2024 Soil Health Program Report

RILEY PURGATORY BLUFF CREEK WATERSHED DISTRICT

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rpbcwd.org/soil-health-study

Introduction

The District and Barr Engineering staff are developing a Soil Health Program as a part of the Ecosystem Health Action Plan (EHAP). The purpose of this program is to assess various functions of urban soils to better understand the relationship between plant communities, soil functions and characteristics, and hydrology. Through on-site assessment and soil sampling, staff will collect data on various soil function metrics, as well as information on plant communities. The District will use these findings to develop baseline soil function classifications for determining what constitutes good and poor soil health functions with our watersheds. These classifications will provide further framework for improving soil functions and implementing water quality projects across the District.

What is soil health?

Soil health can be seen as "the continued capacity of the soil to function as a vital living ecosystem that sustains plants, animals and humans" (NRCS 2023). Soil health and soil quality are considered synonymous. However, many soil professionals will make one distinction between the two: soil quality includes both inherent and dynamic quality (Moebieus-Clune 2017). Inherent quality is the makeup and properties of soil, shaped by long-term geological processes; dynamic qualities, more of the "soil health" qualities, are the properties of the soil which are influenced by use and changes on a human time scale (Moebieus-Clune 2017). It is important to manage and strive for good soil health and function, as it is its own ecosystem, working as a vital part of broader ecosystems. Properly functioning soil will allow for benefits such as nutrient cycling and retention, support of healthy vegetation communities, sequestering of carbon, and greater water infiltration and storage. Extensive research exists on soil health and its effectiveness on improving water quality and water conservation. Staff are currently reviewing literature on the subject to compile research findings and to identify best practices for soil improvement and policies that can result in water conservation improvements in the District.

The following is a summary of the soil assessment efforts staff undertook during late 2023 through the 2024 field season. This includes methods of assessment, as well as data collected pertaining to infiltration (specifically hydraulic conductivity), and soil physical, biological, and chemical characteristics. Further analysis of apparent trends in the data across the different ecosystems and soil types is also discussed.

Soil sample collection

Assessment Metrics

Table 1 contains the current list of sampling metrics collected during a typical site assessment. These metrics may change upon further literature review and reassessment of data. Metrics to be analyzed by Cornell University's Soils Lab as a part of their standard soil health analysis package are noted in the following table.

Table 1. List of current RPBCWD Soil Health Program sampling metrics.

Metric	Assessment
Infiltration rates (MPD infiltrometer)	On-site
Compaction (field penetrometer)	On-site
Soil respiration	Cornell University Soils Lab
pH	Cornell University Soils Lab
Modified Morgan Extractable P	Cornell University Soils Lab
K, Mg, Fe, Mn, Zn, Al, Ca, Cu, S, B	Cornell University Soils Lab
Soil texture	On-site *and* Cornell University Soils Lab
Active carbon	Cornell University Soils Lab
Wet aggregate stability	Cornell University Soils Lab
Soil organic carbon	Cornell University Soils Lab
Predicted Autoclave-citrate Extractable (ACE) protein*	Cornell University Soils Lab
Available water capacity	Cornell University Soils Lab
Surface/sub-surface hardness interpretation (based on field penetrometer readings)	Cornell University Soils Lab
Soil profile/horizon assessment (texture, color, thickness, matrix makeup, redoximorphic features, presence of wetland soils and/or hydrology, etc.)	On-site
Soil moisture	On-site
Vegetation	On-site
Presence of earthworms	On-site

*Autoclave-citrate extractable (ACE) protein and available water capacity are predicted based on other indicators measured.

Assessment Sites

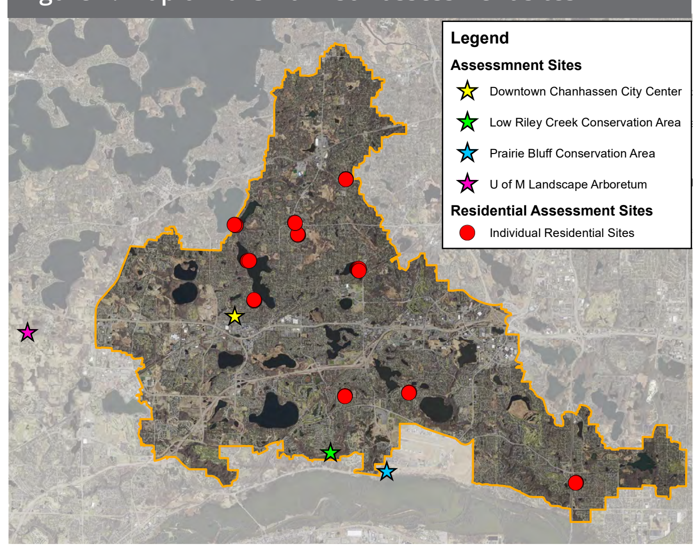
Sample site and point selection was based on identification of representative land use types which fall into two general categories: minimally altered land uses with minimally altered hydrology, and disturbed land uses with moderately-highly altered hydrology (Table 2).

Table 2. List of representative land use types assessed within RPBCWD.

Minimally Altered and Restored Hydrology	Altered Hydrology
• Restored prairie (greater than 30 years old) • Old fallow field (greater than 30 years old) • Forest with good (>50%) herbaceous cover	• Residential lawn • Mowed parkland and multi-activity fields • Forest with poor (<50%) herbaceous cover, or dominated by invasive plants • Rain garden

Specific site selection focused on comparing soil conditions at sites with altered hydrology, and minimally altered or restored hydrology. Initial points were mapped based on USDA mapped soil textures and types. Figure 1 shows sites assessed in the fall of 2023 and during the 2024 field season. After identifying the target ecosystem within a site, multiple points were mapped at that site. Once on site, adjustments to point placement were made, if needed, to accommodate observation of land use boundaries, to add additional assessment points to the sample size, or if other factors called for staff to do so. One

Figure 1. Map of 2023-2024 soil assessment sites



infiltration test was conducted at each mapped point. At least one composite sample, consisting of six subsamples, was taken at each point as well. Subsamples were usually taken within the general area of the corresponding infiltration measurement.

Infiltration

Infiltration testing was conducted to specifically measure the hydraulic conductivity (represented as Ksat in corresponding figures) at each site using a Modified Philip Dunne infiltrometer (MPD). Hydraulic conductivity is the water infiltration rate once the soil has reached 100% saturation and the infiltration rate has become constant. Infiltration testing was conducted on days where there was no precipitation 24 hours prior. At each site, three four-inch diameter graduated cylinders were pounded into the soil at a three-foot radius from a center point. Each test was filled with 30 centimeters of water. Once filled, the MPD sensor heads were placed onto the cylinders and the test was started immediately. Each individual cylinder constituted one test. Once the sensor head was in place and turned on, the MPD automatically recorded data for each test. Each test ran until all the water had drained from the tube. If no drainage was observed after one hour, the test was concluded.

Samples

Clear, sunny days were needed to properly evaluate the soil profile. In instances where it was too overcast to properly assess soil horizon colors, soil profiles were conducted at a later date during sunny conditions.

Each composite sample consisted of at least six subsamples. Each set of subsamples were taken 15 feet apart, with one pair taken adjacent to the infiltration test point. For each subsample, an 8-inch-deep hole was dug using a tile spade. From the side of the hole, the top two inches of surface soil was removed to clear vegetation. Digging where the top two inches of surface soil were removed, a six-by-two-inch sample was removed. Any extra soil was removed from the sample to make it as uniform as possible. At each subsample point, a penetrometer was used to measure surface and subsurface compaction (0-6 inches and 6-18 inches from the surface, respectively). Penetrometer


Example of a soil profile extracted at a residential lawn

readings were recorded with the soil samples to be analyzed by the Soils Lab. Subsamples were placed together in a clean, five-gallon bucket, mixed thoroughly, and five cups were measured out and double bagged in gallon freezer bags. Samples were labeled with site information, refrigerated, and mailed via USPS to the Cornell University Soils Lab for analysis. All samples were sent by end of day or the day following sampling to prevent decomposition of samples.

Infiltration Data Results

From fall 2023 through the close of the 2024 field season, 102 sites were assessed for hydraulic conductivity (Ksat), equating to 346 individual infiltration tests. Of those tests, 284 were successful within representative land uses. In 2022-23, 54 successful tests were taken within representative land uses. Of these 337 successful infiltration tests, an additional 22 tests were discarded after further analysis into their calculated hydraulic conductivity rates. This data analysis will look at all of the 315 successful infiltration tests conducted within each representative site since 2022. This analysis will NOT include tests conducted in newer restored ecosystems. In order to truly observe the effects land use has on the soils over time, any soils data from restored ecosystems younger than 30 years old was not analyzed. This was done because younger restored ecosystems have not had enough time for plant and soil microbial communities to create soil conditions representative of older ecosystems, such as established prairies or forests with good herbaceous cover. Many of the younger BMPs and restoration sites will be re-assessed in the future to see how soil structure and health have changed and healed over time.

At least one set of three tests was conducted at each site; some sites had repeat or extra tests conducted. Some of these extra tests were due to errors in the infiltration that produced "NULL" results. Some tests were stopped early by staff due to slow or no drainage and produced a "NULL" result. In this case, if staff could calculate an average hydraulic conductivity of less than 1 inch/hour, it was assigned a Ksat value of 1 inch/hour; if the average hydraulic conductivity was less than 0.1 inch/hour, the point was assigned a Ksat value of 0 inch/hour. Table 3 provides a breakdown of how many successful tests occurred within each representative ecosystem since sampling began in fall of 2022.

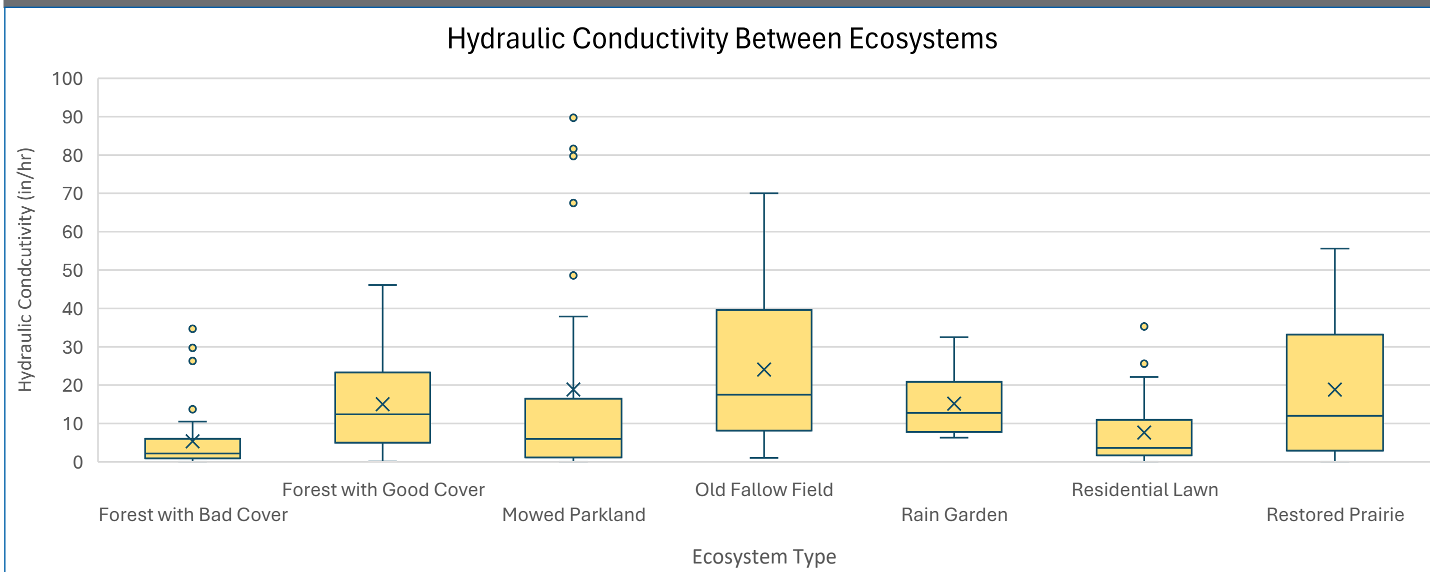
Infiltration varied across the different landscape uses (Figure 2). Representative sites with minimally altered and restored hydrology, as well as rain gardens, tended to have the greater mean Ksat. Restored prairies had an overall average Ksat of 18.82 inches/hour over 69 tests. The Minnesota Landscape

Table 3. List of Ecosystems with respective number of MPD tests over the 2023-2024 field season.

Ecosystem	Number of MPD tests
Restored Prairie	69
Residential Lawn	53
Mowed Parkland/Multi-Activity Field	40
Old Fallow Field	36
Forest with Good Herbaceous Cover	67
Forest with Poor Herbaceous Cover	36
Rain Garden	14

Arboretum restored prairie plant community cover was dense. Most sites had a plant community consisting of a mixture of predominantly native prairie grasses and forbs. The dominant species included Tall Goldenrod (*Solidago altissima*), Creeping Bentgrass (*Agrostis stolonifera*), Big Bluestem (*Andropogon gerardi*), Sky Blue Aster (*Symphyotrichum oolentagiense*), Stiff Goldenrod (*Solidago rigida*), Indiangrass (*Sorghastrum nutans*), and Hairy Sunflower (*Helianthus hirsutus*). The Prairie Bluff Conservation Area prairie had a predominantly dense cover of native prairie grasses such as Big Bluestem, Rough Dropseed, Indiangrass, and Creeping Bentgrass. Rain gardens had an average Ksat of 15.16 inches/hour over 14 tests. They included typical plants planted in raingardens (wetter sedges and forbs in lower parts of the basins and wet-to-drier grasses and forbs

Figure 2. Hydraulic conductivity of successful infiltration tests. "X" indicates the mean hydraulic conductivity (Ksat) value across all the tests within that particular land use type. The lines intersecting each box plot indicate the median Ksat value of the tests conducted for that landscape type.



in upper parts of the gardens). Old fallow fields had an average Ksat of 24.07 inches/hour over 36 tests. The Arboretum fallow fields had a fairly diverse mixture of prairie plants including dominant species such as Tall Goldenrod, Stiff Goldenrod, Bicknell's Sedge (*Carex bicknellii*), Indiangrass, and Creeping Bentgrass. Forests with good herbaceous cover had an average Ksat of 15.01 inches/hour over 67 tests The majority of forested areas both in the District and in the Arboretum were Sugar Maple (*Acer saccharum*) dominated forests.

Two of the four altered hydrology land use types had lower mean Ksat across all of their sites. Residential lawns had a mean Ksat of 7.63 inches/hour over 53 tests. These sites were dominated by Kentucky Bluegrass (*Poa pratensis*) with little to no other vegetation. Forests with poor herbaceous cover had the lowest mean hydraulic conductivity of 5.37 inches/hour over 36 tests. These sites tended to have little to no cover, even void of invasive species such as Common Buckthorn (Rhamnus cathartica) or Garlic Mustard (*Alliaria petiolata*). Like forests with good herbaceous cover, the majority of these sites were within forests dominated by Sugar Maples or a mixture of Sugar Maple and Basswood (Tilia americana).

The mean hydraulic conductivity rate in mowed parkland and multi-activity fields was an exception to this trend. Although the median of the entire dataset was the third lowest along with the other altered hydrology sites (5.95 inches/hour over 40 tests), it had the second highest mean average of all of the ecosystems (18.88 inches/hour). When looking at all of the test points we can see that 75% of the tests came in at 16.5 inches/ hour or less. However, there were several very high test points that pulled that average up a considerable amount. If we were to remove those points that could be considered outliers (more than 1.5 times the Interquartile Range (IQR) higher than the third quartile), the mean average of hydraulic conductivity in mowed parklands and multi-activity activity fields would be 5.35 inches/ hour. Given that no apparent errors occurred when conducting those tests, these points will remain a part of the dataset. Staff are reviewing site conditions within this land use and working to create subcategories of mowed parkland and multi-activity fields. Some of these sites were maintained turfgrass that saw little pedestrian traffic, while others were activity fields seeing heavy, daily foot traffic. By separating these sites by use, as well as conducting more tests in these sub-land use types, staff hope to identify a correlation between higher infiltration and hydraulic conductivity rates on these sites and their usage. The majority of these areas consisted mainly of mowed Kentucky Bluegrass. There were some areas within this ecosystem type sampled that had bare ground as well. Site specific hydraulic conductivity rates can be seen in Appendix B.

Infiltration testing using the MPD Infiltrometer

Sample Data Results

From fall 2023 through the 2024 field season, 102 samples were mailed to the Cornell University Soils Lab for analysis. Lab results and assessment of the samples provided to the District included a comprehensive analysis of soil health for each sample, including measurements of physical, biological, and chemical metrics, as well as a functional score given for each sample submitted. These scores rated each functional metric of a given sample out of 100, 0 being a very low functional score and 100 being a very high functional score. Figure 3 is a sample assessment report for one of three samples taken at North Lotus Lake Park. This site is labeled as “NLLP2” on all the figures displaying functional ratings in this report. The full comprehensive assessment of this example site is included in Appendix E. This assessment is based off the Cornell Comprehensive Assessment of Soil Health (CASH) Training Manual (Moebius-Clune 2017). The assessment report for each sample also includes soil texture composition, (the percentage of sand, silt, and clay), as well as management suggestions

Figure 3. sample assessment report for one of three samples taken at North Lotus Lake Park.

Comprehensive Assessment of Soil Health

From the Cornell Soil Health Laboratory, Department of Soil and Crop Sciences
School of Integrative Plant Science, Cornell University, Ithaca, NY 14853
https://soilhealthlab.cals.cornell.edu

Grower:
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Chanhussen, MN 55317
zdickhausen@rpbcwd.org

Sample ID:	WW2424
Field ID:	N. Lotus Lake Park 2
Date Sampled:	05/09/2023
Given Soil Type:	Lester-Kilkenny
Crops Grown:	PRK/PRK/PRK
Tillage:	no till
Coordinates:	Latitude: 44.884027000000 Longitude: -93.526559000000

Measured Soil Textural Class: **sandy loam**

Sand: **59%** - Silt: **23%** - Clay: **16%**

Group	Indicator	Value	Rating	Constraints
physical	Predicted Available Water Capacity	**0.18**	**76**	
physical	Surface Hardness	**325**	**2**	Rooting, Water Transmission
physical	Subsurface Hardness	**600**	**0**	Subsurface Pan/Deep Compaction, Deep Rooting, Water and Nutrient Access
physical	Aggregate Stability	**39.0**	**48**	
biological	Organic Matter Soil Organic Carbon: 1.73 / Total Carbon: 1.80 / Total Nitrogen: 0.16	**2.8**	**82**	
biological	Predicted Soil Protein	**4.70**	**22**	
biological	Soil Respiration	**0.5**	**34**	
biological	Active Carbon	**359**	**32**	
chemical	Soil pH	**7.4**	**96**	
chemical	Extractable Phosphorus	**2.5**	**72**	
chemical	Extractable Potassium	**62.5**	**87**	
chemical	Additional Nutrients Ca: 2770.2 / Mg: 398.8 / **S: 2.0** Al: 3.2 / B: 0.26 / Cu: 0.03 Fe: 0.6 / Mn: 2.3 / **Zn: 0.1**		**77**	

Overall Quality Score: **52** / Medium

to correct indicators which scored poorly. It is important to note that the CASH framework for assessment and soil health focus around soils within agricultural settings. Chemical functions' ratings listed in these reports are very specific to how the chemical makeup of the soil will influence crop growth. Chemical properties will continue to be a part of the analysis of soil samples collected, but, at this time, it will not be a part of the data analysis of this report. The overall quality score provided on the CASH report will also not be included in this report seeing that chemical analysis has been removed.

Including the 102 samples taken during the 2023-24 season, the following analysis includes a total of 113 samples taken from representative land uses since the study began in the fall of 2022. Graphs of average functional ratings can be found in Appendix C. Scatterplots comparing hydraulic conductivity to functional ratings, and scatterplots comparing physical functional ratings to biological functional ratings can be found in Appendix D.

When looking at the biological functional metrics, staff were expecting to see a trend towards seeing lower average functional scores in altered hydrology land uses, rain gardens being an exception, and higher average scores in the minimally altered hydrology ecosystems. This was somewhat the case with most land uses except for fallow fields and forests with poor cover averages. Mowed parklands, multi-activity fields, and fallow fields had the lowest functional ratings of all the ecosystems. One exception to this was the mowed parklands/multi-activity fields' organic matter average which had a high functional rating. Despite having a fairly robust, diverse, and established plant community across the entirety of the large fallow field area sampled, fallow field averages scored the lowest in all four biological function categories. These sites scored low in organic matter (35/100), predicted soil protein (31/100), soil respiration (39/100), and active carbon (29/100). Mowed parkland and multi-activity fields scored low in average predicted soil protein (35/100) and medium in average soil respiration (47/100) and active carbon (48/100). Outside of a few instances, forests with poor cover, restored prairies, and rain gardens scored high to very high across the biological functional metrics. Surprisingly, forests with poor herbaceous cover averages scored high in predicted soil protein (62/100) and soil respiration (69/100) and very high for both organic matter (84/100) and active carbon (85/100). This is in part surprising given that the majority of these sites had very little understory and herbaceous cover as well as little to no duff layer. Rain garden averages scored high in organic matter (75/100), predicted soil protein (65/100), and active carbon (78/100) and medium rating for average soil respiration (57/100). Restored prairie averages followed a similar trend, scoring high in organic matter (73/100), soil respiration (63/100), and active carbon (64/100). The average predicted soil protein score of restored prairie sites was medium (56/100). Forests with good herbaceous cover and residential lawn averages had similar scores for each category, scoring high in organic matter (74/100 for both) and in active carbon (71/100 and 72/100, respectively) and medium in predicted soil protein (57/100 and 46/100) and soil respiration (51/100 and 58/100).


Prairie at the MN Landscape Arboretum

As with the biological metrics, staff expected to see high functional scores across the land uses with minimal altered hydrology and to see lower functional scores in land uses with altered hydrology for the physical metrics. Functional ratings across the physical metrics varied and did not necessarily trend high or low toward one of the altered hydrology categories. When it came to surface compaction, the majority of these land uses scored a medium average rating for both surface and sub-surface compaction. The two land uses which staff would have expected to have the highest levels of compaction and score

Table 4. Soil Health Indicators - Cornell Framework.

PHYSICAL	**Predicted Available Water Capacity:** reflects the quantity of water that a disturbed sample of soil can store for plant use. It is the difference between water stored at field capacity and at the wilting point, and is measured using pressure chambers.
	Surface Hardness: is a measure of the maximum soil surface (0 to 6 inch depth) penetration resistance (psi), or compaction, determined using a field penetrometer.
	Subsurface Hardness: is a measure of the maximum resistance (psi) encountered in the soil between 6 to 18 inch depths using a field penetrometer.
	Aggregate Stability: is a measure of how well soil aggregates resist disintegration when hit by rain drops. It is measured using a standardized simulated rainfall event on a sieve containing soil aggregates between 0.25 and 2.0 mm. The fraction of soil that remains on the sieve determines the percent aggregate stability.
BIOLOGICAL	**Organic Matter:** is a measure of all carbonaceous material that is derived from living organisms. The percent organic matter is determined by the mass of oven dried soil lost on combustion in a 500° C furnace.
	Predicted Soil Protein: is a measure of the fraction of the soil organic matter which contains much of the organically bound N. Microbial activity can mineralize this N and make it available for plant uptake. This is measured by extraction with a citrate buffer under high temperature and pressure.
	Soil Respiration: is a measure of the metabolic activity of the soil microbial community. It is measured by re-wetting air dried soil, and capturing and quantifying carbon dioxide (CO_2) produced.
	Active Carbon: is a measure of the small portion of the organic matter that can serve as an easily available food source for soil microbes, thus helping fuel and maintain a healthy soil food web. It is measured by quantifying potassium permanganate oxidation with a spectrophotometer.
CHEMICAL	**Soil Chemical Composition:** is a standard soil test analysis package measures levels of pH and plant nutrients. Measured levels are interpreted in this assessment's framework of sufficiency and excess but no crop specific recommendations are provided. Nutrients measured include extractable phosphorus, extractable potassium, calcium, magnesium, iron, zinc, aluminum, boron, copper, manganese, and sulfur.

low, residential lawns and mowed parkland and multi-activity fields, did score the lowest of the land uses. Mowed parkland and multi-activity fields scored very low for both surface compaction (7/100) and subsurface compaction (10/100). Residential lawns scored low for surface compaction (28/100) and subsurface compaction (31/100). Fallow fields did however also score very low, but only for surface compaction (14/100). The rest of the average compaction scores were a medium rating (40-59).

Both forest with poor herbaceous cover and forest with good herbaceous cover land use types had high average ratings for aggregate stability (69/100 and 78/100, respectively) and very high average ratings for available water capacity (88/100 and 84/100 respectively). For all of the other land uses, if their average values scored high to very high in either aggregate stability or available water capacity, their average score for the other metric scored medium to low. See Appendix C to view the rest of these average functional scores.

Data Analysis

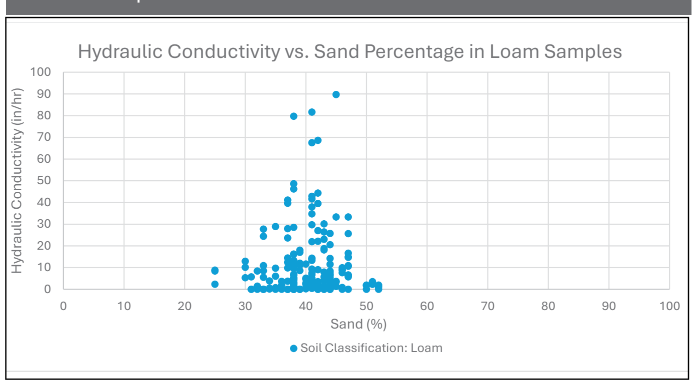
After looking through the infiltration data and sample results, staff wanted to see if any correlations could be identified between hydraulic conductivity and the physical and biological metrics tested. In the District's representative land uses, were any of the functions affecting hydraulic conductivity? If so, by how much? Staff also wanted to see if there was any correlation between the physical and biological metrics tested. Literature shows that when these soil functional metrics have higher function, it leads to better infiltration. Additionally, the biological functions tested are an important influence on physical functions such as aggregate stability and available water capacity. These physical functions directly and positively influence water retention and infiltration. Given the District's findings, there might be need for more sampling and infiltration testing. Additionally, it might warrant a deeper dive into assessing the recorded plant communities at each site and how their soils performed.

Staff started by comparing soil texture to hydraulic conductivity. The majority of samples taken had fairly even proportions of sand, silt, and clay. Where this varied was when the proportion of sand was much greater than the other two textures. Sample sites were categorized into measured soil texture classes based on the same metric measured by the Cornell University Soils Lab (see Figure 3, example report). As seen in the example scatter plot in Figure 4, the percentage of sand present in the sample was used as the x-axis variable. This was done to see if the amount of sand, which has a larger particle size than silt or clay, would significantly positively influence infiltration and hydraulic conductivity. Using a scale of significance where 0.9-1 is very high, 0.7-0.89 is high, 0.4-0.69 is moderate, 0.2-0.39 is low, <0.2 is no apparent correlation, no strong correlations were found between soil texture and hydraulic conductivity. Because of this finding, soil texture proportions were not included in further analysis when comparing functional metrics to infiltration.

The next step was to compare each sample site's hydraulic conductivity to each biological and physical functional score. When looking at hydraulic conductivity versus each of the soil function categories across the entirety of sites, no correlations were found between the two. Staff broke down the analysis and compared hydraulic conductivity with each soil functions for every land use type individually. There were only a handful of soil function-land use combinations that showed a moderate correlation between the function and hydraulic conductivity. Restored prairie had the most correlations. There were negative, moderate correlations between hydraulic conductivity and surface compaction (R^2 = 0.561), subsurface compaction (R^2 = 0.487), and available water capacity (R^2 = 0.476). Rain gardens had a negative, moderate correlation between hydraulic conductivity and aggregate stability (R^2 = 0.442). Mowed parkland and multi-activity field had a positive, moderate correlation between hydraulic conductivity and soil respiration (R^2 = 0.520). Given that none of the functional categories moderately-to-strongly correlating to hydraulic conductivity across multiple ecosystem types, it might be beneficial to collect more sample and infiltration test data within each land use. It also might be beneficial to increase sample density in a given area within a site.

Diving further into the analysis, staff compared the physical functional scores to biological scores. There were no measurable correlations between biological and physical functional scores when comparing them across all sites. However, there were several R^2 values with moderate to high, positive correlation when assessing whether physical functional scores correlated to biological functional scores for individual ecosystems. Available water capacity correlated to organic matter in restored prairies (R^2 = 0.609) and rain gardens (R^2 = 0.700). Available water capacity also correlated to soil respiration in restored prairies (R^2 = 0.639) and rain gardens (R^2 = 0.937). Aggregate stability correlated to soil respiration in residential lawns (R^2 = 0.507) and mowed parkland (R^2 = 0.487). Aggregate stability correlated to organic matter in forests with good herbaceous cover (R^2 = 0.455). Aggregate stability also correlated to predicted soil protein in mowed parkland (R^2 = 0.438) and forest with good

Figure 4. Hydraulic Conductivity vs. Sand Percentage in Loam Samples.



herbaceous cover (R^2 = 0.418).

Discussion

After looking through the data and comparing functional scores and rates of hydraulic conductivity, there were expected and unexpected trends observed. As expected, sites with minimal altered hydrology and rain gardens on average had higher hydraulic conductivity. As mentioned previously, mowed parkland and multi-activity field did have a very wide range of hydraulic conductivity rates, leading to a much higher mean rate than expected. Staff will be dividing this category into subcategories. Once more sites are identified and additional data is collected, staff will reassess hydraulic conductivity across these subcategories and compare them to other ecosystems. Staff were also expecting to see more of a stark difference in soil functions between rain gardens, sites with minimal altered hydrology, and the other highly altered hydrology sites. Outside of a few soil functions, most of the land uses' soils performed moderately to high. This may just boil down to the need to collect more samples and increase the data set. Either way, having more data will increase the confidence in the trends seen thus far.

As far as overall data collection and analysis, staff are considering the possibility that more data in general needs to be collected. This includes collecting more data from across many more sites. Some land uses, such as the restored prairies and fallow fields, only had one or two locations where samples were taken. It will be beneficial to not only to have a much larger sample size but also to get a higher density of samples across a wider representation of sites for each of these ecosystems. Staff hope that this will start to make some of the soil function trends stronger and allow staff to come to stronger conclusions on how different land uses' hydrology and usage affect their soils. Part of identifying future sample sites will include identifying localized areas where multiple ecosystems can be assessed. This was done within the Arboretum. Staff assessed four separate sites within the Arboretum, all within a relatively localized area. This may be beneficial because there is a better chance nearby sites will have similar characteristics such as soil textures, parent soils, topography, and surroundings. Removing some of these variables could provide for a better comparison of soil functions across multiple land uses. Staff may also explore taking infiltration tests and samples from deeper in the profile (e. g. 6 to 12 inches below the surface) in order to produce more consistent results.

Another factor staff are looking into is the actual make-up of the vegetative communities observed at each sample point. Metrics such as percent coverage, average root depth, and plant diversity play significant roles in affecting infiltration, water storage, organic matter accumulation and all of the soil functions tested for in this program. Staff want to start identifying how plants and plant communities, and their percent coverage across these ecosystems are affecting hydraulic conductivity and soil function. Within developed land uses, age and methods of development are potential factors which may be identified and assessed as well.

References

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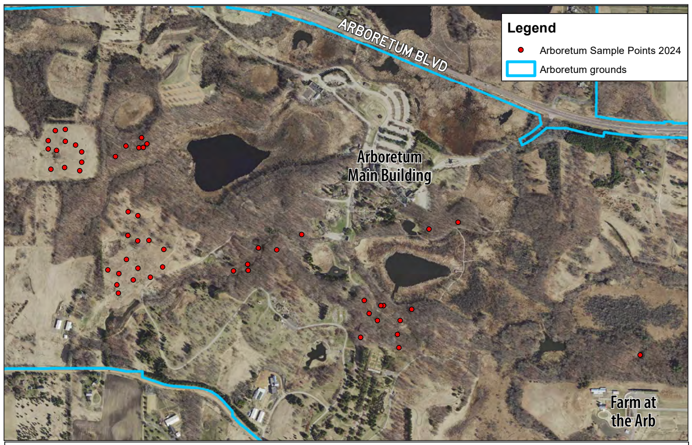
Appendices

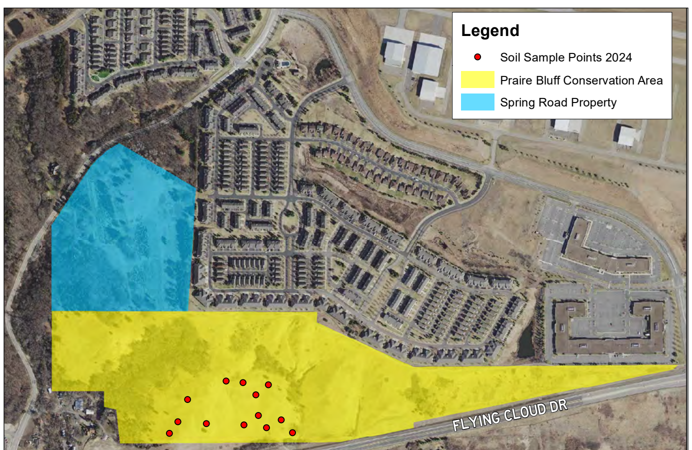
Appendix A

Fall 2023 and 2024 season assessment site maps.

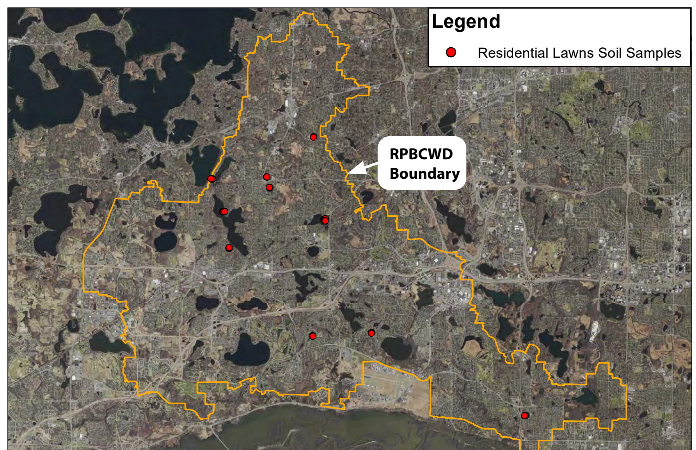


U of M Landscape Arboretum

Lower Riley Creek Conservation Area - Forest



Prairie Bluff Conservation Area/Spring Rd Property

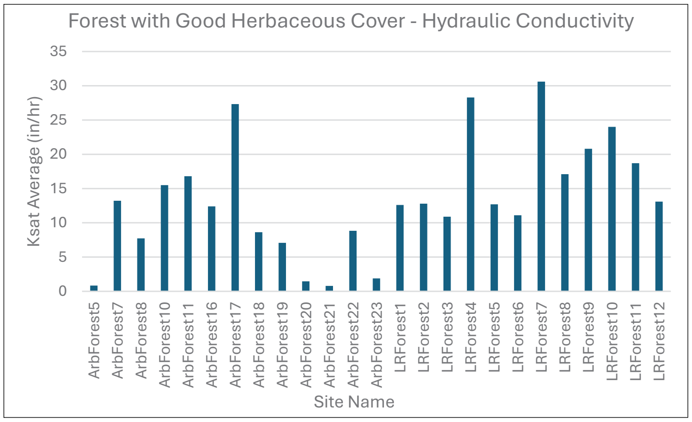


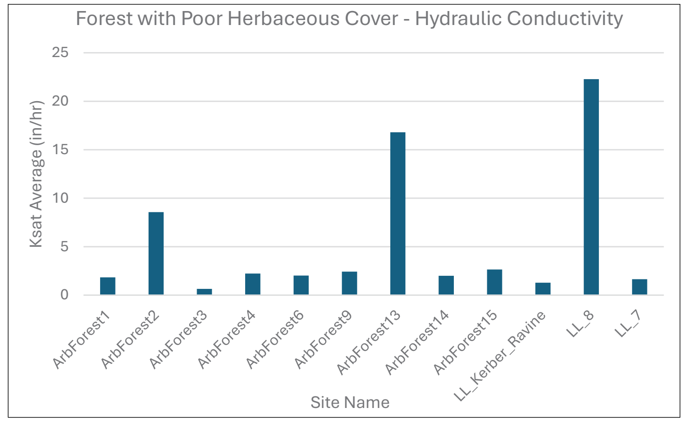
Residential Lawns

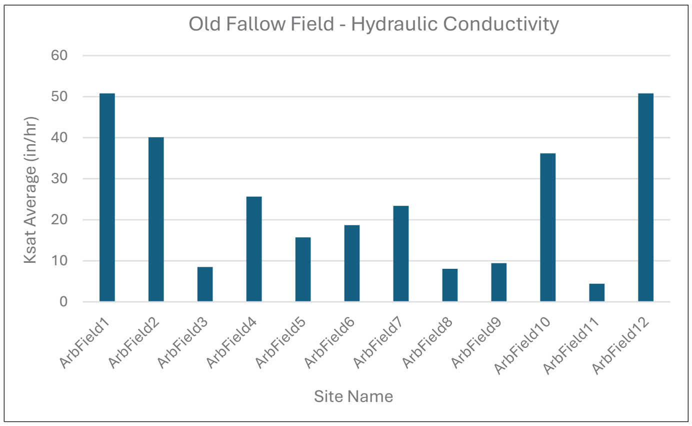
Chanhassen Downtown City Center

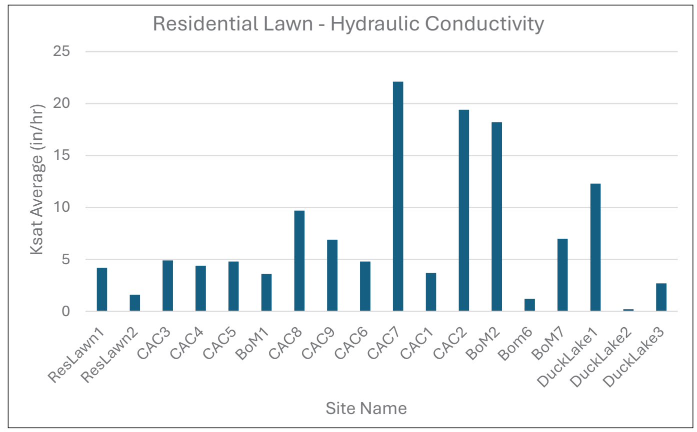
Appendix B

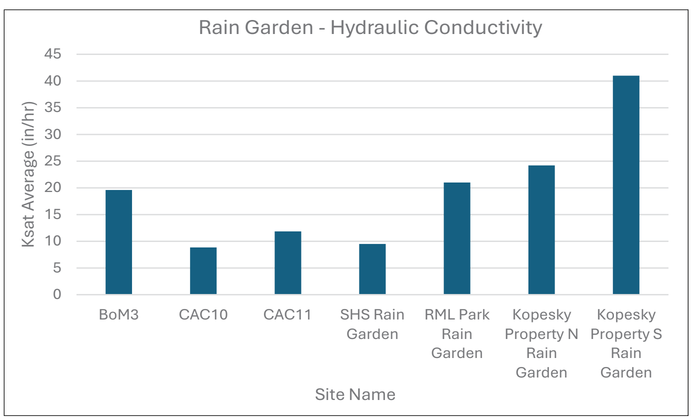
Site-specific hydraulic conductivity measurements across all landscape types.

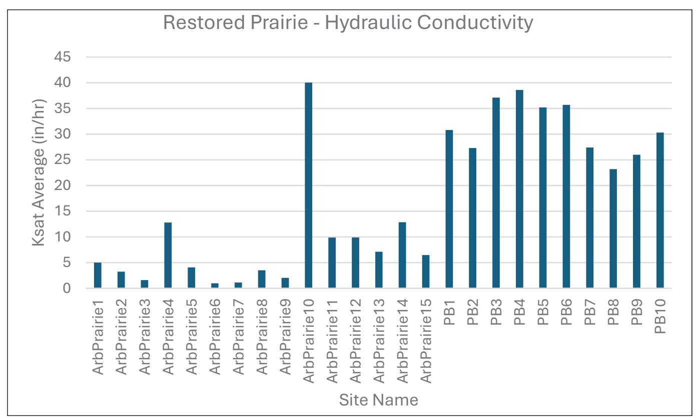


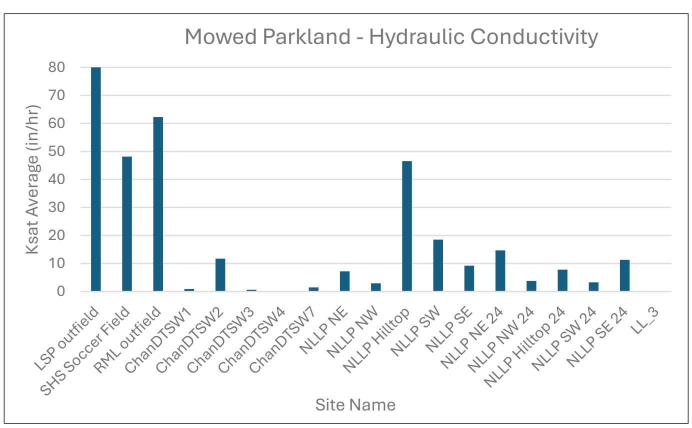






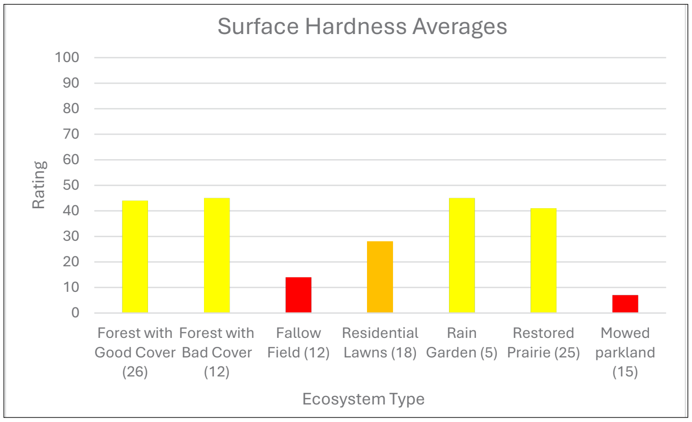


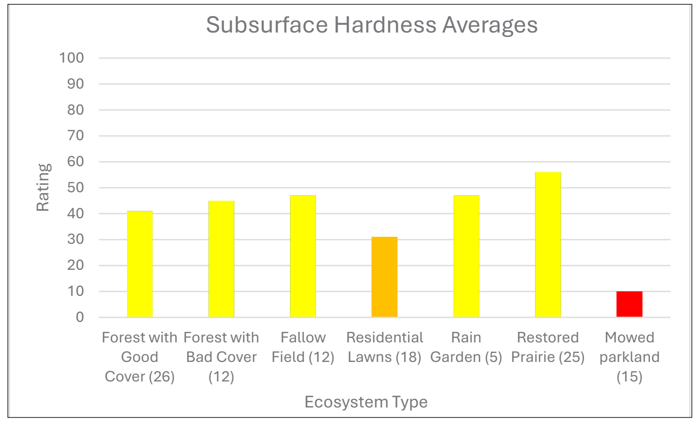


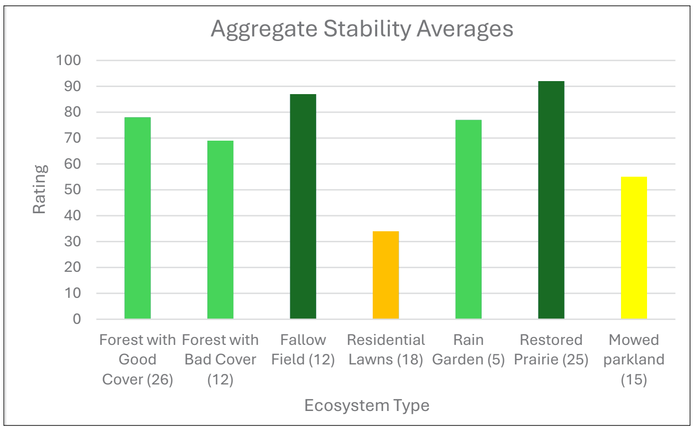


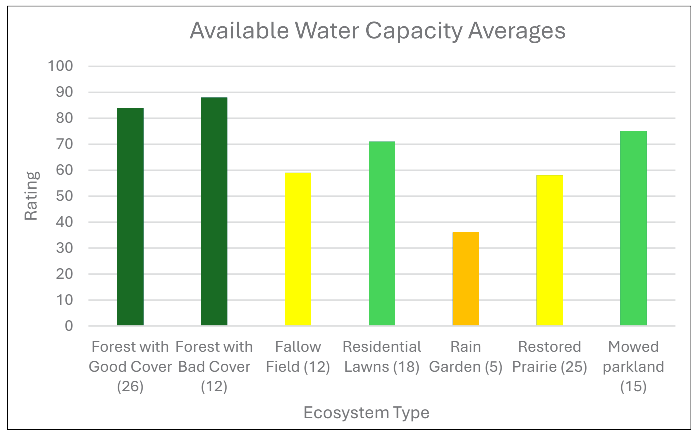
Appendix C

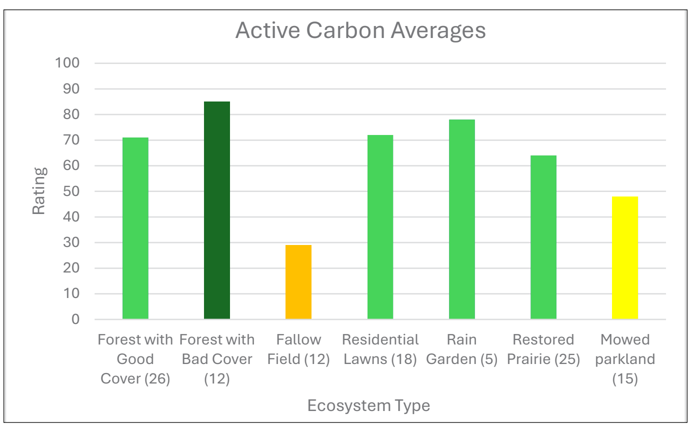
Comprehensive assessment of soil health indicator function/health ratings across all sites sampled.

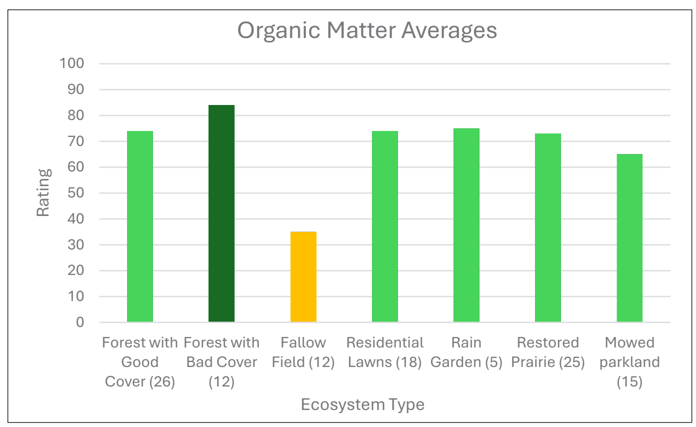


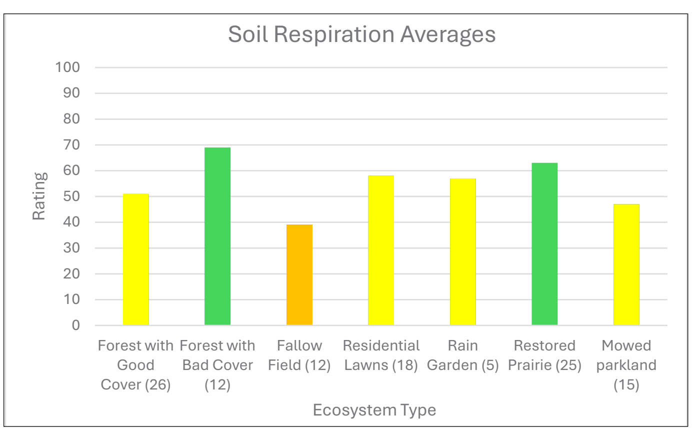


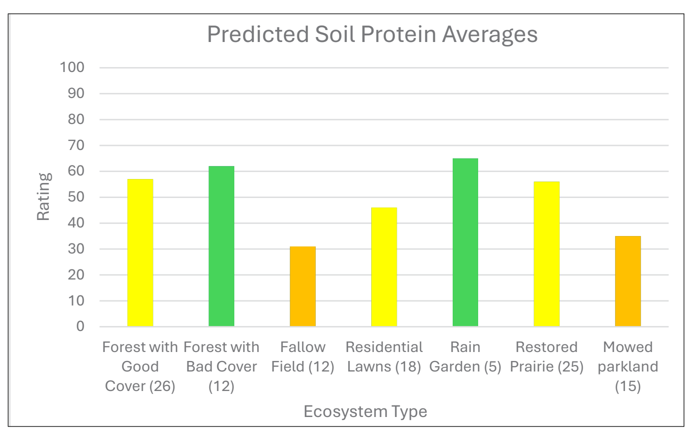






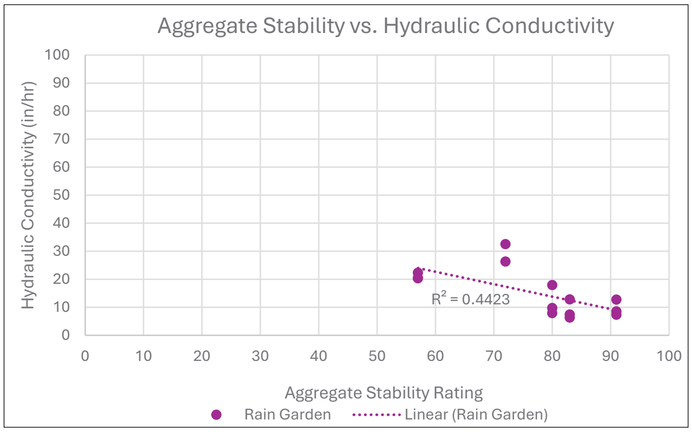


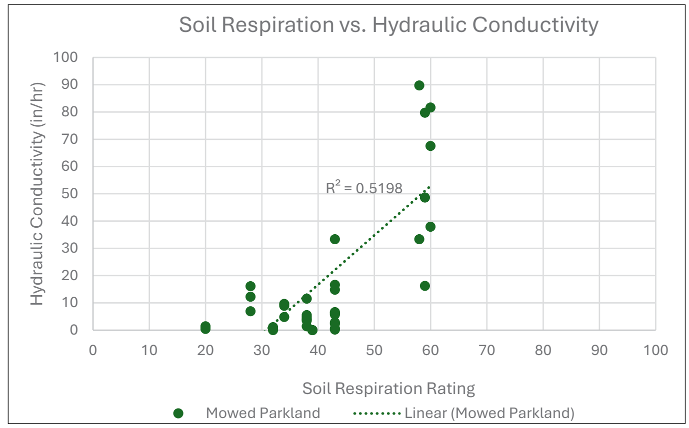


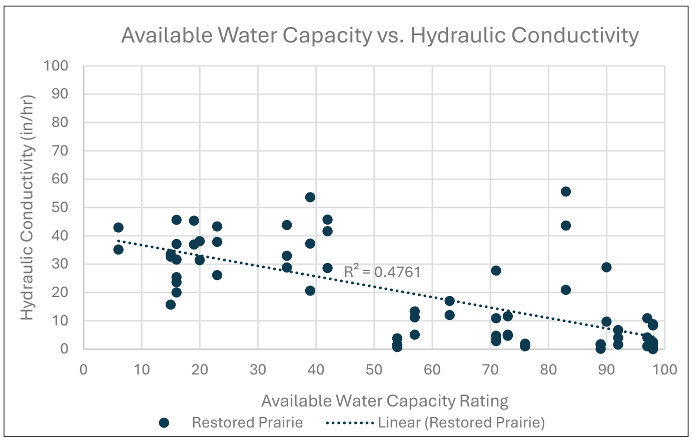


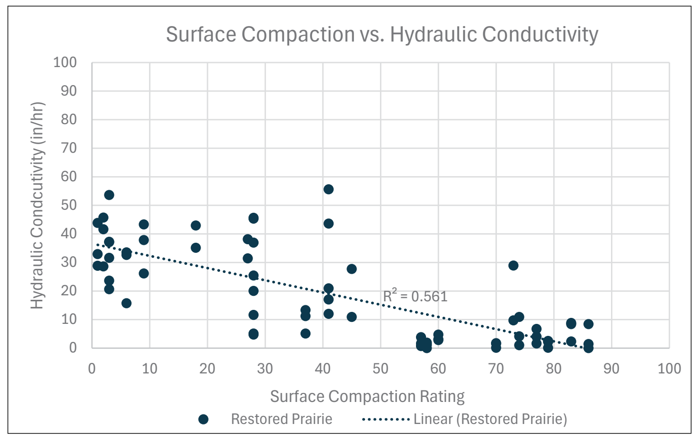
Appendix D

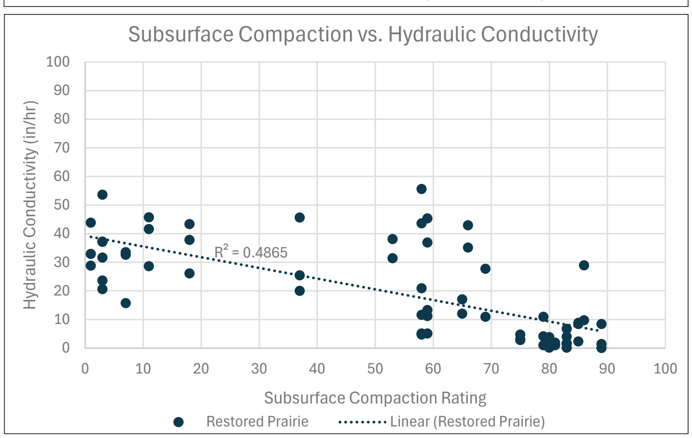
Comparison of hydraulic conductivity to functional ratings and comparison of physical and biological functional ratings across different landscape types. Includes only instances where there was moderate or higher R2 values.

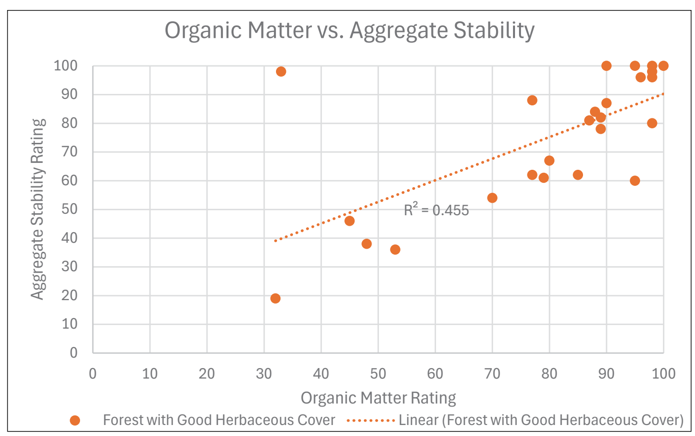


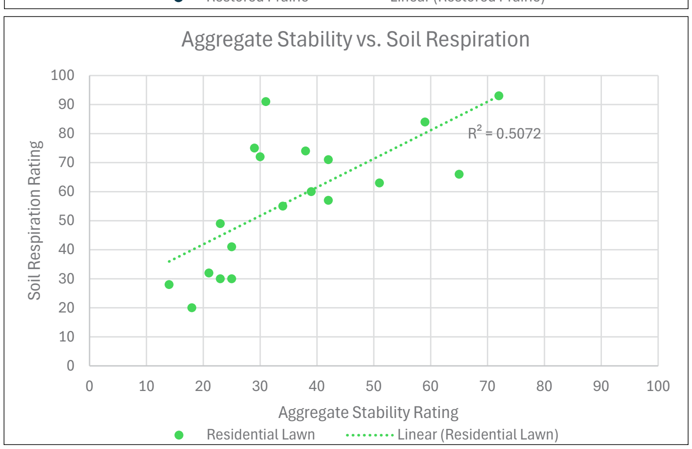


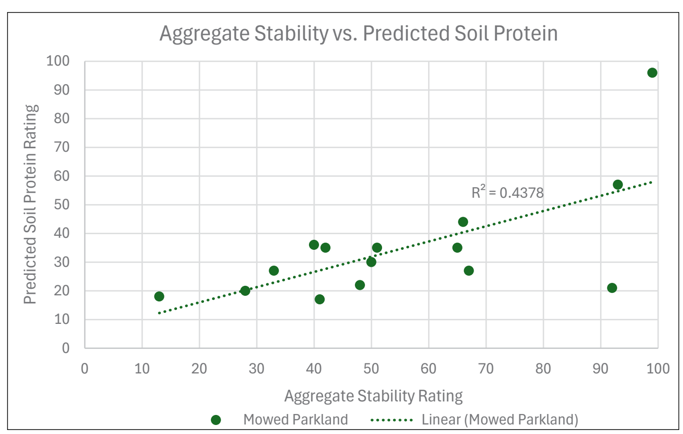


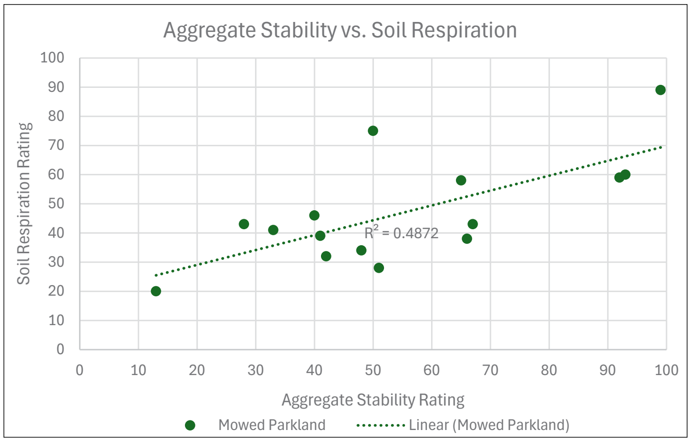


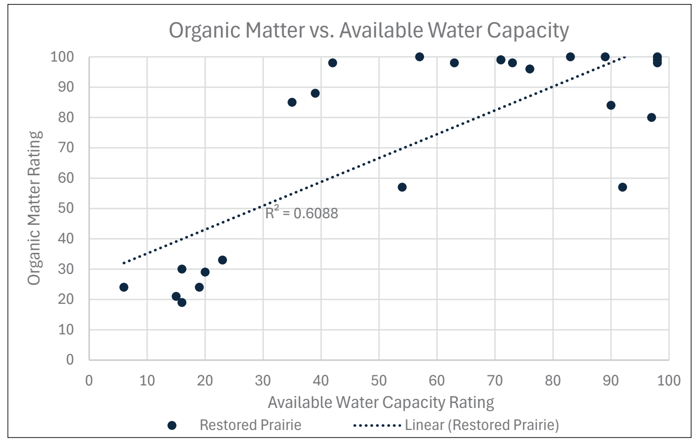


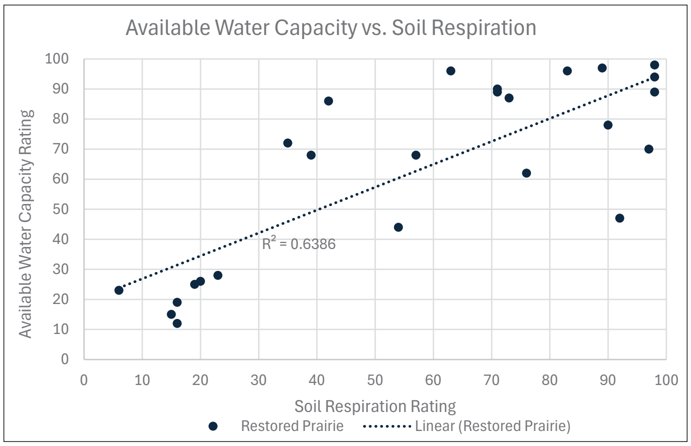


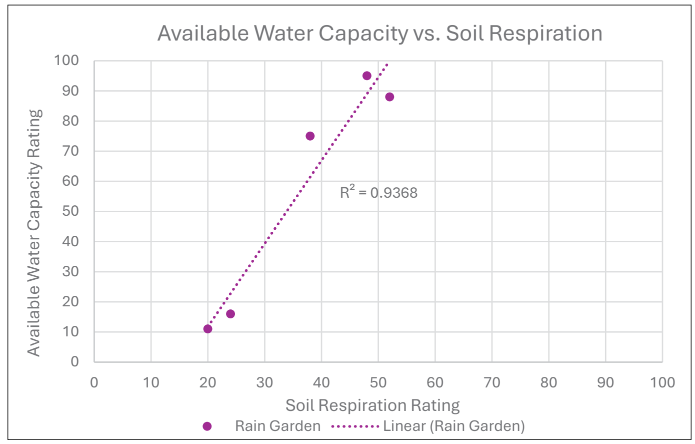





Aggregate Stability vs. Soil Respiration
Soil Respiration Rating
Aggregate Stability Rating
R² = 0.4872
Mowed Parkland
Linear (Mowed Parkland)


Organic Matter vs. Available Water Capacity
Organic Matter Rating
Available Water Capacity Rating
R² = 0.6088
Restored Prairie
Linear (Restored Prairie)


Available Water Capacity vs. Soil Respiration
Available Water Capacity Rating
Soil Respiration Rating
R² = 0.6386
Restored Prairie
Linear (Restored Prairie)


Available Water Capacity vs. Soil Respiration
Available Water Capacity Rating
Soil Respiration Rating
R² = 0.9368
Rain Garden
Linear (Rain Garden)