Site Preparation and Direct Seeding Experiment
LaPlatte Headwaters Town Forest
Hinesburg, VT

2020 Vegetation Monitoring Report

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Introduction

The agricultural history of many floodplain sites in Vermont poses unique challenges for restoration. Old hay fields and pastures often mature into a persistent, dense mix of perennial grasses and other herbaceous species that can inhibit natural recruitment of native floodplain species and create an environment inhospitable to transplanted trees and shrubs.

A species of particular concern is reed canary grass, *Phalaris arundinacea*. Reed canary grass is an invasive exotic perennial grass that forms dense monocultures that readily spread and outcompete other species. Once established, it forms a thick mat of dead thatch that keeps the seeds of other species from reaching the soil and germinating. Areas dominated by reed canary grass have been found to persist on the landscape for decades.

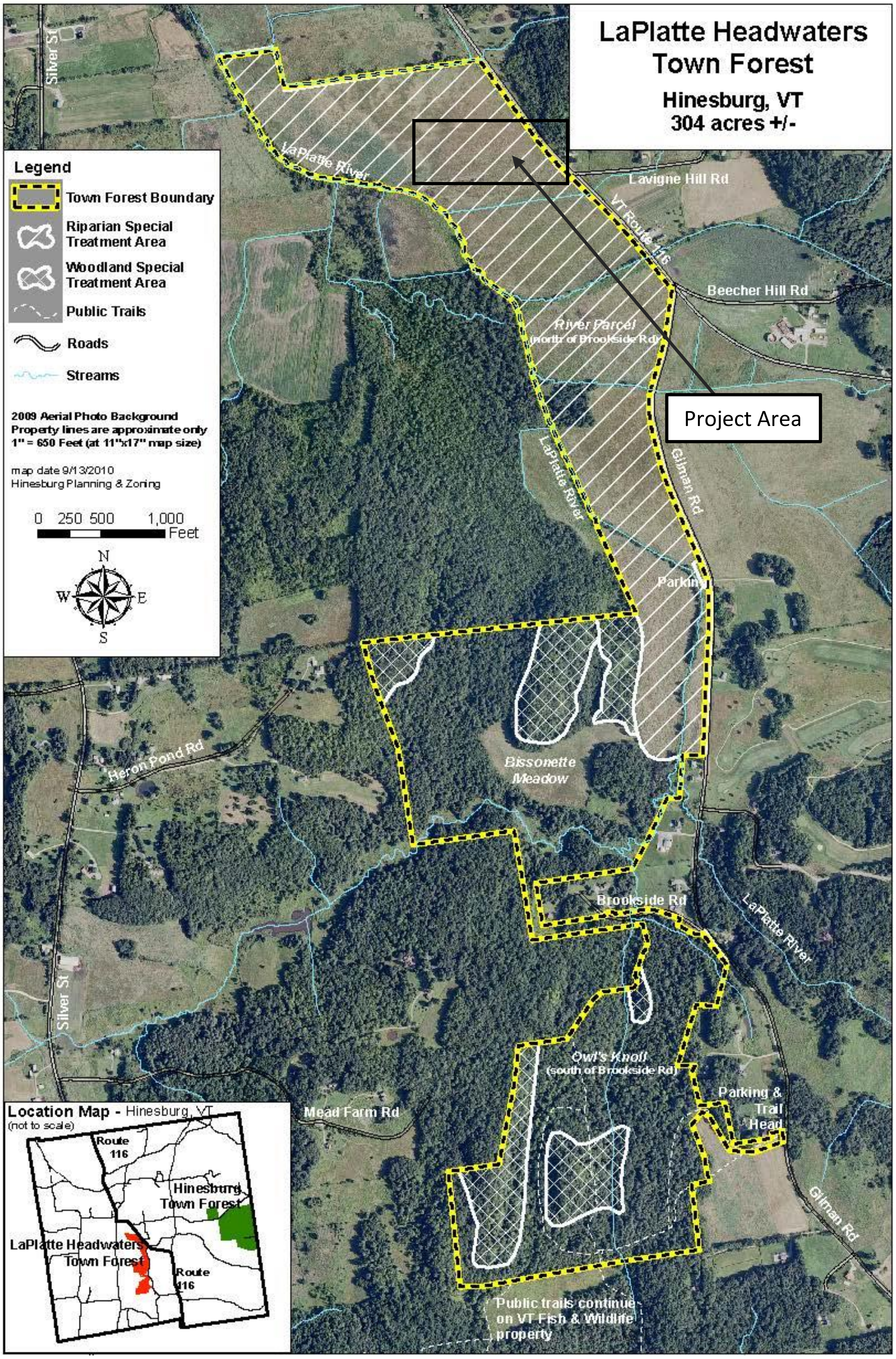
The LaPlatte Headwaters Town Forest is a 304-acre property owned and managed by the town of Hinesburg. The majority of the property was cleared and actively managed for sheep, dairy, and maple through the 1800's. While some of the land previously cleared has reverted to forest, many of the floodplain fields along the LaPlatte River remain open, dominated by reed canary grass and other herbaceous species. Several tree and shrub plantings have been attempted over the last few years with limited success. The primary challenges are dense competing vegetation and deer browse.

With these challenges in mind, the USFWS Partners for Fish and Wildlife Program (PFW) in partnership with the Vermont Fish and Wildlife Department (VFWD) received permission from the Hinesburg Town Forest Committee to initiate trials aimed at testing alternative methods for floodplain forest restoration. In 2019, experimental plots were established in the northernmost field (Figure 1) to compare the effectiveness of different site preparation techniques at (a) reducing the coverage of reed canary grass, (b) exposing enough bare soil at the right time to allow for the successful establishment of native woody species from seed, and (c) increasing plant diversity to improve habitat and ultimately accelerate natural succession in the floodplain.

This project builds on site preparation experiments initiated by VFWD and the Connecticut River Conservancy (CRC) at two sites along the Barton River starting in 2016 (Gerhardt 2020). Initially coined the "cornfield replication experiment", their methods were inspired by the impressive natural recruitment of seedlings seen at many sites when annual crop fields are taken out of production. They used common farming practices including mowing, plowing, and herbicide to reduce the coverage of reed canary grass and replicate bare earth conditions. They have since monitored shifts in ground cover, vegetation composition, and the natural recruitment of seedlings. We adapted the methods they found most effective and added the additional component of direct seeding native tree and shrub species. Our aim was to test if direct seeding could be a reliable alternative in the absence of a proximate, abundant seed source. Direct seeding could be a cost-effective alternative to transplanting, allowing for establishment densities not currently possible when planting trees and shrubs. Denser establishment could also help overcome deer pressure and accelerate the pace of succession and restoration.

This report includes a description of our methods and initial results from our monitoring in June and August of 2020. Due to poor establishment from direct seeding in 2020, we replicated some of our site preparation activities ahead of additional direct seeding now planned for spring 2021. We also expanded our study area to include a zone that was direct seeded in the fall of 2020. These results will be shared in a future report.

Figure 1. Map of LaPlatte Headwaters Town Forest, Hinesburg, VT 44.319250, -73.097003, with project area delineated.

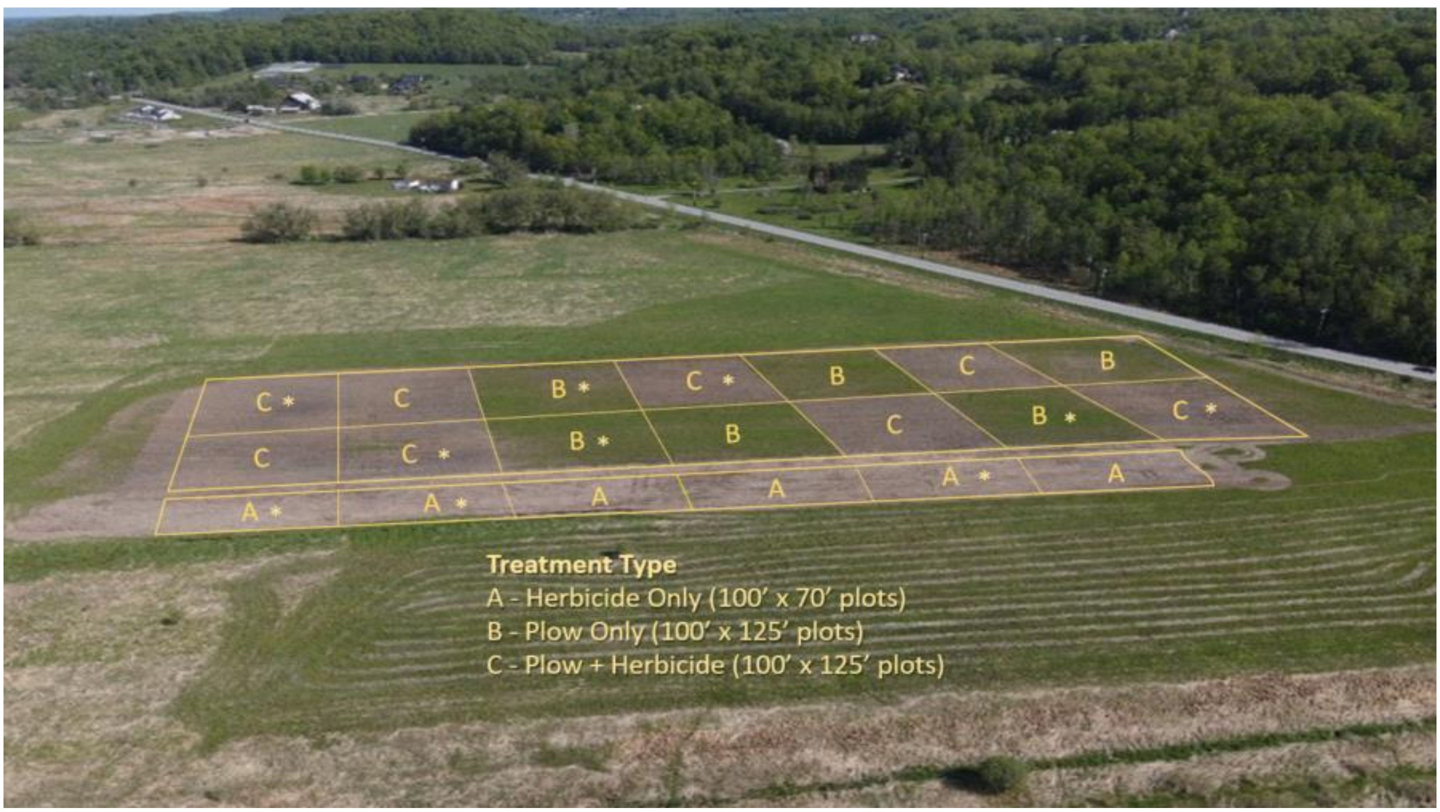


Methods

The project area was chosen in winter 2019 and site preparation began in summer 2019. A contractor was hired to hay the entire project area on July 26th 2019 to remove thatch to facilitate easier plowing. After haying, experimental plots were staked out and flagged (Figure 2). The *Herbicide Only* plots were ultimately positioned in the southern section of the project area because that zone was too wet for plowing. The entire project area was brush mowed again on August 25th 2019. Then, on August 26th 2019, the *Plow Only* and *Plow + Herbicide* plots received two, cross-hatched passes with a chisel plow followed by one pass with a rototiller. The additional rototilling was recommended to further disrupt root systems and create even terrain for the herbicide treatment. After letting vegetation rebound for five weeks, the *Herbicide only* and *Plow + Herbicide* plots received an application of Rodeo brand glyphosate (3 qt/ac) using an ATV-mounted boom sprayer on October 12th 2019.

Direct seeding was completed the following year between June 12th and June 15th 2020 on a randomly selected subset of plots across treatment types (marked with asterisks in Figure 2). The remaining plots were left as controls. Quaking aspen, shrub willow spp., eastern cottonwood, and silver maple seeds were collected from sites across the Champlain Valley between May 15th 2020 and June 10th 2020. A hydroseeder was used to direct seed quaking aspen, shrub willow, and eastern cottonwood using predetermined seeding rates (Figure 4). Our methodology for hydroseeding was adapted from successful hydroseeding restoration efforts completed along the lower Colorado River in Arizona (Grabau et al. 2011). Beyond hydroseeding, silver maple was hand broadcasted at a rate of roughly 1000 seed/ac. Seeding was completed between June 12th and June 15th 2020 (Figure 5). For a complete schedule of activities, see Figure 3.

Figure 2. Drone imagery taken June 1, 2020. Experimental plots are labeled based on treatment type.



Note: A roughly 80'x20' section in each of the treatment types was poke-hole seeded with red oak acorns on May 14th 2020 at 1'x1' spacing. Acorns were collected in October 2019 and stored in breathable seed bags in the walk-in cooler at the Intervale Conservation Nursery over winter. This was not a part of the original project design, and results were only tracked with photos and anecdotal observations. The findings were promising, with an estimated >90% germination and establishment across all treatment types. More on this is included in *Appendix A: Direct Seeding Notes*.

Figure 3. Schedule of Activities, 2019-2020.

Herbicide Only (A)	Plow Only (B)	Plow + Herbicide (C)
7/26/2019 Haying	7/26/2019 Haying	7/26/2019 Haying
8/25/2019 Brush Mow	8/25/2019 Brush Mow	8/25/2019 Brush Mow
	8/26/2019 Chisel Plow + Rototill	8/26/2019 Chisel Plow + Rototill
10/12/2019 Herbicide		10/12/2019 Herbicide
6/12/2020-6/15/2020 Direct seeding	6/12/2020-6/15/2020 Direct seeding	6/12/2020-6/15/2020 Direct seeding

Figure 4. Calculations used for hydroseeding.

Uncleaned Seed							
Estimated Weight/1000 seeds (grams)	Expected Establishment Rate	Target Tree Density		Seed Viability	Seed Application Rate	Seed Application Rate	Seed per Tank
Populous tremuloides							
0.2	0.015	1500	trees/acre	0.9	22.22 g/acre	0.05 lbs/acre	2.1 g
Salix spp.							
0.34528	0.03	1500	trees/acre	0.9	19.18 g/acre	0.04 lbs/acre	1.8 g
Populous deltoides							
4.01102	0.1	1500	trees/acre	0.9	66.85 g/acre	0.15 lbs/acre	6.4 g

Sampling Methodology

Vegetation monitoring was completed in June and August of 2020. We adapted our monitoring protocol from the protocol used for the Barton River experiments (Gerhardt 2020). In each experimental plot, two transect lines were established running N to S, spaced at 40' and 60' along the 100’ plot edge. Along each transect line, five monitoring points were randomly selected, buffered 10’ from the plot edges. A meter plot was then centered at each monitoring point along the transect line (Figure 5).

Within each meter plot, estimates of % bare earth, % litter and % live vegetation were recorded. Live vegetation cover was further broken out into % grass cover, % Phalaris [as percentage of overall grass cover], % sedge cover, % forb cover, and % fern cover. Cover classes used were <1%, 1-5%. 6-25%, 26-50%, 51-75%, 76-95%, and >95%. The most abundant species across vegetation types were noted, but only anecdotally. Any woody seedlings were counted, with height and species noted. Collected data was entered into Excel for processing. % ground cover estimates were averaged for each treatment type.

Due to capacity limitations, not every treatment plot was monitored in both June and August. However, a representative set of treatment plots were monitored between June 8th and June 9th [8 treatment plots, 80 monitoring points] and between August 11th and August 12th [11 treatment plots, 110 monitoring points].

Figure 5. Example of the meter plot monitoring setup in June 2020.

Results

Due to poor germination and establishment of direct seeded species across the entire project area, monitoring results for the 2020 season focus on shifts in ground cover and live vegetation composition across treatment types. More on our direct seeding efforts and adaptive management moving forward are included in *Appendix A: Direct Seeding Notes.*

There were marked differences in % bare soil, % litter, and % live vegetation across treatment types in early June (Figure 6). % bare soil and % litter were captured separately as it was hypothesized thatch cover could be an important variable impacting the efficacy of direct seeding. Both the *Herbicide* Only and *Plow + Herbicide* treatments had the lowest % live vegetation cover (17% and 20.5% respectfully) in June. The *Plow + Herbicide* treatment exhibited by far the greatest % bare soil (76.3%). The *Herbicide Only* exhibited more litter (73.5%) and less bare soil (8.5%) as it was never plowed. The *Plow Only* treatment had by far the highest % live vegetation cover in early June (88.3%) with minimal bare soil and litter (10.5% and 4.6% respectfully).

If you take a closer look at live vegetation composition in June (Figure 7) it is notable that the *Plow Only* treatment was dominated by grasses (67.2%) with substantial reed canary grass presence (32.3% of grass cover). Of the live vegetation present in the *Herbicide Only* and *Plow + Herbicide* treatments, there was minimal grass coverage (2.4% and 4.8% respectfully) with more dominance of forbs (16.4% and 17.3% respectfully). Fern cover was most abundant in the *Herbicide Only* plots (4.5%), while sedge cover was limited across all treatment types in June. There were 6 boxelder seedlings found across the *Plow + Herbicide* plots, and 3 boxelder seedlings found across the *Plow Only* plots.

By August, there was more consistency in the coverage of live vegetation across treatment types (Figure 8) but still marked differences in live vegetation composition (Figure 9). The *Plow Only* treatment was still dominated by grasses (91.2%) and saw an increase in the percent cover of reed canary grass (57.3% of grass cover). Reed canary grass remained nearly non-existent in the *Herbicide Only* and *Plow + Herbicide* treatments (0.8% and 0.9% respectfully) but there was an increase from June to August in the percent cover of other grasses across both treatment types (7.7% and 17.2 % respectfully). Annual witchgrass was by far the most dominant grass in both the *Herbicide Only* and *Plow + Herbicide* treatments, whereas the *Plow Only* treatment exhibited a diversity of perennial and annual grasses.

There was a notable increase in sedge cover in both the *Herbicide Only* and *Plow + Herbicide* treatments (20.2% and 24% respectfully), with yellow nutsedge by far the most abundant sedge across treatment types. Fern cover was still most abundant across the *Herbicide Only* treatment (10.5%), followed by *Plow + Herbicide* (6.2%) and then *Plow Only* (2.6%). Sensitive fern was by far the most abundant across treatment types.

Both the *Herbicide Only* and *Plow + Herbicide* plots were dominated by forbs in August (72.4% and 68.6% respectfully) while the *Plow Only* plots had 7.8% forb cover. The most abundant forb species in the *Plow Only* plots were red-rooted amaranth, Pennsylvania smartweed, wild mustard, bird’s foot trefoil, purple vetch, red clover, and wood sorrel. Forb diversity was significantly greater in the *Herbicide Only* and *Plow + Herbicide* plots, where Joe-Pye weed, blue vervain, common boneset, American burnweed, and swamp milkweed were also abundant. 1 silver maple, 1 boxelder and 2 eastern cottonwood seedlings were found across the *Plow + Herbicide* plots. 1 eastern cottonwood seedling was found across the *Herbicide Only* plots.

Figure 6. Mean percent ground cover across treatment types; monitored between June 8th and June 9th 2020.

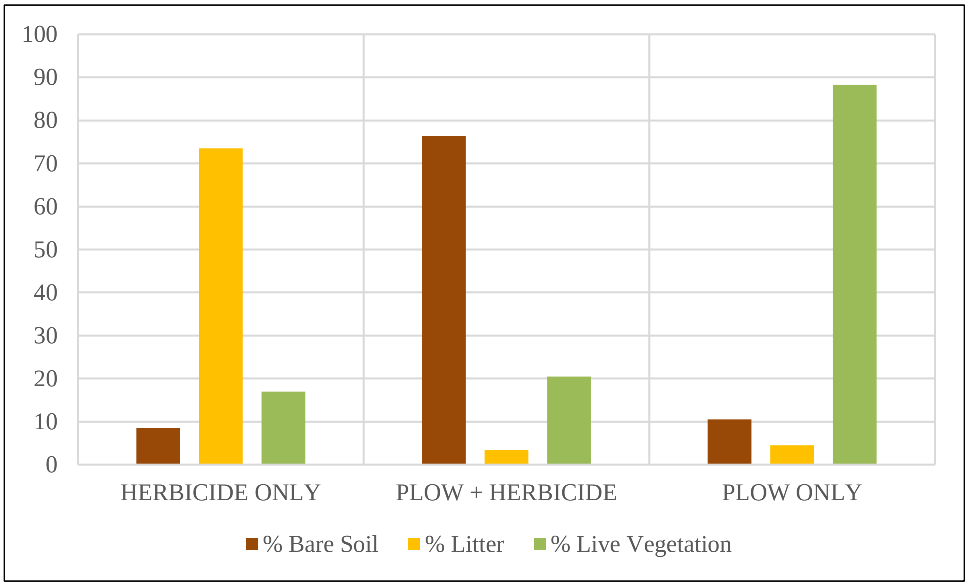


Figure 7. Mean percent ground cover across treatment types; monitored between August 11th and August 12th 2020.

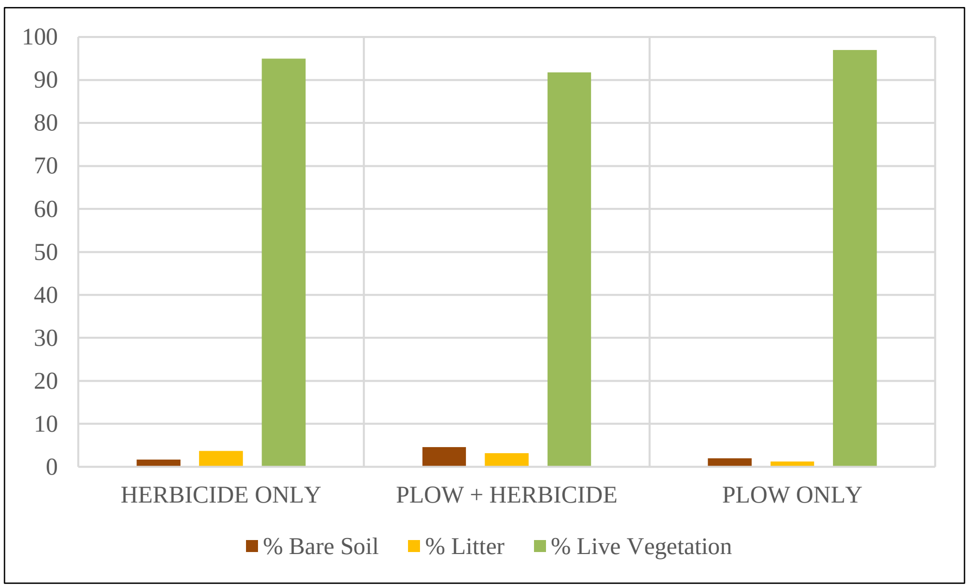


Figure 9. Mean percent ground cover including vegetation classes across treatment types; monitored between June 8th and June 9th 2020.

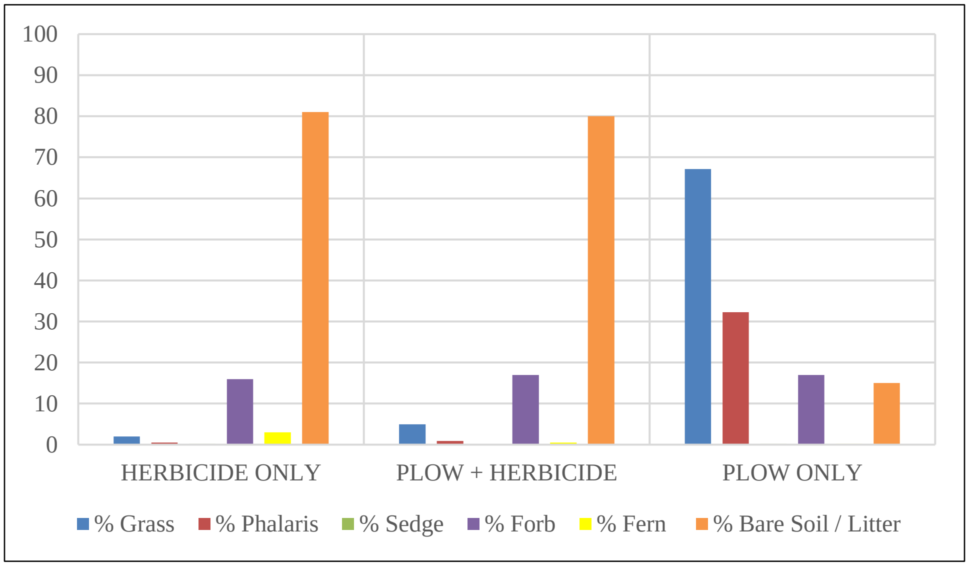


Figure 10. Mean percent ground cover including vegetation classes across treatment types; monitored between August 11th and August 12th 2020.

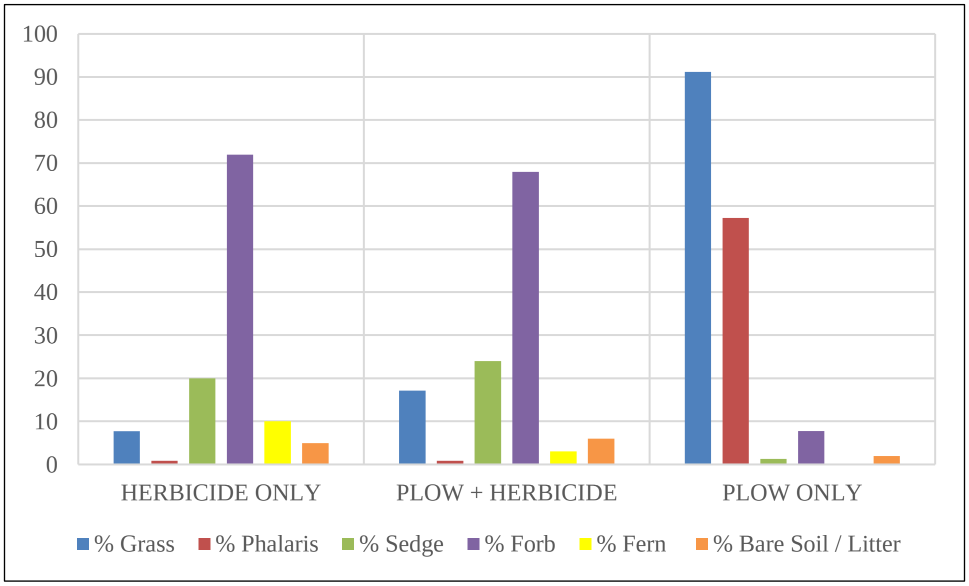


Figure 10. Photo point monitoring of ground surface condition.

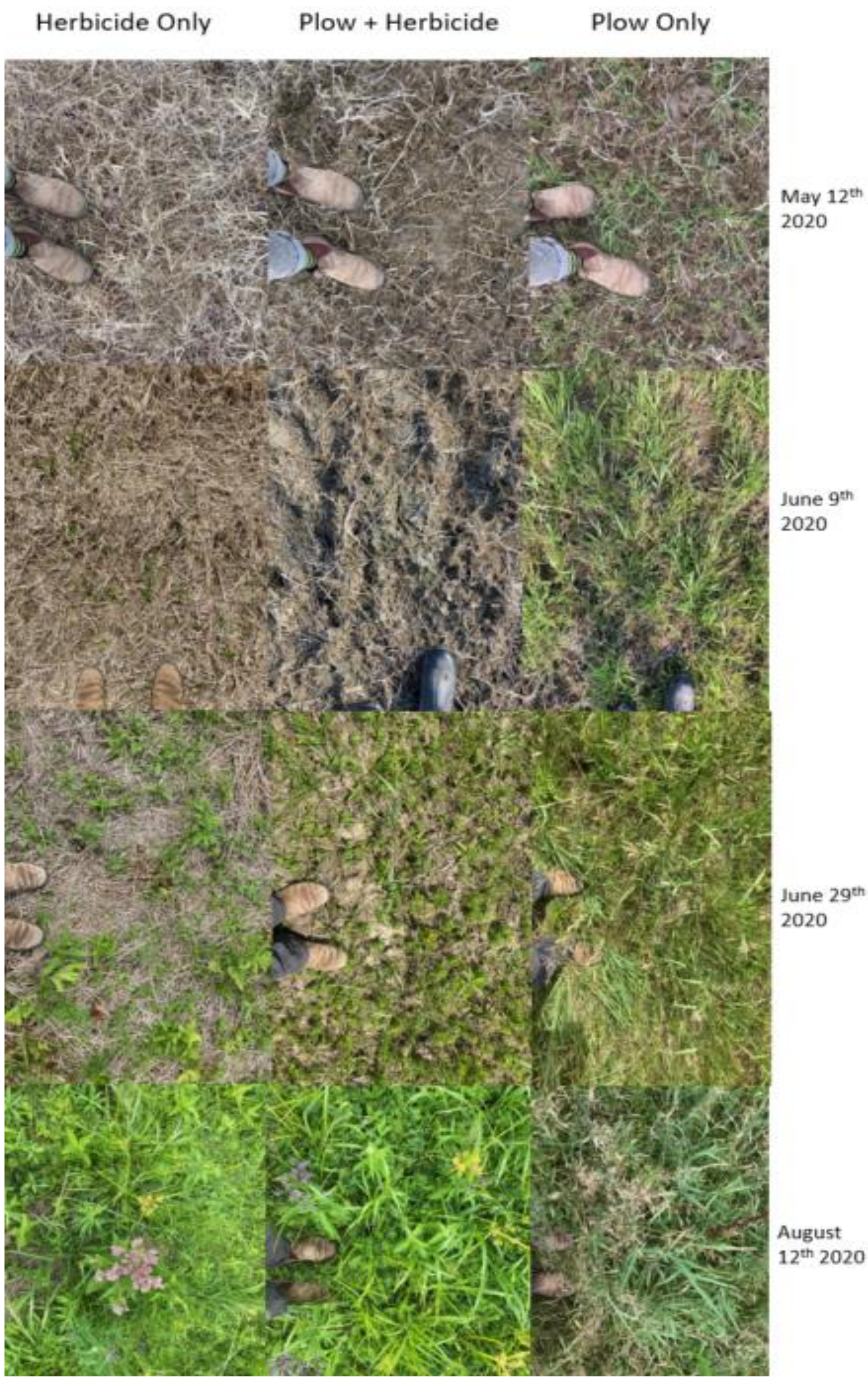
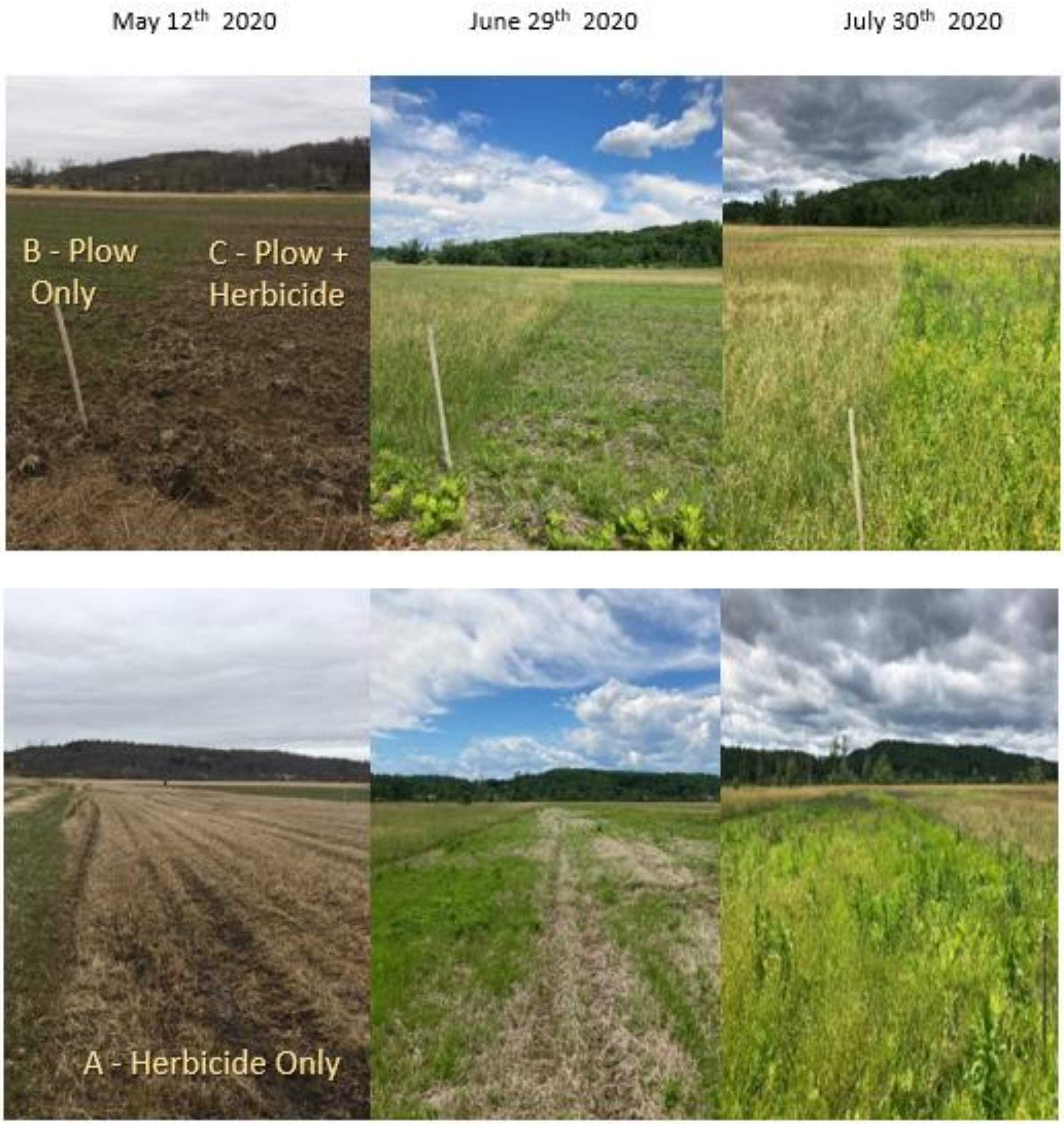


Figure 11. Photo point monitoring looking across treatment plots.



Discussion

While we were unable to compare natural recruitment or direct seeding across treatment types, our findings as they relate to shifts in ground cover and reed canary grass control could have value for other restoration practitioners. The dramatic increase in early season % bare soil across the *Plow + Herbicide* treatment plots was very promising, as was the dramatic increase in species diversity paired with the near absence of reed canary grass throughout the season. The *Herbicide Only* treatment plots also boasted dramatic increases in species diversity paired with the near absence of reed canary grass throughout the season. One significant difference between the *Herbicide Only* and the *Plow + Herbicide* plots was the proportion of early season % bare soil and % litter. We hypothesized that the thatch cover left by the *Herbicide Only* treatment would inhibit seed/soil contact and the germination of direct seeded species in the spring, but we were unable to assess that this season. Regardless, the dramatic shifts in ground cover and live vegetation composition observed with these two treatments could meaningfully accelerate and improve restoration outcomes on sites dominated by reed canary grass.

The *Plow Only* treatment exhibited greater species diversity than the original field condition, but grasses continued to dominate in these plots with reed canary grass reinvading at a faster rate than the other treatment types. These conditions, coupled with the limited early season % bare soil or % litter, made the *Plow Only* treatment appear least effective at achieving our restoration goals. Other complementary work in Vermont suggests that using a plowing method that leaves more variation in microtopography (like moldboard plowing) or plowing at different times in the growing season could positively affect site response when using a *Plow Only* treatment (Crehan 2021).

While vegetation composition within the *Herbicide Only* and the *Plow + Herbicide* plots was similar by August, the *Herbicide Only* plots exhibited slightly greater forb cover with fewer annual grasses and sedges. These differences in species composition can likely be attributed to whether or not the dormant seed bank was released and/or perennial root systems were disturbed by plowing. The *Herbicide Only* plots were also located in a slightly wetter portion of the project area, which may have influenced species composition in these plots. Lastly, it should be noted that the timing of the herbicide application in October 2019 appeared effective at selectively targeting reed canary grass, as many other desirable species (e.g. Joe pye weed) had not regrown after being mowed in August 2019. This could be a strategy used to target reed canary grass without impacting other desirable natives present at a site.

Persistence is a question that can't be answered this season. However, monitoring from the Barton River WMA experiment suggests these conditions could persist over several growing seasons. *"Thus [in 2020], as in 2018 and 2019, we conclude that the Plow Then Herbicide treatment appears to be the most effective method for removing thatch and competing vegetation, especially non-native grasses, and encouraging regeneration of native trees. In fact, at this time, it appears that the Plow Then Herbicide treatment may create an alternate stable state in which the vegetation is dominated by forbs, rather than grasses, and that is more conducive to native tree germination and growth"* (Gerhardt 2020). Our observations in this first season support this. Witchgrass and yellow nutsedge (the most abundant grass and sedge identified across the *Herbicide Only* and *Plow + Herbicide* treatments) are both disturbance-loving species, which suggests they may be outcompeted with succession, leaving forbs and other more desirable species to dominate. It is uncertain how the *Plow + Herbicide* and *Herbicide Only* treatments will diverge from each other if left to progress in the long-term. We replicated our site preparation efforts after the 2020 season with the intention of repeating direct seeding efforts in 2021. A longer-term monitoring protocol will be established after 2021 direct seeding. Two plots of the *Herbicide Only* treatment were left untreated after 2020, which will provide a window into persistence over multiple growing seasons.

Lastly, care should be given to determine the risk of invasive establishment with large-scale site disturbance. We took care to mow an area next to the road at this site that had poison parsnip in June (before it set seed) to try to limit spread. Beyond the seed carried by the wind, tractor tires, or birds to a site, it is difficult to know what will emerge from the seed bank. This is a variable that will be unpredictable when practicing this work at different sites across the state. This can ideally be mitigated by proactive risk assessment at each site and the eventual succession of native woody species.

Works Cited

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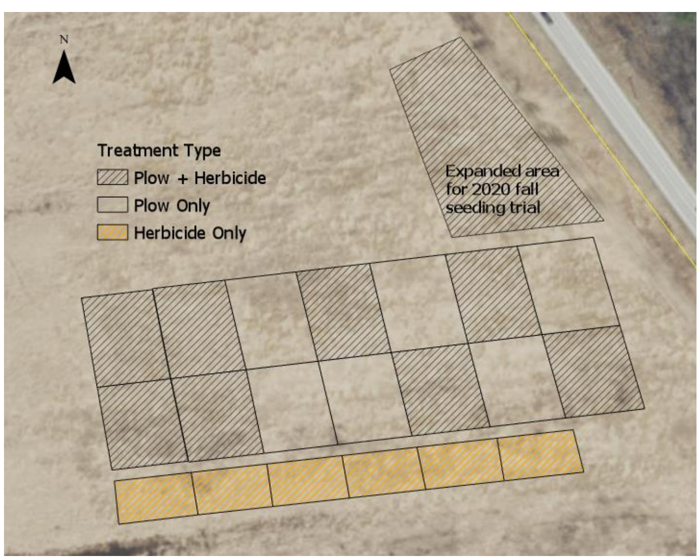
Appendix A. Direct Seeding Notes

The lack of germination and establishment of direct seeded species in the 2020 season was likely due to the fact that the site received little rain and record heat for the several weeks following seeding. Both methods used—hydroseeding and broadcast seeding—leave the seed unprotected on the soil surface. The species we used are adapted to be dispersed by wind and flooding and, while this doesn't necessitate the seed be buried, ample moisture is needed to facilitate germination and establishment. Unpredictable weather will continue to be a risk when direct seeding, just as it has been a challenge for tree and shrub plantings.

Despite it all, we learned many lessons in this first season that will inform our direct seeding practices going forward:

1. For spring seeding, it could be more reliable to hydroseed in May to take advantage of early spring moisture. This is the plan for the 2021 season at LaPlatte Headwaters. As this timing is slightly earlier than natural seed cast, this timing will require collecting or purchasing viable seed the year before and storing it successfully over winter. Beyond allowing for earlier spring seeding, investing in seed storage capacities will help mitigate the fact that seed abundance and viability varies from year to year. When possible, good seed lots should be collected and saved to create a reliable seed bank.
2. For unorthodox seed such as silver maple that cannot be stored overwinter, seeding will still need to occur in June when the seed is ripe. Anecdotal observations from other sites suggests that incorporation could improve germination success by improving seed/soil contact and better protecting the seed from desiccation. This could be accomplished with shallow discs, a heavy-duty drag harrow, and/or a cultipacker.
3. Hydroseeding has its advantages and challenges.
    a. Advantages: Using an ATV hydroseeder means you can be more nimble with site access, particularly when wet spring conditions limit heavy equipment access. You can also buy extra lengths of hose for the hydroseeder to extend its range. For small seed like eastern cottonwood and quaking aspen, it is a method that can ensure consistent application across a site. The added mulch also helps "glue" the small seed to the soil surface preventing it from blowing away. Good seed to soil contact is assured, assuming you have the needed moisture to facilitate germination.
    b. Challenges: It requires a lot of water [>1000gal/ac] which will be a hindrance at some sits. We used a large VFWD hatchery truck as a water source at the LaPlatte Headwaters Town Forest. It is possible pump directly from nearby stream or river, but you would need to ensure water levels are adequate and you have the necessary permitting. We also struggled to achieve consistent mixing and agitation of seed and mulch in the water tank this season. This seemed to be an issue with the specific model we used and we are reconfiguring the frame of the tank to help correct for that next season.
4. Other direct seeding methods to explore further:
    a. Seed drill—could be adapted for tree and shrub seed as small as grass seed or as large as soybean or corn. It would require similar site preparation work and conditions amenable to heavy equipment access, and could potentially pair with an *Herbicide Only* treatment as the drill can work through existing thatch. For some species, additional seed processing would be needed to run it through a drill (i.e. de-winging silver maple).
    b. Broadcasting with incorporation—as was discussed with silver maple, this could be accomplished with shallow discs, a heavy-duty drag harrow, and/or a cultipacker.
    c. Seed Bombs—this is a method whereby you mix clay or another medium with small seeds to make them easier to broadcast and spread. This could be done by hand or with a mechanical seed broadcaster. One provocative, large-scale example of this is a company based in Canada called "Flash Forest". They are using drones to shoot specially-formulated seed pods into prepared ground to reforest large areas.

5. With wild collected seed, careful record keeping, processing and storage matters. Different species have different processing and storage needs, so it will be important to have precise protocol as we start working with larger quantities of seed through this work. It will also be important to track collection locations and specific seed lots to inform genetic variation.
6. Notes on working with oak species:
    a. Oaks are slower growing than some of the other floodplain pioneer species we are seeding. While eastern cottonwood and silver maple can grow 1-3' in a single growing season, oaks will take longer to grow up above competing vegetation. High-mowing is a tool used by practitioners in other states to reduce competition in the first 1-2 growing seasons after oak direct seeding. That said, oaks are more shade-tolerant than other pioneer species, suggesting weed pressure may not hinder long-term establishment.
    b. You can direct seed acorns in the fall, or you can store the seed over winter for a spring seeding. Red oak acorns are more tannic than the white oaks, meaning they are more rot-resistant and easier to store. Red oak can remain viable for multiple years when kept properly in cold storage, whereas white oak species will begin to rot more quickly. Anecdotally, the Intervale Conservation Nursery has successfully kept bur oak and swamp white oak for 6-8 months in cold storage. With this in mind, red and white oak acorns can be seeded in the fall or the following spring, but seed lots of red oak can be stored over multiple seasons. The ability to readily store red oak could help protect against inconsistency in the seed crop, as you could build up your seed store during heavy mast years.
    c. Expanded trials with larger-scale oak seeding are underway at a CREP site in Whiting, VT where 2 acres were direct seeded with bur oak and swamp white oak in October 2020. The site was prepped using the *Plow + Herbicide* method and acorns were hand broadcasted and incorporated 1-2 inches deep using tractor-mounted disk harrows. Findings will be shared later in the 2021 season.
7. Notes on fall seeding:
    a. Seeding in the fall could help mitigate some of the challenges specific to spring seeding. This would involve collecting fall-ripening seed in the late summer and fall, storing it, and sowing the seed once you have dormant winter conditions. This methodology allows the seed to stratify naturally over the winter on-site, ready to germinate in the spring when conditions are right. Different species have different stratification and/or scarification habits, so care should be taken when developing seeding plans.
    a. We expanded the original project area at LaPlatte Headwaters Town Forest to develop an area for fall direct seeding in 2020. We used the *Plow + Herbicide* treatment to prepare the area and then on November 11th, 2020 we spread seed used a mechanical broadcast seeder mounted to an ATV. We then incorporated the seed using an ATV-pulled drag harrow. The species we broadcasted were green ash, gray birch, speckled alder, silky dogwood, gray dogwood, and buttonbush. After broadcasting and incorporating, we poke-hole seeded bur oak at roughly 5'x5' spacing throughout the area. Findings will be shared later in the 2021 season.



Appendix B. Photos

1. Project area during first site visit, February 2019.

2. Project area after mowing and after plowing, July and August 2019, with equipment.

3. Boom sprayer setup and site conditions for the herbicide application in October 2019.

4. A few photos from seed collection, processing, and storage in June 2020.

5. Poke hole seeding red oak on May 14th 2020 and sprouted seedlings on June 9th 2020.

6. A few photos of the hydroseeding setup.