bottom up and seeing what kind of impact buckthorn is having on the community as a whole.

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