Greater Edwards Aquifer Alliance Report:

San Antonio Parks and Recreation Soil Health Assessment

April 7, 2023

Prepared for:
City of San Antonio
Parks and Recreation Department
Horticulture Services

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Executive Summary

The purpose of this project was to identify parks throughout the city that could be used as demonstration sites for implementing modified soil and vegetation best management practices (BMPs). BMPs will be selected to improve ecosystem services and landscape health by improving soil and vegetation health. Thirteen parks were selected, and soil samples were taken and analyzed through a certified laboratory to provide baseline data. Soil health indicators included, but were not limited to, levels of soil aggregation, soil organic matter, soil respiration, water-extractable available organic carbon, and available soil nitrogen

Results indicated that sites within the selected parks typically ranged from slightly below average to slightly above. Several park sites, such as those within the Medina River Natural Area, averaged readings equivalent to a poor rating while those sites for the Olmos Basin and Loop 1604 Salado Creek Trailhead averaged readings of very good to ideal.

Recommendations are given for each park on practices for consideration to increase soil health. It is anticipated that the primary BMP that will be used is modified mowing regimes. Implementation of BMP and others will require training and public input with the understanding that strategies will lead to an increase in ecosystem services for all residents of San Antonio. These improved ecosystem services will assist in providing improved air and water quality, biodiversity, terrestrial and aquatic wildlife habitat, creating healthier landscapes while reducing stormwater runoff.

Soil Health Test Results and Recommendations
Spring 2023

Background

In 2019, the City of San Antonio Parks and Recreation (SAPAR) and the Natural Resource Conservation Service (NRCS), an agency of the United States Department of Agriculture (USDA), entered into a memorandum of understanding where SAPAR would give access to park properties for the NRCS to complete soil carbon sampling. This project was initiated to implement a recommended mitigation strategy within the SA Climate Action and Adaptation Plan to “actively use public green spaces for sequestering atmospheric carbon dioxide (CO_2) and determine current soil carbon levels”. This project also supports Goal 3 of the SA Parks System Plan 2019-2029 which includes:

- The benefits of the urban forest are maximized inside and outside of parks,
- Ecologically sensitive landscape design throughout the parks system supports biodiversity, pollinators, local fauna and flora, and decreases resource-intensive landscape maintenance practices,
- Programming that increases knowledge and stewardship of natural and cultural resources for individuals and groups of all ages,
- Stormwater is slowed, reused, and allowed to recharge the aquifer as much as practical through low-impact, ecologically sensitive design, and
- Policies and practices that model a holistic view of sustainability.

The NRCS, the federal agency responsible for the national soil carbon inventory, began taking soil samples in 2021 (after the COVID-19 pandemic) and has completed the sampling of the originally selected 59 sites across the city. This sampling will provide San Antonio with the desired baseline soil carbon data. After review of the data, the NRCS will then provide the City with additional recommended management practices to increase the capacity of San Antonio’s soils to pull CO_2 out of the atmosphere and store it.

In anticipation of receiving results and recommendations from the NRCS on the 59 sample sites for soil carbon levels, SAPAR has moved forward to select 13 parks as demonstration sites. The 13 parks were selected to provide sites that cover a wide range of soil types and land uses while ensuring that each City Council district would be represented.

In addition, with the knowledge that it may require 10+ years to observe increases in soil carbon (especially at optimal depths of 24”-26”), a parallel study has been initiated. This study will provide baseline data on the “health” of the soil at a 0-6” depth. Monitoring the soil organic matter levels and health at this depth will provide a tool for SAPAR to determine the effectiveness of management practices and strategies in a shorter period.

Soil Health

Soil health is dependent on soil organic matter (SOM) and the microbial populations that use the SOM as a food and energy source. By utilizing management strategies that build and protect SOM, the capacity of the soil to sequester and store CO_2 from the atmosphere is increased.

One of the most important co-benefits of increasing SOM includes increasing the soil's ability to allow more stormwater to enter the soil and be stored for a longer period which provides a buffer against drought; *a 1% increase in SOM can hold an additional 20,000 gallons of water per acre*[1].

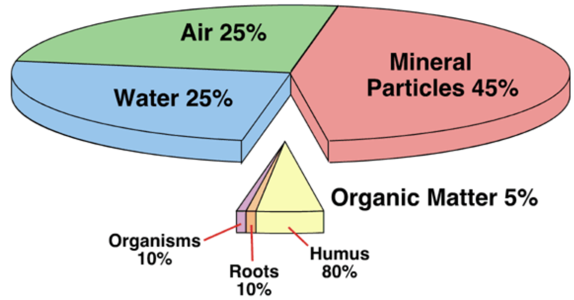

Figure 1: The Composition of Soils

An increase in SOM will also promote additional benefits:

- Reduce peak flows and need for flood control projects,
- Recharge aquifers and groundwater while improving water quality,
- Maintain stream and river flows along with their biodiversity,
- Reduce irrigation needs and improve landscape health,
- Reduce heat stress,
- Improve public health, and
- Provide climate resilience, recreational opportunities, and community cohesiveness.

Soil Health Test Process

<u>Park and Sampling Site Selection</u>

Selected demonstration parks were scattered across San Antonio to better capture its diversity of soils within its two major ecoregions; Blackland Prairie and Edwards Plateau. (Figure 2) An ecoregion is a large area of land with a distinct group of plants and animals adapted to the soil and climate.

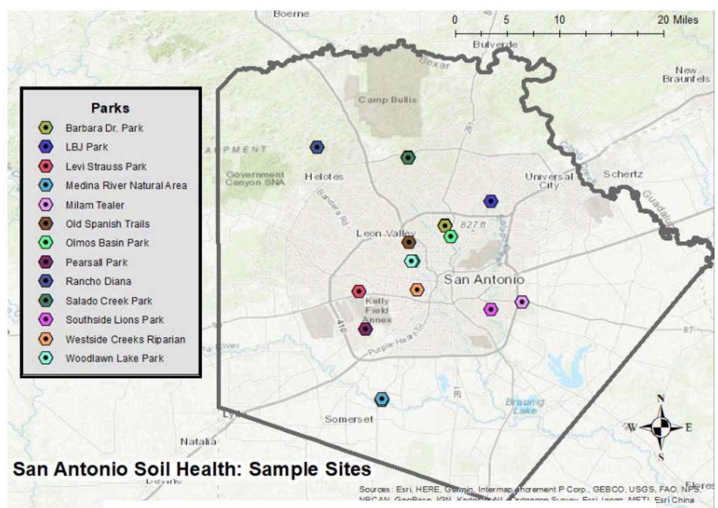

Figure 2: Parks Selected as Demonstration Sites

Sites within each park were primarily located in either a riparian (floodplain) or upland zone. The exceptions are three samples from "improved" drainage channels and one sample from a stormwater detention basin. There was a total of 18 sample sites across the 13 parks.

Composite soil samples were collected at each sampling site and sent to a nationally certified laboratory for analysis, Regen Ag Lab. Samples were collected from the fall of 2022 until the first killing freeze in December 2022 with the exception at the Old Spanish Walking Trail site, which was collected in early January 2023. It was noted that the soils collected during this sampling period were extremely dry due to a prolonged drought. This extreme

[1] https://www.nrdc.org/experts/lara-bryant/organic-matter-can-improve-your-soils-water-holding-capacity

condition will need to be considered for any subsequent sampling to be used for comparison. The soil sampling protocol was maintained for all collections and is given in Appendix A of this report.

Four soil tests were identified to provide needed baseline information on current soil conditions and health. The results of these tests will be used to form the basis for soil and vegetation management recommendations. The tests included:

1. Haney Test
2. Soil Infiltration and Soil Percolation
3. Aggregate Stability
4. Water Holding Capacity

1. <u>The Haney Test</u>

The Haney Test differs from traditional soil tests in that it evaluates soil health indicators such as soil respiration (microbial activity), water-soluble fractions of organic carbon and organic nitrogen (the portion that is currently available for microbial and plant use), and the ratio between organic carbon and organic nitrogen (indicates if there is sufficient food/energy for the microbial population). By giving property managers an understanding of microbial activity and the nutrients that are bioavailable in the soil, better management strategies can be developed to reach desired goals.

In addition, other nutrient levels are evaluated including aluminum, ammonium, calcium, copper, iron, magnesium, manganese, nitrate, potassium, sodium, sulfur, and zinc. When all the results are combined, the site receives an overall soil health score.

2. <u>Soil Infiltration and Soil Percolation Rates</u>

Soil infiltration, the rate at which water enters soils, and soil percolation, the rate at which water moves through soils, are determined by the type of soil (clay, silt, sand, gravel) and its structure (level of aggregation). These two factors influence the type of existing vegetational systems and the nature and speed of stormwater runoff.

3. <u>Aggregate Stability</u>

Soil aggregates are groups of soil particles that bind to each other utilizing organic matter and the "glue", which is a by-product of microbial activity. Aggregate stability is an important physical indicator of soil health and how well the SOM is protected. In clay soils, stable aggregation can greatly increase the organic matter accumulation, and improve soil porosity, drainage, and water availability for plants. Further, stable aggregation in clay soils decreases erosion and compaction while supporting biological activity and nutrient cycling in the soil.

4. <u>Soil Water Holding Capacity</u>

Soil water holding capacity (SWHC) is the amount of water that a given soil can hold for plant or microbial use. This ability provides a buffer for dry conditions. Soil type and organic matter are the key components that determine a soil's water-holding capacity and its availability for plant growth.

Soil Health Test Results

<u>Soil Tests to Be Completed</u>

Sampling for soil health has been completed except for the SWHC and the Soil Infiltration/Soil Percolation rates. Laboratories throughout our region are behind in completing SWHC analysis due to the current high demand and the two-week time required to run each sample. It is anticipated that the project's selected laboratory will be able to deliver results by May 2023. Soil Infiltration/Soil Percolation rates have not been completed due to the extreme drought conditions. The soil needs to be moist to approximately 12” to provide an accurate reading.

Results For Completed Tests

1. Haney Test
2. Aggregate Stability

In Appendix B the results are grouped by land use types and shown in bar graphs to offer a more visual presentation of the data. And in Appendix C the extensive results for the Haney tests are given in their raw format. For this section of the report, it was determined that it would be most beneficial to narrow the discussion to the priority indicators as shown in Table 1 below. When reviewing the results, it should be noted that the results for the selected sampling locations may not be reflective of the entire park.

Table 1: Haney Test and Soil Aggregate Result Highlights

Test Parameter	Barbara Dr. Right: Drainage	Lady Bird Johnson: Riparian	Barbara Dr. Left: Drainage	Olmos Basin: Riparian	Salado Creek 1604: Riparian	Rancho Diana: Upland	Pearsall Park: Upland	Salado Creek 1604: Culvert
Soil pH	7.8	8.1	8.1	7.9	8.1	8.2	8.2	8.2
SOM %	3.7	3	2.5	6.7	8	5.3	1.8	4.9
CO_2-C Respiration	98.6	117.3	46.6	235.9	186.0	73.9	22.1	81.7
H_2O Total Nitrogen	28.4	21.67	20.14	48.35	35.93	18.27	26.98	22.51
H_2O Organic Nitrogen	12.09	14.28	9.14	17.18	18.67	8.05	8.92	10.83
C:N ratio	10.7	13.9	14.6	13.5	13.5	15.9	12.0	10.3
Soil Health Calculation	13.7	15.2	8.2	23.2	22.4	10.8	5.2	11.5
Macro aggregates % > 0.25 mm	50	59	47.1	45.9	73.1	70.2	46.6	45.1
Micro Aggregates % <0.25, >0.053mm	25.3	19.2	29	21.4	10.9	10.1	22.4	12.3
Total Aggregates, %	75.3	78.2	76.2	67.3	84	80.3	69	57.4

Test Parameter	Woodlawn Lake: Riparian	Woodlawn Lake: Upland	Southside Lion: Riparian	Milam Tealer: Upland	Milam Tealer: Pocket Prairie	Levi Strauss: Riparian	Westside Creek: Riparian	Old Spanish Walking Trail: Detention
Soil pH	7.6	7.7	7.9	7.9	8	8.1	8.2	7.9
SOM %	4.2	5	5.2	3.8	3.9	4.3	2.8	6.5
CO_2-C Respiration	185.7	162.5	87.8	46.7	90.9	62.1	78.6	117.9
H_2O Total Nitrogen	35.3	63.1	34.2	69.8	40.5	31.7	31.7	53.2
H_2O Organic Nitrogen	16.85	18.79	20.11	17.96	20.85	16.91	14.6	19.63
C:N ratio	13.0	14.9	13.1	12.8	12.9	12.6	13.8	13.5
Soil Health Calculation	21.6	21.0	16.1	11.05	16.6	12.2	13.4	17.0
Macro aggregates % > 0.25 mm	56.1	58	53.8	51.1	60.7	56.8	53.7	46.6
Micro Aggregates % <0.25, >0.053mm	25.4	20.4	24.7	20.6	15.2	15.3	11.6	22.4
Total Aggregates, %	81.5	78.4	78.5	71.7	75.9	72.1	65.3	69.0

Results of the tests within the Haney test

Soil pH: is the measure of the acidity and the alkalinity of the soil with 7 being neutral. The pH of soil samples ranged from the low occurring at the Woodlawn Lake riparian site (7.1) to the most alkaline at the Rancho Diana upland, Pearsall upland, and Westside Creek riparian (8.2). Overall, the range was narrow with uplands typically having a higher pH than riparian or drainage areas. The higher pH readings in the improved drainage areas are most likely due to the higher alkalinity of the subsoils that were brought to the surface during excavation. Also, high pH readings often correlate with low SOM. SOM can not only reduce soil pH but also provide a buffer from extremes.

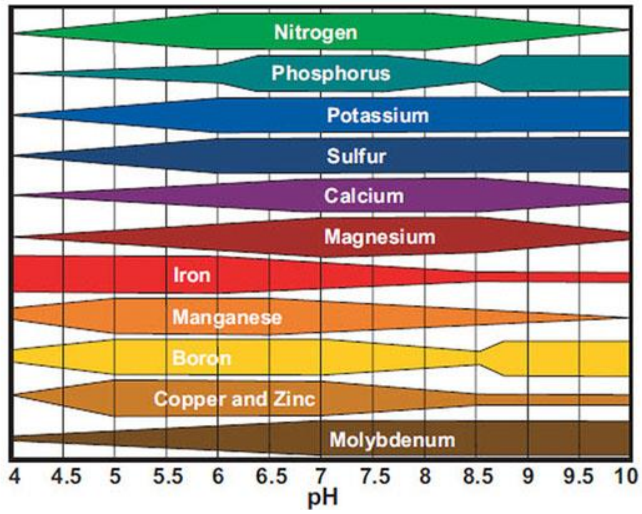

Figure 3: Soil pH Affects the Availability of Soil Nutrients.

The advantage of lower pH readings (closer to 7) is the greater potential that the nutrients present within the soil can be available to plants and soil microbes as shown in Figure 3. Soil pH can also be lowered by the presence of organic acids within the soil. These organic acids are from microbial activity, plant root exudates and SOM[2]. SOM and its decomposition will lead to the production of more organic acids, thus lowering the pH in the area's alkaline soils[3].

SOM% LOI: is the measure of weight loss upon ignition of the dried soil sample (360° F for South Texas calcareous soils), with the assumption that weight loss correlates to the amount of organic matter present in the soil. Research has indicated that there should be a strong correlation between the percent SOM and organic soil carbon, making this one of the most important indicators for the effectiveness of improved soil and vegetation management strategies within demonstration parks[4]. The SOM in the topsoil will provide much of the carbon that will move through the soil profile to depths where it will stabilize and provide long-term CO_2 sequestration.

Movement can be through infiltration and percolation of stormwater through the soil slowly or quickly through stony soils or even through cracks in clay soils. Another method is that provided by deeply rooted plants that release their carbon by exudates or by root tissues dying off. In general, the upland sites had lower SOM levels than the riparian sites. The upland SOM levels ranging from 1.8 at Pearsall Park to 5 at Woodlawn Lake, offer plenty of opportunity for increase. A regenerative grazing operation in the Hondo area reported increasing SOM levels from 5% to 7% in 3 years using only regenerative grazing techniques. During the period of implementation, it will be important to use visual observations such as soil aggregates as an indication that the SOM levels are increasing throughout the demonstration parks.

The low levels at the Medina Natural Area riparian site were unexpected and could be due to erosion and loss of topsoil from previous agricultural activities or flooding. These readings highlight the need for planning strategies to increase floodplain functioning within the park along the river.

CO_2-C Respiration: is aimed at measuring the amount of carbon dioxide a soil can produce over a 24hr incubation period following a significant drying and rewetting event. In other words, how much does your soil breathe when

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[2] https://www.frontiersin.org/articles/10.3389/fpls.2020.00633/full
[3] https://www.sciencedirect.com/science/article/abs/pii/S0013935119300933
[4] https://agris.fao.org/agris-search/search.do?recordID=US202000110699

conditions are optimal? The amount of respiration is linked to the robustness of the soil biome. While having high rates of respiration from a laboratory test indicates soil health, the goal of management strategies will be to maintain these rates by insuring there is sufficient SOM to continue supporting a robust soil biome. Minimizing SOM loss will not only promote a healthy soil biome but also promote other related functions of a healthy soil such as nutrient cycling, soil aggregate formation, water holding capacity, disease suppression, and stimulation of plant growth[5,6]. This is especially important for ensuring that the soil microbes can "fix" atmospheric nitrogen and supplement the plants with phosphorus, potassium, and other soil nutrients; thereby enhancing plant growth and health. Additionally, higher levels of SOM will promote the accumulation of soil carbon storage; thus allowing for more effective CO_2 sequestration and long-term resilience.

One exception to higher SOM levels required for higher respiration rates was seen at the Milam Tealer Park pocket prairie site. This site had recently been mowed to the approximate traditional 2" height following almost 3 years of being a "no mow" area. The 120'x20' site had been seeded with native grasses and wildflowers in 2019. This area was allowed to grow without mowing until Fall 2022. Test results indicate this 3-year period did not have significantly higher SOM levels than the upland site, but the CO_2-C Respiration level was almost double; 46.7 for the upland and 90.9 for the pocket prairie. This would indicate that the process of improving soil health can occur with a mowing reduction only within 3 years, even during drought conditions.

Again, riparian (floodplain) sites typically had higher levels of respiration corresponding to higher rates of microbial activity than upland sites. Their numbers range from 235.9 at Olmos Basin to 39.6 at Medina River Natural Area. Whereas upland sites ranged from 162.5 at Woodlawn Lake to 22.1 at the Pearsall Park site where the soil was over 90% bare.

Overall, with the exception for the 5 sites that were previously agricultural lands, levels were Slightly Above Average to High with a Very High rating for Olmos Basin. It should be noted that this indicator is very sensitive to climate and soils making it difficult to effectively compare results between different seasons or with other parts of the country. Regional comparisons that were located in the literature or conversation included; Texas Blackland Prairie soils at 42 CO_2-C ppm within a conventional corn field and 47.6 CO_2-C ppm for an Edwards Plateau pasture in good condition. The test results and literature search both confirm that land under conventional agriculture management practices could benefit from implementing strategies to increase and protect SOM[7].

Table 2 gives information on the ranking of CO_2-C respiration rates from Very Low to Very High along with the implications of each level.

Table 2: CO_2-Carbon Respiration Rates Modified from Regen Ag Lab

CO_2-C in ppm	Ranking	Implications
0-10	Very Low	Very little potential for microbial activity; slow nutrient cycling and organic matter decomposition. N may be immobilized due to microbial use
11-20	Low	Minimal potential for nutrient cycling
21-30	Below Average	Some potential for nutrient cycling
31-50	Slightly Below Average	Low to moderate potential for microbial activity
51-70	Slightly Above Average	Moderate potential for microbial activity; Moderate N credit may be given

5 https://www.sciencedirect.com/science/article/abs/pii/S1878818119309594
6 https://www.nature.com/scitable/knowledge/library/the-soil-biota-84078125/
7 Data received from the NRCS office located in Kerrville, Texas

71-100	Above Average	Good potential for microbial activity; Moderate N credit may be given depending on the size of the organic N pool
101-200	High	High potential for microbial activity; more carbon inputs may be needed to sustain microbial biomass
>201	Very High	High to very high potential for microbial activity; residue decomposition may be <1 yr.; keeping the soil covered could be a problem in some systems

<u>H_2O Total Nitrogen:</u> measures the total nitrogen, inorganic (nitrate, nitrite and ammonium) and organic (amino acids) forms that are in reserve and can be easily available for plants and microbes to absorb and use for proteins, DNA, etc.[8]. The high readings for Total Nitrogen at Woodlawn Lake Upland and Milam Tealer Park Upland were unexpectedly high probably due to somewhat different reasons. At Woodlawn, the wildlife is responsible for the deposition of high-nitrogen fecal matter which has been kept in the soil due to drought. At Milam Tealer Park, the Upland site was bare soil, the soil nitrogen was not being used by plants nor by microbial activity as shown in the CO_2-C respiration test; therefore, was held in the clay soil. In both cases, rain can cause this nitrogen to leave the soil system and potentially enter nearby waters. Maintaining a viable vegetative cover can reduce this risk.

<u>H2O Organic Nitrogen</u>: measures the portion of organic nitrogen that is in transition between plant and animal residues and stable SOM (Figure 4). This represents the pool of organic nitrogen available to the microbes and is linked to the carbon and food that the microbes are eating.

SOM contains relatively large amounts of organic nitrogen, approximately 1,000 lbs. per acre for every 1% SOM. In this form, it is resistant to loss but typically requires an additional step (decomposition) to make it available in either the organic or inorganic form to be used by plants and soil microbes. Maintaining a robust soil biome, the soil carbon feedstock functions more efficiently to provide the ongoing "low" nitrogen levels sufficient for most native plant systems.

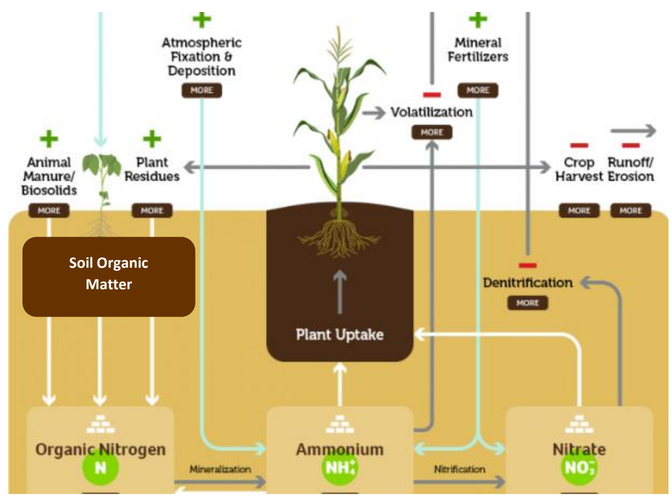


Figure 4: Nitrogen Cycle.

<u>C:N</u>: is the organic carbon to organic nitrogen ratio. This ratio tells if you have a balance between the energy component (carbon) and the nitrogen component (protein building blocks) within the SOM to support an active microbial population. This balance is required to ensure that the microbes have what they need to not only transform the nutrients within SOM into bioavailable forms but, also to provide the desired ecosystem services.

It should be noted that without sufficient carbon levels within urban riparian and floodplain systems, the elevated nitrogen levels promote algae growth within our creeks and drainage channels[9].

Table 3 below gives an index for reading test values. Results indicate that composite samples from the selected sites had between "Good to Ideal" carbon to nitrogen ratios. With rankings ranging from Rancho Diana at 15.9 (just below Good) to the riparian site at the Salado Creek 1604 Trail Head with 10.3 (Ideal). The Rancho Diana

[8] https://www.sciencedirect.com/topics/earth-and-planetary-sciences/inorganic-nitrogen
[9] https://www.publish.csiro.au/mf/mf99112

results indicate that there was not sufficient available nitrogen and or microbial populations to provide needed nitrogen. While the overall Good-to-Ideal readings even for Pearsall Park and the Medina Natural Area are advantageous, these rankings could partially be contributed to the prolonged drought which would reduce microbial activity so that much of the growing season's SOM remained in the soil through the fall sampling period. Future sampling efforts will confirm this hypothesis.

Table 3: Organic C:N Ratio Ranking Table Modified from Regen Ag Lab:

Ratio Result	Ranking	N Implications	Management Needs
>20:1	Poor; Too much organic C and/or not enough organic N	N tie-up by microbes: No N credit was given from WEON pool	Increase high nitrogen residue/ organic matter; reduce high carbon inputs to reduce carbon
Between 15:1 – 20:1	Marginal	Some N tie-up; Slower mineralization; Lower N credit from WEON	Increase legumes in rotation or covers; reduce high carbon inputs; graze longer to reduce carbon
Between 8:1 – 15:1	Good	Less N tie-up; greater potential for N mineralization	Make slight adjustments if near the boundaries to keep within this range
Between 10:1 – 12:1	Ideal	The greatest potential for N mineralization; good balance of available energy/carbon and N for microbes	Increase intensity to drive both WEOC and WEON up together to help increase biological processes
<8:1	Poor; Too little organic C and/or insufficient microbes to use the excessive organic N	Limited energy for the microbial activity or insufficient microbial mass to use N	Increase carbon inputs; mow shorter to retain carbon on site

<u>Soil Health Score</u>: is a summary of the soil respiration, water-extractable organic carbon (WEOC), and water-extractable organic nitrogen (WEON) measured by the Haney Test and represents the current health level of your soil based on these indicators. The score is aimed at providing a property manager with a quick reference regarding the health of their soil compared to other soils under different types of management. The score can range anywhere from 0 to 50, but most soils do not score higher than 30. In general, the higher the score the better.

Results for park samples ranged from the highest of 23.2 at the riparian site in Olmos Basin Park to 5.2 at the Pearsall Park upland site, indicating that each site has potential for improvement. While soil and vegetation management has a profound effect on the soil health score, it can be limited by regional constraints; wetter and warmer leads to higher ratings. These scores need to be compared to other sites within South Central Texas where it is warmer but often without sufficient moisture.

It should also be noted that the measures of the Haney tests are just snapshots of microbially available pools of carbon and nitrogen as well as microbial activity. These organic matter pools flux depending on climate and management; therefore, it is recommended to look for trends and not put as much emphasis on absolute values. Changes in soil biological tests can take time but, it may be possible to determine short-term changes by observation, paying attention to plant health, water infiltration, and soil structure and retention. If you're seeing improvements in these functions, the rest will follow[10].

[10] https://blog-crop-news.extension.umn.edu/2020/05/5-things-to-know-about-haney-soil.html

Soil Aggregate Tests

Definition and Principles of Soil Aggregation

Figure 5: Aggregated Soil.

Soil aggregates are clumps of soil particles that are held together by moist clay, organic matter, root exudates, gums (from bacteria and fungi), and fungal hyphae (Figure 5). Soil aggregation and the development of soil structure play a crucial role in determining soil functions and ecosystem services[11].

Relatively stable aggregates create the pore space used for storing air, water, organic matter, and nutrients while creating a habitat for microbes. Soil aggregates produced by soil bacteria can often resist decomposition more than those produced by plant root exudates, but both are important. In addition to bacteria and root exudates, fungi, especially mycorrhizal fungi play a crucial role in the aggregation process by colonizing and decomposing fresh organic matter[12].

Aggregate stability is the soil health indicator that determines the ability of the aggregates to resist destruction by outside forces; physically or biologically. Soil exposure to raindrop impact, wind and water erosion, high temperatures, and physical compaction due to equipment or foot traffic can reduce or eliminate aggregate stability. For the San Antonio area, the higher temperatures also increase the rates of decomposition in the soil by microbial activity which can reduce the amount of carbon, thus reducing aggregate stability because the microbes will begin “eating” the glue that holds the aggregates together. The other influences that climate has on soil aggregate stability are due to interactions of soil type with wetting/drying and shrinking/swelling as occurs with clay soils[13].

The Importance of Mycorrhizae and Its Role in Aggregation

Mycorrhizae is a specialized type of fungi that develops a symbiotic association with plant roots. A major role they perform for plants is to enhance water uptake and nutrient (especially phosphorus) by exploiting a larger volume of soil than roots alone can do thus creating nutrient microsites as shown in Figure 6.

They even release enzymes and acids which break down organic materials, including stones, to absorb nutrients. The nutrients and minerals are then shared with the host plant in exchange for carbohydrates produced by the plant[14].

Mycorrhizae contribute greatly to the formation of stable soil aggregates improving soil health, resiliency, and biodiversity of the soil biome. Such biodiversity in the soil leads to greater stability and resiliency in levels of ecosystem services[15].

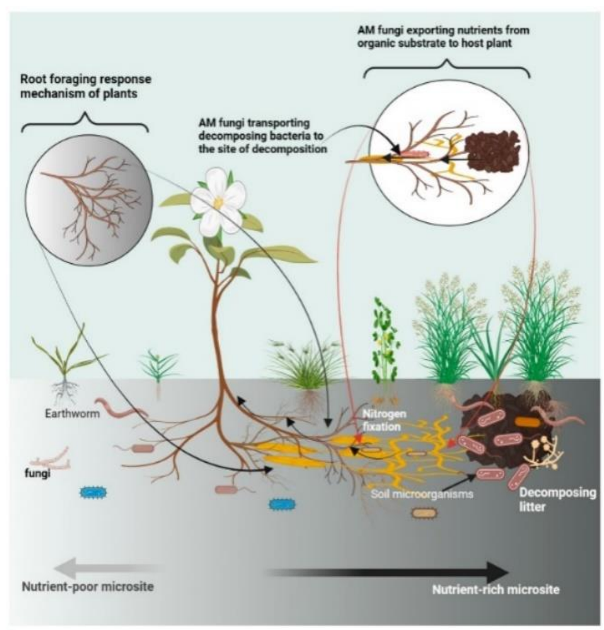


Figure 6: The Role of Mycorrhizae in the Soil

[11] https://www.sciencedirect.com/topics/agricultural-and-biological-sciences/soil-aggregation
[12] http://www.soilhealth.com/soil-health/biology/
[13] https://www.tandfonline.com/doi/abs/10.1300/J064v14n02_08
[14] https://urbanwormcompany.com/magical-mycorrhizae-natures-underground-network/
[15] https://www.nature.com/scitable/knowledge/library/biodiversity-and-ecosystem-services-is-it-the-96677163/

Soil Aggregate Test Results

The results indicate that all sites had a mixture of soil aggregate sizes with a greater percentage of macro aggregates than micro aggregates, which is preferred. The exception to this preferred ratio was found at the Medina Natural Area upland site. A larger percentage of micro aggregates leads to more compacted soils affecting other soil health indicators.

In addition, the lower the total aggregate percent reading, the greater the tendency toward forming surface crusts resulting in poor drainage and more surface runoff. Overall, total aggregate percent readings ranged from 57.4% from the Salado Creek Trailhead at 1604 (where 6”-10” of sediment had been discharged from an abutting property’s culvert) to the excellent aggregation of 84.0% in the same park’s riparian area. Overall, results were satisfactory, especially when compared to those reported from conventionally tilled fields that average 30 percent.

It should also be noted that the sampling site used for the soil health tests will not necessarily represent conditions found throughout the park. Sampling site locations were selected in areas where modified soil and vegetation management practices and/or stormwater best management practices (BMPs) could easily and effectively be applied.

Percolation and Water Holding Capacity

While the results for these two tests are not available for review at this time, information is provided on their importance and the role these soil characteristics play within healthy soils. Percolation rate and water holding capacity are linked. Soil texture and organic matter are the key components that determine soil water-holding capacity[16].

How much water a soil can hold against gravity is important for plant and microbial growth. The water retained in the soil can compensate for a lack of precipitation under dry conditions even though not all of the water held may be available for plant growth. This is especially true for clay soils, making it even more crucial to have sufficient levels of SOM, which not only holds the water in the soil but also “gives it up” for plant and microbial use.

While soil texture is fixed, soil structure can be improved by increasing SOM by using the appropriate management practices. Appropriate practices will promote a beneficial ratio of pore sizes for good drainage while maintaining a proper balance between water and air within the pores.

This balance is critical since *both* water and air are required by most biological processes. In Figure 7, the left image shows that water and air can enter and move through the soil while allowing for good water-holding capacity. Whereas the image on the right shows the lack of air and water movement because sediment and or micro aggregates have filled and blocked the pore space.

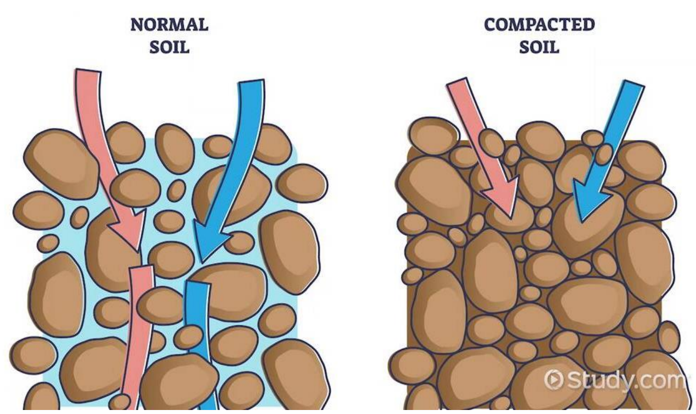


Figure 7: Pore size relationship With Air and Water Movement

One of the main functions of soil is to store moisture and air within the pore space and supply it to plants and soil microbes as needed. Evaporation from the soil surface, use by plants, and deep percolation reduce soil moisture. It is the water-holding capacity of the soil that provides a buffer against this and drought or flood.

[16] https://www.noble.org/regenerative-agriculture/soil/soil-and-water-relationships/

Basic Information on the Ecoregions, Blackland Prairie, and Edwards Plateau

1. Blackland Prairie

The dominant ecoregion in San Antonio is the Blackland Prairie, where the typical soil associations are Houston Black and Lewisville as shown in Figure 8. These soils are deep, moderately well-drained expansive clays with chalky subsoil. The soil depth over the chalky subsoil depends on the amount of erosion that has occurred due to slopes and previous land uses.

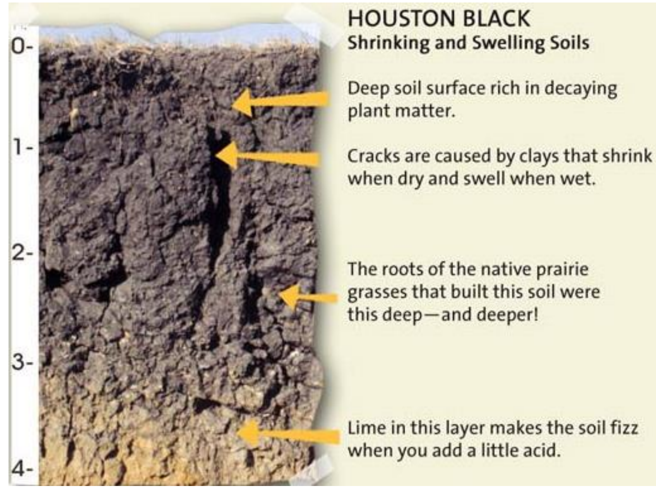


Figure 8: Houston Black Clay is the State Soil of Texas.

These soils were originally developed by prairie plants (grass and wildflowers) under a fire regime which contributed to the relatively high levels of organic matter and darker surface soil color. In general, these soils respond well to management practices that protect and increase SOM levels and, due to their depth, have great potential for increasing soil health and ecosystem services on both upland and riparian sites.

2. Edwards Plateau

This ecoregion is located in the upper portion of San Antonio/Bexar County and contains primarily the Tarrant Brackett soil associations; clay loam, stony clay over rocky clay, chalky marl, or fractured or solid limestone. While these soils also developed within a prairie regime, erosion has left most of the region with very shallow soils of less than 10 inches allowing the Ashe juniper and associated shrubs to dominate. And while it can take 500 to even 1,000 years to create one inch of new mineral topsoil, the depth of these soils can be increased and soil health improved within a shorter period with the addition of organic matter[17].

While there may be less "potential" due to shallow soils, this area is crucial to the city's drinking water supply. This area contains portions of the Edwards-Trinity aquifer complex with significant Edwards aquifer recharge and contributing zone acreage. The value of applying best management practices to parks and other public properties within this region is imperative. Practices would not only include those to increase SOM and depths for improved water holding capacity and stormwater runoff reduction but also those that would restore and/or protect recharge and contributing features such as sinkholes, dry creek beds and tributary headwaters.

Land Use Also Affects Potential

The primary land uses that have been identified by the sampling sites are upland, riparian or floodplains, improved drainage channels, and stormwater detention facility; each with potential for improvement. Restoration of deforested and degraded landscapes is a globally recognized strategy to sequester carbon, improve ecological integrity, conserve biodiversity, and provide additional benefits to human health and well-being.

Parks with Riparian/Floodplains

A previous literature search identified riparian and floodplains as having the greatest potential for carbon sequestration, second only to wetlands. Global investment in riparian forest restoration has received less attention, in part due to their relatively small spatial extent. Yet, riparian forest restoration may be a particularly valuable strategy because they have the potential for rapid carbon sequestration, are hotspots of biodiversity, and

[17] https://www.uvm.edu/seagrant/sites/default/files/files/publication/DybalaEtAl_2018_Carbon%20storage%20riparian%20forests.pdf

provide numerous valuable ecosystem services. One research model predicted that the establishment of riparian forests will more than triple the baseline of unforested soil carbon stock, and that riparian forests hold on average 30-71 tons of carbon per acre in biomass at maturity, with the highest values in relatively warm and wet climates. It was also found that actively planting riparian forests substantially jumpstarts biomass carbon accumulation, with initial growth rates more than double those of naturally regenerating riparian forests[18].

Figure 9: Olmos Basin Park parking area.

In addition, results from an Oregon research effort suggest higher organic carbon stocks in reaches where restoration practices were implemented than the organic carbon stocks found in the degraded floodplain area where no BMPs were implemented[19].

In the San Antonio parks system, the riparian areas have the greatest potential. And, while many linear creek parklands are forested and in fair to good condition as indicated by the data, long-term restoration efforts should be considered for other locations, such as seen in Figure 9, where restoration efforts could increase not only carbon sequestration, but also flood resilience.

Figure 10 : Brackenridge Park tributary that leads to the San Antonio River at the Hildebrand entrance.

Other park sites, such as seen in Figure 10, can be improved immediately by allowing vegetation on slopes to grow to 5- 6” while never mowing less than 4”. Additional tree planting would also improve functionality and soil health.

Parks with Uplands, Improved Drainage Channels, and Stormwater Detention Facilities

The potential for an individual site within these property types may be less than what can be expected from riparian and floodplain areas due to their limitations, but they can play a significant role in mitigating climate change due to the sheer extent of acreage that can be improved. Adding a stormwater BMP, increasing mowing heights, creating no mow/let it grow zones and planting additional trees will lead to increased functioning.

Natural Area Uplands

Natural areas will typically already have “Good” soil health which could be enhanced with minor modifications to management practices or by using more proactive approaches that would include the implementation of stormwater BMPs where runoff is slowed, captured and allowed to infiltrate. Other BMPs would include minor restoration strategies such as improving low biodiversity areas infested with non-native plants such as KR Bluestem to more highly functioning grasslands. These lower cost solutions, such as bioswales and grasslands, can be more desirable than more complex systems requiring engineering and the possibility of incorporating hardscapes like those seen within Phil Hardberger Park. No matter, any location that includes a stormwater BMP will improve soil health due to the additional soil moisture provided for vegetation and soil microbes. The soil health analysis for the upland site within the Medina Natural Area indicates that such low-cost solutions could improve soil health, biodiversity, and ecosystem services. The recent “beaver dam” project within the natural area’s tributaries is an excellent example of a low-cost BMP with multiple benefits.

[18] https://www.uvm.edu/seagrant/sites/default/files/files/publication/DybalaEtAl_2018_Carbon%20storage%20riparian%20forests.pdf
[19] https://www.frontiersin.org/articles/10.3389/feart.2021.708895/full

Traditional parks
Traditional parks have the greatest constraints due to space, public use, real and perceived safety concerns, aesthetic values, and maintenance concerns for newly installed BMPs. The pocket prairie data from Milam Tealer Park indicates that modifying mowing practices can lead to improved soil health along with co-benefits no matter which ecoregion the park is located in. Creating small no mow ("let it grow") areas away from high public traffic locations can offer a more acceptable approach for landscape modifications.

With a concerted effort in non-drought conditions, it is reasonable to expect that modifying mowing regimes could improve soil functioning within 5 years. To ensure the adoption of possible changes within the parks, it will be crucial to reach out to park users, especially those from neighborhoods within proximity, before changes are initiated. Interpretive signage will be invaluable to increasing understanding and acceptance of changes within traditional parks.

Improved drainage and stormwater detention facilities
While these areas have been drastically manipulated, there is potential for their improved soil health to increase ecosystem services and aesthetics. Mowing heights, no mow/let it grow zones and additional tree planting (where allowed) will lead to increased functioning. Increasing SOM within stormwater detention facilities could potentially increase their capacity to capture and store more runoff to prevent flooding. Test results for the Old Spanish Walking Trail detention facility were surprisingly good and could probably be improved with modified mowing regimes and overseeding to increase biodiversity.

Best Soil and Vegetation Management Practices (BMPs) for Consideration

These are basic goals and will require fine-tuning on a site-by-site basis. Not all five BMPs need to be applied to every site, but it is recommended that bundling methods within the demonstration parks will provide additional benefits and the data SAPAR needs to determine effectiveness.

Reasons why these methods can be effective:

1. Keeping the soil covered lowers soil temperatures. Soil temperatures at Woodlawn Lake Park differed by 14 degrees in full sun sites. The scalped soil in a median was 111° and the soil under landscape mulch at the Island House was 97°. The hotter the soil, the faster the microbes use the SOM. Cooler soils reduce the rate of this process, reducing the loss of SOM and avoiding re-release of CO_2 to the atmosphere; thereby preventing a double negative impact.

2. Letting vegetation grow; mowing less, leaving it longer, or transforming to no mow/prairie/xeriscape landscape is one of the quickest ways to increase soil carbon and health. Mowing turf areas 3.5"-4" when the climate is wetter and up to 5" when San Antonio is experiencing dry conditions, will not only accomplish keeping the soil cooler, it will also ensure that the roots of turf and landscape plants will maintain sufficient robustness to survive drought conditions.

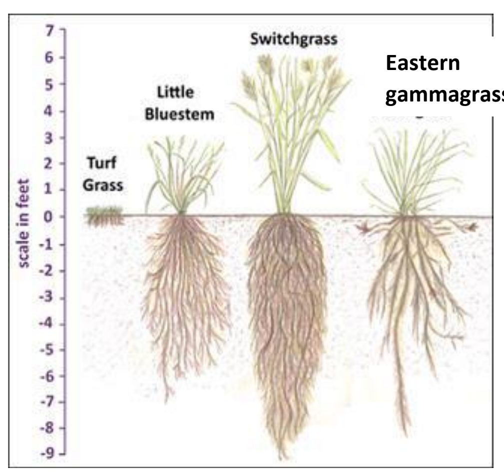


Figure 11: Root Systems of Several Native Grasses

3. Soil amendment; top dressing areas ¼"-1" depths, with a soil amendment selected under strict specifications. Specifications would ensure that the amendment is weed-free and well-aged (a 10:1 C:N ratio) with a nitrogen content of less than 3%. This

is especially important for properties over the Edwards Aquifer Recharge, Transition, or Contributing Zones.

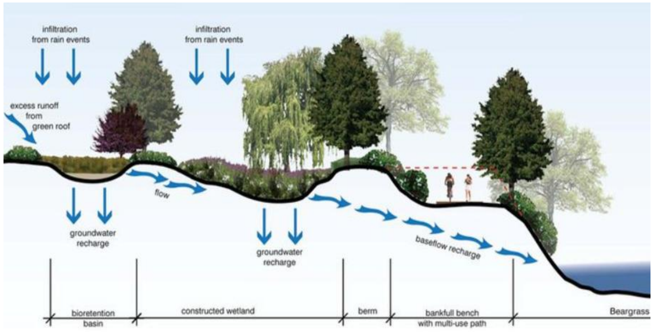


Figure 12: A Series of bioswales protects water quality and enhances low flows.

4. Add a rain garden/bioswale to increase the collection of stormwater into the soil and reduce runoff, erosion, water pollution, and provide moisture for increased SOM and plant growth. The water from this increased infiltration will also slowly recharge groundwater, aquifers, and streams with clean water as seen in Figure 12. This BMP is especially beneficial on slopes leading to nearby water bodies[20].

5. Ecological restoration in urban parks is an underutilized strategy, partially due to the level of commitment, experience, and resources needed, but the benefits are great not only for increasing carbon sequestration and other ecosystem benefits but to also improve the nature and human experience[21]. Ecological restoration in urban parks may not follow traditional ecological restoration protocols with the use of “reference reaches” to recreate what was there before human disturbance but would create new functioning landscapes with an emphasis on the use of native plants in schemes that would not only provide habitat but can easily be maintained.

Figure 13 : A monoculture of Webberville sedge allows for easier maintenance by removing what is not the sedge.

In Figure 13 the approach implemented is creating “pocket” sites with the use of small monoculture areas to facilitate maintenance, “if it is not the desired plant, then it is removed”, eliminating the need for species identification.

The drawback is this elimination process will need to be completed with hand tools and not with a line-trimmer.

[20] https://www.sfbetterstreets.org/find-project-types/greening-and-stormwater-management/stormwater-overview/swales/
[21] https://www.frontiersin.org/articles/10.3389/frsc.2021.709357/full

Modifying Mowing Standards Will Assist in Keeping the Soil Covered and Protect SOM

As it is expected that this BMP will be the most implemented strategy, additional information is given along with photos of examples where current practices have had undesirable effects. The soil health data indicates that overall, soils can be improved with minor changes such as modifying mowing standards. While this appears to be an easy strategy to adopt, it will require not only training for maintenance staff and contractors but will depend on clearly marking areas to receive modified mowing standards and eventually, specifications within maintenance contracts. The other barrier will be the acceptance by park users, which can be facilitated by engagement before implementation and interpretive signage.

Current issues and concerns

Within San Antonio parks, the most common "turf" vegetation is Bermuda grass, most often mixed with other annual or perennial native and/or non-native grasses and broadleaf plants. When these "turf" areas are regularly mowed to the same low heights no matter the climate conditions and over a long period, a surface similar to asphalt is produced that encourages weedy annuals. These soil crusts prevent stormwater from entering and replenishing soils, which leads to increased runoff and erosion and eventually poor soil and landscape plant health as shown in Figure 14.

Figure 14: Soil surface crust created by mowing regime, erosion and drought.

Another result of soil crusts is the unseen negative impacts on the environment by increasing air and water pollution. When soils are in an increasing state of degradation, they not only have a reduced ability to sequester carbon dioxide from the atmosphere, they become a net source of greenhouse gas as microbes continue to break down SOM in an unsustainable manner[22]. Also, the erosion from such surfaces is considered a non-point source pollutant, which is one of San Antonio's greatest water quality challenges

Figure 15: Two-inch turf height after mowing operations in Milam T Park.

And while there is a policy to mow a minimum of 3" height, this is often not reflected in the field, as shown in Figure 15, where vegetation measurements were taken shortly after mowing operations at Milam Tealer Park.

This practice of removing above-ground vegetation to extremely low heights is an even greater concern where line-trimming operators often leave the surface "scalped" of most vegetation. While this technique seems to produce a cleaner final product, it leads to undesirable consequences that are easier to prevent than fix. Below is a literature search summary for why adopting modified mowing standards can provide many benefits.

[22] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8792611/

Why mowing high and reducing frequency is good

- Keeps the topsoil covered to protect SOM.
- Makes scalping (turf damage from mowing too short) much less likely to happen.
- Allows you to clip about 30 percent of the leaf blade each time you mow (the optimum proportion).
- Promotes establishment of a larger root system, which is more drought tolerant.
- Provides broadleaf weed and non-native grass control by shading the soil.
- Establishes a grub-tolerant turf because of the larger root mass.
- Increases the accumulation of soil organic matter leading to improved soil and plant health and ecosystem services.
- Reduces soil temperatures, which reduces the loss of soil organic matter, nutrients, and water.
- Reduces stormwater runoff and its pollutants by promoting infiltration and filtration.
- Mowing less reduces mower emissions.

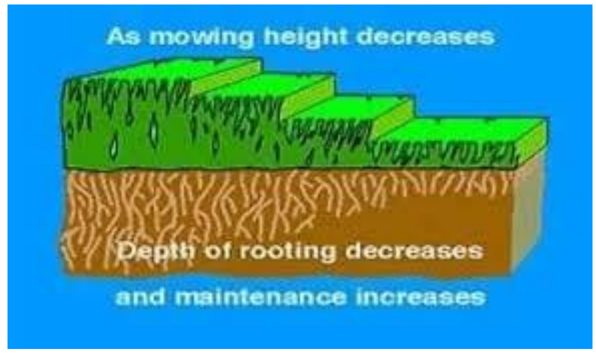


Figure 16: Mowing heights and frequency affects root growth and drought tolerance.

Having a routine mowing schedule is common. However, it should only be mowed when it needs mowing, following the "cut only 1/3 of the height" rule. Turf will grow at different rates depending on soil fertility, season, and weather conditions. In the spring, with longer days, cooler temperatures, and plenty of rain, grass and weeds grow quicker than in the summer so more frequent mowing is expected. Lower mowing heights may also be needed due to wet conditions or use. Most public areas are typically left at a higher height than athletic fields or golf courses that will receive a specific use and are much more critical if not mowed appropriately. It should be noted that a healthy soil with a robust soil biome should not suffer from thatch build up that often occurs where there is high use of fertilizers, pesticides and irrigation.

Most commercial mowers offer a 3.75" or 4" cutting height. It is recommended to cut at the maximum height whenever possible and have the height set by a supervisor. On a park site, have the line trimmers begin with edging operations, allowing the mowers to set the height as a guide for any additional line trimming to reduce scalping.

Slopes present a challenge. Typically, they require line trimmers to reduce the height of any vegetation and are treated the same as the turf mix found on level ground. This is of special concern when eroded soil washes into water ways or onto trail surfaces and the slope no longer supports a healthy vegetated cover. To protect slopes, it is recommended that they become no mow zones whenever possible to prevent the loss of the vegetation that holds the soil in place. When not possible, modify operations to remove only 1/3 of the height, ensuring the remaining vegetation is at a 4"-5" minimum height. It is reasonable to expect this height to become commonly used in areas away from public access where it will be more acceptable for taller vegetation.

One of the most important revisions to mowing regimes will be to minimize any mowing during an extended San Antonio drought; a situation that is expected to increase in frequency.

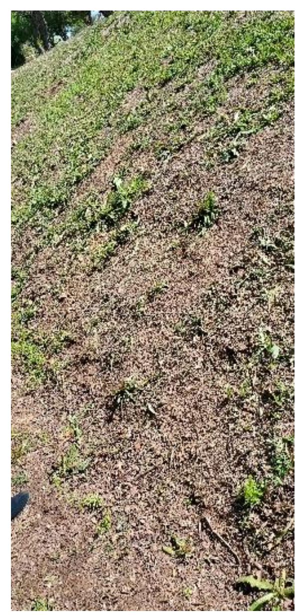


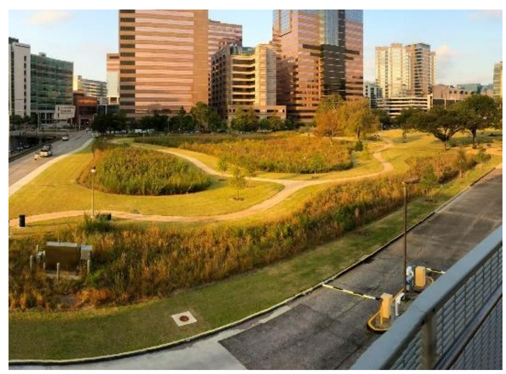
Figure 17: Slope along trail at Wilshire Terrace Salado Creek Trailhead.

Ecological Restoration with Native Prairies

As many of the demonstration Parks' upland sites have soils that developed under deep-rooted prairie grasses and wildflowers, they often respond well to their re-introduction. Non-native grasses, weedy annuals, and woody species are the most difficult to control as this task cannot be completed with mowers and line trimmers. For true success, maintenance training and maybe even specialized equipment will be needed. Additionally, as most commercially available mixes are primarily warm-season grasses, it will be important to include cool-season ones to reduce colonization by weedy non-native plants that tolerate cool weather.

Cool season grass species for which seed can be purchased include Texas bluegrass (*Poa arachnifera*), Western wheatgrass (*Pascopyrum smithii*), Virginia and Canada wild rye (*Elymus spp*), Texas little barley *(Hordeum pusillum*) and Texas winter grass (*Nassella leucotricha*) as live plants.

The grasses in the area's pre-settlement prairies that included short, medium, and tall grass were primarily bunch grasses versus the stoloniferous or "creeping" grasses such as the introduced Bermuda grass. The exception is Buffalo grass, which occurs in some parks and is often a part of seed mixes. While the introduced Bermuda grass allowed ranchers to graze vegetation to 1"-1.5" without killing the grass, the bunch grasses have their growing points higher up on the stem, which left these native grasses more vulnerable to over-grazing. This characteristic, along with the erosion of topsoil and agriculture activities, are the main causes for the loss of native bunch grasses across the region. In re-introducing them into an urban area, their growth characteristics will need to be considered for where they are used and how they are to be maintained. And if native wildflowers are to be a primary goal, then this too will be a part of the maintenance plan.



Typically, these areas can be mowed to 3.5"-5" in the late summer/early fall to allow the emergence of annual wildflowers in the fall to produce their spring show. The wildflower plants will then be allowed to produce and disburse their seeds for the following year. It is during this time when there will probably be more complaints from the public due to reduced aesthetics. Interpretive signage, even temporary signage, can assist and assure the public that the area is under maintenance. An additional summer mowing to 5" after the bloom period can also provide that assurance.

Figure 19: Standing Cypress (*Ipomopsis rubra)*

Native grass prairies with a mixture of annual, biennial, and even perennial wildflowers would have even greater benefits but would also have greater mowing restrictions. The Edwards Plateau wildflower, Standing Cypress, used to dominate properties along Hwy 281 north of Loop 1604. It has been lost in and around San Antonio primarily due to its biannual growth habit, creating a rosette in the first year and blooming the second year. In urbanized areas, this plant has been relegated to garden settings along with others such as Gayfeather *(Liatris spp)*, Scarlet Musk flower (*Nyctaginia capitata)*, Beard's tongues (*Penstemon spp)* and Milkweeds (*Asclepias spp)* which would not thrive if repeatedly mowed less than 5-6". Where such restrictive mowing regimes could be tolerated, or in a landscape garden, it is recommended that an effort be made to include these species and others to maintain biodiversity and increase public awareness of the roles they play.

Reforestation

While reforestation has been touched on previously within the Riparian/Floodplain section, it plays such a crucial role in effective and long-term CO_2 sequestration and the reduction of stormwater runoff, as well as mitigating high summer temperatures/energy use, that it should be considered on a large scale. Incorporating tree planting with other efforts to improve soil health can greatly increase below and above-ground benefits. In addition, research indicates that tree seedlings inoculated with mycorrhizae sequestered 17% more CO_2 than controls[23].

Observations of tree planting efforts around the city highlight the challenge of keeping newly planted trees watered sufficiently for survival, especially during drought conditions. This is also an issue with tree planting in connection with capital improvement projects, where contractors are typically responsible for their survival during their first year before the project site is turned over to Parks for maintenance.

Subsequently, keeping the trees in good health after establishment is also essential for them to provide desired services. Two issues seem to be reoccurring at a level where additional steps are needed:

1. Trunk protection to prevent damage from line trimmers.
2. Proper pruning of existing trees

Figure 20: Line Trimmer

Line-trimmer damage will not only damage a young tree but can kill it. This damage is caused by cutting the line of cells (located just under the bark) that transfer water from the roots to the tree canopy. Prevention requires that the trunks of newly planted trees be protected for 3-5 years as a line-trimmer operator's goal is to reduce the height of vegetation around tree trunks. Eventually, most trees produce a thick enough bark to protect themselves.

Figure 21: Improper Pruning of Argentina Mesquite.

Proper tree pruning is a key maintenance requirement. Without proper pruning trees become diseased and decay can lead to future failures and removal before their time. To minimize the negative impact of improper pruning, it will be important that only maintenance staff or contractors that have received training be allowed to prune trees. This requirement should also apply to property lessees such as those leasing sports fields that may be responsible for the area's maintenance.

These protocols will be another beneficial step to ensure that the urban forest on park lands continues to be a public asset providing maximum ecosystem services versus becoming a liability. Below is a table created by Houston Wilderness to provide more insight into the value of an individual tree within the urban forest[24].

[23] https://www.nature.com/articles/srep34336
[24] https://houstonwilderness.org/ecosystem-services

Table 4: Ecosystem Services provide each year by a (healthy) 10-year-old tree in the Houston area

HOUSTON WILDERNESS
It's Our Nature

Ecosystem Services of Regional Native Tree Species

Tree species	Total CO_2 Stored (lbs.) DBH ≈ 10 years*	CO_2 sequestrated (lbs./tree/year) DBH ≈ 10 years*	Tree species	Flood mitigation (gal./year) DBH ≈ 10 years*	Tree Species	Air pollutants removal w PM2.5 (lbs./year) DBH.≈ 10 years*	Tree Species	Canopy width (ft) DBH.≈ 10 years*	Tree Species	Mycorrhiza Fungi Relationship AM or EM**
Live Oak	1023	268	Tulip Tree	3006	American Sycamore	1.9	American Sycamore	17	Live Oak	AM/EM
Black Cherry	971	101	Water Oak	2879	Live Oak	1.9	American Elm	16	Black Cherry	AM
River Birch	925	215	American Sycamore	2747	Tulip Tree	1.9	River Birch	15	River Birch	AM/EM
Boxelder	898	159	Live Oak	2656	Black Walnut	1.9	Tulip Tree	14	Boxelder	AM
Laurel Oak	875	194	River Birch	2646	Red Maple	1.6	Black Walnut	14	Laurel Oak	AM/EM
Water Oak	869	173	Red Maple	2592	Slippery Elm	1.5	Red Maple	14	Water Oak	AM/EM
Red Maple	859	139	Black Walnut	2528	Sweetgum	1.5	Sweetgum	14	Red Maple	AM
Willow Oak	739	142	Laurel Oak	2518	Water Oak	1.4	White Ash	14	Willow Oak	AM/EM
Sweetgum	719	150	Sweetgum	2395	American Elm	1.4	Live Oak	13	Sweetgum	AM
Slippery Elm	669	197	American Elm	2364	Laurel Oak	1.3	Water Oak	13	Slippery Elm	AM
American Elm	667	114	Willow Oak	2316	Boxelder	1.3	Black Cherry	11	American Elm	AM
Tulip Tree	659	81	Slippery Elm	2199	River Birch	1.3	Green Ash	11	Tulip Tree	AM
American Sycamore	652	111	Black Cherry	2095	Green Ash	1.3	Laurel Oak	11	American Sycamore	AM
Green Ash	624	200	Boxelder	2051	White Ash	1.3	Loblolly Pine	11	Green Ash	AM/EM
Loblolly Pine	479	106	Green Ash	1977	Willow Oak	1.1	Willow Oak	11	Loblolly Pine	AM/EM
White Ash	447	118	White Ash	1839	Black Cherry	1.1	Slippery Elm	9	White Ash	AM/AM
Black Walnut	386	76	Loblolly Pine	1480	Loblolly Pine	1.1	Boxelder	9	Black Walnut	EM+AM
Eastern Cottonwood	591	176	Hickory	1907	Southern Magnolia	1.3	Southern red Oak	17	Eastern Cottonwood	AM/EM
Black Willow	590	169	Red Mulberry	1876	Black Tupelo	1.2	Swamp chestnut Oak	16	Black Willow	AM/EM
Washington Hawthorn	448	68	Black Tupelo	1858	Eastern Cottonwood	1.1	Pecan	16	Washington Hawthorn	AM
Southern Crabapple	445	27	Southern red Oak	1858	Red Mulberry	1	Red Mulberry	14	Southern Crabapple	AM
Plum	445	139	Eastern Cottonwood	1791	Hickory	1	Black Willow	14	Plum	AM
Baldcypress	443	146	Oak	1740	Redbay	1	Willow	14	Baldcypress	AM
Longleaf Pine	425	85	Swamp chestnut Oak	1729	Flowering Dogwood	0.9	Southern Magnolia	13	Longleaf Pine	AM/EM
Southern red Oak	416	121	Flowering Dogwood	1639	Black Willow	0.9	Sugarberry/Hackberry	13	Southern red Oak	AM/EM
Shumard Oak	413	90	Plum	1493	Sugarberry/Hackberry	0.9	Hickory	12	Shumard Oak	AM/EM
Swamp chestnut Oak	412	114	Shumard Oak	1492	Shumard Oak	0.9	Shumard Oak	12	Swamp chestnut Oak	AM/EM
Oak	407	94	Black Willow	1466	Elm	0.9	Oak	11	Oak	AM/EM
Shortleaf Pine	374	91	Southern Magnolia	1458	Southern red Oak	0.9	Shortleaf Pine	11	Shortleaf Pine	AM/EM
Hickory	355	75	Redbay	1368	Oak	0.9	Southern Crabapple	11	Hickory	EM
Black Tupelo	354	46	Southern Crabapple	1359	Shortleaf Pine	0.9	Eastern Redbud	11	Black Tupelo	AM
Flowering Dogwood	338	46	Shortleaf Pine	1332	Carolina cherry Laurel	0.9	Sugar Maple	11	Flowering Dogwood	AM
Holly	337	59	Elm	1323	Southern Crabapple	0.8	American Hornbeam	11	Holly	AM
Winged Elm	327	179	Carolina cherry Laurel	1312	Swamp chestnut Oak	0.8	Common Persimmon	11	Winged Elm	AM
Elm	326	151	Pecan	1283	Plum	0.8	White Oak	11	Elm	AM
Southern Magnolia	322	55	Winged Elm	1267	American Basswood	0.8	Black Tupelo	9	Southern Magnolia	AM
Redbay	322	64	Eastern Redbud	1238	Eastern Redbud	0.8	Flowering Dogwood	9	Redbay	AM
Willow	281	79	American Basswood	1199	Winged Elm	0.7	Baldcypress	9	Willow	AM/EM
American Basswood	261	76	Sugarberry/Hackberry	1157	Sugar Maple	0.7	Washington Hawthorn	9	American Basswood	EM
Carolina cherry Laurel	232	2	Mockernu Hickory	1145	Mockernu Hickory	0.7	Savannah Holly	7	Carolina cherry Laurel	AM
Red Mulberry	219	44	Willow	1114	Longleaf Pine	0.7	American Holly	6	Red Mulberry	AM
Savannah Holly	192	63	Bitternut Hickory	1098	American Hornbeam	0.6	Holly	5	Savannah Holly	AM
Sugar Maple	191	71	Longleaf Pine	1094	Common Persimmon	0.6	Eastern red Cedar	4	Sugar Maple	AM
Common Persimmon	164	38	Common Persimmon	1093	Willow	0.6	American Basswood	7	Common Persimmon	AM
Mockernu Hickory	140	44	Baldcypress	1078	Baldcypress	0.6	Bitternut Hickory	9	Mockernu Hickory	EM
Post Oak	139	55	American Hornbeam	1037	Holly	0.6	Carolina cherry Laurel	7	Post Oak	AM/EM
Bitternut Hickory	138	54	White Oak	907	Savannah Holly	0.6	Eastern Cottonwood	17	Bitternut Hickory	EM
White Oak	136	54	Sugar Maple	891	Bitternut Hickory	0.5	Elm	16	White Oak	AM/EM
Pecan	135	44	Washington Hawthorn	790	Pecan	0.5	Longleaf Pine	11	Pecan	EM
American Hornbeam	133	31	Post Oak	691	White Oak	0.5	Mockernu Hickory	9	American Hornbeam	AM/EM
American Holly	127	33	Holly	665	American Holly	0.3	Plum	7	American Holly	AM
Sugarberry/Hackberry	111	58	Savannah Holly	629	Post Oak	0.3	Post Oak	13	Sugarberry/Hackberry	AM
Eastern Redbud	72	19	American Holly	525	Washington Hawthorn	0.2	Redbay	7	Eastern Redbud	AM
Eastern red Cedar	45	17	Eastern red Cedar	324	Eastern red Cedar	0.2	Winged Elm	16	Eastern red Cedar	AM+EM

References:

Native tree species selected from City of Houston tree ordinance

* Total CO2 stored and CO2 sequestration Calculated with CUFR Carbon Calculator (CTCC)

* Flood mitigation, Air pollutants removal calculated with i- Tree planting tool

Annual value calculated = total 10 year - total 9 year

Flood mitigation = Rainfall interception + avoided runoff

Air pollutants include O_3 + NO_2 + SO_2 + small particulate matter ($PM_{2.5}$)

* Biogenic VOC emission rate includes Isoprene and Monoterpenes volatile organic compounds

* Diameter at breast height (DBH) - calculated for each tree species whenapproximately 10 years old

* The references of the arbuscular mycorrhizal (AM) and ectomycorrhizal (EM) structural characteristics:

** Teste, François P., et al. "Dual-mycorrhizal Plants: Their Ecology and Relevance." *The New Phytologist*, vol. 225, no. 5, 2020, pp. 1835–51, https://doi.org/10.1111/nph.16190.

** Heklau, Heike, et al. "Mixing Tree Species Associated with Arbuscular or Ectotrophic Mycorrhizae Reveals Dual Mycorrhization and Interactive Effects on the Fungal Partners." *Ecology and Evolution*, vol. 11, no. 10, Wiley, 2021, pp. 5424–40, https://doi.org/10.1002/ece3.7437.

** https://extension.okstate.edu/fact-sheets/mycorrhizal-fungi.html

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Conclusions

Soil health is the continued capacity of soil to function as a vital living ecosystem that sustains plants, animals, and humans. In urban areas, this ability is crucial for maintaining livable communities by mitigating environmental impacts including climate change, impaired air and water quality, and increasing flood frequency[25].

The City of San Antonio recognizes the valuable role that parks and green space offer when used as a mitigation strategy that includes both above-ground vegetation and its soils. To enhance the functioning of these areas, the city has initiated a project in partnership with the NRCS focusing on the soil's role as a mitigation strategy. This two-phase project includes baseline data for current soil carbon levels at depths up to 3' while providing soil health information (0"-6") that will reduce monitoring time.

Baseline soil health data indicates that while most selected sites have a minimum of average soil health or better, all sites would benefit by modifying current soil and vegetation practices. Literature searches indicate that "natural" riparian areas have the greatest potential for providing ecosystem services, followed by improved drainage channels and lastly, uplands. Soil health results support this data. The highest functioning riparian areas are those with established hardwood forests and healthy overbank and buffer zones. Enhancing existing wetlands or constructing new ones in these areas could triple services, especially for CO_2 sequestration. Research also indicates that reforestation of riparian areas with little to no trees can jump-start the sequestration potential.

As Uplands comprise the greatest amount of area within San Antonio, their improvement can potentially provide the greatest amount of CO_2 sequestration and other ecosystem services. Research indicates that for these areas, ecosystem services could be significantly increased by modifying mowing practices only, basically mowing at higher heights and less frequently. The highest functioning ecosystem for uplands is a native grass and wildflower prairie. And while this landscape may not currently be appreciated by the public in general, it could be used in small areas that are located away from high pedestrian and bike traffic. These small areas or pocket prairies would not only improve ecosystem services but also the human nature experience. Interpretive signage and public relations efforts would facilitate adoption. Adding additional BMPs at any of the sites, such as soil amendments and or stormwater bioswales, rain gardens, and or infiltration sites would exponentially increase services provided within any selected area.

While the Blackland Prairies ecoregion with its deep soils typically have greater potential to increase ecosystem services by improving soil health, the inclusion of areas within the Edwards Plateau ecoregion; Edwards Aquifer contributing, transition, and recharge zones requires these parklands to remain a higher priority for receiving modified soil and vegetation practices that will lead to an increase in the quantity and quality of aquifer recharge.

Implementing recommended BMPs will require maintenance training, evaluation, and assessment over time to effectively meet goals within the city's physical, social, and financial limitations. Future recommendations may change with new research and provide better strategies, but at this time, San Antonio Parks and Recreation is leading the effort to improve practices for managing public green spaces. The City of San Antonio understands that it is a globally recognized strategy to restore deforested and degraded landscapes to sequester carbon, improve ecological integrity, conserve biodiversity, and provide additional benefits to human health and well-being[26].

[25] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7116140/

26[26] https://pubmed.ncbi.nlm.nih.gov/30411449/

Summary of Soil Health and Recommended Best Management Practices for Demonstration Parks

Soil health is defined as the continued capacity of soil to function as a vital living ecosystem that sustains plants, animals, and humans.

Healthy soil gives us clean air and water, bountiful crops and forests, productive grazing lands, diverse wildlife, and beautiful landscapes. Soil does all this by performing five essential functions:

- *Regulating water* – Soil helps control where rain and irrigation water goes. Water flows over the land or into and through the soil.
- *Sustaining plant and animal life* – The diversity and productivity of living things depend on soil.
- *Filtering and buffering potential pollutants* – The minerals and microbes in the soil are responsible for filtering, buffering, degrading, immobilizing, and detoxifying organic and inorganic materials, including industrial and municipal by-products and atmospheric deposits.
- *Cycling nutrients* – Carbon, nitrogen, phosphorus, and many other nutrients are stored, transformed, and cycled in the soil.
- *Providing physical stability and support* – Soil structure provides a medium for plant roots.

Soil health research has determined how to manage soil to improve soil function.

The main principles to manage soil for health are:

- Maximize the Presence of Living Roots as shown (Figure 22)
- Minimize Disturbance
- Maximize Soil Cover
- Maximize Biodiversity[27]

Figure 22: Maximizing root mass for healthy soils.

Recommended Best Management Practices (BMPs) to use for accomplishing goals

- Keep the soil covered
- Modify mowing regimes
    - Create no mow/let it grow zones (cut to 5”-6”, 1-2x/yr.)
    - Mow at higher levels (3.75”-5” regularly with less frequency during summer)
    - Mow only when needed focusing on the growing season
- Add soil amendments
- Create catchment areas such as rain gardens, bioswales, infiltration trenches, etc.
- Use ecological restoration practices that are adapted for urban areas

Utilize an agreed-upon standard method of marking areas that will receive modified mowing heights and frequency.

[27] https://www.nrcs.usda.gov/conservation-basics/natural-resource-concerns/soils/soil-health

Recommended BMPs for Demonstration Parks

1. Barbara Drive Park – Improved Drainage Channel

This park has some of the greatest limitations due to its high public visibility and stormwater conveyance requirements. Modified mowing heights maybe allowed in the channel but any additional BMP implementation is limited to the areas from the top of the channel banks to the abutting streets.

As noted, there are also significant data differences between the two sides of the channel. It is assumed that this is primarily due to more subsoil being deposited on the Left Bank during excavation where soil health indicators were much lower across test results.

Following construction, the site was seeded with Bermuda grass and a scattering of trees were planted as a part of the construction contract. When Parks took the responsibility for the park's maintenance, native wildflower seeds were also sowed over the site.

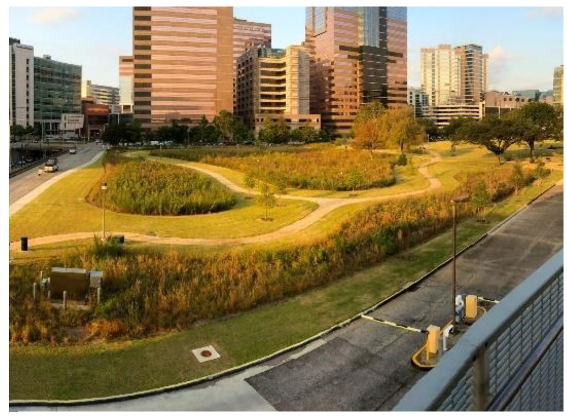


Figure 23: Urban pocket prairie at the Houston Medical Center.

Modifying mowing regimes across the site will be an easy first step. This area also lends itself to the creation of pocket prairies (short to mid-grass) with an abundance of perennial and annual wildflowers (Figure 23).

In the future, infiltration trenches that are shallow and large enough to easily mow with riding mowers could be included with additional tree plantings to not only increase benefits but also assist in cooling the mini-heat island created by the drainage project.

2. Lady Bird Johnson Park – Riparian

This sample site and the entire riparian length through the park lends itself to stream restoration. It is recommended that Parks work with its Advisory Board and other committees to seek approval for taking the initiative for funding. Funding sources could include it being submitted as a flood mitigation/park project for the 2027 Bond cycle. MS4 funding may also be available as bank failures along the reach are eroding, causing an increase in downstream pollution and a loss of conveyance capacity.

Other outside funding opportunities may be available, especially with this Federal administration's Investing in Nature initiative[28], Urban Waters Federal Partnership, and the Texas Commission on the Environment's Clean Water Grant program.

In the meantime, modifying mowing regimes will assist in stabilizing the riparian areas within the park with an emphasis on no mow zones within a 10-15' buffer along the channel, including the drainage tributary. The other aspect is to stop the head cut on this tributary that runs into the main channel. These efforts should go a long way to improve riparian conditions but, will need to be monitored for effectiveness.

3. Olmos Basin Park – Riparian

This site had the highest level of soil health indicators, which illustrates the resiliency of riparian areas. The site was selected to monitor the effects of current Public Works Stormwater maintenance operations where a hydro-axe is used to shred vegetation less than 6" in diameter to the water's edge.

The hydro-axe maintenance operations are scheduled to be repeated on a 4-year cycle (conversation with N. Garza, past Stormwater Manager) therefore future sampling will assist in evaluating impact. Observations noted a loss of biodiversity, topsoil and SOM.

Recommendations are given for modifying this current maintenance practice:

1. Ensure trash catchments are installed and maintained before the concrete channel enters the "natural" portion of Olmos Creek.
2. Evaluate conveyance requirements after the effective removal of non-native tree species.
3. Allow a native vegetated buffer of a minimum of 15' to remain and be managed by hand.
4. Remove debris by hand with volunteers.
5. Use equipment only for removal of large woody debris ensuring that equipment will not enter the area when soils are saturated.
6. Develop strategies that will protect utility crossings from further erosion and exposure.
7. Ensure maintenance practices protect riparian soils, aquatic and terrestrial habitats, and riparian plants including those less than 6" diameter to ensure not only new recruitment of the hardwood forest but also protect those key riparian species that rarely reach 6" diameter.
8. Jump-start the improvement of ecosystem services by actively planting riparian trees and plants.

Other long-term solutions may include enhancing the natural over-banking features found along this stretch of Olmos Creek. These slightly depressed areas are critical for providing moisture for riparian plants during times of no rain and can assist in removing pollutants from stormwater before it enters the stream.

[28] https://www.whitehouse.gov/ostp/news-updates/2023/03/22/investing-in-nature/

4. Salado Creek 1604 - Riparian & Culvert

Riparian Site:

The riparian site was selected in proximity to the creek which is a dry portion of Salado Creek over the Edwards Aquifer Recharge Zone. This portion of the creek also contains a significant recharge feature.

The selected sampling site within the riparian zone had the second-highest soil health indicator reading while leading with 8% SOM.

At this time, there are no recommended changes to maintenance practices. This section of the creek could be used as an urban reference reach as indicated in Figure 24. The goal for this site and the entire riparian area within the park will be to protect it from impacts such as upstream development or projects that could change flows within the creek. It will be important to monitor the site for impacts from the Loop 1604 widening project.

Figure 24: Riparian Site with Healthy Stands of Eastern gamagrass.

Figure 25: Culvert Site showing sediment deposition from the abutting property.

Culvert Site:

The culvert site is located along the trail where sediment from an abutting private property is accumulating (current depth is 6-10" shown in Figure 25). It is recommended that the park installs at a minimum vegetative BMPs to reduce sediment and prevent it from crossing the trail and entering into the environmentally sensitive riparian area.

A minimum strategy would be to plant/seed a combination of medium and tall native grasses that will assist in capturing sediment. Utilizing several varieties of Switchgrass *(Panicum virgatum)* along with more shade tolerant grasses such as Inland sea oats (*Chasmanthium latifolium*) and Canadian wild rye (*Elymus canadensis*) could provide a rapid and effective strategy.

5. Rancho Diana - Upland

This project site is a 1,300-acre nature preserve purchased through the Aquifer Protection Proposition. As it is not open to the public the nature reserve offers an opportunity for the implementation of BMPs without requiring resident patrons' input.

The sample site is located in an open field that lends itself to a prairie restoration effort. This location would allow native prairie grasses to achieve their maximum potential without requiring the 1-2x per year mowing for more urban parks.

While rooting depths such as seen in Figure 26 may not be achieved on this shallow upland site, maximizing live root mass will go a long way to not only improving soil health but also increasing its depth. A desirable ratio for prairie grasses to fulfill their potential in sequestering and storing carbon is a **1:3 ratio of above-ground to below-ground mass.**

The greatest concern for restoring this site as a native prairie grass wildflower system is the dominance of KR bluestem. As research indicates, there is no single, surefire method to control KR bluestem. The methods under investigation are:

1. Herbicides alone—The conclusion of several of the papers is that herbicides alone are not an effective control for KR bluestem.
2. Tilling (disking or harrowing) alone—Here is the recommendation from the Native Prairies Association of Texas in their article, "Seed Bed Preparation: The Johnson Grass Wars. Want to Plant a Prairie?" by Lee Stone and Arnold Davis
3. Prescribed burns—Mark Simmons of the Lady Bird Johnson Wildflower Center reported in Selective and Non-Selective Control of King Ranch Bluestem: The Short-Term Effects of Growing-Season Prescribed Fire, Herbicide, and Mowing in Texas Prairie that prescribed burns during the growing season (summer) were "effective at reducing the abundance of *B. ischaemum*" while dormant season (winter) burns encouraged KR growth. Also, the advantage of a growing season prescribed fire over tilling/herbicide is that many native types of grass can tolerate fire, hence this technique is selective rather than wholesale[29].

Figure 26: Example of native prairie grass root growth potential.

[29] https://www.wildflower.org/expert/show.php?id=1873

6. Pearsall Park upland

This site had the lowest readings across all of the soil health test parameters. The lack of vegetation and compacted soils can be seen in Figure 27. By applying a mixture of BMPs and increasing maintenance for the area for a year, the site should readily improve and provide an example of effectiveness within 2-3 years. If observations indicate that there is significant improvement, it is recommended to retest and compare differences in the before and after treatment results.

Due to its high visibility and use by families and pet owners, it will be necessary to select BMPs that would be most acceptable to patrons while minimizing park maintenance.


Figure 27: Sampling Site at Pearsall Park

Since this site is an empty palette the recommended BMPs would include:

- Surface tilling to break the crust.
- Creation of a bioswale or berm parallel to the fence and sidewalk that would accommodate mowing.
- Add a soil amendment to the entire site.
- Plant with a sod-type ground cover and additional trees.
- Weed and water appropriately for a growing season ensuring a minimum of 75% vegetated cover.
- A rain garden with interpretive signage would not only be beneficial to the site but would also increase awareness within this socially vulnerable community.

7. Medina River Natural Area – Riparian & Upland

Riparian Area:
While the sampling at this site only reflects soil conditions in this location, it can be assumed that it is representative, which indicates that the soils in the riparian area for the Medina River are in poor condition. The selected site did have a good vegetative cover, but a large percentage contained "pioneer" plants, especially annual plants that dominate disturbed sites.
While this is not a negative aspect as such, pioneer plants are crucial for returning functioning to disturbed sites. What it does indicate is that actively managing the riparian area could bring more desirable conditions in a

shorter period. These strategies along with the current project to install “beaver dams” in the tributaries will lead to higher functioning riparian areas that are more protected from flood waters.

While Natural Area staff have the expertise to manage their areas appropriately, the soil health data will assist in their decision-making process.

Therefore, no specific BMPs are recommended but several are given for consideration:

1. Installation of bioswales above the top of the bank within the first terrace.
2. In these areas or anywhere along the buffer utilizing several of the formidable grasses such as Switchgrass and Eastern gamma grass could jump-start the healing process. These 2 riparian species will not only stabilize banks but provide additional benefits including laying down to reduce resistance to stormwater flows and CO_2 sequestration (Figure 28).

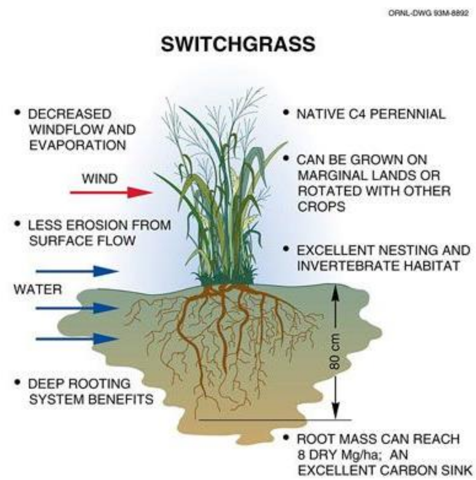


Figure 28: Benefits of Switchgrass

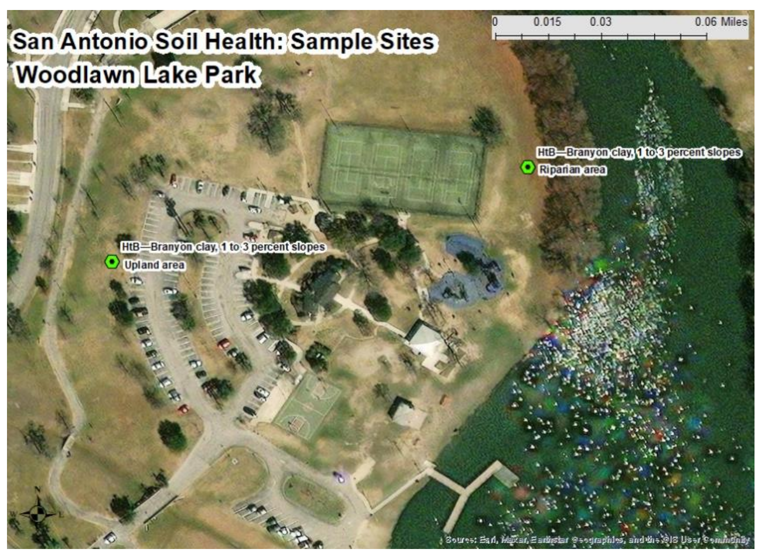
Upland site

The upland site would lend itself to the short-mid grass prairie mix with annual and perennial wildflowers as proposed by staff. A bioswale or infiltration site located near the abutting property line could capture some of the runoff entering the park from this property.

9. Woodlawn Lake Park

Riparian site

While the riparian sample site has a line of healthy Bald Cypress trees, there was basically no understory or riparian plant buffer as seen in Figure 29. While any initiatives would require public input, a recommendation with minimum changes is given:



The selected site was strategically located between the fence surrounding the tennis courts in an area with less traffic but high visibility. The area from the fence down the slope to the water’s edge would include a walking path (along the length of the fence) with a mulch surface. This path would provide an alterntive path from the hard packed area at the water’s edge.

this designated walking path would mark the edge of the small drainage area that would direct low flows into a very low bermed bioswale just outside the proposed 10-12’riparian buffer. The bioswale would provide additional moisture for plantings in front and behind the small berm.

Figure 29: Woodlawn Lake Park riparian Site

While it is recommended to secure neighborhood approval before the design phase, recommendations could be as simple as Eastern gamagrass for the berm area and Pickerelweed at the water's edge. Pickerelweed is a native flowering aquatic plant that provides for pollinators while also providing water quality services and a habitat for bait fish. It is low growing so would not block views.

This strategy would protect the water's edge and be a first attempt to manage the lake's edge in a more environmentally sound manner, which would assist not only in improving carbon sequestration but also water quality within the lake.

This area would also require exclusion fencing for geese to allow the newly planted riparian vegetation to establish. It is envisioned that this area may be monitored and maintained by neighborhood volunteers, including Master Naturalists.

Upland

The upland site as shown in Figure 32 is really on a slope running from the Island House parking lot to the vegetated drainage where Parks has already established several rows of tall bunch grasses strategically perpendicular across the drainage. This site was located where water collects in the parking lot and would lend itself to the construction of a bioswale to intercept and filter stormwater runoff before entering the drainage that flows directly to the lake.

Figure 32: Upland site was location for Master Naturalist volunteers to receive instructions from NRCS staff on how to collect samples to be used for soil health testing.

Creating a curb cut within an existing curb can be completed with Parks' staff. Also utilizing a monoculture of a native, drought-tolerant plant such as the sedge shown in Figure 31 could reduce ongoing maintenance and provide year-round filtration services and aesthetics.

As noted in the Total Organic Nitrogen test results, wildlife fecal matter is a source of nitrogen loading in the watershed. Increasing vegetation and turf heights in the upland areas can assist in reducing the amount of this nitrogen that reaches the lake.

Figure 31: Bioswale Planted with Sedge Species to Facilitate Maintenance.

10. Southside Lion Park - Riparian

This riparian site on Salado Creek is located within a portion of the creek that runs through the park, which is located southeast of San Antonio. Throughout this region, soils were "highly disturbed" primarily due to previous agricultural activities. Consequently, soil health indicators were relatively low for a "natural" riparian area within the Blackland prairie.

Slopes were steep above the sample site and would limit recommended activities along the slope, but a first step would be to Increase mowing heights (may require some revegetation) around the picnic and building area. Also, if space allows, create a minimum-mow buffer at top of bank. This would reduce some runoff that is forming gullies down the slope towards the creek. The runoff from the building roof is a significant source of stormwater eroding the slope. Addressing the roof runoff at the building is recommended. Creating terracing across the slope with "beaver dams" could also assist in repairing the gullies.

The removal of non-native trees and vegetation could be the material used for the "beaver dams" ensuring that no more than 25% of vegetation is removed in any area. Following removal, new plantings of trees, small woody plants, and grasses would assist in bank stabilization. Irrigation may be accomplished by utilizing a pump within the creek for establishment.

In addition, to the runoff from the top of bank, it was noted that the area had contained a public-made trail that cut straight down the slope to the water's edge. This area is a source of erosion and gully formation. Constructing a trail following approved methods that include switchbacks would provide safer and more environmentally friendly access for pedestrians. By preventing erosion of topsoil, soil carbon sequestration is increased and protected.

11. Milam Tealer Park -Upland & Pocket Prairie

Upland site

The upland site in Figure 32 reflects the results of conventional mowing operations that occur in parks with high public use where mowing height averages 1.5"-2" and even less where line trimmers are used. Therefore, modifying mowing practices will be the first step in improving not only soil health but water quantity and quality in the lake.

Since previous attempts to modify mowing practices did not result in long-term adoption, the new approach with training and monitoring should facilitate establishing new standards for maintenance workers.

It will be important to have areas identified where each of the following modifications is implemented:

1. *No mow/let it grow zones*
2. *Mow at higher levels*
3. *Mow less frequently*

Figure 32: Upland site at Milam Tealer Park

In the past, this neighborhood has been active in the decision-making process for managing the park. Therefore, efforts to continue communications should be made before implementation. It is also recommended to use interpretive signage within the park for increasing community awareness regarding the use of selected BMPs that will assist in maintaining lake water levels.

Figure 33: Pocket Prairie Site at Milam Tealer Park

<u>Pocket prairie</u>

The Pocket Prairie site (Figure 33) will be incorporated into the newly selected mowing standards for the park. It is recommended that the site receive at a minimum the highest setting possible and be mowed only during growing seasons while the abutting picnic table area receives the new "regularly" standard at 3.75"-5" ht.

12. Levi Strauss riparian

This riparian site lends itself to the first step in improving urban riparian areas by removing non-natives and slowly increasing the planting of native long-lived tree species. On the west side of the bank, where there is more open property, there is the opportunity to enhance the over-banking zone which would provide additional protection from runoff sediment, etc. from the abutting property.

Riparian plants that can tolerate inundation and drought could be used, including Eastern gammagrass, Frog fruit (*Phyla nodiflora*) and Cherokee sedge (*Carex cherokeensis*).

Other recommendations will include improving the function of each riparian zone including the upland. Modifying mowing regimes in all non-sport field areas will be a priority. In addition, installing a stormwater BMP between the trail and Hwy 90 would also be beneficial.

As flooding along the lower Leon Creek is of great concern, especially in District 4, any installations of stormwater BMPs such as infiltration sites could assist in reducing peak flows. A BMP such as depressions planted with prairie grasses and wildflowers would provide a habitat for pollinators and songbirds, enriching the experience for trail and park users.

13. Westside Creek at Escobar Park

Soil health test results reveal that this area functions at a very low level. Unfortunately, this site also has limitations due to its high public visibility and stormwater conveyance requirements. Any BMP implementation other than increasing mowing heights will be limited to the areas from the top of the channel banks to the abutting streets or trails.

Increased mowing heights and additional tree plantings will increase the area's potential to provide greater ecosystem services and reduce summer temperatures. It will be a good site for monitoring the potential for these 2 basic BMPs within older drainage systems.

14. Old Spanish Walking Trails

This site offers a unique opportunity to increase not only ecosystem services but also capacity within the stormwater detention facility. Overall soil test results rank the soil as average in comparison to other sites which could be improved by modifying mowing regimes.

Working with the leasee, additional strategic areas could be planted with the pocket prairie concept; native grasses and wildflowers cut 2x per year.

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Figure 1: https://fieldcropnews.com/understanding-soil-compaction/

Figure 2: Shaun Speck, GEAA 2022-2023 UTSA Intern

Figure 3: https://www.marinrose.org/how-sweet-is-your-soil/

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Figure 10: photo by D Reid

Figure 11: https://mgnv.org/public-education/grasses-vs-sedges/

Figure 12: https://columbiamywoodlot2017.weebly.com/bioswales.html

Figure 13: photo by D Reid

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Figure 17: photo by D Reid

Figure 18: https://www.houstonchronicle.com/local/gray-matters/article/What-s-a-prairie-doing-in-the-middle-of-the-12290862.php

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Figure 22: https://keep.konza.k-state.edu/prairieecology/TallgrassPrairieEcology.pdf

Figure 23: https://www.houstonchronicle.com/local/gray-matters/article/What-s-a-prairie-doing-in-the-middle-of-the-12290862.php

Figure 24: photo by D Reid

Figure 25: photo by D Reid

Figure 26: https://www.kshs.org/p/forces-of-nature-part-5/16708

Figure 27: https://www.iowaswitchgrass.com/benefits~onfarmbenefits.html

Figure 28: photo by D Reid

Figure 29: https://www.gardenia.net/plant/pontederia-cordata

Figure 30: photo by D Reid

Figure 31: https://www.harvestingrainwater.com/resource/do-it-yourself-curb-cut-guide/

Figure 32: photo by D Reid

Figure 33: photo by D Reid

Figure 34: https://sustainabilityworldorm.wordpress.com/2012/11/21/land-habitat-sustainability-blog-no-mow-zones/

Figure 35: photo by D Reid

Figure 36: https://prairiefarmland.com/riparian-buffers-indiana-soil-watershed-conservation/

Figure 31: photo by D Reid

Figure 31: photo by D Reid

Appendix A: Protocol for Soil Sampling in Parks

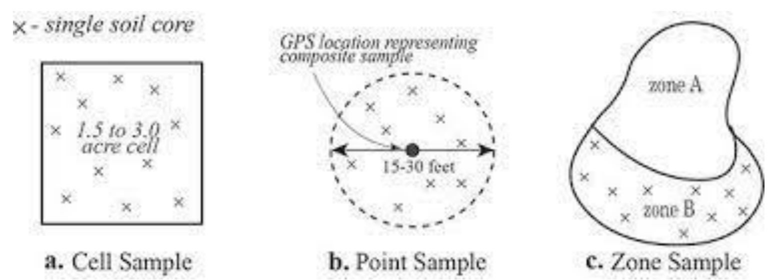
These tests will provide baseline information on soil conditions and health and will be used to form the basis for soil and vegetation management recommendations to be applied to each site.

Soil tests will include:

1. Soil temperature
2. Soil percolation (infiltration rates) to be provided by the NRCS (delayed due to current soil moisture conditions)
3. Soil health tests will require collecting composite samples (~ 2qts/sample) from each location, preparing the sample, and mailing it to a soil testing laboratory (Regen Ag Lab). The tests will include:
    a. Standard Haney test*
    b. Soil aggregate test
    c. Water holding capacity

Supplies and materials that will be supplied by staff (rope, stake, hammer)

Vegetation clearing equipment (clearing will be completed by staff)
Ice chest with Cool packs
1-gallon Ziplock bag(s)
1-gallon water for hands
Measure tape and ruler for 6" depth
Paint or pins to mark sampling sites
Soil temperature thermometer
Soil sampling augers
Spade and hand shovels
Data collection sheets



Personal items for volunteers to ensure they have

Work gloves, Sun and insect protection, and Drinking water

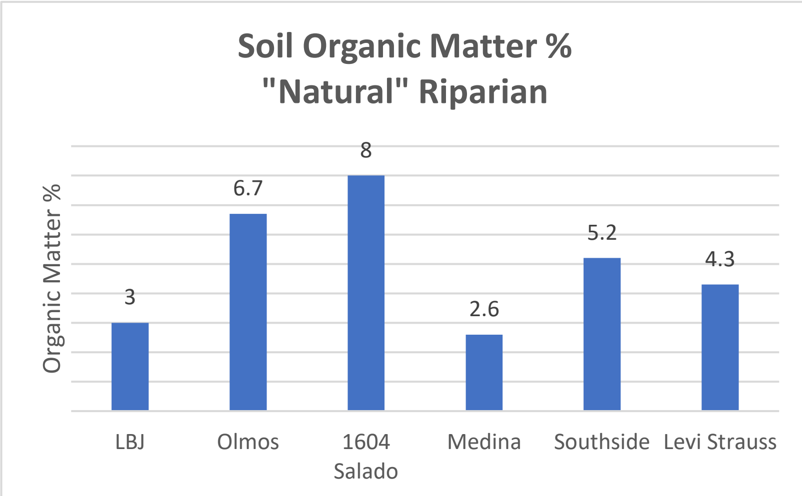
Steps for collecting composite soil samples of 2 qts. each

1. Select a point and create a 30' diameter circle or a 30' line for areas such as along a stream or lake.
2. Set up a data sheet and GPS for the center point.
3. Record date, location, soil temperatures, and vegetation cover; type, height.
4. It is not necessary to remove vegetation as this will be removed during the sample mixing.
5. Divide the circle in half and then quarters and stagger collection points along these lines or for a tangent line, take samples at 10' intervals staggering points online and 2' to either side.
6. Collect soil samples to 6" ensuring 2 qts. of soil are collected in the bucket or on a tarp.
7. Mix samples, break up clods and remove any rocks and material larger than 1" in size and pour the sample into the 1-gallon Ziplock bag.
8. Number and label the Ziplock bag and place it into the cooler with cool packs.
9. Clean equipment between sample locations.

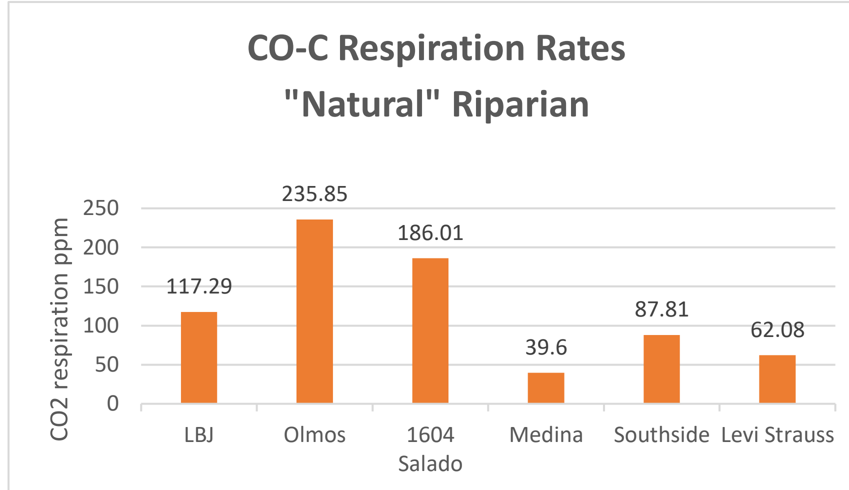
Appendix B: Graphs for Soil Health Test Results In-Depth Haney Test Results

Riparian Sites:

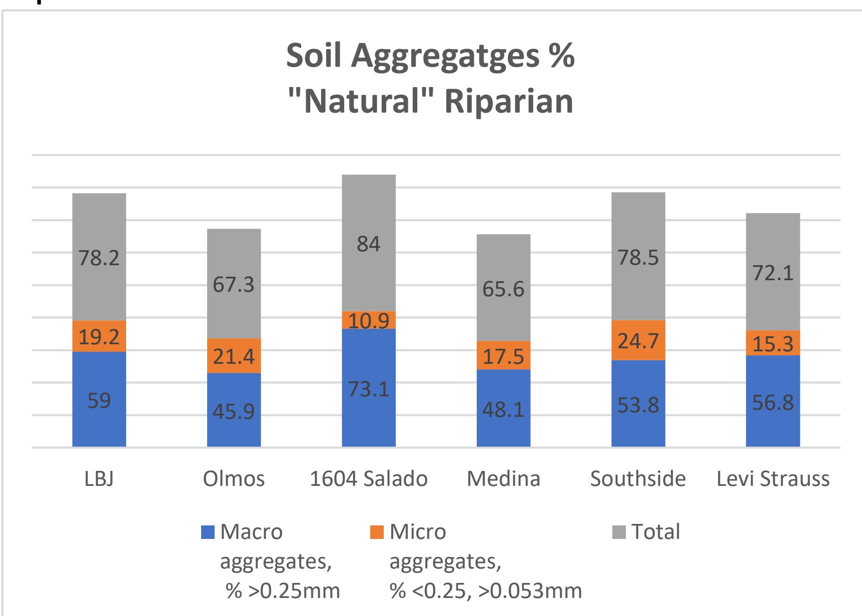
Graph 1:



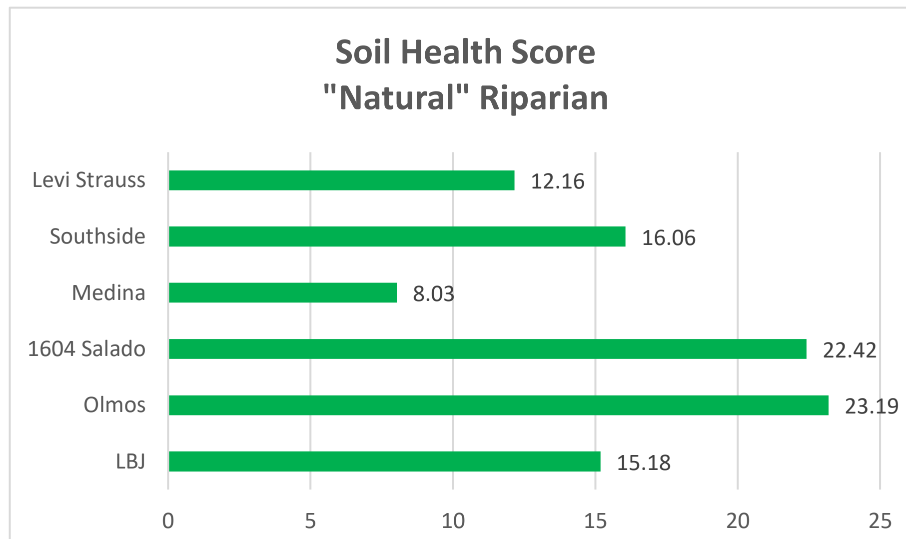
Graph: 2



Graph: 3

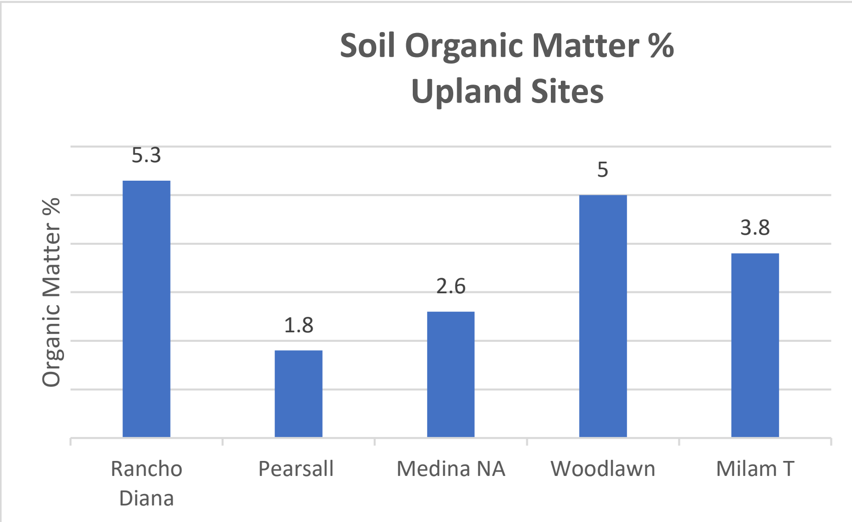


Graph: 4

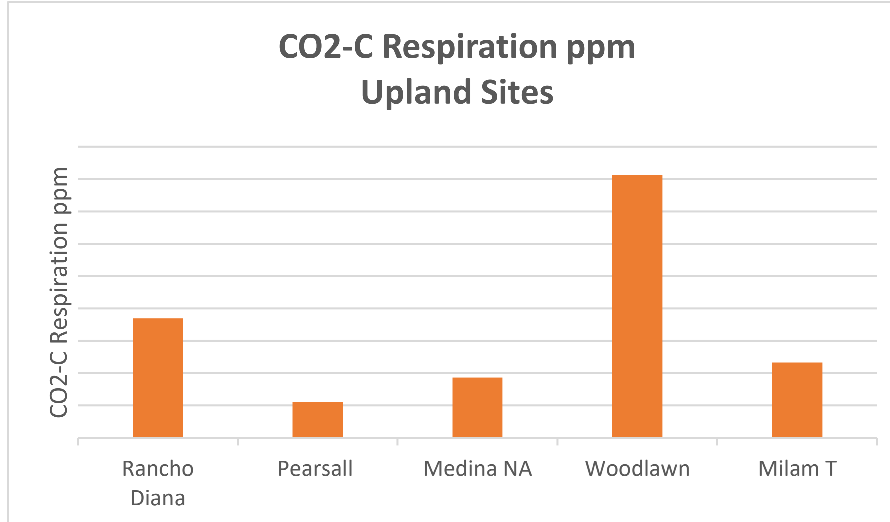


Upland Sites:

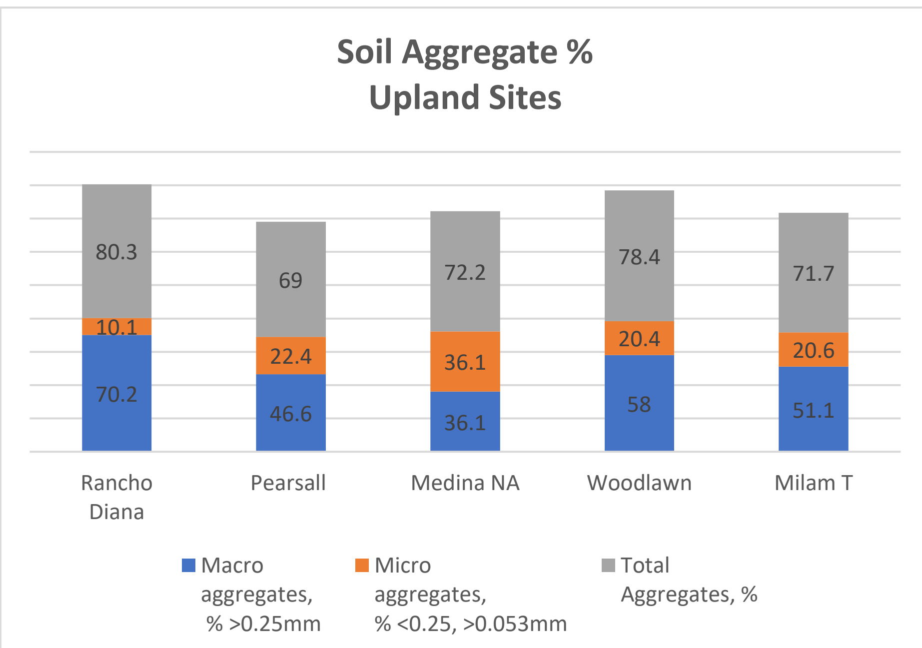
Graph 5



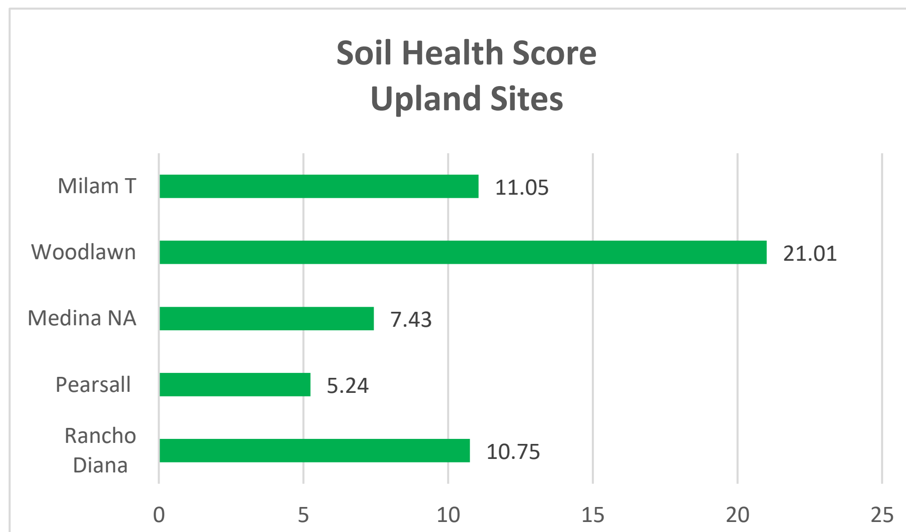
Graph 6



Graph 7



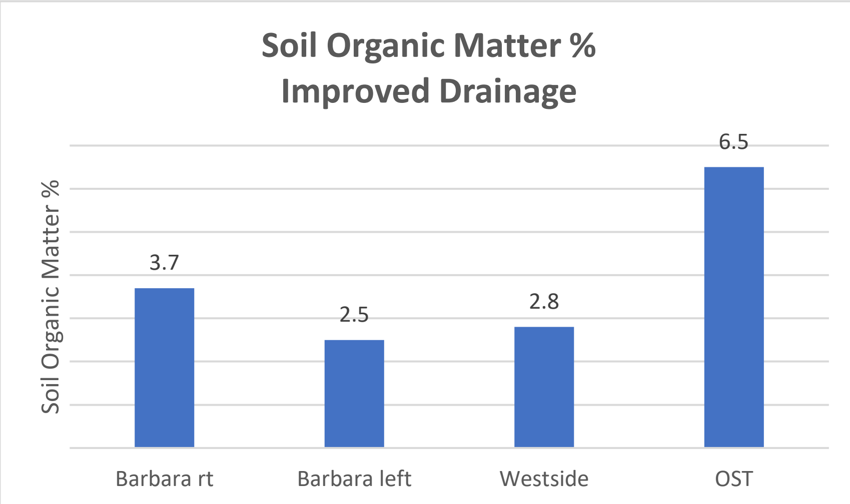
Graph 8



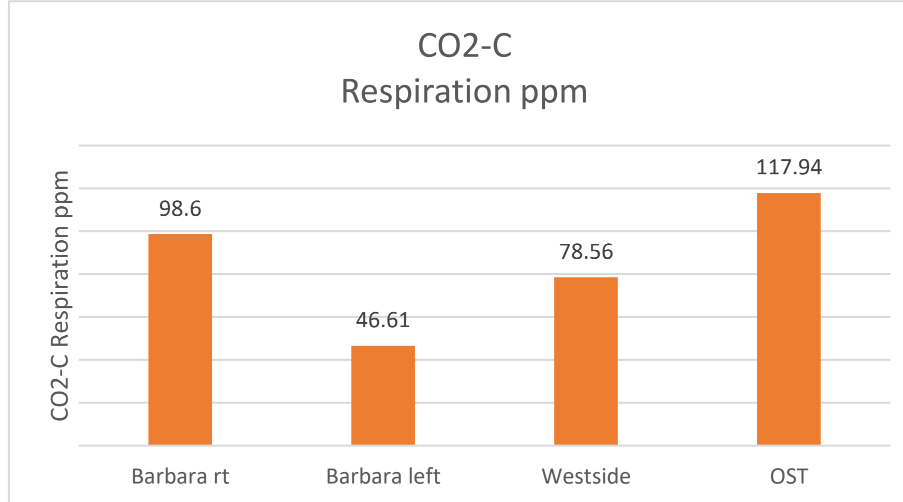
* = Woodlawn reading affected by high nitrogen provided by wildlife

Improved Drainage sites

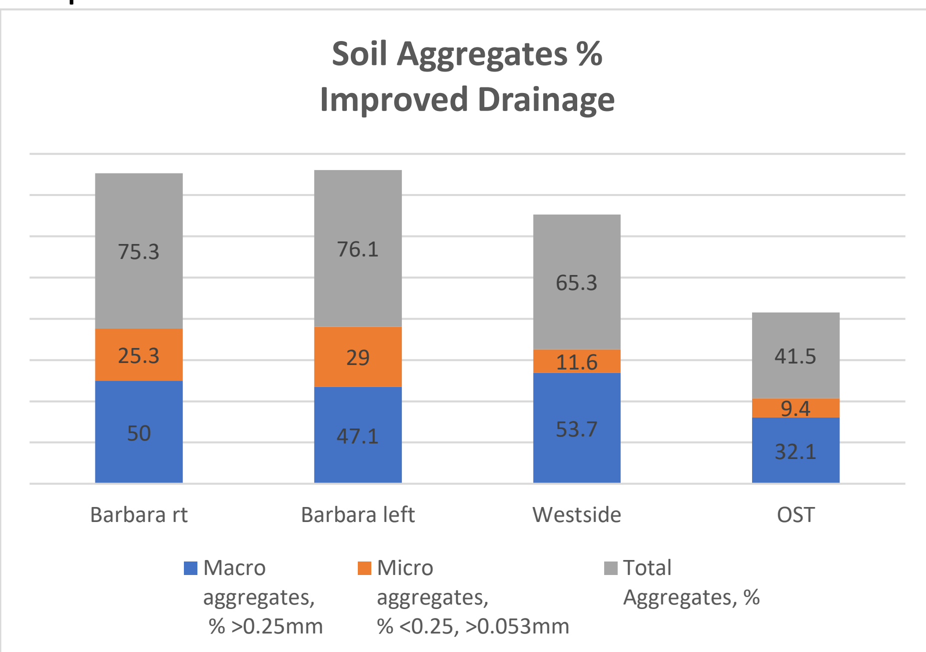
Graph 9



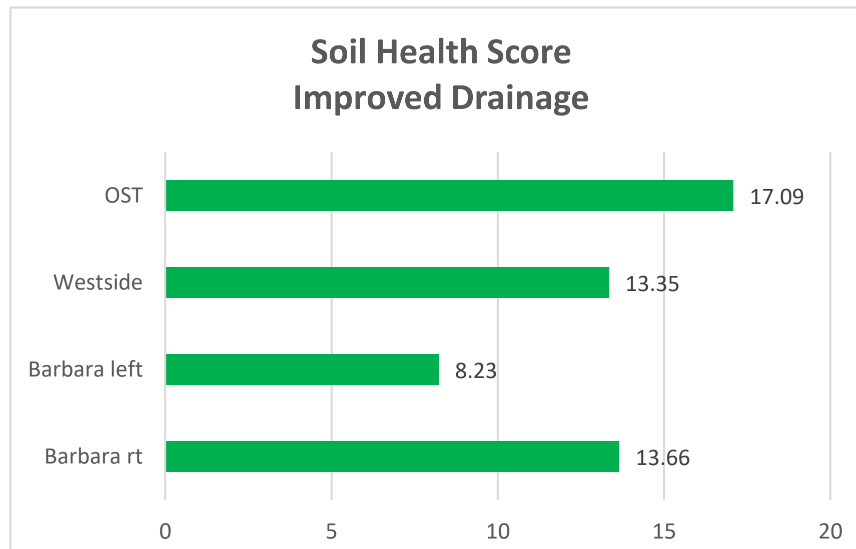
Graph 10



Graph 11

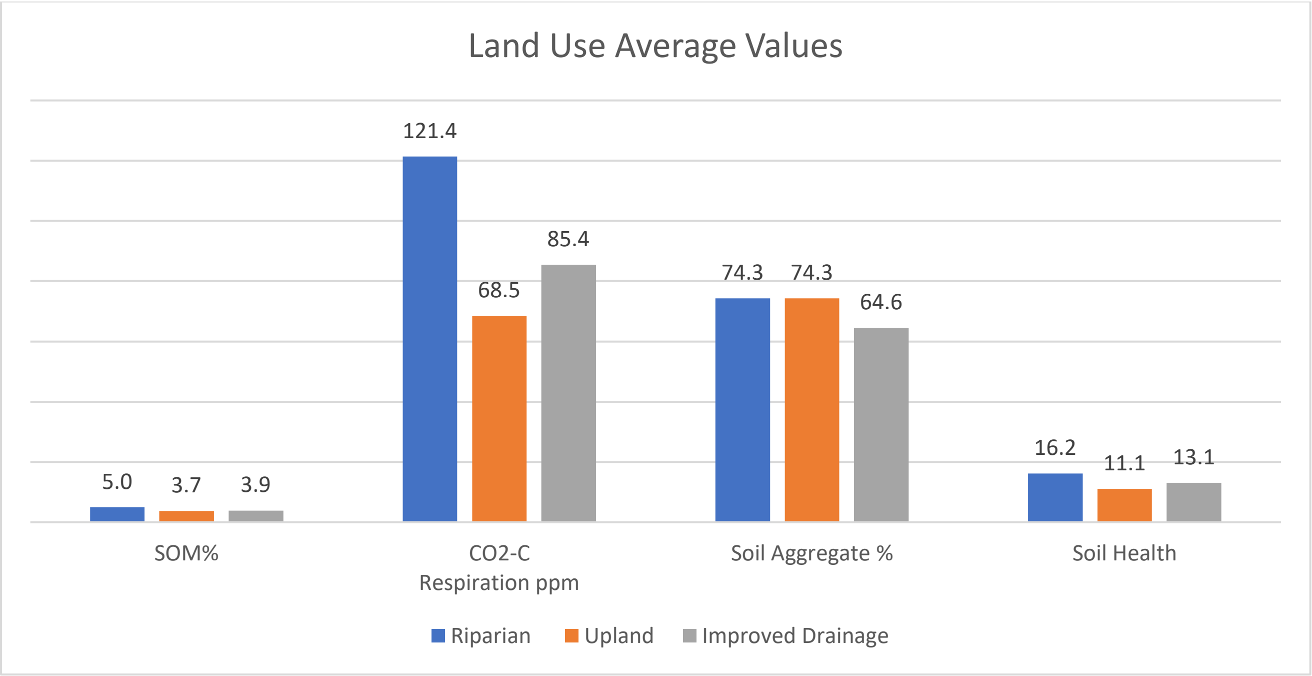


Graph 12



Comparison of Averages for Riparian "Natural", Upland and Improved Drainage

Graph 13



Appendix C: In-Depth Haney Test Results

Account No.:	1421	Name:	DEBBIE REID	Grower:	ER EDWARDS AQUIFER ALL
Invoice No.:		Company:	EATER EDWARDS AQUIFER ALLIAN	Field ID:	BARBARA DR PARK RIGHT
Date Recd:	12/20/2022	Address:	PO BOX 15618	Sample ID 1:	1
Date Repd:	12/22/2022	City, State, ZIP:	SAN ANTONIO, TX 78212	Sample ID 2:	
				Sample Depth:	0-6

HANEY SOIL HEALTH ANALYSIS

Lab #	Nitrogen									Phosphorus					
	H3A Extract			H2O Extract						H3A Extract					
	Nitrate ppm NO3-N	Ammonium ppm NH4-N	Inorg. N ppm N	Total N ppm N	Org. N ppm N	Org. N: Inorg. N	Org. N Rel. ppm N	Org. N Res. ppm N	Avail. N lbs/A	Total P ppm P	Inorg. P ppm PO4-P	Org. P ppm P	Org. P Rel ppm P	Org. P Res. ppm P	Avail. P lbs/A
30836	13.7	1.8	15.5	28.4	12.1	0.74	12.1	0.0	49.7	2.2	2.0	0.2	0.2	0.0	5.0
Rank															

Lab #	Other Soil Measures					Fertility									
						H3A Extract									
	Soil pH 1:1	Buffer pH Mod. WDRF	Soluble Salt mmho/cm	Excess Lime	Soil OM % LOI	Potassium ppm K	Calcium ppm Ca	Magnesium ppm Mg	Sodium ppm Na	Zinc ppm Zn	Manganese ppm Mn	Iron ppm Fe	Copper ppm Cu	Aluminum ppm Al	Sulfur ppm S
30836	7.8	-	0.36	HIGH	3.7	81	2822	128	48	0.03	0.5	5	0.03	24	52.14
Rank															

Lab #	Soil Health						Nitrogen Comparison				Reviewer Comments
		H2O Extract					Traditional	Haney	Differ.	Savings	
	Soil Resp. ppm CO2-C	Org. C ppm C	MAC %	C:N	SHC	Cover Crop Suggestion	N lbs/A	N lbs/A	N lbs/A	N $/A	
30836	98.6	130	76.0	10.74	13.66	40% Legume 60% Grass	24.7	49.7	25.1	26.06	
Rank											

Lab #	Intended		N Credits, lbs/A			Fertility Recommendations, lbs of Required Nutrients per Acre									
	Crop	Yield Goal	Past Crop	Subsoil	Haney	N	P2O5	K2O	S	Zn	Mg	Fe	Mn	Cu	Lime T/A

Reviewed By: Emily Shafto
Date: 12/23/2022

Recommendations Provided by Regen Ag Lab, LLC
Analysis Performed by Regen Ag Lab, LLC

Regen Ag Lab, LLC
31740 Hwy 10, Pleasanton NE 68866

Gain Ground

308-627-0065
regenaglab.com

Account No.:	1421	Name:	DEBBIE REID	Grower:	ER EDWARDS AQUIFER ALI
Invoice No.:		Company:	EATER EDWARDS AQUIFER ALLIAN	Field ID:	LADY BIRD JOHNSON PARK
Date Recd:	12/20/2022	Address:	PO BOX 15618	Sample ID 1:	2
Date Repd:	12/22/2022	City, State, ZIP:	SAN ANTONIO, TX 78212	Sample ID 2:	
				Sample Depth:	0-6

HANEY SOIL HEALTH ANALYSIS

Lab #	Nitrogen									Phosphorus					
	H3A Extract			H2O Extract						H3A Extract					
	Nitrate ppm NO3-N	Ammonium ppm NH4-N	Inorg. N ppm N	Total N ppm N	Org. N ppm N	Org. N: Inorg. N	Org. N Rel. ppm N	Org. N Res. ppm N	Avail. N lbs/A	Total P ppm P	Inorg. P ppm PO4-P	Org. P ppm P	Org. P Rel ppm P	Org. P Res. ppm P	Avail. P lbs/A
30837	4.2	1.5	5.6	21.7	14.3	1.93	14.3	0.0	35.8	1.7	1.5	0.2	0.2	0.0	3.9
Rank															

Lab #	Other Soil Measures					Fertility									
						H3A Extract									
	Soil pH 1:1	Buffer pH Mod. WDRF	Soluble Salt mmho/cm	Excess Lime	Soil OM % LOI	Potassium ppm K	Calcium ppm Ca	Magnesium ppm Mg	Sodium ppm Na	Zinc ppm Zn	Manganese ppm Mn	Iron ppm Fe	Copper ppm Cu	Aluminum ppm Al	Sulfur ppm S
30837	8.1	-	0.22	HIGH	3.0	51	2812	97	145	0.12	0.4	5	0.01	18	12.86
Rank															

Lab #	Soil Health						Nitrogen Comparison				Reviewer Comments
		H2O Extract									
	Soil Resp. ppm CO2-C	Org. C ppm C	MAC %	C:N	SHC	Cover Crop Suggestion	Traditional N lbs/A	Haney N lbs/A	Differ. N lbs/A	Savings N $/A	
30837	117.3	199	59.0	13.93	15.18	30% Legume 70% Grass	7.5	35.8	28.3	29.44	
Rank											

Lab #	Intended		N Credits, lbs/A			Fertility Recommendations, lbs of Required Nutrients per Acre									
	Crop	Yield Goal	Past Crop	Subsoil	Haney	N	P2O5	K2O	S	Zn	Mg	Fe	Mn	Cu	Lime T/A

Reviewed By: Emily Shafto
Date: 12/23/2022

Recommendations Provided by Regen Ag Lab, LLC
Analysis Performed by Regen Ag Lab, LLC

Regen Ag Lab, LLC
31740 Hwy 10, Pleasanton NE 68866

Gain Ground

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Regen Ag Lab

Account No.:	1421
Invoice No.:	
Date Recd:	12/20/2022
Date Repd:	12/22/2022

Name:	DEBBIE REID
Company:	EATER EDWARDS AQUIFER ALLIAN
Address:	PO BOX 15618
City, State, ZIP:	SAN ANTONIO, TX 78212

Grower:	TER EDWARDS AQUIFER ALL
Field ID:	BARBARA DR PARK LEFT
Sample ID 1:	3
Sample ID 2:	
Sample Depth:	0-6

HANEY SOIL HEALTH ANALYSIS

Lab #	Nitrogen									Phosphorus					
	H3A Extract			H_2O Extract						H3A Extract					
	Nitrate ppm NO_3-N	Ammonium ppm NH_4-N	Inorg. N ppm N	Total N ppm N	Org. N ppm N	Org. N: Inorg. N	Org. N Rel. ppm N	Org. N Res. ppm N	Avail. N lbs/A	Total P ppm P	Inorg. P ppm PO_4-P	Org. P ppm P	Org. P Rel ppm P	Org. P Res. ppm P	Avail. P lbs/A
30838	8.4	1.4	9.8	20.1	9.1	0.83	9.1	0.0	34.1	1.6	1.5	0.1	0.1	0.0	3.8
Rank															

Lab #	Other Soil Measures					Fertility									
						H3A Extract									
	Soil pH 1:1	Buffer pH Mod. WDRF	Soluble Salt mmho/cm	Excess Lime	Soil OM % LOI	Potassium ppm K	Calcium ppm Ca	Magnesium ppm Mg	Sodium ppm Na	Zinc ppm Zn	Manganese ppm Mn	Iron ppm Fe	Copper ppm Cu	Aluminum ppm Al	Sulfur ppm S
30838	8.1	-	0.27	HIGH	2.5	54	2832	108	45	0.02	0.3	4	0.01	26	13.56
Rank															

Lab #	Soil Health						Nitrogen Comparison				Reviewer Comments
		H_2O Extract									
	Soil Resp. ppm CO_2-C	Org. C ppm C	MAC %	C:N	SHC	Cover Crop Suggestion	Traditional N lbs/A	Haney N lbs/A	Differ. N lbs/A	Savings N $/A	
30838	46.6	133	35.1	14.55	8.23	50% Legume 50% Grass	15.1	34.1	18.9	19.69	
Rank											

Lab #	Intended		N Credits, lbs/A			Fertility Recommendations, lbs of Required Nutrients per Acre									
	Crop	Yield Goal	Past Crop	Subsoil	Haney	N	P_2O_5	K_2O	S	Zn	Mg	Fe	Mn	Cu	Lime T/A

Reviewed By: Emily Shafto
Date: 12/23/2022

Recommendations Provided by Regen Ag Lab, LLC
Analysis Performed by Regen Ag Lab, LLC

Regen Ag Lab, LLC
31740 Hwy 10, Pleasanton NE 68866

Gain Ground

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Regen Ag Lab

Account No.:	1421	Name:	DEBBIE REID	Grower:	ER EDWARDS AQUIFER ALL
Invoice No.:		Company:	EATER EDWARDS AQUIFER ALLIAN	Field ID:	OLMOS BASIN PARK
Date Recd:	12/20/2022	Address:	PO BOX 15618	Sample ID 1:	4
Date Repd:	12/22/2022	City, State, ZIP:	SAN ANTONIO, TX 78212	Sample ID 2:	
				Sample Depth:	0-6

HANEY SOIL HEALTH ANALYSIS

Lab #	Nitrogen									Phosphorus					
	H3A Extract			H2O Extract						H3A Extract					
	Nitrate ppm NO3-N	Ammonium ppm NH4-N	Inorg. N ppm N	Total N ppm N	Org. N ppm N	Org. N: Inorg. N	Org. N Rel. ppm N	Org. N Res. ppm N	Avail. N lbs/A	Total P ppm P	Inorg. P ppm PO4-P	Org. P ppm P	Org. P Rel ppm P	Org. P Res. ppm P	Avail. P lbs/A
30839	31.5	1.7	33.2	48.4	17.2	0.55	17.2	0.0	90.7	5.6	3.7	1.9	1.9	0.0	12.9
Rank															

Lab #	Other Soil Measures					Fertility									
						H3A Extract									
	Soil pH 1:1	Buffer pH Mod. WDRF	Soluble Salt mmho/cm	Excess Lime	Soil OM % LOI	Potassium ppm K	Calcium ppm Ca	Magnesium ppm Mg	Sodium ppm Na	Zinc ppm Zn	Manganese ppm Mn	Iron ppm Fe	Copper ppm Cu	Aluminum ppm Al	Sulfur ppm S
30839	7.9	-	0.30	HIGH	6.7	84	2784	87	16	0.24	0.6	7	0.05	10	15.21
Rank															

Lab #	Soil Health						Nitrogen Comparison				Reviewer Comments
		H2O Extract					Traditional	Haney	Differ.	Savings	
	Soil Resp. ppm CO2-C	Org. C ppm C	MAC %	C:N	SHC	Cover Crop Suggestion	N lbs/A	N lbs/A	N lbs/A	N $/A	
30839	235.9	231	102.0	13.46	23.19	20% Legume 80% Grass	56.7	90.7	34.0	35.36	
Rank											

Lab #	Intended		N Credits, lbs/A			Fertility Recommendations, lbs of Required Nutrients per Acre									
	Crop	Yield Goal	Past Crop	Subsoil	Haney	N	P2O5	K2O	S	Zn	Mg	Fe	Mn	Cu	Lime T/A

Reviewed By: Emily Shafto
Date: 12/23/2022

Recommendations Provided by Regen Ag Lab, LLC
Analysis Performed by Regen Ag Lab, LLC

Regen Ag Lab, LLC
31740 Hwy 10, Pleasanton NE 68866

Gain Ground

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Regen Ag Lab

Account No.:	1421	Name:	DEBBIE REID	Grower:	ER EDWARDS AQUIFER ALI
Invoice No.:		Company:	EATER EDWARDS AQUIFER ALLIAN	Field ID:	ALADO CREEK 1604 RIPARIA
Date Recd:	12/20/2022	Address:	PO BOX 15618	Sample ID 1:	5
Date Repd:	12/22/2022	City, State, ZIP:	SAN ANTONIO, TX 78212	Sample ID 2:	
				Sample Depth:	0-6

HANEY SOIL HEALTH ANALYSIS

Lab #	Nitrogen									Phosphorus					
	H3A Extract			H2O Extract						H3A Extract					
	Nitrate ppm NO3-N	Ammonium ppm NH4-N	Inorg. N ppm N	Total N ppm N	Org. N ppm N	Org. N: Inorg. N	Org. N Rel. ppm N	Org. N Res. ppm N	Avail. N lbs/A	Total P ppm P	Inorg. P ppm PO4-P	Org. P ppm P	Org. P Rel ppm P	Org. P Res. ppm P	Avail. P lbs/A
30840	15.5	2.1	17.6	35.9	18.7	1.08	18.7	0.0	65.2	2.8	2.0	0.8	0.8	0.0	6.5
Rank															

Lab #	Other Soil Measures					Fertility									
						H3A Extract									
	Soil pH 1:1	Buffer pH Mod. WDRF	Soluble Salt mmho/cm	Excess Lime	Soil OM % LOI	Potassium ppm K	Calcium ppm Ca	Magnesium ppm Mg	Sodium ppm Na	Zinc ppm Zn	Manganese ppm Mn	Iron ppm Fe	Copper ppm Cu	Aluminum ppm Al	Sulfur ppm S
30840	8.1	-	0.21	HIGH	8.0	85	2730	91	15	0.04	0.4	3	0.03	15	6.65
Rank															

Lab #	Soil Health						Nitrogen Comparison				Reviewer Comments
		H2O Extract									
	Soil Resp. ppm CO2-C	Org. C ppm C	MAC %	C:N	SHC	Cover Crop Suggestion	Traditional N lbs/A	Haney N lbs/A	Differ. N lbs/A	Savings N $/A	
30840	186.0	252	73.7	13.53	22.42	20% Legume 80% Grass	27.9	65.2	37.3	38.84	
Rank											

Lab #	Intended		N Credits, lbs/A			Fertility Recommendations, lbs of Required Nutrients per Acre									
	Crop	Yield Goal	Past Crop	Subsoil	Haney	N	P2O5	K2O	S	Zn	Mg	Fe	Mn	Cu	Lime T/A

Reviewed By: Emily Shafto
Date: 12/23/2022

Recommendations Provided by Regen Ag Lab, LLC
Analysis Performed by Regen Ag Lab, LLC

Regen Ag Lab, LLC
31740 Hwy 10, Pleasanton NE 68866

Gain Ground

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Regen Ag Lab

Account No.:	1421	Name:	DEBBIE REID	Grower:	TER EDWARDS AQUIFER ALL
Invoice No.:		Company:	EATER EDWARDS AQUIFER ALLIAN	Field ID:	RANCHO DIANE
Date Recd:	12/20/2022	Address:	PO BOX 15618	Sample ID 1:	6
Date Repd:	12/22/2022	City, State, ZIP:	SAN ANTONIO, TX 78212	Sample ID 2:	
				Sample Depth:	0-6

HANEY SOIL HEALTH ANALYSIS

Lab #	Nitrogen									Phosphorus					
	H3A Extract			H2O Extract						H3A Extract					
	Nitrate ppm NO3-N	Ammonium ppm NH4-N	Inorg. N ppm N	Total N ppm N	Org. N ppm N	Org. N: Inorg. N	Org. N Rel. ppm N	Org. N Res. ppm N	Avail. N lbs/A	Total P ppm P	Inorg. P ppm PO4-P	Org. P ppm P	Org. P Rel ppm P	Org. P Res. ppm P	Avail. P lbs/A
30841	6.6	1.5	8.1	18.3	8.1	0.79	8.1	0.0	29.0	1.6	1.5	0.2	0.2	0.0	3.8
Rank															

Lab #	Other Soil Measures					Fertility									
						H3A Extract									
	Soil pH 1:1	Buffer pH Mod. WDRF	Soluble Salt mmho/cm	Excess Lime	Soil OM % LOI	Potassium ppm K	Calcium ppm Ca	Magnesium ppm Mg	Sodium ppm Na	Zinc ppm Zn	Manganese ppm Mn	Iron ppm Fe	Copper ppm Cu	Aluminum ppm Al	Sulfur ppm S
30841	8.2	-	0.17	HIGH	5.3	45	2624	68	12	0.01	0.2	3	0.01	28	3.92
Rank															

Lab #	Soil Health						Nitrogen Comparison				Reviewer Comments
		H2O Extract									
	Soil Resp. ppm CO2-C	Org. C ppm C	MAC %	C:N	SHC	Cover Crop Suggestion	Traditional N lbs/A	Haney N lbs/A	Differ. N lbs/A	Savings N $/A	
30841	73.9	128	57.9	15.85	10.75	40% Legume 60% Grass	11.8	29.0	17.2	17.90	
Rank											

Lab #	Intended		N Credits, lbs/A			Fertility Recommendations, lbs of Required Nutrients per Acre									
	Crop	Yield Goal	Past Crop	Subsoil	Haney	N	P2O5	K2O	S	Zn	Mg	Fe	Mn	Cu	Lime T/A

Reviewed By: Emily Shafto
Date: 12/23/2022

Recommendations Provided by Regen Ag Lab, LLC
Analysis Performed by Regen Ag Lab, LLC

Regen Ag Lab, LLC
31740 Hwy 10, Pleasanton NE 68866

Gain Ground

308-627-0065
regenaglab.com

Regen Ag Lab

Account No.:	1421	Name:	DEBBIE REID
Invoice No.:		Company:	EATER EDWARDS AQUIFER ALLIAN
Date Recd:	12/20/2022	Address:	PO BOX 15618
Date Repd:	12/22/2022	City, State, ZIP:	SAN ANTONIO, TX 78212

Grower:	ER EDWARDS AQUIFER ALL
Field ID:	PEARSALL PARK
Sample ID 1:	7
Sample ID 2:	
Sample Depth:	0-6

HANEY SOIL HEALTH ANALYSIS

Lab #	Nitrogen									Phosphorus					
	H3A Extract			H2O Extract						H3A Extract					
	Nitrate ppm NO3-N	Ammonium ppm NH4-N	Inorg. N ppm N	Total N ppm N	Org. N ppm N	Org. N: Inorg. N	Org. N Rel. ppm N	Org. N Res. ppm N	Avail. N lbs/A	Total P ppm P	Inorg. P ppm PO4-P	Org. P ppm P	Org. P Rel ppm P	Org. P Res. ppm P	Avail. P lbs/A
30842	16.3	1.6	17.9	27.0	8.9	0.49	7.4	1.5	45.6	2.0	1.8	0.3	0.2	0.1	4.5
Rank															

Lab #	Other Soil Measures					Fertility									
						H3A Extract									
	Soil pH 1:1	Buffer pH Mod. WDRF	Soluble Salt mmho/cm	Excess Lime	Soil OM % LOI	Potassium ppm K	Calcium ppm Ca	Magnesium ppm Mg	Sodium ppm Na	Zinc ppm Zn	Manganese ppm Mn	Iron ppm Fe	Copper ppm Cu	Aluminum ppm Al	Sulfur ppm S
30842	8.2	-	0.31	HIGH	1.8	79	3005	132	33	0.01	0.4	3	0.01	18	19.60
Rank															

Lab #	Soil Health						Nitrogen Comparison				Reviewer Comments
		H2O Extract									
	Soil Resp. ppm CO2-C	Org. C ppm C	MAC %	C:N	SHC	Cover Crop Suggestion	Traditional N lbs/A	Haney N lbs/A	Differ. N lbs/A	Savings N $/A	
30842	22.1	107	20.7	11.99	5.24	50% Legume 50% Grass	29.3	45.6	16.2	16.85	
Rank											

Lab #	Intended		N Credits, lbs/A			Fertility Recommendations, lbs of Required Nutrients per Acre									
	Crop	Yield Goal	Past Crop	Subsoil	Haney	N	P2O5	K2O	S	Zn	Mg	Fe	Mn	Cu	Lime T/A

Reviewed By: Emily Shafto
Date: 12/23/2022

Recommendations Provided by Regen Ag Lab, LLC
Analysis Performed by Regen Ag Lab, LLC

Regen Ag Lab

Account No.:	1421	Name:	DEBBIE REID	Grower:	ER EDWARDS AQUIFER ALL
Invoice No.:		Company:	EATER EDWARDS AQUIFER ALLIAN	Field ID:	ALADO IBOU PARK CULVER
Date Recd:	12/20/2022	Address:	PO BOX 15618	Sample ID 1:	8
Date Repd:	12/22/2022	City, State, ZIP:	SAN ANTONIO, TX 78212	Sample ID 2:	
				Sample Depth:	0-6

HANEY SOIL HEALTH ANALYSIS

Lab #	Nitrogen									Phosphorus					
	H3A Extract			H2O Extract						H3A Extract					
	Nitrate ppm NO3-N	Ammonium ppm NH4-N	Inorg. N ppm N	Total N ppm N	Org. N ppm N	Org. N: Inorg. N	Org. N Rel. ppm N	Org. N Res. ppm N	Avail. N lbs/A	Total P ppm P	Inorg. P ppm PO4-P	Org. P ppm P	Org. P Rel ppm P	Org. P Res. ppm P	Avail. P lbs/A
30843	7.6	2.4	10.0	22.5	10.8	0.93	10.8	0.0	37.5	1.9	1.8	0.1	0.1	0.0	4.3
Rank															

Lab #	Other Soil Measures					Fertility									
						H3A Extract									
	Soil pH 1:1	Buffer pH Mod. WDRF	Soluble Salt mmho/cm	Excess Lime	Soil OM % LOI	Potassium ppm K	Calcium ppm Ca	Magnesium ppm Mg	Sodium ppm Na	Zinc ppm Zn	Manganese ppm Mn	Iron ppm Fe	Copper ppm Cu	Aluminum ppm Al	Sulfur ppm S
30843	8.2	-	0.19	HIGH	4.9	55	2698	59	52	0.02	0.3	3	0.01	16	7.16
Rank															

Lab #	Soil Health						Nitrogen Comparison				Reviewer Comments
		H2O Extract									
	Soil Resp. ppm CO2-C	Org. C ppm C	MAC %	C:N	SHC	Cover Crop Suggestion	Traditional N lbs/A	Haney N lbs/A	Differ. N lbs/A	Savings N $/A	
30843	81.7	111	73.4	10.29	11.48	40% Legume 60% Grass	13.7	37.5	23.8	24.78	
Rank											

Lab #	Intended		N Credits, lbs/A			Fertility Recommendations, lbs of Required Nutrients per Acre									
	Crop	Yield Goal	Past Crop	Subsoil	Haney	N	P2O5	K2O	S	Zn	Mg	Fe	Mn	Cu	Lime T/A

Reviewed By: Emily Shafto
Date: 12/23/2022

Recommendations Provided by Regen Ag Lab, LLC
Analysis Performed by Regen Ag Lab, LLC

Regen Ag Lab, LLC
31740 Hwy 10, Pleasanton NE 68866

Gain Ground

308-627-0065
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Account No.:	1421	Name:	DEBBIE REID
Invoice No.:		Company:	EATER EDWARDS AQUIFER ALLIAN
Date Recd:	12/20/2022	Address:	PO BOX 15618
Date Repd:	12/22/2022	City, State, ZIP:	SAN ANTONIO, TX 78212

Grower:	TER EDWARDS AQUIFER ALL
Field ID:	A RIVER NATURAL AREA RI
Sample ID 1:	9
Sample ID 2:	
Sample Depth:	0-6

HANEY SOIL HEALTH ANALYSIS

Lab #	Nitrogen									Phosphorus					
	H3A Extract			H2O Extract						H3A Extract					
	Nitrate ppm NO3-N	Ammonium ppm NH4-N	Inorg. N ppm N	Total N ppm N	Org. N ppm N	Org. N: Inorg. N	Org. N Rel. ppm N	Org. N Res. ppm N	Avail. N lbs/A	Total P ppm P	Inorg. P ppm PO4-P	Org. P ppm P	Org. P Rel ppm P	Org. P Res. ppm P	Avail. P lbs/A
30844	11.5	1.8	13.3	24.9	11.4	0.85	11.4	0.0	44.5	6.5	5.0	1.5	1.2	0.3	14.3
Rank															

Lab #	Other Soil Measures					Fertility									
						H3A Extract									
	Soil pH 1:1	Buffer pH Mod. WDRF	Soluble Salt mmho/cm	Excess Lime	Soil OM % LOI	Potassium ppm K	Calcium ppm Ca	Magnesium ppm Mg	Sodium ppm Na	Zinc ppm Zn	Manganese ppm Mn	Iron ppm Fe	Copper ppm Cu	Aluminum ppm Al	Sulfur ppm S
30844	8.1	-	0.25	HIGH	2.6	81	2870	134	27	0.04	0.6	9	0.01	11	20.36
Rank															

Lab #	Soil Health						Nitrogen Comparison				Reviewer Comments
		H2O Extract									
	Soil Resp. ppm CO2-C	Org. C ppm C	MAC %	C:N	SHC	Cover Crop Suggestion	Traditional N lbs/A	Haney N lbs/A	Differ. N lbs/A	Savings N $/A	
30844	39.6	147	27.0	12.85	8.03	50% Legume 50% Grass	20.7	44.5	23.8	24.72	
Rank											

Lab #	Intended		N Credits, lbs/A			Fertility Recommendations, lbs of Required Nutrients per Acre									
	Crop	Yield Goal	Past Crop	Subsoil	Haney	N	P2O5	K2O	S	Zn	Mg	Fe	Mn	Cu	Lime T/A

Reviewed By: Emily Shafto
Date: 12/23/2022

Recommendations Provided by Regen Ag Lab, LLC
Analysis Performed by Regen Ag Lab, LLC

Regen Ag Lab, LLC
31740 Hwy 10, Pleasanton NE 68866

Gain Ground

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Account No.:	1421	Name:	DEBBIE REID	Grower:	ER EDWARDS AQUIFER ALL
Invoice No.:		Company:	EATER EDWARDS AQUIFER ALLIAN	Field ID:	A RIVER NATURAL AREA U
Date Recd:	12/20/2022	Address:	PO BOX 15618	Sample ID 1:	10
Date Repd:	12/22/2022	City, State, ZIP:	SAN ANTONIO, TX 78212	Sample ID 2:	
				Sample Depth:	0-6

HANEY SOIL HEALTH ANALYSIS

Lab #	Nitrogen									Phosphorus					
	H3A Extract			H2O Extract						H3A Extract					
	Nitrate ppm NO3-N	Ammonium ppm NH4-N	Inorg. N ppm N	Total N ppm N	Org. N ppm N	Org. N: Inorg. N	Org. N Rel. ppm N	Org. N Res. ppm N	Avail. N lbs/A	Total P ppm P	Inorg. P ppm PO4-P	Org. P ppm P	Org. P Rel ppm P	Org. P Res. ppm P	Avail. P lbs/A
30845	34.9	5.6	40.5	49.3	10.9	0.28	10.9	0.0	92.4	2.9	2.4	0.4	0.4	0.1	6.5
Rank															

Lab #	Other Soil Measures					Fertility									
						H3A Extract									
	Soil pH 1:1	Buffer pH Mod. WDRF	Soluble Salt mmho/cm	Excess Lime	Soil OM % LOI	Potassium ppm K	Calcium ppm Ca	Magnesium ppm Mg	Sodium ppm Na	Zinc ppm Zn	Manganese ppm Mn	Iron ppm Fe	Copper ppm Cu	Aluminum ppm Al	Sulfur ppm S
30845	8.1	-	0.32	HIGH	2.6	167	3039	115	14	0.01	0.4	3	0.01	12	10.73
Rank															

Lab #	Soil Health						Nitrogen Comparison				Reviewer Comments
		H2O Extract									
	Soil Resp. ppm CO2-C	Org. C ppm C	MAC %	C:N	SHC	Cover Crop Suggestion	Traditional N lbs/A	Haney N lbs/A	Differ. N lbs/A	Savings N $/A	
30845	37.2	131	28.4	12.08	7.43	10% Legume 90% Grass	62.8	92.4	29.6	30.75	
Rank											

Lab #	Intended		N Credits, lbs/A			Fertility Recommendations, lbs of Required Nutrients per Acre									
	Crop	Yield Goal	Past Crop	Subsoil	Haney	N	P2O5	K2O	S	Zn	Mg	Fe	Mn	Cu	Lime T/A

Reviewed By: Emily Shafto
Date: 12/23/2022

Recommendations Provided by Regen Ag Lab, LLC
Analysis Performed by Regen Ag Lab, LLC

Regen Ag Lab, LLC
31740 Hwy 10, Pleasanton NE 68866

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Account No.:	1421	Name:	DEBBIE REID	Grower:	ATER EDWARDS AQUIFER ALLIA
Invoice No.:		Company:	EATER EDWARDS AQUIFER ALLIAN	Field ID:	WOOD LAWN LAKE RIPARIAN
Date Recd:	12/21/2022	Address:	PO BOX 15618	Sample ID 1:	SAMPLE 11
Date Repd:	12/23/2022	City, State, ZIP:	SAN ANTONIO, TX 78212	Sample ID 2:	
				Sample Depth:	0-6

HANEY SOIL HEALTH ANALYSIS

Lab #	Nitrogen									Phosphorus					
	H3A Extract			H2O Extract						H3A Extract					
	Nitrate ppm NO3-N	Ammonium ppm NH4-N	Inorg. N ppm N	Total N ppm N	Org. N ppm N	Org. N: Inorg. N	Org. N Rel. ppm N	Org. N Res. ppm N	Avail. N lbs/A	Total P ppm P	Inorg. P ppm PO4-P	Org. P ppm P	Org. P Rel ppm P	Org. P Res. ppm P	Avail. P lbs/A
31021	15.5	4.1	19.6	35.3	16.9	0.91	16.9	0.0	65.6	3.3	2.0	1.3	1.3	0.0	7.5
Rank															

Lab #	Other Soil Measures					Fertility									
						H3A Extract									
	Soil pH 1:1	Buffer pH Mod. WDRF	Soluble Salt mmho/cm	Excess Lime	Soil OM % LOI	Potassium ppm K	Calcium ppm Ca	Magnesium ppm Mg	Sodium ppm Na	Zinc ppm Zn	Manganese ppm Mn	Iron ppm Fe	Copper ppm Cu	Aluminum ppm Al	Sulfur ppm S
31021	7.6	-	1.10	HIGH	4.2	106	3171	137	196	0.17	0.8	6	0.07	17	306.35
Rank															

Lab #	Soil Health						Nitrogen Comparison				Reviewer Comments
		H2O Extract									
	Soil Resp. ppm CO2-C	Org. C ppm C	MAC %	C:N	SHC	Cover Crop Suggestion	Traditional N lbs/A	Haney N lbs/A	Differ. N lbs/A	Savings N $/A	
31021	185.7	220	84.6	13.04	21.55	20% Legume 80% Grass	27.9	65.6	37.7	39.18	
Rank											

Lab #	Intended		N Credits, lbs/A			Fertility Recommendations, lbs of Required Nutrients per Acre									
	Crop	Yield Goal	Past Crop	Subsoil	Haney	N	P2O5	K2O	S	Zn	Mg	Fe	Mn	Cu	Lime T/A

Reviewed By: Emily Shafto
Date: 12/28/2022

Recommendations Provided by Regen Ag Lab, LLC
Analysis Performed by Regen Ag Lab, LLC

Regen Ag Lab, LLC
31740 Hwy 10, Pleasanton NE 68866

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Account No.:	1421	Name:	DEBBIE REID	Grower:	ATER EDWARDS AQUIFER ALLIA
Invoice No.:		Company:	EATER EDWARDS AQUIFER ALLIAN	Field ID:	WOOD LAWN LAKE UPLAND
Date Recd:	12/21/2022	Address:	PO BOX 15618	Sample ID 1:	SAMPLE 12
Date Repd:	12/23/2022	City, State, ZIP:	SAN ANTONIO, TX 78212	Sample ID 2:	
				Sample Depth:	0-6

HANEY SOIL HEALTH ANALYSIS

Lab #	Nitrogen									Phosphorus					
	H3A Extract			H2O Extract						H3A Extract					
	Nitrate ppm NO3-N	Ammonium ppm NH4-N	Inorg. N ppm N	Total N ppm N	Org. N ppm N	Org. N: Inorg. N	Org. N Rel. ppm N	Org. N Res. ppm N	Avail. N lbs/A	Total P ppm P	Inorg. P ppm PO4-P	Org. P ppm P	Org. P Rel ppm P	Org. P Res. ppm P	Avail. P lbs/A
31022	42.0	2.1	44.1	63.1	18.8	0.42	18.8	0.0	113.2	5.6	3.4	2.2	2.2	0.0	12.8
Rank															

Lab #	Other Soil Measures					Fertility									
						H3A Extract									
	Soil pH 1:1	Buffer pH Mod. WDRF	Soluble Salt mmho/cm	Excess Lime	Soil OM % LOI	Potassium ppm K	Calcium ppm Ca	Magnesium ppm Mg	Sodium ppm Na	Zinc ppm Zn	Manganese ppm Mn	Iron ppm Fe	Copper ppm Cu	Aluminum ppm Al	Sulfur ppm S
31022	7.7	-	0.63	HIGH	5.0	151	2836	143	22	0.06	0.4	4	0.07	22	20.74
Rank															

Lab #	Soil Health						Nitrogen Comparison				Reviewer Comments
		H2O Extract					Traditional	Haney	Differ.	Savings	
	Soil Resp. ppm CO2-C	Org. C ppm C	MAC %	C:N	SHC	Cover Crop Suggestion	N lbs/A	N lbs/A	N lbs/A	N $/A	
31022	162.5	279	58.2	14.85	21.01	10% Legume 90% Grass	75.6	113.2	37.6	39.13	
Rank											

Lab #	Intended		N Credits, lbs/A			Fertility Recommendations, lbs of Required Nutrients per Acre									
	Crop	Yield Goal	Past Crop	Subsoil	Haney	N	P2O5	K2O	S	Zn	Mg	Fe	Mn	Cu	Lime T/A

Reviewed By: Emily Shafto
Date: 12/28/2022

Recommendations Provided by Regen Ag Lab, LLC
Analysis Performed by Regen Ag Lab, LLC

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Account No.:	1421	Name:	DEBBIE REID	Grower:	GREATER EDWARDS AQUIFER ALLIANCE
Invoice No.:		Company:	EATER EDWARDS AQUIFER ALLIAN	Field ID:	SOUTHSIDE LIONS RIPARIAN
Date Recd:	12/27/2022	Address:	PO BOX 15618	Sample ID 1:	13
Date Repd:	12/29/2022	City, State, ZIP:	SAN ANTONIO, TX 78212	Sample ID 2:	
				Sample Depth:	0-6

HANEY SOIL HEALTH ANALYSIS

Lab #	Nitrogen									Phosphorus					
	H3A Extract			H2O Extract						H3A Extract					
	Nitrate ppm NO3-N	Ammonium ppm NH4-N	Inorg. N ppm N	Total N ppm N	Org. N ppm N	Org. N: Inorg. N	Org. N Rel. ppm N	Org. N Res. ppm N	Avail. N lbs/A	Total P ppm P	Inorg. P ppm PO4-P	Org. P ppm P	Org. P Rel ppm P	Org. P Res. ppm P	Avail. P lbs/A
31476	11.0	2.1	13.1	34.2	20.1	1.42	20.1	0.0	59.8	3.1	2.1	1.1	1.1	0.0	7.2
Rank															

Lab #	Other Soil Measures					Fertility									
						H3A Extract									
	Soil pH 1:1	Buffer pH Mod. WDRF	Soluble Salt mmho/cm	Excess Lime	Soil OM % LOI	Potassium ppm K	Calcium ppm Ca	Magnesium ppm Mg	Sodium ppm Na	Zinc ppm Zn	Manganese ppm Mn	Iron ppm Fe	Copper ppm Cu	Aluminum ppm Al	Sulfur ppm S
31476	7.9	-	0.37	HIGH	5.2	82	2800	97	21	0.12	0.3	9	0.04	15	12.51
Rank															

Lab #	Soil Health						Nitrogen Comparison				Reviewer Comments
		H2O Extract									
	Soil Resp. ppm CO2-C	Org. C ppm C	MAC %	C:N	SHC	Cover Crop Suggestion	Traditional N lbs/A	Haney N lbs/A	Differ. N lbs/A	Savings N $/A	
31476	87.8	264	33.3	13.10	16.06	30% Legume 70% Grass	19.8	59.8	40.0	41.60	
Rank											

Lab #	Intended		N Credits, lbs/A			Fertility Recommendations, lbs of Required Nutrients per Acre									
	Crop	Yield Goal	Past Crop	Subsoil	Haney	N	P2O5	K2O	S	Zn	Mg	Fe	Mn	Cu	Lime T/A

Reviewed By: Emily Shafto
Date: 12/29/2022

Recommendations Provided by Regen Ag Lab, LLC
Analysis Performed by Regen Ag Lab, LLC

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31740 Hwy 10, Pleasanton NE 68866

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Gain Ground

Regen Ag Lab

Account No.:	1421	Name:	DEBBIE REID
Invoice No.:		Company:	EATER EDWARDS AQUIFER ALLIAN
Date Recd:	12/27/2022	Address:	PO BOX 15618
Date Repd:	12/29/2022	City, State, ZIP:	SAN ANTONIO, TX 78212

Grower:	GREATER EDWARDS AQUIFER ALLIANCE
Field ID:	MILAM TEALER UPLAND
Sample ID 1:	14
Sample ID 2:	
Sample Depth:	0-6

HANEY SOIL HEALTH ANALYSIS

Lab #	Nitrogen									Phosphorus					
	H3A Extract			H2O Extract						H3A Extract					
	Nitrate ppm NO3-N	Ammonium ppm NH4-N	Inorg. N ppm N	Total N ppm N	Org. N ppm N	Org. N: Inorg. N	Org. N Rel. ppm N	Org. N Res. ppm N	Avail. N lbs/A	Total P ppm P	Inorg. P ppm PO4-P	Org. P ppm P	Org. P Rel ppm P	Org. P Res. ppm P	Avail. P lbs/A
31477	49.1	1.8	50.9	69.8	18.0	0.35	14.6	3.3	117.9	6.5	5.0	1.5	0.9	0.6	13.6
Rank															

Lab #	Other Soil Measures					Fertility									
						H3A Extract									
	Soil pH 1:1	Buffer pH Mod. WDRF	Soluble Salt mmho/cm	Excess Lime	Soil OM % LOI	Potassium ppm K	Calcium ppm Ca	Magnesium ppm Mg	Sodium ppm Na	Zinc ppm Zn	Manganese ppm Mn	Iron ppm Fe	Copper ppm Cu	Aluminum ppm Al	Sulfur ppm S
31477	7.9	-	0.50	HIGH	3.8	149	2646	108	20	0.02	0.4	5	0.08	31	14.97
Rank															

Lab #	Soil Health						Nitrogen Comparison				Reviewer Comments
		H2O Extract									
	Soil Resp. ppm CO2-C	Org. C ppm C	MAC %	C:N	SHC	Cover Crop Suggestion	Traditional N lbs/A	Haney N lbs/A	Differ. N lbs/A	Savings N $/A	
31477	46.7	229	20.3	12.77	11.05	10% Legume 90% Grass	88.4	117.9	29.5	30.65	
Rank											

Lab #	Intended		N Credits, lbs/A			Fertility Recommendations, lbs of Required Nutrients per Acre									
	Crop	Yield Goal	Past Crop	Subsoil	Haney	N	P2O5	K2O	S	Zn	Mg	Fe	Mn	Cu	Lime T/A

Reviewed By: Emily Shafto
Date: 12/29/2022

Recommendations Provided by Regen Ag Lab, LLC
Analysis Performed by Regen Ag Lab, LLC

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Gain Ground

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Regen Ag Lab

Account No.:	1421	Name:	DEBBIE REID	Grower:	GREATER EDWARDS AQUIFER ALLIANCE
Invoice No.:		Company:	EATER EDWARDS AQUIFER ALLIAN	Field ID:	MILAM TEALER POCKET PRAIRIE
Date Recd:	12/27/2022	Address:	PO BOX 15618	Sample ID 1:	15
Date Repd:	12/29/2022	City, State, ZIP:	SAN ANTONIO, TX 78212	Sample ID 2:	
				Sample Depth:	0-6

HANEY SOIL HEALTH ANALYSIS

Lab #	Nitrogen									Phosphorus					
	H3A Extract			H2O Extract						H3A Extract					
	Nitrate ppm NO3-N	Ammonium ppm NH4-N	Inorg. N ppm N	Total N ppm N	Org. N ppm N	Org. N: Inorg. N	Org. N Rel. ppm N	Org. N Res. ppm N	Avail. N lbs/A	Total P ppm P	Inorg. P ppm PO4-P	Org. P ppm P	Org. P Rel ppm P	Org. P Res. ppm P	Avail. P lbs/A
31478	17.1	1.8	18.9	40.5	20.9	1.06	20.9	0.0	71.6	8.0	5.7	2.3	2.3	0.0	18.5
Rank															

Lab #	Other Soil Measures					Fertility									
						H3A Extract									
	Soil pH 1:1	Buffer pH Mod. WDRF	Soluble Salt mmho/cm	Excess Lime	Soil OM % LOI	Potassium ppm K	Calcium ppm Ca	Magnesium ppm Mg	Sodium ppm Na	Zinc ppm Zn	Manganese ppm Mn	Iron ppm Fe	Copper ppm Cu	Aluminum ppm Al	Sulfur ppm S
31478	8.0	-	0.45	HIGH	3.9	133	2204	154	22	0.09	0.5	9	0.09	51	12.40
Rank															

Lab #	Soil Health						Nitrogen Comparison				Reviewer Comments
		H2O Extract									
	Soil Resp. ppm CO2-C	Org. C ppm C	MAC %	C:N	SHC	Cover Crop Suggestion	Traditional N lbs/A	Haney N lbs/A	Differ. N lbs/A	Savings N $/A	
31478	90.9	268	33.9	12.87	16.55	30% Legume 70% Grass	30.8	71.6	40.8	42.41	
Rank											

Lab #	Intended		N Credits, lbs/A			Fertility Recommendations, lbs of Required Nutrients per Acre									
	Crop	Yield Goal	Past Crop	Subsoil	Haney	N	P2O5	K2O	S	Zn	Mg	Fe	Mn	Cu	Lime T/A

Reviewed By: Emily Shafto
Date: 12/29/2022

Recommendations Provided by Regen Ag Lab, LLC
Analysis Performed by Regen Ag Lab, LLC

Regen Ag Lab, LLC
31740 Hwy 10, Pleasanton NE 68866

Gain Ground

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Account No.:	1421	Name:	DEBBIE REID
Invoice No.:		Company:	EATER EDWARDS AQUIFER ALLIAN
Date Recd:	12/27/2022	Address:	PO BOX 15618
Date Repd:	12/29/2022	City, State, ZIP:	SAN ANTONIO, TX 78212

Grower:	GREATER EDWARDS AQUIFER ALLIANCE
Field ID:	LEVI STRAUSS PARK RIPARIAN
Sample ID 1:	16
Sample ID 2:	
Sample Depth:	0-6

HANEY SOIL HEALTH ANALYSIS

Lab #	Nitrogen									Phosphorus					
	H3A Extract			H2O Extract						H3A Extract					
	Nitrate ppm NO3-N	Ammonium ppm NH4-N	Inorg. N ppm N	Total N ppm N	Org. N ppm N	Org. N: Inorg. N	Org. N Rel. ppm N	Org. N Res. ppm N	Avail. N lbs/A	Total P ppm P	Inorg. P ppm PO4-P	Org. P ppm P	Org. P Rel ppm P	Org. P Res. ppm P	Avail. P lbs/A
31479	12.0	1.8	13.8	31.7	16.9	1.14	16.9	0.0	55.3	3.9	3.0	0.9	0.8	0.1	8.7
Rank															

Lab #	Other Soil Measures					Fertility									
						H3A Extract									
	Soil pH 1:1	Buffer pH Mod. WDRF	Soluble Salt mmho/cm	Excess Lime	Soil OM % LOI	Potassium ppm K	Calcium ppm Ca	Magnesium ppm Mg	Sodium ppm Na	Zinc ppm Zn	Manganese ppm Mn	Iron ppm Fe	Copper ppm Cu	Aluminum ppm Al	Sulfur ppm S
31479	8.1	-	0.30	HIGH	4.3	156	2823	83	16	0.03	0.3	4	0.05	12	8.71
Rank															

Lab #	Soil Health						Nitrogen Comparison				Reviewer Comments
		H2O Extract									
	Soil Resp. ppm CO2-C	Org. C ppm C	MAC %	C:N	SHC	Cover Crop Suggestion	Traditional N lbs/A	Haney N lbs/A	Differ. N lbs/A	Savings N $/A	
31479	62.1	213	29.2	12.59	12.16	40% Legume 60% Grass	21.6	55.3	33.7	35.02	
Rank											

Lab #	Intended		N Credits, lbs/A			Fertility Recommendations, lbs of Required Nutrients per Acre									
	Crop	Yield Goal	Past Crop	Subsoil	Haney	N	P2O5	K2O	S	Zn	Mg	Fe	Mn	Cu	Lime T/A

Reviewed By: Emily Shafto
Date: 12/29/2022

Recommendations Provided by Regen Ag Lab, LLC
Analysis Performed by Regen Ag Lab, LLC

Regen Ag Lab, LLC
31740 Hwy 10, Pleasanton NE 68866

Gain Ground

308-627-0065
regenaglab.com

Regen Ag Lab

Account No.:	1421	Name:	DEBBIE REID
Invoice No.:		Company:	EATER EDWARDS AQUIFER ALLIAN
Date Recd:	12/27/2022	Address:	PO BOX 15618
Date Repd:	12/29/2022	City, State, ZIP:	SAN ANTONIO, TX 78212

Grower:	GREATER EDWARDS AQUIFER ALLIANCE
Field ID:	WEST SIDE CREEKS RIPARIAN
Sample ID 1:	17
Sample ID 2:	
Sample Depth:	0-6

HANEY SOIL HEALTH ANALYSIS

Lab #	Nitrogen									Phosphorus					
	H3A Extract			H2O Extract						H3A Extract					
	Nitrate ppm NO3-N	Ammonium ppm NH4-N	Inorg. N ppm N	Total N ppm N	Org. N ppm N	Org. N: Inorg. N	Org. N Rel. ppm N	Org. N Res. ppm N	Avail. N lbs/A	Total P ppm P	Inorg. P ppm PO4-P	Org. P ppm P	Org. P Rel ppm P	Org. P Res. ppm P	Avail. P lbs/A
31480	4.9	3.1	8.0	22.8	14.6	1.79	14.6	0.0	40.6	2.3	1.8	0.5	0.5	0.0	5.3
Rank															

Lab #	Other Soil Measures					Fertility									
						H3A Extract									
	Soil pH 1:1	Buffer pH Mod. WDRF	Soluble Salt mmho/cm	Excess Lime	Soil OM % LOI	Potassium ppm K	Calcium ppm Ca	Magnesium ppm Mg	Sodium ppm Na	Zinc ppm Zn	Manganese ppm Mn	Iron ppm Fe	Copper ppm Cu	Aluminum ppm Al	Sulfur ppm S
31480	8.2	-	0.27	HIGH	2.8	79	2859	81	24	0.10	0.5	5	0.04	16	8.53
Rank															

Lab #	Soil Health						Nitrogen Comparison				Reviewer Comments
		H2O Extract									
	Soil Resp. ppm CO2-C	Org. C ppm C	MAC %	C:N	SHC	Cover Crop Suggestion	Traditional N lbs/A	Haney N lbs/A	Differ. N lbs/A	Savings N $/A	
31480	78.6	202	38.9	13.83	13.35	40% Legume 60% Grass	8.8	40.6	31.8	33.10	
Rank											

Lab #	Intended		N Credits, lbs/A			Fertility Recommendations, lbs of Required Nutrients per Acre									
	Crop	Yield Goal	Past Crop	Subsoil	Haney	N	P2O5	K2O	S	Zn	Mg	Fe	Mn	Cu	Lime T/A

Reviewed By: Emily Shafto
Date: 12/29/2022

Recommendations Provided by Regen Ag Lab, LLC
Analysis Performed by Regen Ag Lab, LLC

Regen Ag Lab, LLC
31740 Hwy 10, Pleasanton NE 68866

Gain Ground

308-627-0065
regenaglab.com

Regen Ag Lab

Account No.:	1421	Name:	DEBBIE REID	Grower:	GEAA
Invoice No.:		Company:	GEAA	Field ID:	OLD SPANISH TRAILS DETENTION
Date Recd:	1/30/2023	Address:	PO BOX 15618	Sample ID 1:	SAMPLE 18
Date Repd:	2/1/2023	City, State, ZIP:	SAN ANTONIO, TX 78212	Sample ID 2:	
				Sample Depth:	0-6

HANEY SOIL HEALTH ANALYSIS

Lab #	Nitrogen									Phosphorus					
	H3A Extract			H2O Extract						H3A Extract					
	Nitrate ppm NO3-N	Ammonium ppm NH4-N	Inorg. N ppm N	Total N ppm N	Org. N ppm N	Org. N: Inorg. N	Org. N Rel. ppm N	Org. N Res. ppm N	Avail. N lbs/A	Total P ppm P	Inorg. P ppm PO4-P	Org. P ppm P	Org. P Rel ppm P	Org. P Res. ppm P	Avail. P lbs/A
1278	29.7	2.4	32.1	53.2	19.6	0.58	19.6	0.0	93.1	7.5	5.2	2.3	2.3	0.0	17.2
Rank															

Lab #	Other Soil Measures					Fertility									
						H3A Extract									
	Soil pH 1:1	Buffer pH Mod. WDRF	Soluble Salt mmho/cm	Excess Lime	Soil OM % LOI	Potassium ppm K	Calcium ppm Ca	Magnesium ppm Mg	Sodium ppm Na	Zinc ppm Zn	Manganese ppm Mn	Iron ppm Fe	Copper ppm Cu	Aluminum ppm Al	Sulfur ppm S
1278	7.9	-	0.33	HIGH	6.5	167	2757	140	73	0.14	1.2	10	0.08	17	16.25
Rank															

Lab #	Soil Health						Nitrogen Comparison				Reviewer Comments
		H2O Extract									
	Soil Resp. ppm CO2-C	Org. C ppm C	MAC %	C:N	SHC	Cover Crop Suggestion	Traditional N lbs/A	Haney N lbs/A	Differ. N lbs/A	Savings N $/A	
1278	117.9	265	44.5	13.50	17.09	30% Legume 70% Grass	53.5	93.1	39.6	41.22	
Rank											

Lab #	Intended		N Credits, lbs/A			Fertility Recommendations, lbs of Required Nutrients per Acre									
	Crop	Yield Goal	Past Crop	Subsoil	Haney	N	P2O5	K2O	S	Zn	Mg	Fe	Mn	Cu	Lime T/A

Reviewed By: Emily Shafto
Date: 2/2/2023

Recommendations Provided by Regen Ag Lab, LLC
Analysis Performed by Regen Ag Lab, LLC

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