

Plant Community Characterization in Stormwater Control Measure Water Quality Basins within Austin, Texas

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Abstract

Stormwater control measures (SCMs) within the City of Austin are used to sequester and/or process non-point source pollutants in urban stormwater runoff. Biofiltration SCMs incorporate the chemical, biological, and physical properties of plants, microbes, and substrates as part of the treatment to remove pollutants from surface waters before discharging into local waterways. Plant communities within biofiltration systems remain understudied within in-situ environments, given the variety of environmental variables found in the local Austin area. This project examined plant communities within both sand sedimentation/filtration and biofiltration sedimentation/filtration SCMs to characterize the plant community, develop a list of common species adapted to environmental conditions in water quality SCMs, and identify any environmental variables which contribute to differentiation between SCM types. Results of a vegetation field survey and multi-variate data analysis identified the prevalence of non-native grasses exerting disproportionate control over ecosystem structure and function in sand and biofiltration SCMs. Plant species success is primarily driven by disturbance regimes, particularly in hydrologic fluctuations and vegetation management. These disturbances facilitate colonization by low-growing species adapted to mechanical disturbance, such as bermudagrass (*Cynodon dactylon*) and straggler daisy (*Calyptracarpus vialis*). Drought conditions are presumed to have exacerbated SCM plant community homogeneity during the Fall 2024 survey, suppressing the ability to provide environmental gradient inference. The Spring 2025 dataset exhibited greater heterogeneity, determined by maintenance activities. Unmaintained systems generally supported desirable native bunchgrasses and forb species, which was substantiated by the clustering analysis. Drought conditions and maintenance regimes should be taken into consideration when

designing, permitting, and inspecting biofiltration SCMs across the City of Austin. Recommendations to improve SCM systems include removal of the 18-inch height requirement for vegetation within biofiltration systems, a warranty period following SCM construction to correct vegetation planting failures, and additional educational signage at biofiltration facilities to clarify the intent of ecologically functioning systems.

Keywords: Stormwater Control Measure ▪ SCM ▪ Biofiltration ▪ Rain Garden ▪ Plant Ecology ▪ Stormwater

Introduction

Non-point source pollutants in urban stormwater runoff can negatively affect surface water quality throughout Austin-area streams, reservoirs, and the Colorado River. A Stormwater Control Measures (SCM) is defined by the Environmental Protection Agency (EPA) as “a technique, measure or structural control that is used for a given set of conditions to manage the quantity and improve the quality of storm water runoff in the most cost-effective manner” (EPA 1999). Constructed or engineered systems designed to mitigate non-point source pollution by retaining sediment and other constituents such as organic and inorganic particulate, bacteria, nutrients, and metals from the water column are structural controls. Sedimentation and filtration SCMs are the primary structural water quality control used to reduce non-point source pollution across the City of Austin’s (herein referred to as “the City”) regulated watersheds including the classifications of urban, suburban, water supply urban, and water supply rural watershed landscapes outside of the Barton Springs Zone as defined in the Land Development Code § 25-8-2 (Descriptions of Regulated Areas)(City of Austin 2026).

As provided by *Section 1.6.5 of the City’s Environmental Criteria Manual* (ECM), a full sedimentation with filtration system includes a sediment basin which receives the water quality volume and is designed to detain it for a drawdown time of 48-96 hours. As defined in the ECM Section 1.6.2, the “water quality volume” is the minimum volume of stormwater runoff for treatment captured by the SCM sedimentation basin. Stormwater detained in the sedimentation basin discharges into the filtration basin through an outlet structure, such as a riser pipe. The filtration basin consists of the filtration inlet structure, a filter bed, an underdrain piping, and a basin liner.

In a full sedimentation/sand filtration (FSF) SCM, runoff is screened through a sand bed with a gravel layer to filter pollutants before discharging into local waterways. ECM Section 1.6.7 (*Green Storm Water Quality Infrastructure*) describes the design criteria for full biofiltration sedimentation/filtration (FBF) SCMs which use the chemical, biological, and physical properties of plants, microbes, and substrates to remove pollutants from urban stormwater runoff. In comparison to the traditional FSF SCM, pollutants are filtered through a biofiltration medium by gravity-fed hydraulics, filter media characteristics, and plant physiological architecture. Biofiltration is noted as being functionally equivalent to the more traditional sand filtration systems

in the ECM. However, biological uptake can potentially improve the performance of nutrient removal and enhance the removal of heavy metals, petroleum hydrocarbons, and polycyclic aromatic hydrocarbons (PAHs) via phytoremediation (Pilon-Smits 2005; Schnoor et al. 1995). Previous work done by WPD has documented biofiltration designs which included a saturated zone reduced the load of nutrients (total nitrogen and total phosphorus) and some metals such as zinc more effectively than the more traditional sand/filter design (Richter 2018). The removal of total suspended solids was documented as being equivalent between designs.

As part of the biofiltration design, a diverse suite of plant species is required (although City maintained projects may use only turf and/or ground cover only) based on their viability in alternating drought and inundated hydrologic environments; however, the ability of the biofiltration basin to maintain water quality standards and soil stabilization remains the highest functional priority. Current design measures suggest a selection of plants which is limited, due to the medium depth of 1.5-feet. Non-native and noxious plant species are not allowed or are not recommended in biofiltration facilities.

Optimal implementation of biofiltration systems is dependent on correctly selecting plant species as well as careful attention to filter medium mixture (Oversby et al. 2014). The correct selection of plant species has indicated that biofiltration systems are able to remove a range of pollutants from stormwater runoff including metals, sediment, nitrogen, phosphorus, and pathogens while also increasing water infiltration rates particularly for studies using shrubs and small trees (Read et al. 2008a; Hatt et al. 2009; Oversby et al. 2014; Payne et al. 2018; Szota et al. 2024). Urban landscape designers often advocate for a diverse range of plant species with extensive root systems to be selected for biofiltration systems as functional plant diversity can allow effective species to thrive within the biofilter environment, support growth and productivity, and increase rapid uptake of nutrient pulses passing through the filter medium during stormwater inflow events (Oversby et al. 2014; Payne et al. 2018). However, rarely do research studies on biofiltration systems aim to understand plant species present within these SCMs in-situ. A variety of research studies have relied on controlled greenhouse environments for understanding biofiltration systems, but they do not consider the microcosm of variable dynamics which may contribute to plant species expression present within SCM basins in urban environments (Read et al. 2008; Hatt et al. 2009; Payne et al. 2015; Barrett et al. 2013; Payne et al. 2018).

Though it is often recommended by environmental regulators and urban landscape designers to use a variety of native plant species in biofiltration systems, a meta-analysis of biofiltration systems identified no empirical research evidence to support this guidance when considering the functionality of the hydrologic and pollutant treatment performance (Dagenais et al. 2018). However, when considering the implementation of biofiltration SCMs in urban systems, local biodiversity, aesthetic value, social acceptance, and climate resilience should also be considered. Current knowledge gaps exist pertaining to plant-microbial interactions in biofiltration systems and their effects on nutrient acquisition. Additional research is needed to expand the current geographic scope of research studies in biofiltration systems as studies in one climate may not be applicable to others (Dagenais et al. 2018). Further, additional research may be needed to determine the ability of plants to effectively remove pollutants while being grown in competition with each other, as plants may behave differently in planted mixtures due to inter-species interactions.

The ECM currently recommends that landscape designers implement planting plans that use species from the *Grow Green Native and Adapted Landscape Plants* guide when designing biofiltration SCMs; however, no additional plant species requirements accounting for periodic fluctuations in wet/dry conditions, functional diversity, or compatibility with the biofilter medium are provided. The City requires a minimum of five different species to be planted, and a certain percentage of the basins should be planted with one-gallon rooted plants to provide immediate temporary stabilization. An alternative design may be allowed with approval by City staff; therefore, consistency in planting plans City-wide has not been established. The City requires routine maintenance of biofiltration basins according to the ECM 1.6.3 Maintenance and Construction Requirements; maintenance is often conducted by private Homeowner's Associations or third-party contractors for the privately maintained SCMs. Therefore, maintenance methods are not always consistently applied throughout the City. Furthermore, inspections by City staff are conducted on an annual basis for City-maintained SCMs or three-year cycle for privately maintained SCMs. Lapses in maintenance may therefore go unnoticed for up to three years. When intensive mechanical maintenance regimes are adopted, the compliance inspections lead to notice of violations, corrective actions, and costs due to the absence of vegetation plantings within biofiltration systems.

As of April 2026, Austin Watershed Protection (WPD) oversees the maintenance of 1,798 SCMs throughout the city. Of those, 46 are FBF SCMs with a combination of full or partial diverse vegetation management plans included in the original civil engineering designs approved by the City. Vegetation maintenance in FBF basins is a common environmental compliance and monitoring issue for both private and City-owned water quality SCMs. A review of work orders created by City inspection staff reveals the FBF SCMs lack the presence of vegetation or have low plant survivability due to mechanical removal. In addition, these facilities are issued notices of violation for the presence of standing water. A better understanding of the vegetation communities within water quality SCMs across the city can assist in maintaining SCM compliance, as well as inform WPD staff on ways to relieve costs associated with maintenance activities.

To our knowledge, there has been no previous WPD published characterization study of the plant communities typically present in FSF and FBF water quality controls within the City of Austin. This project focused on identifying plant communities within water quality SCMs, as well as environmental parameters which may be contributing to plant community expression.

This project evaluated the plant communities present within 44 water quality SCMs throughout the City's full-purpose jurisdiction. The specific project objectives included:

1. Characterize the plant community composition present within FSF, FBF, partial sand filtration (PSF), and partial biofiltration (PBF) water quality SCMs.
2. Develop a list of plant species that are common and appear adapted to environmental conditions in water quality SCM basins in-situ.
3. Describe the plant species traits such as the origin of the species, duration of the species, morphological habit structure of the species, and the 2022 U.S. Army Corps of Engineers Great Plains Region National Wetland Plant List classification of the species present that appear better adapted to existing environmental conditions in FBF and PBF SCMs. Plant species will also be identified in FSF and PSF systems to better identify possible environmental factors which contribute to plant species differentiation across the City.
4. Identify environmental variables and structural patterns which contribute to plant species differentiation within FSF and FBF systems.

A better understanding of plant community assemblages in water quality SCMs will provide practical information to assess and update the City's ECM. Improved understanding of plant species expression and vegetation structure in water quality SCMs may specifically assist with informing the ECM Section 1.6.7 recommendations for biofiltration SCM planting plans based on ecological plant community dynamic principles, informing the ECM Section 1.6.7 recommendations for biofiltration SCMs maintenance provisions aimed at improving planted vegetation survival, and inform recommendations for inspection protocols (criteria for vegetation success, function, etc.).

Methods

Site Selection

We selected SCMs which align with the categories of FSF, FBF, PSF, and PBF systems. The resulting list was composed of four types of SCMs. From the initial list of >10,000 privately- and publicly-owned SCMs located throughout the City, we applied a criteria that excluded SCMs which may contribute confounding effects of clay-based liners, stacked detention, City retrofits, SCMs built before 2009 due to updated code and criteria, any SCMs which may have pump functionality errors, SCMs with reported influence of groundwater and/or drainage issues, SCM facilities located underground which would not contain plant communities, and any SCMs located within the extra-territorial jurisdiction area due to changing Texas-state level laws and ordinances.

After the exclusion criteria was applied, a random list of sites was generated in the R programming language (R Core Team 2026) through the RStudio integrated development environment (IDE)(Posit Team 2026) using the "randomizeR" package (Schindler et al. 2015). This randomization exercise generated a list of 44 SCMs (n=44) of which 12 were FSF, 11 PBF, 11 PSF, and 10 FBF SCMs. Selected sites were largely concentrated in the eastern half of the City's full-purpose jurisdiction, due to study exclusion criteria (Figure 1).

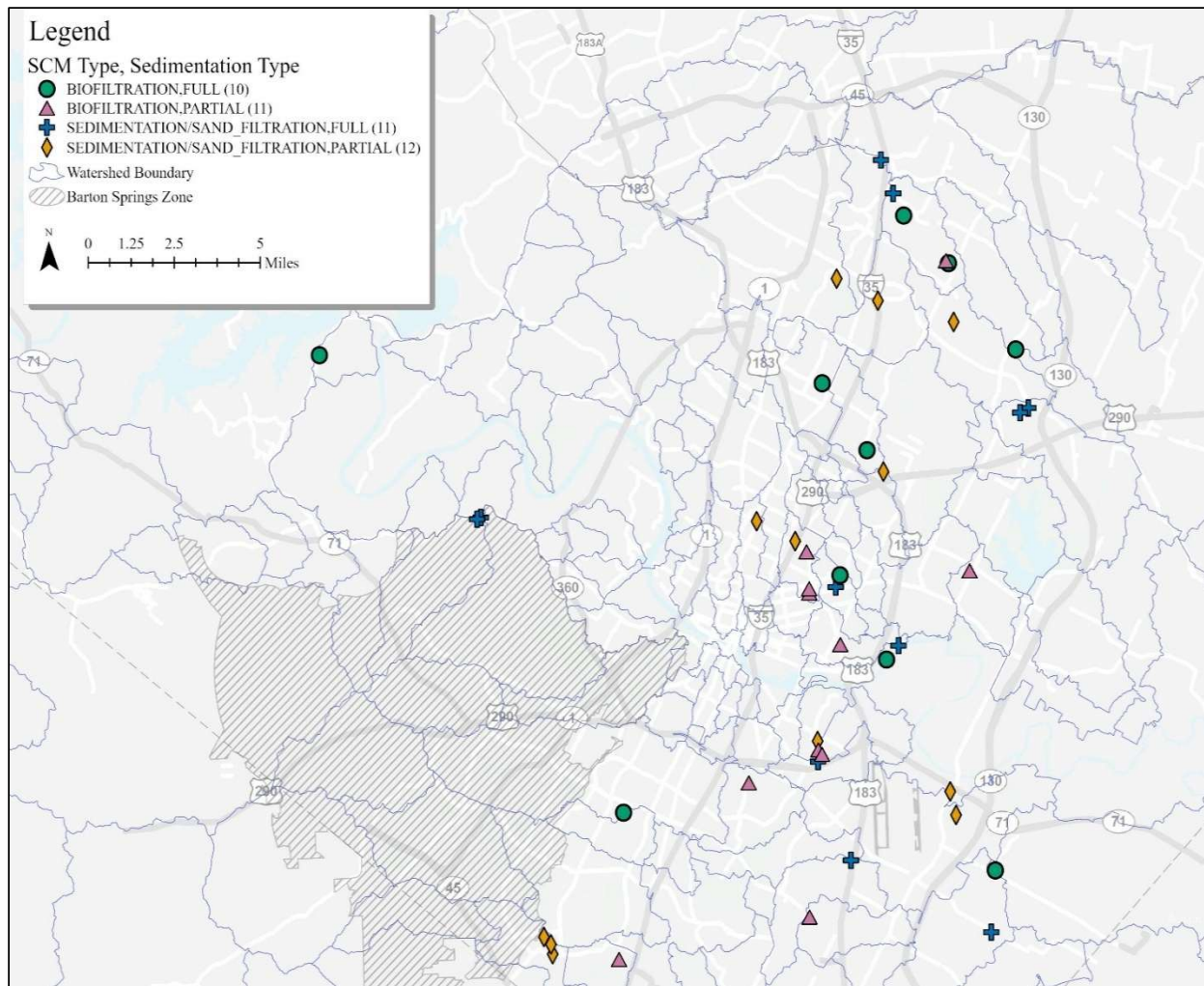


Figure 1. Location of the 44 SCMs analyzed for this study.

Desktop Data Collection

A desktop-level analysis using ArcGIS Pro software, a review of the Natural Resource Conservation Service (NRCS) Web Soil Survey soil characteristics, digital elevation models (DEMs), and a review of approved engineered site plans was completed to identify and evaluate potential environmental factors contributing to plant species success for each water quality SCM. The parameters discussed below are based on literature review, feasibility of data access, and best professional judgement. The desktop analysis was completed between June 2024 and December 2024. For each water quality SCM, we assessed vegetation maintenance regimes based on whether each SCM was privately or publicly maintained, if the SCM was planted with a diverse palette of plant species or turfgrass, the age of the SCM based on time of construction to time of survey, percent slope of SCM drainage areas using DEMs, soil textures of SCM drainage areas using

NRCS Soil Surveys, age of SCM in days for each surveyed season, and an analysis of antecedent precipitation conditions during the field survey using the U.S. Army Corps of Engineers (USACE) antecedent precipitation tool (APT) (USACE 2026).

The APT was developed by USACE to streamline and automate evaluation of precipitation normalcy and other climatic variables at an inputted site. To assess precipitation at a provided site location, the APT identifies all weather stations located within a 30-mile radius from an inputted site. Each weather station is then ranked based on a weighted difference value, incorporating both the distance to the inputted site and the difference in elevation. The APT determines antecedent precipitation normalcy by comparing rainfall data from the previous three months to the same three-month period over a rolling 30-year record at the inputted site. With use of rainfall data from the weather stations of the inputted site, the APT calculates 30-day rolling totals for each of the three 30-day periods preceding the observation date. The APT adjusts for changes in climate conditions by calculating normal precipitation conditions based on a rolling 30-year period. The 30-year period is calculated specifically for the observation data of interest and is adjusted over time if conditions are changing. Results of the APT for an inputted site are as follows: 1) dry season, 2) wet season, 3) drought conditions, 4) lower than normal antecedent precipitation conditions, 5) normal antecedent conditions, and 6) greater than normal antecedent precipitation conditions (U.S. EPA, n.d.)

Field Data Collection

The field survey included a visual estimation of SCM basin characteristics during the months of October 2024 and May 2025 to allow for temporal heterogeneity in plant community data. The determination of analytes was based on literature review and an evaluation of field survey feasibility. The field survey of SCM characteristics included the following parameters: the overall percentage of vegetation cover of the SCM, a visual estimation of vegetation maintenance frequency based on an observation of woody plant species and leftover plant litter, the percentage of the entire SCM covered in shade based on readings of a canopy densiometer, identification of vegetation species previously planted in the SCM based on landscape design plans, and if there is any presence of water depth in the SCM at the time of the field survey, measured as the depth between the soil surface to the water surface.

Vegetation species parameters were collected using quadrats distributed throughout each SCM using a weighted stratified random sampling method to capture plant species' surficial biomass within each basin chamber of each SCM (Mueller-Dombois and Ellenberg 1974). The SCMs were divided between two strata ("upland community" and "wetland community") based on SCM basin topography. The strata were created based on the expectation that outer edges of SCM basins, or "upland community", differ in management, species composition, and ecological function from the inner portions of the SCM basins, or "wetland community".

Upland community basin strata were not expected to be inundated with stormwater under normal hydrologic conditions. The upper elevation limits of the upland community strata were established at the Water Quality Volume (WQV) elevation listed in the submitted engineering design plans of each SCM down-gradient to the inner most elevation contour. The WQV elevation was chosen as the lower elevation of the upland strata due to the increased likelihood of sustained inundation. The wetland community basin strata were expected to be intermittently inundated with stormwater and occur between the WQV elevation and the bottom of each SCM basin. For those portions of the SCM sedimentation basins which did not contain elevation differences between the WQV elevation and the bottom-most elevation contour, no stratification was created for the SCM. These chambers which lacked stratification were treated as upland communities.

A power analysis was conducted using the "pwr" package in R to calculate the appropriate sample size needed for statistical analysis (Champely 2025). At $k =$ four different group types of SCMs, 90 samples per SCM type were identified from the power analysis at a small effect size of 0.2, power of test at 0.9, and statistical significance level of 0.05. A total sample size of 360 ($n=360$) was identified at 90 samples per SCM type (Cohen 1988).

Wetland communities were expected to contain the preferred planted communities. To effectively sample each community strata while also prioritizing preferred planted communities, a weight was applied to calculate sample size where wetland communities received a higher weight (60), and upland communities received a lower weight (30). Results of the weighted community strata analysis gave wetland communities five sampling units each per SCM basin and upland communities two sampling units each per SCM basin, for the four different types of water quality SCMs. Therefore, for each water quality SCM containing basin stratification, the plant community may be assessed from up to 14 sampling quadrats.

To alleviate field sampling bias, sampling units were created prior to the field sampling effort within both the sedimentation and filtration basin chambers of each SCM using the “Create Random Points” geoprocessing tool in ArcGIS Pro (ESRI, n.d.). A 1-meter buffered distance was placed between each randomly created point to prevent overlapping sampling units (Figure 2). Because field sampling will occur during two seasonal intervals (Fall and Spring), the random point generation occurred twice to most adequately sample the SCM basin above ground biomass.



Figure 2. Example of vegetation survey plot generation for one SCM using ArcGIS Pro. Points labeled beginning with a “W” represent wetland community sampling points. Points labeled beginning with a “U” represent upland community sampling points.

Data Analysis

All data analysis for this project was conducted in the R programming language (R Core Team 2026) through the RStudio IDE (Posit Team 2026) during the winter of 2024 and the summer and fall of 2025, following the field data collection periods.

Percent cover values for each species recorded across all quadrats within an SCM were averaged to produce a mean cover value per taxon per SCM. Mean relative cover was calculated for each taxon as the average relative cover across only those SCMs in which the taxon was detected.

Frequency of occurrence (i.e. number of SCMs where encountered), species richness, species evenness, and the Shannon-Weiner diversity index were calculated using the R "vegan" package (Oksanen 2026) for each SCM type as well as for the entire plant community identified for each season (i.e., Fall 2024 and Spring 2025). A Kruskal-Wallis Rank Sum test was used to test if there were significant differences in the means between the diversity metrics of the four different SCM types due to unequal sampling sizes used between the differing SCM types (Kruskal and Wallis 1952).

Species accumulation curves were created from the survey results to visually estimate the survey completeness of each season using the R "vegan" package (Oksanen et al. 2026). Point estimations of species richness were completed using a 95% confidence interval to account for a different number of quadrats from which plant species cover and identification were collected between different sites.

A non-metric multidimensional scaling (NMDS) ordination was used to display the correspondence between different environmental parameters and plant species identified during the field survey. Specifically, NMDS was used to identify environmental variables and structural patterns which contribute to plant species composition in SCMs. NMDS was the most appropriate ordination technique to use for this project because the data were anticipated to be nonnormal or on arbitrary scales (McCune and Grace 2002). We used the 'metaMDS' function in the R "vegan" package to execute the NMDS analysis. Our approach was to construct an NMDS ordination scatterplot displaying the plant species coverage fitted against environmental vectors (Oksanen et al. 2026). All percent cover data were transformed using the square root to minimize the influence of highly abundant species and to aid in alleviating the effect of rare species, given the geographic scope of the project (International Society for Ecological Modeling 1981).

Maximo Asset Number 401400189 was removed from the Fall 2024 and Spring 2025 NMDS analysis because only one species was identified during the field survey within the SCM. The NMDS ordination was then run with a Bray-Curtis Dissimilarity measure and 999 permutations using the Rstudio "vegan" package. The resulting ordination retained a stress of 0.20 in two dimensions, indicating an acceptable representation of community structure. The same analytical workflow methods applied to the Fall 2024 dataset were used for the Spring 2025 analysis. The final two-dimensional solution yielded a stress value of 0.23, indicating a fair but interpretable

representation of community dissimilarity in reduced ordination space. Species vectors were also fitted within the NMDS to identify taxa associated with patterns in the ordination space.

Following the NMDS ordination, a similarity percentage (SIMPER) was calculated to identify which species were contributing to groups identified during the NMDS ordination using the R “vegan” package (Oksanen et al. 2026). The SCM groupings were created by plant species occurring within more actively managed sites and less actively managed sites identified during the field surveys.

We also completed a hierarchical agglomerative clustering analysis to determine which plant communities are grouped together by site or species types (McCune and Grace 2002). Raw cover data were again square root transformed prior to creating a Bray-Curtis dissimilarity measure. Then data were passed through a Ward's minimum variance analysis to create the clustering dendrogram (McCune and Grace 2002). Clustering analysis was carried out using the "cluster" package in R (Maechler et al. 2026), and an indicator species analysis was performed on the different clusters using “indicspecies” package in R to identify indicator species of each cluster based on the distance matrix (Cáceres 2025; Cáceres and Legendre 2009), the Shannon Diversity of each cluster was calculated using the R “vegan” package, and a Welch’s two sample t-test was used to test the differences in community diversity between the clusters using base R given the differences in sample sizes between the created clusters (Welch 1947; Oksanen et al. 2026).

Results

Characteristics of the Species Pool

All 44 SCMs were surveyed twice; once during the spring and once during the fall (n=88). Across both survey seasons, 227 total plant species from 51 plant families were identified. Of those species observed, 97 species were identified exclusively during the spring season, 84 species were identified during both the spring and fall seasons, and 46 were identified exclusively during the fall season. Nine vegetative species were identified to the genus level, which included species from the Acanthaceae, Cyperaceae, Euphorbiaceae, Moraceae, Poaceae, Solanaceae, and Asteraceae families. These individuals came from immature seedlings or species that are known to hybridize which could not be morphologically identified to species. Approximately 96% of observed individuals were identified to the species level; therefore, most of the plant taxa within the study

were identified to species. A full list of identified species can be found in Appendix A: Full Species List. Approximately 75% of the surveyed vegetation cover came from the following families: Poaceae, Asteraceae, Cyperaceae, Euphorbiaceae, Convolvulaceae, Fabaceae, Apiaceae, and Verbenaceae.

The sample coverage estimate for the surveyed area was 93.8%, which represents an estimation of the probability that any additional individual plant encountered would belong to a species already detected during the survey. A sample coverage of ~93.8% indicates that the survey approached but did not reach 100% completeness for plant species coverage. The asymptotic richness estimate was approximately 320.5 indicating additional surveying could have led to an increase in species richness (C.I. of 264 – 376.9) (Figure 3). The gap between species richness detected (227 plant species identified during surveying) and the asymptotic estimate (320.5) suggests that additional sampling would likely have detected more plant taxa. The asymptotic estimate of 320.5 species suggests an estimated 93 species remained undetected, representing 29% of the predicted species pool. Sampling would be considered sufficient when observed richness approaches or meets the asymptotic estimate and the species accumulation curve reaches a plateau. When the slope of the curve reaches zero, additional surveying yields negligible detection results; however, with a sample coverage of 93.8% and 71% of estimated species pool detected, results remain sufficient enough to draw reasonable conclusions about the plant community present within SCMs (Colwell et al. 2012; Chao et al. 2009).

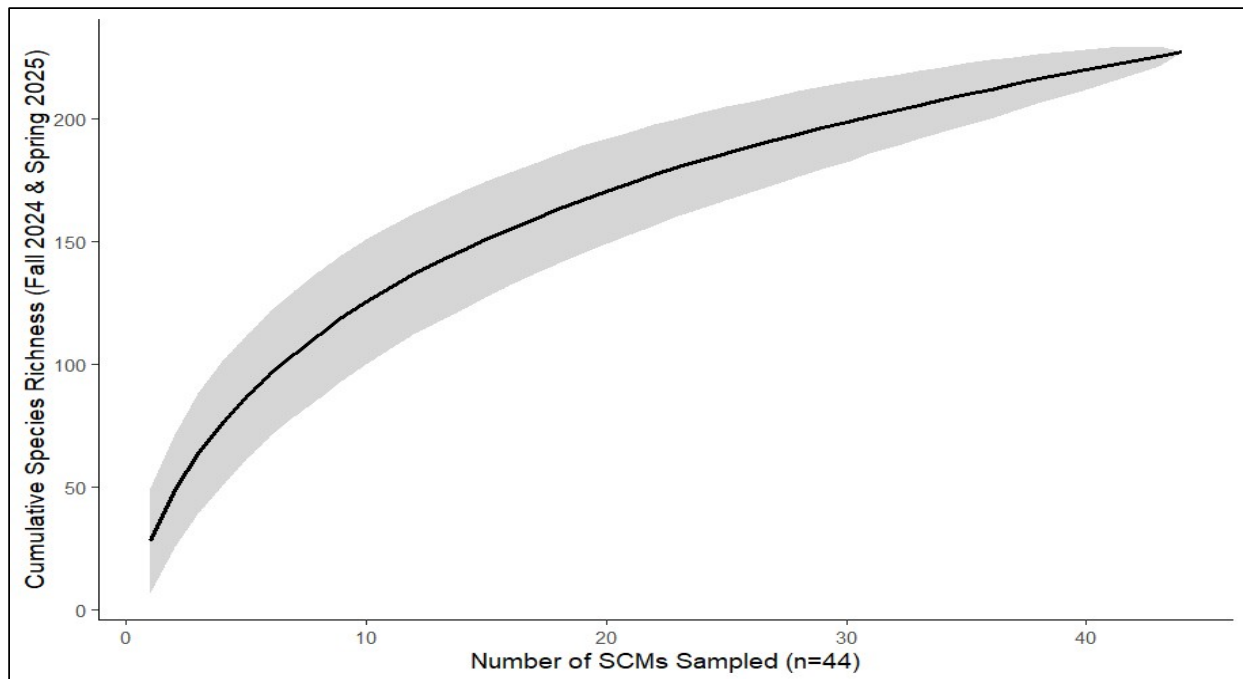


Figure 3. Species Accumulation Curve for Both Surveyed Seasons (CI = 95%).

Dominance of the plant community was assessed by calculating the mean relative cover percentage among sites where each taxon was detected, and frequency of occurrence (i.e., number of SCMs where detected) of each plant taxa across the entire survey (n=88). The top five species by mean relative cover percentage included black willow (*Salix nigra*) (24.35%, six sites), switchgrass (*Panicum virgatum*) (14.88%, nine sites), Lindheimer's muhly (*Muhlenbergia lindheimeri*) (14.75%, nine sites), deep-rooted sedge (*Cyperus entrerianus*) (11.09%, six sites), and bermudagrass (*Cynodon dactylon*) (10.66%, 53 sites).

Several individuals including *Morus* spp., pampasgrass (*Cortaderia selloana*), winged elm (*Ulmus alata*), and *Paspalum* spp. retained high relative cover estimates (>10%) among sites where detected but occurred at fewer than three SCMs (Table 1). Despite their local dominance, their infrequent occurrence results in a low overall contribution to plant community composition across the surveyed SCMs.

Species exhibiting higher mean relative cover were primarily bunchgrasses, trees, shrubs, and large forbs (Table 1). Most plant taxa with high mean relative cover percent are also perennial species of facultative upland class. The dominant plant families by mean relative cover percent include Poaceae, Moraceae, Salicaceae, and Cyperaceae. Across all SCM types, mean relative cover values were similar between non-native species (2.34%) and native species (2.04%). These values reflect

the average of the individual mean relative cover values across all non-native and native species respectively and are therefore lower than the species-level values in Table 1, which report the mean relative cover for each individual taxon among sites where it was detected. Native species were more numerous (172 taxa), whereas a smaller number of non-native species (55 taxa) contributed disproportionately higher cover values to the total vegetative cover (Figure 4).

Table 1. Dominant Plant Taxa by Mean Relative Cover $\geq 5\%$ where Taxon Detected (n=88).

Plant Species Name	Mean Relative Cover (%)	Plant Status	Plant Cycle	Plant Structure	Family	USACE Wetland Class
<i>Cortaderia selloana</i>	30.02	Non-Native	Perennial	Bunchgrass	Poaceae	FACU
<i>Salix nigra</i>	24.35	Native	Perennial	Tree	Salicaceae	FACW
<i>Ulmus alata</i>	21.69	Native	Perennial	Tree	Ulmaceae	FACU
<i>Panicum virgatum</i>	14.88	Native	Perennial	Bunchgrass	Poaceae	FAC
<i>Muhlenbergia lindheimeri</i>	14.75	Native	Perennial	Bunchgrass	Poaceae	FACW
<i>Paspalum</i> spp.	11.43	Native	Perennial	Bunchgrass	Poaceae	UPL
<i>Cyperus entrerianus</i>	11.09	Non-Native	Perennial	Sedge	Cyperaceae	FACW
<i>Cynodon dactylon</i>	10.66	Non-Native	Perennial	Turfgrass	Poaceae	FACU
<i>Viguiera dentata</i>	10.65	Native	Perennial	Forb	Asteraceae	UPL
<i>Morus indica</i>	10.24	Non-Native	Perennial	Tree	Moraceae	UPL
<i>Ligustrum lucidum</i>	8.10	Non-Native	Perennial	Shrub	Oleaceae	FACU
<i>Bouteloua curtipendula</i>	7.87	Native	Perennial	Bunchgrass	Poaceae	UPL
<i>Sorghum halepense</i>	7.82	Non-Native	Perennial	Bunchgrass	Poaceae	FACU
<i>Eleusine indica</i>	7.71	Non-Native	Annual	Bunchgrass	Poaceae	FACU
<i>Ambrosia trifida</i>	7.63	Native	Annual	Forb	Asteraceae	FAC
<i>Bothriochloa ischaemum</i>	7.58	Non-Native	Perennial	Bunchgrass	Poaceae	UPL
<i>Morus rubra</i>	7.28	Native	Perennial	Tree	Moraceae	FACU
<i>Heterotheca subaxillaris</i>	7.21	Native	Annual	Forb	Asteraceae	UPL
<i>Ambrosia psilostachya</i>	6.63	Native	Perennial	Forb	Asteraceae	FACU
<i>Calypocarpus vialis</i>	6.37	Native	Perennial	Forb	Asteraceae	FAC
<i>Phyllanthus urinaria</i>	6.35	Non-Native	Annual	Forb	Euphorbiaceae	FAC
<i>Fraxinus pennsylvanica</i>	6.21	Native	Perennial	Tree	Oleaceae	FAC
<i>Bacopa monnieri</i>	6.09	Native	Perennial	Forb	Scrophulariaceae	OBL
<i>Muhlenbergia capillaris</i>	6.05	Native	Perennial	Bunchgrass	Poaceae	FACU
<i>Melochia pyramidata</i>	5.94	Native	Perennial	Forb	Sterculiaceae	FAC
<i>Eleocharis palustris</i>	5.85	Native	Perennial	Rush	Cyperaceae	OBL
<i>Panicum anceps</i>	5.81	Native	Perennial	Bunchgrass	Poaceae	FAC
<i>Tripsacum dactyloides</i>	5.80	Native	Perennial	Bunchgrass	Poaceae	FAC
<i>Stellaria media</i>	5.78	Non-Native	Perennial	Forb	Caryophyllaceae	FACU
<i>Baccharis neglecta</i>	5.73	Native	Perennial	Shrub	Asteraceae	FAC
<i>Alternanthera philoxeroides</i>	5.65	Non-Native	Perennial	Forb	Amaranthaceae	OBL
<i>Trifolium repens</i>	5.61	Non-Native	Perennial	Forb	Fabaceae	FACU
<i>Phyla nodiflora</i>	5.56	Native	Perennial	Forb	Verbenaceae	FAC
<i>Carya illinoensis</i>	5.40	Native	Perennial	Tree	Juglandaceae	FAC
<i>Iva annua</i>	5.35	Native	Annual	Forb	Asteraceae	FAC
<i>Stenaria nigricans</i>	5.33	Native	Perennial	Forb	Rubiaceae	UPL

Plant Species Name	Mean Relative Cover (%)	Plant Status	Plant Cycle	Plant Structure	Family	USACE Wetland Class
<i>Tridens albescens</i>	5.26	Native	Perennial	Bunchgrass	Poaceae	FAC
<i>Symphotrichum divaricatum</i>	5.23	Native	Annual	Forb	Asteraceae	OBL
<i>Cyperus</i> spp.	5.14	Native	Perennial	Sedge	Cyperaceae	FACW
<i>Paspalum dilatatum</i>	5.11	Non-Native	Perennial	Bunchgrass	Poaceae	FAC

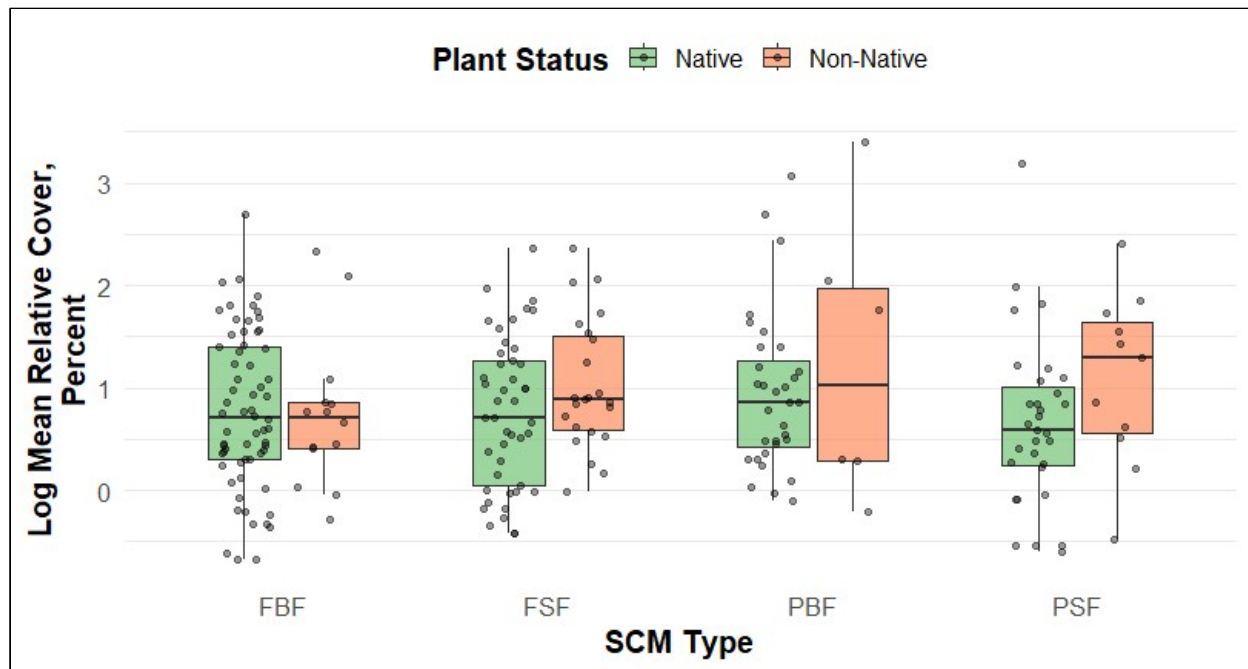


Figure 4. Log-transformed mean relative cover percentages of native and non-native plant species across four SCM types included for analysis. The boxes represent the interquartile range (IQR) with the median shown as the horizontal line. Individual points represent the log-transformed species-level relative cover calculations per SCM. Non-native species show notably higher variance in most of the SCM types.

The top species by frequency of occurrence included bermudagrass (*Cynodon dactylon*) occurring at 53/88 sites (60.23%), straggler daisy (*Calyptracarpus vialis*) occurring at 45/88 sites (51.14%), southern annual salt marsh aster (*Symphotrichum divaricatum*) occurring at 40/88 sites (45.45%), johnsongrass (*Sorghum halepense*) occurring at 39/88 sites (44.32%), and wood sorrel (*Oxalis dillenii*) occurring at 39/88 sites (44.32%) (Table 2). Of the top ten species by frequency of occurrence, only two species, bermudagrass (*Cynodon dactylon*) and johnsongrass (*Sorghum halepense*), are considered non-native species to Texas. The remaining nine species are all native species (U.S. Department of Agriculture 2024).

Table 2. Dominant Plant Taxa by Frequency of Occurrence ≥ 15 (n=88).

Plant Species Name	Frequency of Occurrence	Plant Status	Plant Cycle	Plant Structure	Family	USACE Wetland Class
<i>Cynodon dactylon</i>	53	Non-Native	Perennial	Turfgrass	Poaceae	FACU
<i>Calyptocarpus vialis</i>	45	Native	Perennial	Forb	Asteraceae	FAC
<i>Symphotrichum divaricatum</i>	40	Native	Annual	Forb	Asteraceae	OBL
<i>Oxalis dillenii</i>	39	Native	Perennial	Forb	Oxalidaceae	FACU
<i>Sorghum halepense</i>	39	Non-Native	Perennial	Bunchgrass	Poaceae	FACU
<i>Ipomoea cordatotriloba</i>	35	Native	Perennial	Vine	Convolvulaceae	FAC
<i>Chamaesyce serpens</i>	33	Native	Annual	Forb	Euphorbiaceae	FACU
<i>Dichondra carolinensis</i>	33	Native	Perennial	Forb	Convolvulaceae	FAC
<i>Ambrosia psilostachya</i>	31	Native	Perennial	Forb	Asteraceae	FACU
<i>Phyla nodiflora</i>	30	Native	Perennial	Forb	Verbenaceae	FAC
<i>Bothriochloa ischaemum</i>	29	Non-Native	Perennial	Bunchgrass	Poaceae	UPL
<i>Paspalum dilatatum</i>	29	Non-Native	Perennial	Bunchgrass	Poaceae	FAC
<i>Bromus arvensis</i>	28	Non-Native	Annual	Bunchgrass	Poaceae	FACU
<i>Oenothera speciosa</i>	28	Native	Perennial	Forb	Onagraceae	UPL
<i>Medicago lupulina</i>	27	Non-Native	Perennial	Forb	Fabaceae	FACU
<i>Cyclosporum leptophyllum</i>	25	Non-Native	Annual	Forb	Apiaceae	FACW
<i>Modiola caroliniana</i>	23	Native	Perennial	Forb	Malvaceae	FAC
<i>Geranium carolinianum</i>	22	Native	Annual	Forb	Geraniaceae	UPL
<i>Sonchus asper</i>	21	Non-Native	Annual	Forb	Asteraceae	FAC
<i>Solidago nemoralis</i>	20	Native	Perennial	Forb	Asteraceae	UPL
<i>Lolium perenne</i>	19	Non-Native	Perennial	Bunchgrass	Poaceae	FACU
<i>Sherardia arvensis</i>	18	Non-Native	Annual	Forb	Rubiaceae	UPL
<i>Croton monanthogynus</i>	17	Native	Annual	Forb	Euphorbiaceae	UPL
<i>Rumex crispus</i>	17	Non-Native	Perennial	Forb	Polygonaceae	FAC
<i>Ruellia humilis</i>	17	Native	Perennial	Forb	Acanthaceae	FAC
<i>Cyperus esculentus</i>	16	Native	Perennial	Sedge	Cyperaceae	FACW
<i>Neptunia pubescens</i>	16	Native	Perennial	Forb	Fabaceae	FAC
<i>Ratibida columnifera</i>	16	Native	Perennial	Forb	Asteraceae	UPL
<i>Torilis arvensis</i>	16	Non-Native	Annual	Forb	Apiaceae	UPL
<i>Solanum elaeagnifolium</i>	15	Native	Perennial	Forb	Solanaceae	UPL

Forbs and bunchgrasses comprised most vegetation occurrence records, accounting for 67.90% and 18.24% of all observations, respectively. Although these functional groups were most prevalent overall, bermudagrass was the single most frequently identified species making turfgrass observations up to 3.58% of all vegetation observations. Vines (3.85%), sedges (2.59%), trees (1.99%), rushes (1.06%), and shrubs (0.80%) occurred at comparatively low frequencies.

Native species were more frequently encountered (69.43%) than non-natives comprising 30.57% of observations (Table 2). With respect to USACE wetland classification, either upland or facultative upland species were dominant at 29.24% and 28.78%, respectively. Obligate wetland

(4.71%) and facultative wetland (9.42%) were less dominant than facultative species (27.85%). Most species were also classified as perennial (68.30%).

Ten FBF SCMs were surveyed across both spring and fall seasons (n=20). The SCM type with the highest species richness, FBF systems contained a total of 145 plant species across both surveyed seasons. The dominant species by frequency of occurrence within FBF systems were bermudagrass (*Cynodon dactylon*) (12), straggler daisy (*Calypocarpus vialis*) (11), frogfruit (*Phyla nodiflora*) (10), southern annual salt marsh aster (*Symphyotrichum divaricatum*) (9), and western ragweed (*Ambrosia psilostachya*) (8). Species dominance by cover was quantified as the mean proportional cover contributed by each species across sites within an SCM type. The top five species by mean site proportional cover within full biofiltration SCMs included switchgrass (*Panicum virgatum*) (3.85%), Lindheimer's muhly (*Muhlenbergia lindheimeri*) (3.82%), bermudagrass (*Cynodon dactylon*) (3.15%), sideoats grama (*Bouteloua curtipendula*) (2.71%), and camphorweed (*Heterotheca subaxillaris*) (2.49%).

Eleven FSF SCMs were surveyed across both survey seasons (n=22). There were 125 total plant species identified within FSF systems. The dominant species by frequency of occurrence within FSF systems were bermudagrass (*Cynodon dactylon*) (16), ponyfoot (*Dichondra carolinensis*) (11), wood sorrel (*Oxalis dillenii*) (11), johnsongrass (*Sorghum halepense*) (11), and black medick (*Medicago lupulina*) (10). The most dominant species by mean proportional cover was *Morus* spp. (17.75%); however, this value was driven primarily by a single SCM in which this taxon was highly dominant. The remaining dominant taxa by proportional cover include Lindheimer's muhly (*Muhlenbergia lindheimeri*) (5.24%), bermudagrass (*Cynodon dactylon*) (3.37%), switchgrass (*Panicum virgatum*) (2.64%), and johnsongrass (*Sorghum halepense*) (2.18%).

Eleven PBF SCMs were surveyed across both survey seasons (n=22). There were 114 total plant species identified within partial biofiltration systems, making partial biofiltrations the least species rich of all SCM types included in the study. The dominant species by frequency of occurrence within partial biofiltration systems were straggler daisy (*Calypocarpus vialis*) (15), matted sandmat (*Chamaesyce serpens*) (12), bermudagrass (*Cynodon dactylon*) (12), tievine (*Ipomoea cordatotriloba*) (12), and wood sorrel (*Oxalis dillenii*) (11). The most dominant species by mean site proportional cover included black willow (*Salix nigra*) (9.25%), pampasgrass (*Cortaderia*

selloana) (5.70%), switchgrass (*Panicum virgatum*) (4.24%), winged elm (*Ulmus alata*) (4.12%), and Lindheimer's muhly (*Muhlenbergia lindheimeri*) (3.74%).

There were 12 PSF SCMs surveyed across both survey seasons (n=24). Partial sand filtration systems contained 131 of the 227 plant species recorded across all surveyed SCMs. The dominant species by frequency of occurrence within partial sand filtration systems included straggler daisy (13), bermudagrass (*Cynodon dactylon*) (13), King Ranch bluestem (*Bothriochloa ischaemum*) (*Calyptracarpus vialis*) (10), ponyfoot (*Dichondra carolinensis*) (10), and wood sorrel (*Oxalis dillenii*) (10). The most dominant species by mean site proportional cover included black willow (8.73%), switchgrass (*Panicum virgatum*) (5.33%), deep-rooted sedge (*Cyperus entrerianus*) (3.98%), bermudagrass (*Cynodon dactylon*) (3.55%), and sideoats grama (*Bouteloua curtipendula*) (2.82%). w

Across all four SCM types surveyed, bermudagrass (*Cynodon dactylon*) consistently ranked in the top species by frequency of occurrence. In contrast, switchgrass (*Panicum virgatum*) was among the most dominant species by proportional cover across SCM types, indicating that regardless of it being encountered less frequently, it substantially contributed to vegetation cover where present.

Diversity Metrics

Shannon Diversity was calculated for each surveyed site and summarized across all sites and both seasons. The highest Shannon Diversity was observed within FBF systems with a mean Shannon Diversity metric of 2.89, although differences among SCMs types were relatively limited. This is followed by PSF systems (2.86), PBF (2.75), and FSF (2.70). FBF sites contained the highest median Shannon Diversity (3.18), followed by FSF (3.01), PSF (2.92), and PBF (2.69). Additionally, FSF systems contained the highest variability in data, with a standard deviation of 0.92 (Figure 5). The site with the highest Shannon Diversity (~3.60), Maximo Asset Number 5000071572, is a PSF system; the site with the lowest Shannon Diversity (0.00), Maximo Asset Number 401400189, is a FSF system (Figure 5; Table 3). Despite mean Shannon Diversity varying slightly among SCM types, the Kruskal-Wallis Rank Sum test identified no significant differences in Shannon Diversity between the different groups ($p\text{-value} = 0.68$).

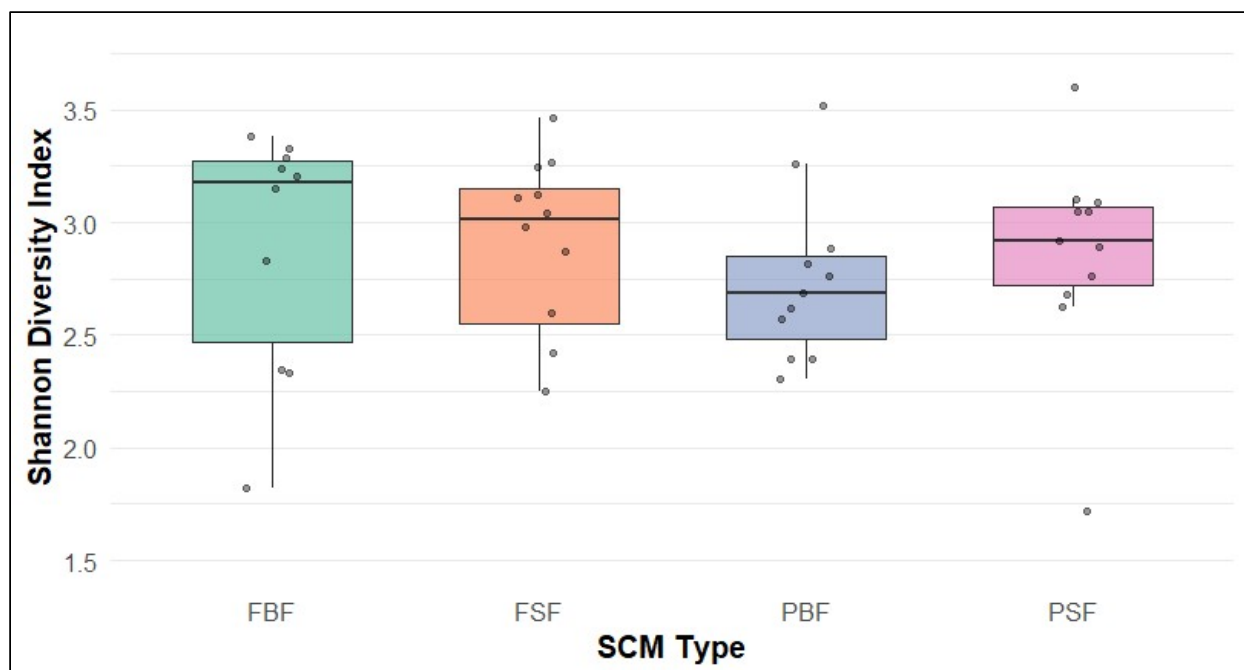


Figure 5. Shannon Diversity Index comparison by the four SCM types. Boxes represent the IQR, with the horizontal line indicating the median; whiskers represent the minimum and maximum values identified for each SCM type. Individual points represent the calculated Shannon Diversity index of an individual site. FBF systems displayed the largest variability in Shannon Diversity across the four types.

Table 3. Shannon Diversity Metrics by SCM Maximo Asset Number and Project Name displayed in descending order by calculated diversity. Shannon Diversity Index values approaching 0 indicate low diversity, expressed as a metric of species richness and species evenness. Higher values indicate greater species diversity; values above 3 are generally considered high.

SCM Maximo Asset Number	SCM Project Name	SCM Type	Shannon Diversity Metric
5000071572	Grove Tract Loft Development	PSF	3.60
12072352	Fort Dessau Condos W	PBF	3.52
401312230	River Ranch	FSF	3.46
5000082144	Knollwood on the Colorado 2B	FBF	3.38
401456890	Asian American Resource Center	FBF	3.33
12050959	Lynd at Lake Travis	FBF	3.28
1207471	Knollwood on the Colorado 1	FSF	3.26
5000515205	Newton Collins Elementary	PBF	3.26
401465737	Bellingham Meadows Section 1	FSF	3.25
401312215	Morris Williams Golf Course	FBF	3.24
12072351	Fort Dessau Condos E	FBF	3.21
401513131	Howard Lane	FBF	3.15
12067984	Montopolis Water Reclamation	FSF	3.12
11176354	TriOffice Complex W	FSF	3.11
12090908	Lot 1, Velocity Center	PSF	3.11

SCM Maximo Asset Number	SCM Project Name	SCM Type	Shannon Diversity Metric
401354000	Austin Transition Center	PSF	3.09
1200118	Glazer's Distributors Expansion	PSF	3.05
401409442	Running Bird Condos	PSF	3.05
12066499	Bellingham Meadows Section 2B	FSF	3.04
401465514	Addison Section 1	FSF	2.98
1205291	Frate Barker Nursing Center	PSF	2.92
12082803	Summerow Condos	PSF	2.89
5000067139	Todd Lane Improvement	PBF	2.89
11176202	TriOffice Complex E	FSF	2.87
401312702	COA YMCA North	FBF	2.83
12082798	The Mont W	PBF	2.81
401488837	Whitehouse Tract	PBF	2.76
12067176	QT	PSF	2.76
5000514950	M Station South	PBF	2.69
401312046	Central Texas Rehab Hospital	PSF	2.68
12065440	Menchaca Elementary	PSF	2.62
401336286	EMS Station No. 33	PBF	2.62
401312162	5F Mechanical	FSF	2.60
5000514959	M Station North	PBF	2.57
5000516787	EM Franklin	FSF	2.42
12084021	Altra Trailhead	PBF	2.40
12082806	JD's Market No. 7	PBF	2.39
401460350	Cottages at Beaver Creek	FBF	2.35
12076809	Eastridge Lot	FBF	2.33
12082807	The Mont E	PBF	2.31
401312190	Formula One	FSF	2.25
401513121	Matthews Lane	FBF	1.82
12075073	Airport/I35	PSF	1.72
401400189	Wells Branch Burger King	FSF	0.00

The spring survey identified a comparatively higher species richness (181 total plant species) than the fall (130 total plant species), which further resulted in a higher diversity metric during the spring season (Figure 6). The mean spring Shannon Diversity was 2.64 compared to the mean fall Shannon Diversity of 2.15.

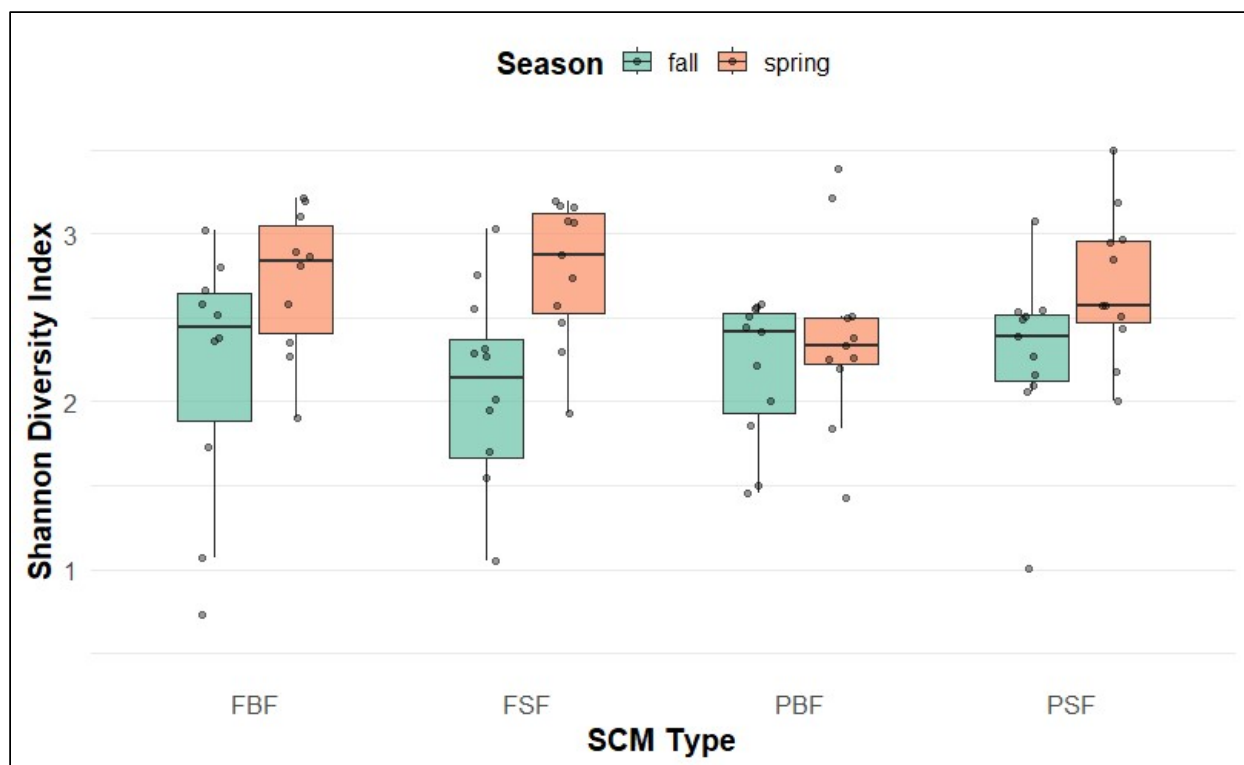


Figure 6. Shannon Diversity Metrics by Survey Season and SCM Type. Boxes represent the IQR, with the horizontal line indicating the median; whiskers represent the minimum and maximum values. Individual points represent the calculated Shannon Diversity index of an individual site during each of the surveyed seasons (sites are repeated across seasons). Shannon Diversity Index values approaching 0 indicate low diversity, while higher values indicate higher diversity. Spring values are generally higher median Shannon Diversity than fall values across most of the SCM types.

NMDS Ordination

Fall 2024 NMDS Results

The ordination revealed separation along NMDS1, with unmaintained SCMs occupying negative ordination space and maintained SCMs occupying positive ordination space (Figure 7). This pattern generally indicates that maintenance regimes of SCMs is a primary factor structuring plant community composition across SCMs. Unmaintained systems exhibited greater dispersion in ordination space, suggesting higher compositional heterogeneity, whereas maintained systems were more tightly clustered, indicating greater compositional similarity.

The most influential environmental variables, represented by the longest arrows, included shade percentage and hydrologic condition, which were closely aligned in ordination space, as well as vegetation cover percentage, which was closely associated with unmaintained systems. The

alignment of shade and hydrologic condition suggests mild covariance; however, this relationship likely reflects broader site or climatic factors rather than a direct effect of maintenance on woody vegetation structure. The remaining environmental vectors including SCM type, vegetation maintenance based on private or public responsibility, SCM drainage area soil type, SCM drainage area slope, planting palette, age of SCM, observed frequency of vegetation maintenance during field work surveys, and observable notable vegetation species remaining from initial plantings remained non-significant ($p\text{-value} > 0.05$) (Figure 7).

Results of the APT indicated the Fall 2024 hydrologic conditions were drier than the 30-year rolling average for October, a typically wet month in the region. This drought condition likely constrained the ability of the NMDS to capture meaningful variation among sites, with antecedent precipitation levels reflecting a shared climatic signal rather than a true environmental gradient and should be interpreted with caution. Greater overlap of sites in ordination space is indicated highlighting that prolonged drought may have dampened ecological differentiation among sites during the Fall 2024 survey (Figure 7).

A species vector fitting analysis was conducted to identify taxa significantly associated with patterns in ordination space. At $p\text{-value} \leq 0.05$, the most significant species contributing to the unmaintained clusters (those that aligned most in the negative space along NMDS1) were black willow (*Salix nigra*), deep-rooted sedge (*Cyperus entrerianus*), gray goldenrod (*Solidago nemoralis*), green ash (*Fraxinus pennsylvanica*), silverleaf nightshade (*Solanum elaeagnifolium*), and western ragweed (*Ambrosia psilostachya*). The identified species, especially those of which are native trees, are more likely to have high relative cover and are closely aligned with less maintained systems. In contrast, species associated with positive NMDS1 scores (i.e., corresponding to maintained SCMs) included southern annual salt marsh aster (*Symphyotrichum divaricatum*), matted sandmat (*Chamaesyce serpens*), straggler daisy (*Calyptocarpus vialis*), little hogweed (*Portulaca oleracea*), wild petunia (*Ruellia humilis*), and dallisgrass (*Paspalum dilatatum*) (Table 4). These species align with the vegetation maintenance vector, suggesting active management promotes more disturbance-tolerant, low-growing species. However, species-environment relationships may be partially confounded by extreme drought and lower than average antecedent precipitation conditions based on a comparison of rainfall data from the previous 90 days to the same three-month period over a rolling 30-year precipitation data record at the specific SCM site.

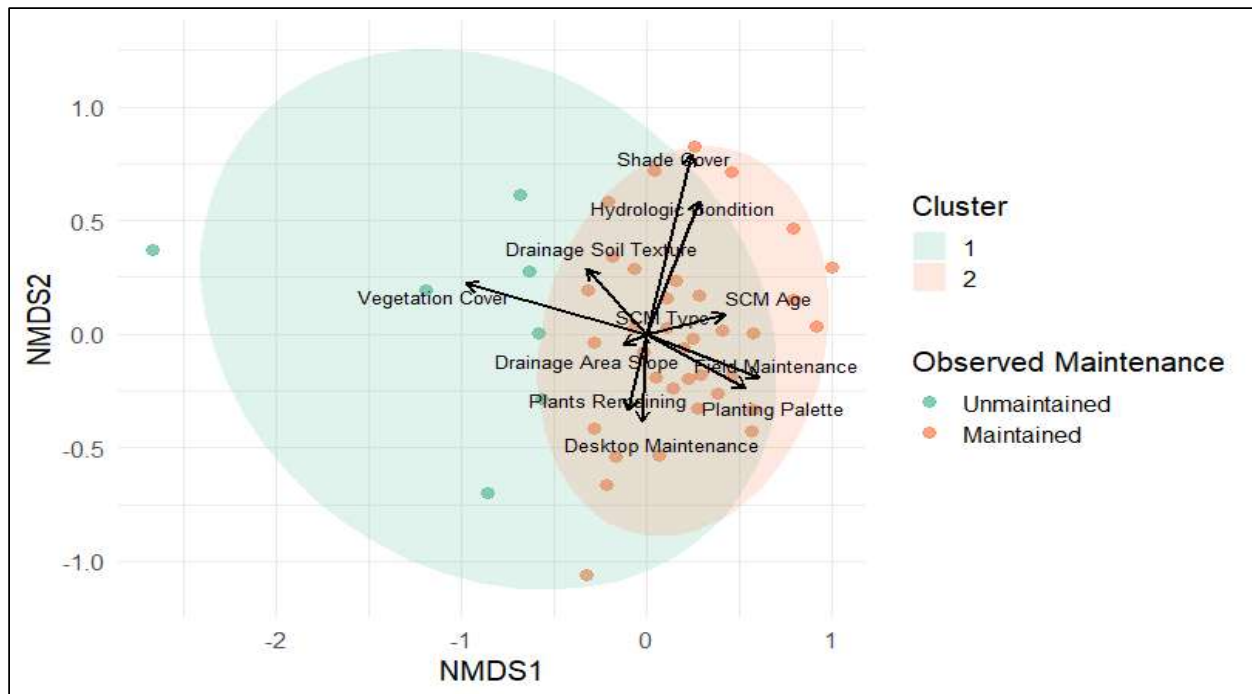


Figure 7. Fall 2024 NMDS biplot of site-level plant community composition, overlaid with environmental vectors and site classifications. Points represent individual sites, colored by sites which were classified as maintained or unmaintained during field surveys. Shaded ellipses denote clusters of sites. Arrows represent environmental vectors, with directions indicating the gradient of increasing influence and arrow length proportional to the strength of association with the ordination. NMDS axes represent gradients of compositional dissimilarity among sites; axis values are unitless and interpreted relative to one another, rather than by defined measurements. Sites scoring higher and more positive along NMDS1 are associated with maintained conditions; sites scoring lower and more negative along NMDS1 are associated with unmaintained sites with overall higher above ground vegetation coverage. Sites scoring higher and more negative along NMDS2 are associated with higher present shade coverage and increased antecedent precipitation prior to field surveys while lower NMDS2 values correspond to more open canopy and drier conditions. Overlap of sites between the two clusters reflects shared climatic conditions driven by anomalously dry antecedent precipitation during the Fall survey.

Table 4. Fall 2024 NMDS Species Vector Fitting Results.

NMDS1	NMDS2	P-Value	Plant Species Name	Plant Status	Plant Cycle	Plant Structure	Plant Family	USACE Wetland Class
-0.68	0.29	0.001	<i>Salix nigra</i>	Native	Perennial	Tree	Salicaceae	FACW
-0.66	0.25	0.005	<i>Cyperus entrerianus</i>	Non-Native	Perennial	Sedge	Cyperaceae	FACW
-0.33	0.30	0.015	<i>Solidago nemoralis</i>	Native	Perennial	Forb	Asteraceae	UPL

NMDS1	NMDS2	P-Value	Plant Species Name	Plant Status	Plant Cycle	Plant Structure	Plant Family	USACE Wetland Class
-0.64	0.21	0.023	<i>Fraxinus pennsylvanica</i>	Native	Perennial	Tree	Oleaceae	FAC
-0.24	0.34	0.024	<i>Solanum elaeagnifolium</i>	Native	Perennial	Forb	Solanaceae	UPL
-0.16	-0.38	0.028	<i>Ambrosia psilostachya</i>	Native	Perennial	Forb	Asteraceae	FACU
0.05	-0.66	0.001	<i>Symphyotrichum divaricatum</i>	Native	Annual	Forb	Asteraceae	OBL
0.56	-0.06	0.001	<i>Chamaesyce serpens</i>	Native	Perennial	Forb	Euphorbiaceae	UPL
0.39	0.33	0.002	<i>Calyptocarpus vialis</i>	Native	Perennial	Forb	Asteraceae	FAC
0.41	-0.09	0.021	<i>Portulaca oleracea</i>	Native	Annual	Forb	Portulacaceae	FAC
0.02	-0.39	0.037	<i>Ruellia humilis</i>	Native	Perennial	Forb	Acanthaceae	FAC
0.10	-0.37	0.046	<i>Paspalum dilatatum</i>	Non-Native	Perennial	Bunchgrass	Poaceae	FAC
0.36	-0.14	0.047	<i>Echinochloa crus-galli</i>	Non-Native	Annual	Bunchgrass	Poaceae	FAC
0.34	-0.16	0.049	<i>Malvasatrum coromandelianum</i>	Non-Native	Perennial	Forb	Malvaceae	FAC

Spring 2025 NMDS Results

The NMDS ordination revealed clear separation along the NMDS1 axis, with negative scores primarily associated with maintained SCMs and positive scores associated with unmaintained SCMs (Figure 8). Overlap between these groups was limited, suggesting more distinctive differences in plant community composition by maintenance condition during the spring sampling period. Environmental vector fitting indicated that vegetation maintenance status observed during field activities and water depth measured during field activities (expressed in inches from the soil surface to the surface water surface) were the strongest environmental gradients structuring community composition ordination space. The direction and magnitude of these vectors suggest that increasing water depth and lack of maintenance are associated with shifts toward the plant assemblages observed in unmaintained SCMs (Figure 8). The remaining environmental vectors remained non-significant ($p\text{-value} > 0.05$).

A species vector fitting analysis was conducted to identify taxa significantly associated with patterns in ordination space. At $p\text{-value} \leq 0.05$, the most significant species contributing to the unmaintained clusters (those that aligned most in the positive space along NMDS1) were gray goldenrod (*Solidago nemoralis*), fiddledock (*Rumex pulcher*), black willow (*Salix nigra*), southern dewberry (*Rubus trivialis*), and Torrey's rush (*Juncus torreyi*). Many of these species are classified as facultative wetland by the USACE, suggesting an association with more hydrologically saturated conditions. This pattern is consistent with the direction of the water depth environmental vector, indicating that increasing water depth is an important gradient structuring plant communities in unmaintained systems. In contrast, species associated with negative NMDS1 scores-corresponding to maintained SCMs-included tievine (*Ipomoea cordatotriloba*), Lindheimer's muhly (*Muhlenbergia lindheimeri*), Carolina bristlemallow (*Modiola caroliniana*), marsh parsley (*Cyclospermum leptophyllum*), and johnsongrass (*Sorghum halepense*) (Table 5). These species align with the vegetation maintenance vector, suggesting active management promotes a more disturbance-tolerant plant assemblage with upland condition species.

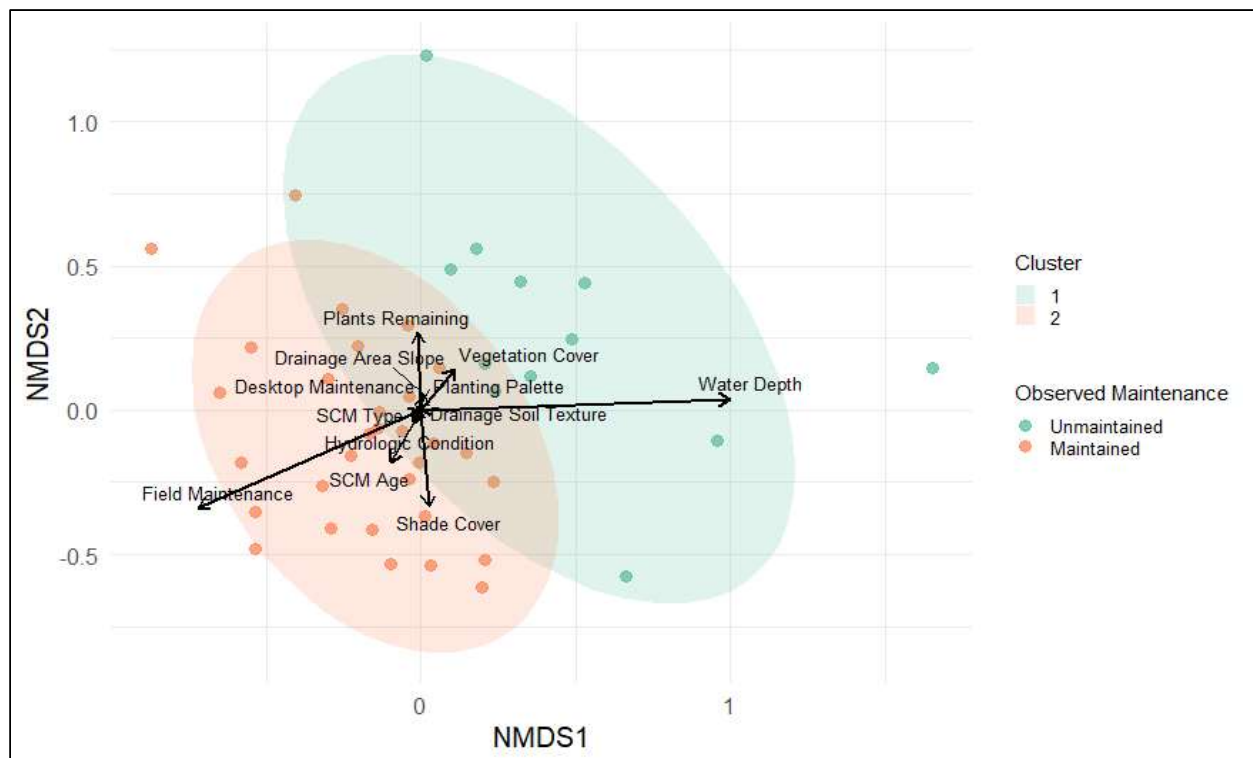


Figure 8. Spring 2025 NMDS biplot of site-level plant community composition, overlaid with environmental vectors and site classifications. NMDS axes represent gradients of compositional dissimilarity among sites; axis values are unitless and interpreted relative to one another rather than by

measurable parameters. Positive scores along NMDS1 are associated with greater depth of water identified during field surveys, while negative NMDS1 scores correspond to more frequent vegetation maintenance identified during the field survey. Sites scoring negative along NMDS2 are associated with greater shade coverage. Points themselves represent individual sites, colored by observed vegetation maintenance regime. Shaded ellipses denote clusters by maintenance. Arrows represent fitted environmental vectors, with longer arrows proportional to the strength of association and direction indicating the gradient of increasing influence. Only statistically significant ($p\text{-value} \leq 0.05$) are discussed.

Table 5. Spring 2025 NMDS Species Vector Fitting Results.

NMDS1	NMDS2	P-Value	Plant Species Name	Plant Status	Plant Cycle	Plant Structure	Plant Family	USACE Wetland Class
0.20	0.64	0.001	<i>Solidago nemoralis</i>	Native	Perennial	Forb	Asteraceae	UPL
0.58	-0.06	0.003	<i>Rumex pulcher</i>	Non-Native	Perennial	Forb	Polygonaceae	FACW
0.50	0.23	0.003	<i>Salix nigra</i>	Native	Perennial	Tree	Salicaceae	FACW
0.46	0.26	0.005	<i>Rubus trivialis</i>	Native	Perennial	Forb	Rosaceae	FACU
0.55	0.08	0.01	<i>Juncus torreyi</i>	Native	Perennial	Rush	Juncaceae	FACW
0.58	0.07	0.015	<i>Alternanthera philoxeroides</i>	Non-Native	Perennial	Forb	Amaranthaceae	OBL
0.58	0.07	0.015	<i>Fraxinus pennsylvanica</i>	Native	Perennial	Tree	Oleaceae	FAC
0.58	0.07	0.015	<i>Ulmus americana</i>	Native	Perennial	Tree	Ulmaceae	FAC
0.58	0.07	0.015	<i>Morus rubra</i>	Native	Perennial	Tree	Moraceae	FACU
0.38	-0.20	0.02	<i>Cyperus entrerianus</i>	Non-Native	Perennial	Sedge	Cyperaceae	FACW
0.16	-0.40	0.02	<i>Geranium carolinianum</i>	Native	Annual	Forb	Geraniaceae	UPL
0.07	0.39	0.033	<i>Solanum elaeagnifolium</i>	Native	Perennial	Forb	Solanaceae	UPL
0.12	0.41	0.043	<i>Typha latifolia</i>	Native	Perennial	Forb	Typhaceae	OBL
-0.51	-0.04	0.001	<i>Ipomoea cordatotriloba</i>	Native	Perennial	Vine	Convolvulaceae	FAC
-0.08	0.57	0.002	<i>Muhlenbergia lindheimeri</i>	Native	Perennial	Bunchgrass	Poaceae	FACW
-0.08	-0.48	0.004	<i>Modiola caroliniana</i>	Native	Perennial	Forb	Malvaceae	FAC
-0.11	-0.45	0.008	<i>Cyclospermum leptophyllum</i>	Non-Native	Annual	Forb	Apiaceae	FACW
-0.15	0.42	0.01	<i>Sorghum halepense</i>	Non-Native	Perennial	Bunchgrass	Poaceae	FACU
-0.05	0.44	0.011	<i>Ambrosia psilostachya</i>	Native	Perennial	Forb	Asteraceae	FACU
-0.30	-0.34	0.014	<i>Calyptocarpus vialis</i>	Native	Perennial	Forb	Asteraceae	FAC
-0.37	-0.17	0.023	<i>Oxalis dillenii</i>	Native	Perennial	Forb	Oxalidaceae	FACU
-0.14	-0.38	0.025	<i>Cynodon dactylon</i>	Non-Native	Perennial	Turfgrass	Poaceae	FACU
-0.36	0.18	0.035	<i>Euphorbia dentata</i>	Native	Annual	Forb	Euphorbiaceae	UPL
-0.05	0.44	0.041	<i>Muhlenbergia capillaris</i>	Native	Perennial	Bunchgrass	Poaceae	FACU

NMDS1	NMDS2	P-Value	Plant Species Name	Plant Status	Plant Cycle	Plant Structure	Plant Family	USACE Wetland Class
-0.36	-0.13	0.046	<i>Chamaesyce serpens</i>	Native	Annual	Forb	Euphorbiaceae	FACU

SIMPER Analysis

Fall 2024 SIMPER Analysis Results

The similarity percentage (SIMPER) analysis was calculated from the Fall 2024 plant cover data matrix to identify species that most consistently contributed to within group similarity. Species with higher cumulative contribution percentages were those detected more consistently across sites within a group, indicating they are characteristic of that plant community (i.e., species with high cumulative contributions were those species that had a high contribution to the difference between the groups) (Clarke 1993). In this case, groups were created based on SCMs which had active vegetation maintenance as identified during the field survey. Plant species which contributed the most significant differences ($p\text{-value} \leq 0.05$) in management regimes included giant ragweed (*Ambrosia trifida*), gray goldenrod (*Solidago nemoralis*), camphorweed (*Heterotheca subaxillaris*), winged elm (*Ulmus alata*), annual marshelder (*Iva annua*), and sideoats grama (*Bouteloua curtipendula*). No species showed significantly higher cover in systems which were more maintained (Figure 9).

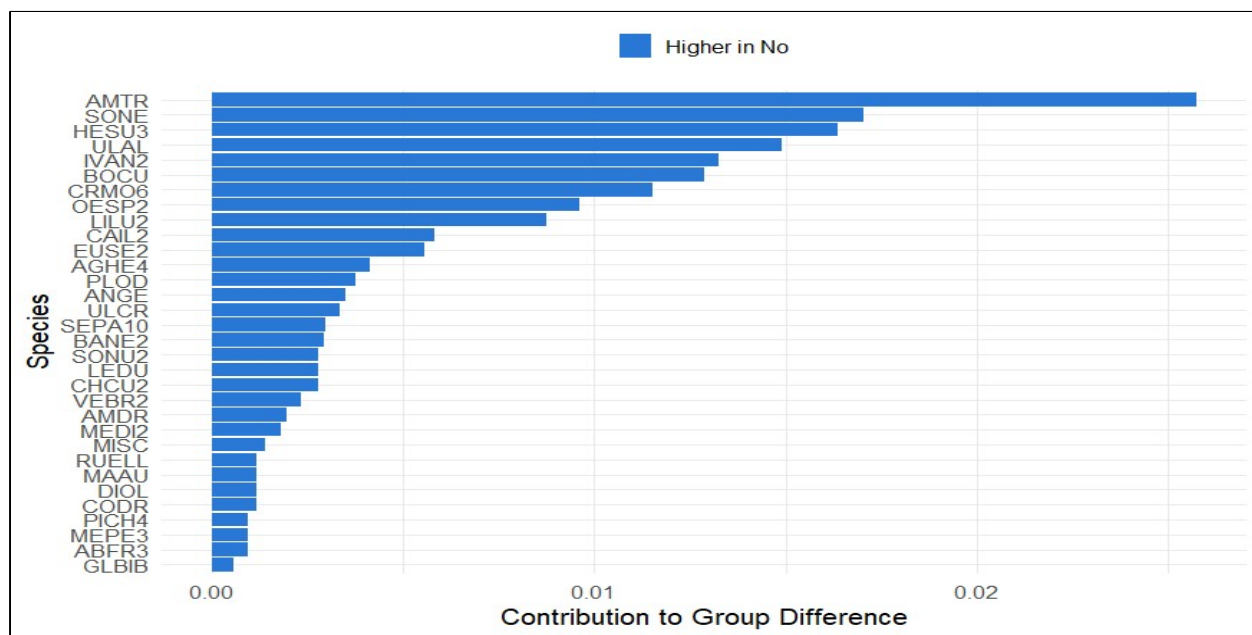


Figure 9. Species contributing significantly (SIMPER, $p \leq 0.05$) to Bray-Curtis dissimilarity in percent cover between sites with unmaintained (“No”) and sites with maintained (“Yes”) systems. Bars show each species’ average contribution to overall between-group dissimilarity. All significant species had higher

mean cover in unmaintained (“No”) sites; no species showed significantly higher cover in maintained systems. Species codes follow USDA plants database nomenclature.

Spring 2025 SIMPER Analysis Results

The Spring 2025 SIMPER analysis was calculated using methods similar to the Fall 2024 dataset. Groups were created based on SCMs with more active vegetation maintenance as identified during the field survey. Plant species which contributed the most significant differences ($p\text{-value} \leq 0.05$) in management regimes included black willow (*Salix nigra*), giant ragweed (*Ambrosia trifida*), fiddledock (*Rumex pulcher*), white tridens (*Tridens albescens*), beaked panicgrass (*Panicum anceps*), and Indian blanket (*Gaillardia pulcher*). No species showed significantly higher cover in systems which were more maintained (Figure 10).

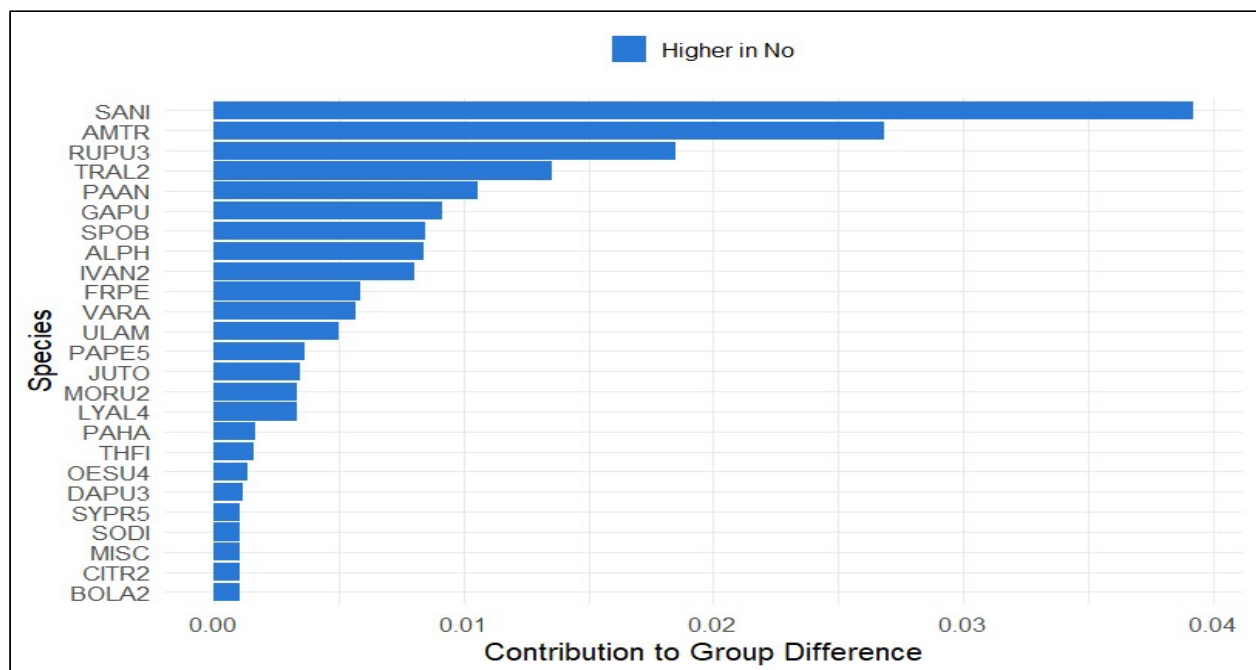


Figure 10. Species contributing significantly (SIMPER, $p \leq 0.05$) to Bray-Curtis dissimilarity in percent cover between sites with unmaintained (“No”) and sites with maintained (“Yes”) systems. Bars show each species’ average contribution to overall between-group dissimilarity. All significant species had higher mean cover in unmaintained (“No”) sites; no species showed significantly higher cover in maintained systems. Species codes follow USDA plants database nomenclature.

Clustering Analysis

Fall 2024 Clustering Analysis Results

The hierarchical clustering analysis was performed on the Fall 2024 plant cover data and created two distinct clusters. The dendrogram identified in Figure 11 below indicates clustering by vegetation maintenance regime, whereby clusters viewed in cluster 1 (left-based cluster in green) are those which primarily contained species with high relative cover such as trees, large bunchgrasses, and shrubs. Cluster 2, identified in the right-based orange cluster, were those SCMs which primarily contain frequently maintained SCMs, composed of low-growing plant species tolerant of frequent mechanical disturbance.

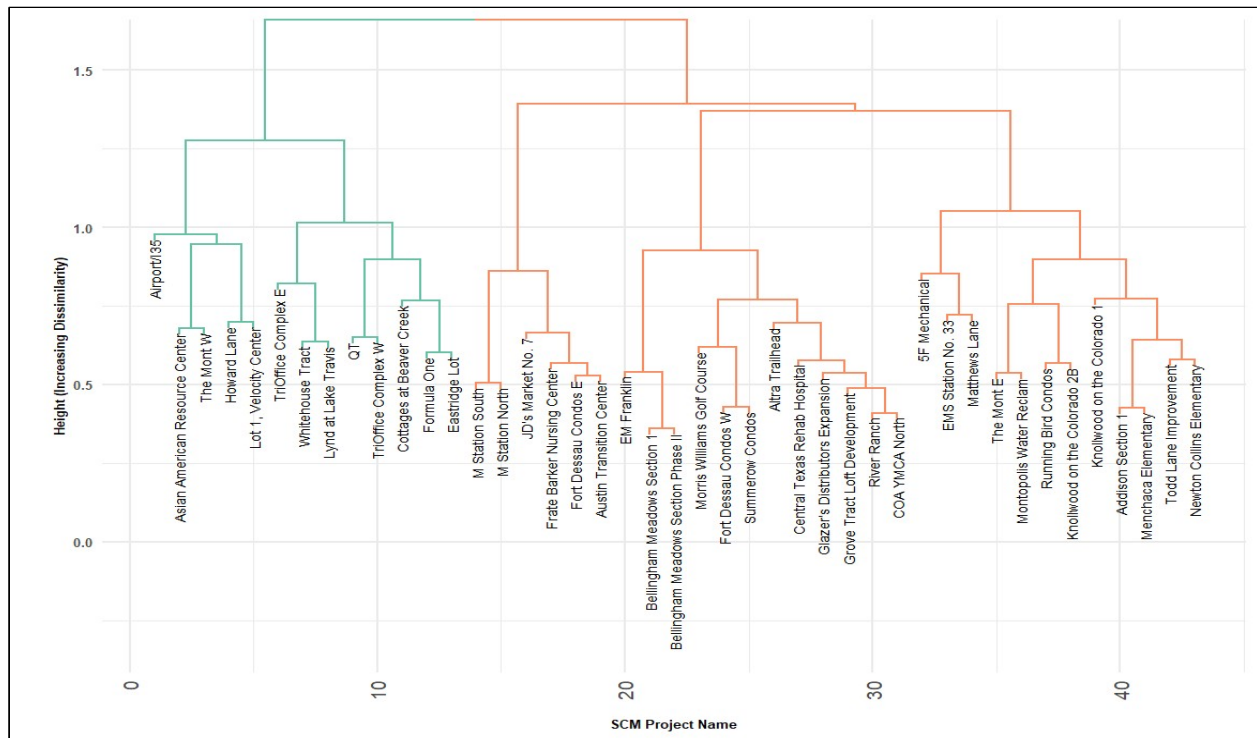


Figure 11. Dendrogram of hierarchical clustering results for SCM project names, grouped by similarity in plant species identified cover. The y-axis represents height, indicating the dissimilarity between projects or clusters at each merge point (i.e., lower merge heights indicate greater similarity). Branch colors distinguish the two primary clusters identified when the dendrogram is cut at $k = 2$. SCM project names are listed along the x-axis at the base of each corresponding branch.

An indicator species analysis was also performed to identify species most strongly associated with each cluster and contributing to differences in cluster community compositions. The most significant species ($p\text{-value} \leq 0.05$) identified within cluster 1 (left chain) included western

ragweed (*Ambrosia psilostachya*), gray goldenrod (*Solidago nemoralis*), giant ragweed (*Ambrosia trifida*), silverleaf nightshade (*Solanum elaeagnifolium*), marsh elder (*Iva annua*), black willow (*Salix nigra*), and Lindheimer's muhly (*Muhlenbergia lindheimeri*). This is contrasted to the most significant species identified within cluster 2 (right chain), which included matted sandmat (*Chamaesyce serpens*), straggler daisy (*Calypocarpus vialis*), barnyardgrass (*Echinochloa crus-galli*), ponyfoot (*Dichondra carolinensis*), and little hogweed (*Portulaca oleracea*).

The diversity of each group was calculated for each cluster using the Shannon Diversity metric. The mean Shannon Diversity of cluster 1 was 2.00, which compares to the mean Shannon Diversity of cluster 2 of 2.28. Although cluster 2 contained a slightly higher Shannon Diversity, results of Welch's two-sample t-test identified that the two clusters did not significantly differ in overall diversity ($p\text{-value} = 0.20$) (Figure 12).

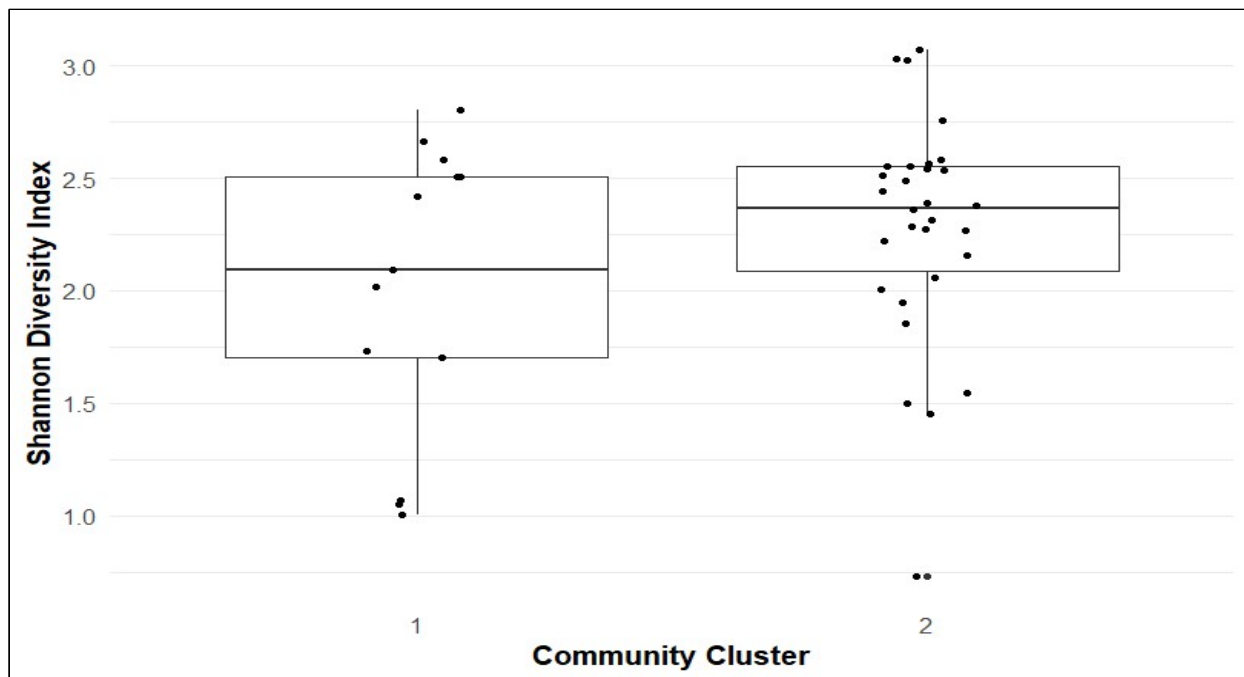


Figure 12. Boxplots of Shannon Diversity Index values identified by plant communities representative of SCM project names grouped by cluster (Cluster 1, $n = 13$; Cluster 2, $n = 20$), corresponding to the two clusters identified in the SCM project name dendrogram (Figure 11). Boxes represent the interquartile range

(IQR) with the horizontal line indicating the median; whiskers extending to the most extreme values, and individual points represent the Shannon Diversity values for each project site with a cluster.

Spring 2025 Clustering Analysis Results

An identical clustering analysis workflow was employed for the Spring 2025 that was used for the Fall 2024 data. The clustering analysis created two distinct clusters based on plant cover data. The dendrogram identified in Figure 13 below indicates clustering by vegetation maintenance regime, whereby clusters viewed in cluster 1 (left green chain) are those which primarily contained species characterized by high tolerance to disturbance. Cluster 2 (right orange chain) was characterized by perennial forbs of upland USACE wetland classification which require less disturbance to successfully propagate.

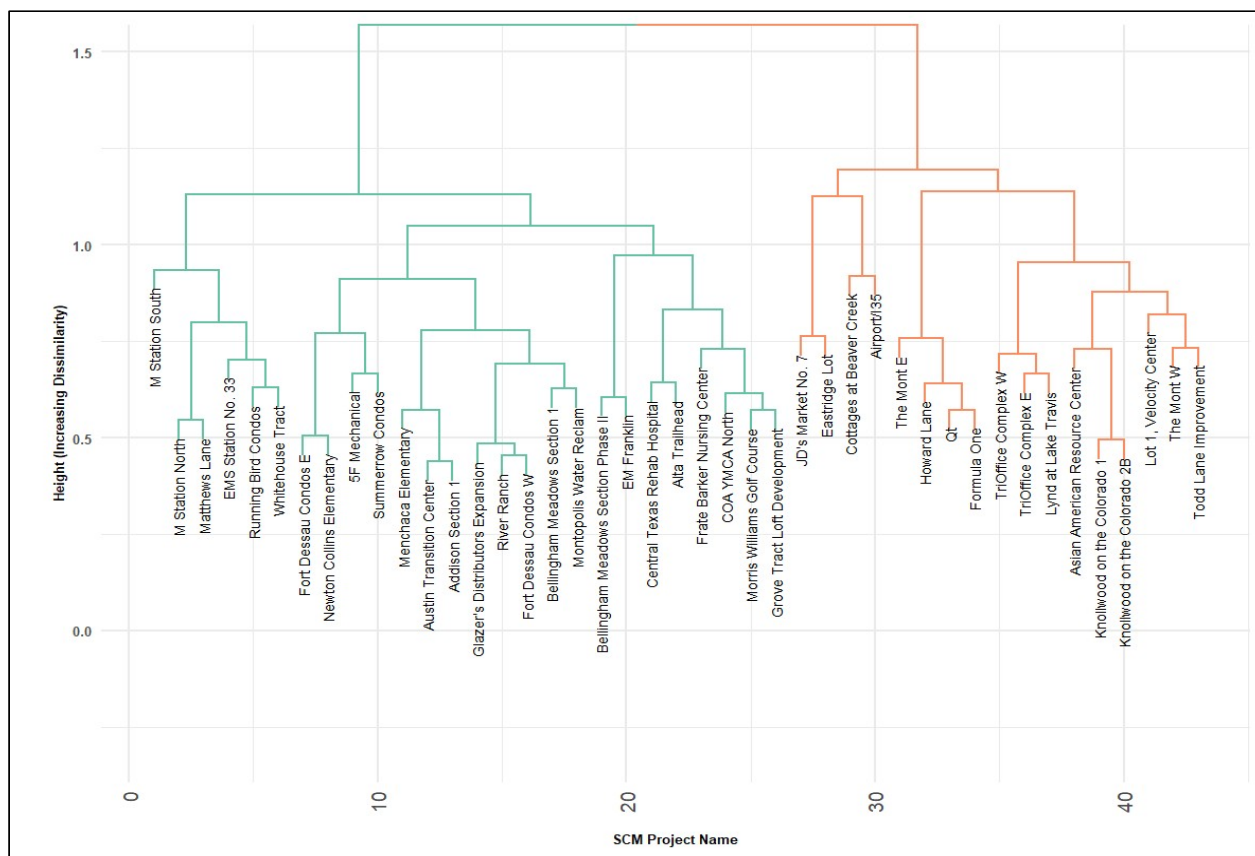


Figure 13. Dendrogram of hierarchical clustering results for SCM project names, grouped by similarity in plant species identified cover. The y-axis represents height, indicating the dissimilarity between projects or clusters at each merge point (i.e., lower merge heights indicate greater similarity). Branch colors distinguish the two primary clusters identified when the dendrogram is cut at $k = 2$. SCM project names are listed along the x-axis at the base of each corresponding branch.

An indicator species analysis was also performed to identify species contributing to differentiation between clustered groups for the Spring 2025 surveyed results. The most significant species ($p\text{-value} \leq 0.05$) identified within cluster 1 included bermudagrass (*Cynodon dactylon*), field madder (*Sherardia arvensis*), straggler daisy (*Calyptocarpus vialis*), cretanweed (*Hedypnois cretica*), Carolina bristlemallow (*Modiola caroliniana*), and knotted hedgeparsley (*Torilis nodosa*). This is contrasted to the most significant species identified within cluster 2, which included gray goldenrod (*Solidago nemoralis*), lemon beebalm (*Monarda citriodora*), and Indian blanket (*Gaillardia pulchella*). Mean Shannon Diversity was similar between clusters, with values of 2.68 for cluster 1 and 2.60 for cluster 2. A Welch's two-sample t-test confirmed no significant difference in the mean diversity between clusters ($p\text{-value} = 0.62$) (Figure 14).

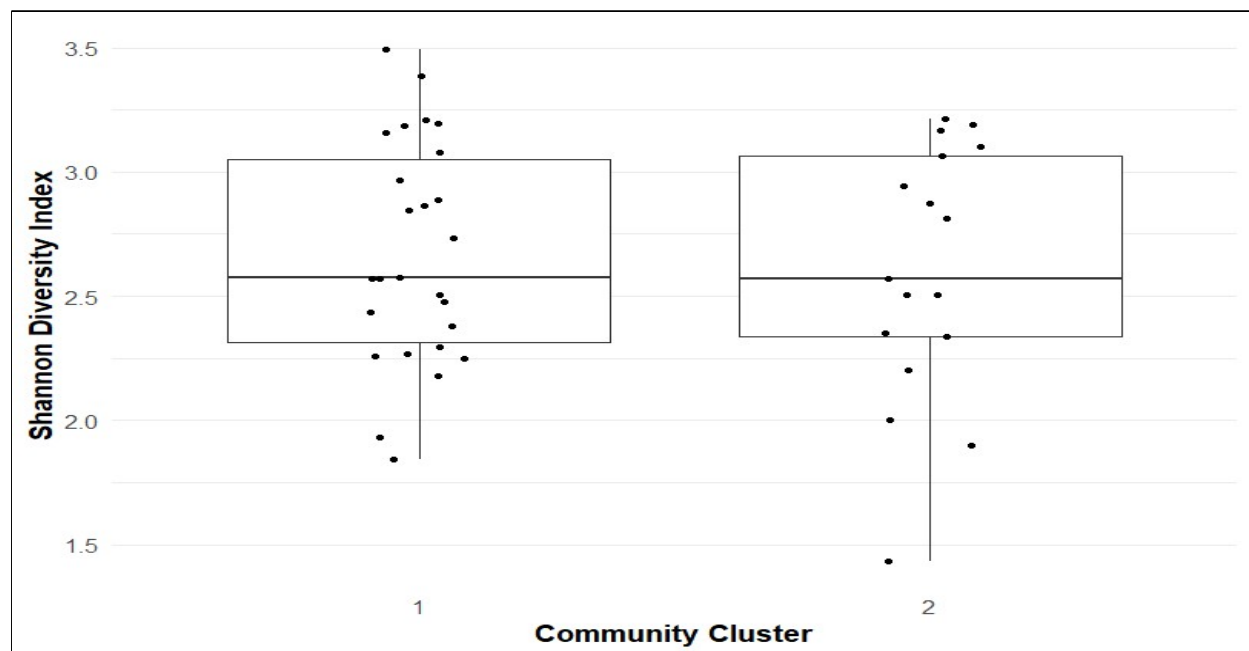


Figure 14. Boxplots of Shannon Diversity Index values identified by plant communities representative of SCM project names grouped by cluster (Cluster 1, $n = 26$; Cluster 2, $n = 17$), corresponding to the two clusters identified in the SCM project name dendrogram (Figure 13). Boxes represent the IQR with the horizontal line indicating the median; whiskers extending to the most extreme values, and individual points represent the Shannon Diversity values for each project site with a cluster.

Discussion

The analysis of species occurrence frequency across both surveyed seasons indicates that the plant community is numerically dominated by native species (69.43%), with high occurrences of taxa such as straggler daisy, southern annual salt marsh aster, and wood sorrel. From both a richness

and frequency standpoint, native taxa are well established across all SCM types included in this study. In contrast, several non-native species exhibited disproportionately high frequency of occurrence (30.57%), particularly bermudagrass, johnsongrass, and King Ranch bluestem. These species are characterized by rapid growth, clonal propagation, and strong competitive ability, suggesting they exert substantial influence on community structure despite representing a smaller proportion of overall species richness (Zhou et al. 2024; Basham 2013).

Although native species dominate in terms of richness and frequency, a smaller subset of highly prevalent non-native grasses likely exerts disproportionate control over ecosystem structure and function, indicating a decoupling between taxonomic dominance and functional dominance within SCM plant communities (Maarel and Franklin 2013). Relative cover data further support this pattern, demonstrating that vegetation within individual SCMs is often controlled by a small number of dominant species. These dominants include both native taxa (e.g., black willow, switchgrass, Lindheimer's muhly) and non-native grasses (e.g., bermudagrass, johnsongrass, dallisgrass), indicating that functional dominance is not limited to invasive species alone.

Analysis of species composition identified 20 native bunchgrass and forb species that were among the most dominant taxa based on mean relative cover and frequency of occurrence across SCMs. Because plant diversity metrics did not significantly differ among SCM types, these species occurred consistently across multiple biofiltration and sand filtration systems and may be considered representative of the plant communities currently established within Austin SCMs. These species included switchgrass (*Panicum virgatum*), Lindheimer's muhly (*Muhlenbergia lindheimeri*), Plateau goldeneye (*Viguiera dentata*), sideoats grama (*Bouteloua curtipendula*), and others.

Although there were limited diversity differences between SCM types, the dominant species reflected across all systems shared similar plant traits. Communities were primarily characterized by upland or facultative upland classified bunchgrasses within unmaintained systems, perennially growing disturbance-tolerant low-growing turfgrasses within more maintained systems, or opportunistic forb species; however, many of the SCMs included in this survey lacked stratification between the WQV and the innermost contour of the basin and therefore were treated as uplands. Due to this, upland plants were encountered more frequently than wetland plants. The overwhelming prevalence of upland or facultative upland species, rather than wetland dominant

species, indicates that hydrologic conditions within existing SCMs are largely dry or intermittently dry rather than experiencing sustained periods of saturation. This is likely due to the filter media composition, which is composed of 70-90% sand and the intended drainage of stormwater within 48-96 hours.

Variation in plant community species richness between the different SCMs was likely driven by disturbance regimes inherent to SCM design and maintenance, including drought conditions, shade coverage, and vegetation management. These disturbances facilitate ongoing colonization and contribute to high overall richness, but also favor species with traits that confer competitive advantage under repeated disturbance (Maarel and Franklin 2013; Musso et al. 2020). Non-native grasses, with their rapid growth, clonal spread, and tolerance to disturbance, are well positioned to dominate local communities particularly within systems with urban-impacted hydrology (Basham 2013; Reichmann et al. 2016; Hess et al. 2022). Because SCM occurrence spatially coincides with areas of intense human activity, these systems experience a higher proportion of non-native species colonization (Godefroid and Koedam 2007).

The Fall 2024 NMDS analysis identified shade percentage and hydrologic conditions as the most influential environmental variables structuring plant community composition in SCMs. However, antecedent precipitation during this period characterized the hydrologic conditions as experiencing extreme drought with far below average rainfall across the Austin region (National Weather Service 2024) which likely constrained the environmental vector response and limited the detectability of other drivers. The plant communities observed during the Fall 2024 survey were therefore likely water-stressed, resulting in increased plant community compositional homogeneity among sites and a reduced signal of plant species richness. In contrast, the APT identified the Spring 2025 dataset was collected during normal hydrologic conditions with average rainfall conditions across the region based on a rolling 30-year average (Morris 2025). This led to an increased differentiation in plant communities, particularly observable between those subjected to intensive mechanical maintenance and those that were not. Because normal antecedent precipitation levels were observed during this period, the expressed environmental pattern suggests that reduced maintenance promotes greater community heterogeneity, likely by allowing increased establishment and persistence of desirable native bunchgrasses and forbs such as goldenrod, southern dewberry, and Torrey's rush. These species are intolerant of above-ground biomass removal which reduces their ability to compete with non-native species. Following their removal,

non-native and undesirable species are more able to follow natural ecological succession within biofiltration systems and spread more readily. This consistency in management intensity effects has also been reflected across other urban systems, whereby less intensively managed systems contained higher abundance and vegetation diversity (Skovira and Bohlen 2023).

These findings are further supported by the clustering analysis, which consistently partitioned sites into two primary groups across both seasons, largely structured by maintenance regime. Unmaintained clusters were characterized by native perennial bunchgrasses and forbs, including western ragweed, giant ragweed, silverleaf nightshade, marsh elder, Lindheimer's muhly, lemon beebalm, and Indian blanket. In contrast, intensively managed SCMs were dominated by disturbance-tolerant and low-growing species such as matted sandmat, straggler daisy, ponyfoot, little hogweed, bermudagrass, crenateweed, Carolina bristlemallow, and knotted hedgeparsley. Many of these species exhibit prostrate or stoloniferous growth patterns that allow them to persist through frequent mowing. In contrast to the perennial species found in unmaintained clusters, these fast-growing species associated with more intensively managed SCMs allocate biomass to lateral spread and maintenance of low-growing canopies rather than vertical growth.

There are still significant knowledge gaps about biofiltration systems in the City of Austin that this study could not address. Specifically, further study is needed to assess the suitability of saturated zones with different plant communities; how different plant communities contribute to nutrient absorption and filtering of the water column in-situ; how trees, shrubs, and other woody species contribute to increased evapotranspiration and infiltration rates in biofiltration systems within Austin; and how specific plant functional traits are correlated to specific biofilter functions.

The experimental design and subsequent site selection of this study did not incorporate saturated zones as a variable. Although two of the partial biofiltration SCMs included in this study did have saturated zones, this is not a sufficient sample size on which to infer conclusions regarding saturated zones and plant communities. The plant communities present within these two SCMs were primarily dominated by switchgrass and Lindheimer's muhly; however, a quantitative measurement of the vitality of these two species was not assessed. Further study is needed to address this knowledge gap before suitability of plant communities within partial biofiltration systems with saturated zones are considered. Previous studies funded by the City have shown that within laboratory experiment columns and modeled environments, biofiltration media with

saturated zones can increase the vigor of plants species such as Lindheimer's muhly and buffalograss (*Bouteloua dactyloides*) and may provide increased metal and phosphorus treatments (Barrett et al. 2013; Richter 2018). However, the persistence of plant species in partial biofiltration systems with saturated zones experiencing real-world conditions so far remains understudied.

Conclusions

This project examined the plant community composition of 44 SCMs throughout the City of Austin's full-purpose jurisdiction during two seasons. This study identified 227 total plant taxa from 51 plant families across four types of SCMs, which included both private and publicly maintained systems. Prior to this study, no other characterization of plant communities or species lists for SCMs in situ have been published. This inventory of plant taxa will serve as a baseline dataset for the City's environmental policy recommendations, especially in biofiltration systems within the City's jurisdiction. This study will ultimately assist with understanding the role of SCM vegetation throughout the City of Austin as it prioritizes climate resilience and sustainability through green stormwater infrastructure. This study was also able to identify drought conditions and maintenance regimes of SCMs as two of the most important environmental gradients in all stormwater systems across the City. To promote biodiversity in future biofiltration projects, maintenance regimes and climatic changes should be taken into consideration when designing and permitting these systems. As drought conditions are anticipated to lengthen with changing weather patterns (Z. Li et al. 2019), maintenance regimes should be adaptable to adequately promote the ecosystem services the City values. The proceeding discussions will attempt to make specific recommendations for biofiltration systems within the Austin.

Recommendations

- Due to a lack of significant differences in plant community diversity among SCM types, future planting specifications should prioritize native facultative upland bunchgrass species demonstrated to persist successfully across multiple SCM types. Native drought-tolerant species exhibiting high frequency of occurrence and high mean relative cover, such as switchgrass (*Panicum virgatum*), Lindheimer's muhly (*Muhlenbergia lindheimeri*), and sideoats grama (*Bouteloua curtipendula*), may serve as foundational species for SCM planting palettes because they appear well adapted to local SCM conditions. These species

are unable to persist through consistent above ground biomass removal. As such, we suggest trimming bunchgrasses to one-third of the tiller height once per year during the late winter, preferably February. Appendix B: Recommended Vegetation Species for Biofiltration SCMs provides a full list of 20 recommended native vegetation species commonly identified in SCMs across Austin, based on an analysis of relative cover and frequency of occurrence.

- This study identified drought conditions and intensive vs non-intensive maintenance regimes as the primary drivers of plant community composition across Austin SCMs. As drought conditions are projected to become more frequent and prolonged (Li et al. 2019), vegetation management practices should be adjusted to reduce disturbance during periods of environmental stress. Specifically, the frequency of intensive maintenance activities (i.e., mowing and vegetation removal) should be reduced within biofiltration systems where it is feasible to promote plant establishment and persistence. We recommend discontinuing mowing to the ground level for the entire SCM. We recommend the introduction of bunchgrass trimming to one-third of the tiller height once per year during late winter, preferably February. Any woody plant recruitment that occurs within SCMs should be removed by hand but should not necessitate removal of all vegetation within the SCM. Removal of all vegetation within the SCM will increase the ability of non-native and undesirable vegetation to colonize the SCM.
- Future biofiltration design criteria should allow planting palettes to be adjusted based on anticipated site conditions, particularly shade and hydrologic regimes. Urban development is anticipated to increase building height and density geographically adjacent to SCMs across the eastern half of the city. Urban landscape designers or engineers should evaluate expected shading conditions during the project design and select vegetation species according to expected shade effects. For facilities expected to experience substantial shading, selection of shade-tolerant native ground cover species such as straggler daisy (*Calyptracarpus vialis*), ponyfoot (*Dichondra carolinensis*), and frog fruit (*Phyla nodiflora*) should be incorporated into planting palettes for that specific SCM. Design guidance should periodically review and update approved plant palettes to reflect observed field

identified performance under changing climatic, hydrologic, and urban development conditions.

- If initial vegetation planting removal is required, planting specifications should allow the use of native seed mixes as an alternative to container plantings. Use of native seed mixes primarily composed of facultative upland bunchgrasses and ground cover species (e.g., Lindheimer's muhly (*Muhlenbergia lindheimeri*), switchgrass (*Panicum virgatum*), sideoats grama (*Bouteloua curtipendula*), straggler daisy (*Calypocarpus vialis*), ponyfoot (*Dichondra carolinensis*), and frog fruit (*Phyla nodiflora*) listed above may reduce long-term maintenance and replacement costs.
- Specific recommendations to change existing criteria to promote native bunchgrasses and forb species include 1) removal of the 18-inch vegetation height limitation and replacing current maintenance language to include trimming to one-third of the bunchgrass tiller height in late winter, 2) replacement of the five minimum species requirements to two minimum species from biofiltration SCMs for ease of maintenance within biofiltration systems, and 3) require native seeding along with containerized plantings of biofiltration SCMs to aid in native plant species recruitment and establishment. Species recommendations are provided in Appendix B: Recommended Vegetation Species for Biofiltration SCMs. The two minimum species required for container plantings should be native facultative upland bunchgrass species outlined above; or in the case of shaded systems, the three shade-tolerant native ground cover species identified above. Because many of the above species are adapted to significant drought regimes experienced throughout Central Texas, they should be prioritized for biofiltration plantings. Prior City-funded biofiltration studies have shown that Lindheimer's muhly (*Muhlenbergia lindheimeri*) is able to adequately remove pollutants such as total nitrogen and total phosphorus from synthetic stormwater (Barrett et al. 2013). Minimizing the frequency and severity of mechanical disturbance is required for their growth rate and survival.
- We recommend a warranty period following SCM construction, during which the developer retains financial responsibility for SCM maintenance, ensuring adequate time and incentive to correct vegetation establishment failures before financial responsibility is released. Planting failures are common due to lapses in vegetation inspection frequency.

This has been shown through previously published WPD studies on sapling survival in riparian corridors, particularly where soil moisture is elevated (González and Richter 2014). Frequent monitoring of biofiltration systems may be necessary to ensure desired species (e.g. switchgrass and Lindheimer's muhly) recruitment and establishment. Additional monitoring may be further necessitated to prevent domination by undesirable species, which could increase the likelihood of removal of all vegetation throughout the system.

- Should initial vegetation plantings be removed and/or replaced due to natural successional ecological processes, we recommend that the following species are allowable within biofiltration SCMs and should not be considered nuisance species for removal nor should a notification of violation be issued: southern annual salt marsh aster (*Symphyotrichum divaricatum*), western ragweed (*Ambrosia psilostachya*), tievine (*Ipomoea cordatotriloba*), evening primrose (*Oenothera speciosa*), gray goldenrod (*Solidago nemoralis*), prairie petunia (*Ruellia humilis*), upright prairie coneflower (*Ratibida columnifera*), silverleaf nightshade (*Solanum elaeagnifolium*), plateau goldeneye (*Viguiera dentata*), giant ragweed (*Ambrosia trifida*), camphorweed (*Heterotheca subaxillaris*), gulf muhly (*Muhlenbergia capillaris*), and annual marshelder (*Iva annua*).
- In contrast, we recommend that the following nuisance species be added to ECM Section Table 1.6.7.C-2. The following invasive species found in SCMs across Austin may aid in the spread of nuisance species into local riparian areas and waterways, further decreasing local biodiversity (Sinclair et al. 2020): pampasgrass (*Cortaderia selloana*), deep-rooted sedge (*Cyperus entrerianus*), Korean mulberry (*Morus indica*), glossy privet (*Ligustrum lucidum*), johnsongrass (*Sorghum halepense*), Indian goosegrass (*Eleusine indica*), King Ranch bluestem (*Bothriochloa ischaemum*), chamber bitter (*Phyllanthus urinaria*), common chickweed (*Stellaria media*), alligatorweed (*Alternanthera philoxeroides*), white clover (*Trifolium repens*), dallisgrass (*Paspalum dilatatum*), field brome (*Bromus arvensis*), black medick (*Medicago lupulina*), marsh parsley (*Cyclospermum leptophyllum*), spiny sowthistle (*Sonchus asper*), perennial ryegrass (*Lolium perenne*), and common hedge parsley (*Torilis arvensis*).

- Additional materials related to education, communications, and public outreach of green stormwater infrastructure are recommended to prevent community members from performing maintenance of private and publicly maintained facilities. Currently, there is limited public understanding of green stormwater infrastructure facilities, and residents mistake the ecologically functioning systems as neglected and/or unsafe areas. To bolster the appeal of these systems, educational materials such as signs and markings should be established at biofiltration facilities to clarify the intent and benefits of natural areas and to improve community understanding.

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Appendix A: Full Species List

USDA Plant Code	Plant Species Name	Plant Status	Plant Cycle	Plant Structure	Plant Family	USACE Wetland Class
ABFR3	<i>Abutilon fruticosum</i>	Native	Perennial	Forb	Malvaceae	UPL
ACPH3	<i>Acalpha phleoides</i>	Native	Perennial	Forb	Euphorbiaceae	UPL
AGHE4	<i>Agalinis heterophylla</i>	Native	Annual	Forb	Scrophulariaceae	FAC
ALPH	<i>Alternanthera philoxeroides</i>	Non-Native	Perennial	Forb	Amaranthaceae	OBL
AMAR	<i>Ampelopsis arborea</i>	Native	Perennial	Forb	Amaranthaceae	FAC
AMDR	<i>Amphyiachyris dracunculoides</i>	Native	Annual	Forb	Asteraceae	UPL
AMPA	<i>Amaranthus palmeri</i>	Native	Annual	Forb	Amaranthaceae	FACU
AMPO	<i>Amaranthus polygonoides</i>	Native	Annual	Forb	Amaranthaceae	UPL
AMPS	<i>Ambrosia psilostachya</i>	Native	Perennial	Forb	Asteraceae	FACU
AMTR	<i>Ambrosia trifida</i>	Native	Annual	Forb	Asteraceae	FAC
ANAR	<i>Anagallis arvensis</i>	Non-Native	Annual	Forb	Primulaceae	FACU
ANGE	<i>Andropogon gerardii</i>	Native	Perennial	Bunchgrass	Poaceae	FACU
ARDO4	<i>Arundo donax</i>	Non-Native	Perennial	Shrub	Poaceae	FAC
ARHU5	<i>Argythamnia humilis</i>	Native	Perennial	Forb	Euphorbiaceae	UPL
ARPU9	<i>Aristida purpurea</i>	Native	Perennial	Bunchgrass	Poaceae	UPL
BAMO	<i>Bacopa monnieri</i>	Native	Perennial	Forb	Scrophulariaceae	OBL
BANE2	<i>Baccharis neglecta</i>	Native	Perennial	Shrub	Asteraceae	FAC
BICA	<i>Bignonia capreolata</i>	Native	Perennial	Vine	Bignoniaceae	FAC
BOCO	<i>Boerhavia coccinea</i>	Native	Perennial	Forb	Nyctaginaceae	UPL
BOCU	<i>Bouteloua curtipendula</i>	Native	Perennial	Bunchgrass	Poaceae	UPL
BODA	<i>Bouteloua dactyloides</i>	Native	Perennial	Bunchgrass	Poaceae	FACU
BOER	<i>Boerhavia erecta</i>	Native	Perennial	Forb	Nyctaginaceae	UPL
BOIN3	<i>Bowlesia incana</i>	Native	Annual	Forb	Apiaceae	FACU
BOIS	<i>Bothriochloa ischaemum</i>	Non-Native	Perennial	Bunchgrass	Poaceae	UPL
BOLA2	<i>Bothriochloa laguroides</i>	Native	Perennial	Bunchgrass	Poaceae	UPL
BRAR5	<i>Bromus arvensis</i>	Non-Native	Annual	Bunchgrass	Poaceae	FACU
BRCA6	<i>Bromus catharticus</i>	Non-Native	Annual	Bunchgrass	Poaceae	UPL
CAAM2	<i>Callicarpa americana</i>	Native	Perennial	Shrub	Verbenaceae	FACU
CAHA13	<i>Cardiospermum halicacabum</i>	Non-Native	Perennial	Forb	Sapindaceae	FAC
CAIL2	<i>Carya illinoensis</i>	Native	Perennial	Tree	Juglandaceae	FAC
CAIN13	<i>Castilleja indivisa</i>	Native	Annual	Forb	Scrophulariaceae	FAC
CAIN2	<i>Callirhoe involucrata</i>	Native	Perennial	Forb	Malvaceae	UPL

USDA Plant Code	Plant Species Name	Plant Status	Plant Cycle	Plant Structure	Plant Family	USACE Wetland Class
CAPA47	<i>Calibrachoa parviflora</i>	Non-Native	Annual	Forb	Solanaceae	FACW
CAPL3	<i>Carex planostachys</i>	Native	Perennial	Sedge	Cyperaceae	UPL
CAVI2	<i>Calyptocarpus vialis</i>	Native	Perennial	Forb	Asteraceae	FAC
CELA	<i>Celtis laevigata</i>	Native	Perennial	Tree	Ulmaceae	FAC
CETE2	<i>Centaurium texense</i>	Native	Annual	Forb	Gentianaceae	UPL
CHCU2	<i>Chloris cucullata</i>	Native	Perennial	Bunchgrass	Poaceae	UPL
CHED	<i>Chamaesaracha edwardsiana</i>	Native	Perennial	Forb	Solanaceae	UPL
CHHY3	<i>Euphorbia hyssopifolia</i>	Native	Perennial	Forb	Euphorbiaceae	FACU
CHPR6	<i>Chamaesyce prostrata</i>	Native	Perennial	Forb	Euphorbiaceae	UPL
CHSE4	<i>Chamaesyce serpens</i>	Native	Perennial	Forb	Euphorbiaceae	FACU
CITE2	<i>Cirsium texanum</i>	Native	Perennial	Forb	Asteraceae	UPL
CITR2	<i>Cissus trifoliata</i>	Native	Perennial	Vine	Vitaceae	FACU
CIUN	<i>Cirsium undulatum</i>	Native	Perennial	Forb	Asteraceae	FACU
CLDR	<i>Clematis drummondii</i>	Native	Perennial	Vine	Ranunculaceae	UPL
COAR4	<i>Convolvulus arvensis</i>	Non-Native	Perennial	Forb	Convolvulaceae	UPL
COCA5	<i>Conyza canadensis</i>	Native	Annual	Forb	Asteraceae	UPL
CODI5	<i>Commelina diffusa</i>	Native	Perennial	Forb	Commelinaceae	FACW
CODR	<i>Cornus drummondii</i>	Native	Perennial	Tree	Cornaceae	FAC
COEQ	<i>Convolvulus equitans</i>	Native	Perennial	Forb	Convolvulaceae	FACU
COER	<i>Commelina erecta</i>	Native	Perennial	Forb	Commelinaceae	FACU
COSE4	<i>Cortaderia selloana</i>	Non-Native	Perennial	Bunchgrass	Poaceae	FACU
COTI3	<i>Coreopsis tinctoria</i>	Native	Perennial	Forb	Asteraceae	FAC
CRMO6	<i>Croton monanthogynus</i>	Native	Annual	Forb	Euphorbiaceae	UPL
CROTO	<i>Croton spp.</i>	Native	Perennial	Forb	Euphorbiaceae	UPL
CYAC2	<i>Cyperus acuminatus</i>	Native	Perennial	Sedge	Cyperaceae	OBL
CYDA	<i>Cynodon dactylon</i>	Non-Native	Perennial	Turfgrass	Poaceae	FACU
CYEN2	<i>Cyperus entrerianus</i>	Non-Native	Perennial	Sedge	Cyperaceae	FACW
CYES	<i>Cyperus esculentus</i>	Native	Perennial	Sedge	Cyperaceae	FACW
CYLE7	<i>Cyclospermum leptophyllum</i>	Non-Native	Annual	Forb	Apiaceae	FACW
CYPER	<i>Cyperus spp.</i>	Native	Perennial	Sedge	Cyperaceae	FACW
DAPU3	<i>Daucus pusillus</i>	Native	Annual	Forb	Apiaceae	UPL
DEVI3	<i>Desmanthus virgatus</i>	Native	Perennial	Forb	Fabaceae	FACU

USDA Plant Code	Plant Species Name	Plant Status	Plant Cycle	Plant Structure	Plant Family	USACE Wetland Class
DICA3	<i>Dichondra carolinensis</i>	Native	Perennial	Forb	Convolvulaceae	FAC
DIOLS	<i>Dichanthelium oligosanthes</i>	Native	Perennial	Bunchgrass	Poaceae	FACU
DISA	<i>Digitaria sanguinalis</i>	Non-Native	Annual	Bunchgrass	Poaceae	FACU
DITE2	<i>Diodia teres</i>	Native	Perennial	Forb	Rubiaceae	FACU
DRAM	<i>Rudbeckia amplexicaulis</i>	Native	Annual	Forb	Asteraceae	FAC
ECCO2	<i>Echinochloa colona</i>	Non-Native	Annual	Bunchgrass	Poaceae	FACW
ECCR	<i>Echinochloa crus-galli</i>	Non-Native	Annual	Bunchgrass	Poaceae	FAC
ECPR	<i>Eclipta prostrata</i>	Native	Perennial	Forb	Asteraceae	FACW
ELEOC	<i>Eleocharis spp.</i>	Native	Perennial	Rush	Cyperaceae	OBL
ELIN3	<i>Eleusine indica</i>	Non-Native	Annual	Bunchgrass	Poaceae	FACU
ELPA3	<i>Eleocharis palustris</i>	Native	Perennial	Rush	Cyperaceae	OBL
ENPE4	<i>Engelmannia peristenia</i>	Native	Perennial	Forb	Asteraceae	UPL
ERCI6	<i>Erodium cicutarium</i>	Non-Native	Annual	Forb	Geraniaceae	UPL
EUDE4	<i>Euphorbia dentata</i>	Native	Annual	Forb	Euphorbiaceae	UPL
EUSE2	<i>Eupatorium serotinum</i>	Native	Perennial	Forb	Asteraceae	FAC
EVVE	<i>Evax verna</i>	Native	Annual	Forb	Asteraceae	UPL
FRPE	<i>Fraxinus pennsylvanica</i>	Native	Perennial	Tree	Oleaceae	FAC
GAAP2	<i>Galium aparine</i>	Native	Annual	Forb	Rubiaceae	FACU
GAPE2	<i>Gamochaeta pensylvanica</i>	Native	Annual	Forb	Asteraceae	UPL
GAPU	<i>Gaillardia pulchella</i>	Native	Annual	Forb	Asteraceae	UPL
GECA5	<i>Geranium carolinianum</i>	Native	Annual	Forb	Geraniaceae	UPL
GLBIB	<i>Glandularia bipinnatifida</i> var. <i>bipinnatifida</i>	Native	Perennial	Forb	Verbenaceae	UPL
HEAM	<i>Helenium amarum</i>	Native	Annual	Forb	Asteraceae	FACU
HEAN3	<i>Helianthus annuus</i>	Native	Annual	Forb	Asteraceae	FACU
HECR2	<i>Hedypnois cretica</i>	Non-Native	Annual	Forb	Asteraceae	UPL
HERE3	<i>Hedeoma reverchonii</i>	Native	Perennial	Forb	Lamiaceae	UPL
HESU3	<i>Heterotheca subaxillaris</i>	Native	Annual	Forb	Asteraceae	UPL
HOPU	<i>Hordeum pusillum</i>	Native	Annual	Bunchgrass	Poaceae	FACU
ILVO	<i>Ilex vomitoria</i>	Native	Perennial	Shrub	Aquifoliaceae	FAC
INMI	<i>Indigofera miniata</i>	Native	Perennial	Forb	Fabaceae	UPL
IPCOC2	<i>Ipomoea cordatotriloba</i>	Native	Perennial	Vine	Convolvulaceae	FAC
IVAN2	<i>Iva annua</i>	Native	Annual	Forb	Asteraceae	FAC

USDA Plant Code	Plant Species Name	Plant Status	Plant Cycle	Plant Structure	Plant Family	USACE Wetland Class
JUTE	<i>Juncus tenuis</i>	Native	Perennial	Rush	Juncaceae	FAC
JUTO	<i>Juncus torreyi</i>	Native	Perennial	Rush	Juncaceae	FACW
KOMA	<i>Koeleria macrantha</i>	Native	Perennial	Bunchgrass	Poaceae	UPL
LAAM	<i>Lamium amplexaule</i>	Non-Native	Annual	Forb	Lamiaceae	UPL
LASE	<i>Lactuca serriola</i>	Non-Native	Annual	Forb	Asteraceae	FAC
LEAU3	<i>Lepidium austrinum</i>	Native	Annual	Forb	Brassicaceae	UPL
LEDU	<i>Leptochloa dubia</i>	Native	Perennial	Bunchgrass	Poaceae	UPL
LIAR	<i>Limnodea arkansana</i>	Native	Annual	Bunchgrass	Poaceae	UPL
LILU2	<i>Ligustrum lucidum</i>	Non-Native	Perennial	Shrub	Oleaceae	FACU
LIPU2	<i>Limnoscium pumilum</i>	Native	Annual	Forb	Apiaceae	FACW
LOPE	<i>Lolium perenne</i>	Non-Native	Perennial	Bunchgrass	Poaceae	FACU
LUOC	<i>Ludwigia octovalvis</i>	Native	Perennial	Forb	Onagraceae	OBL
LUPA	<i>Ludwigia palustris</i>	Native	Perennial	Forb	Onagraceae	OBL
LUTE	<i>Lupinus texensis</i>	Native	Annual	Forb	Fabaceae	FACU
LYAL4	<i>Lythrum alatum</i>	Native	Perennial	Forb	Lythraceae	OBL
MAAU	<i>Malvastrum aurantiacum</i>	Native	Perennial	Forb	Malvaceae	UPL
MACO6	<i>Malvastrum coromandelianum</i>	Non-Native	Perennial	Forb	Malvaceae	FAC
MAPU7	<i>Mazus pumilus</i>	Non-Native	Annual	Forb	Scrophulariaceae	FAC
MEDI2	<i>Merremia dissecta</i>	Native	Perennial	Vine	Convolvulaceae	FAC
MELU	<i>Medicago lupulina</i>	Non-Native	Perennial	Forb	Fabaceae	FACU
MEOF	<i>Melilotus officinalis</i>	Non-Native	Perennial	Forb	Fabaceae	FACU
MEPE3	<i>Melothria pendula</i>	Native	Perennial	Vine	Cucurbitaceae	FAC
MEPO3	<i>Medicago polymorpha</i>	Non-Native	Annual	Forb	Fabaceae	FACU
MEPR2	<i>Mecardonia procumbens</i>	Native	Perennial	Forb	Scrophulariaceae	FACW
MEPY	<i>Melochia pyramidata</i>	Native	Perennial	Forb	Sterculiaceae	FAC
MISC	<i>Mikania scandens</i>	Native	Perennial	Vine	Asteraceae	FACW
MOAL	<i>Morus alba</i>	Non-Native	Perennial	Shrub	Moraceae	FACU
MOCA	<i>Modiola caroliniana</i>	Native	Perennial	Forb	Malvaceae	FAC
MOCI	<i>Monarda citriodora</i>	Native	Perennial	Forb	Lamiaceae	UPL
MOIN	<i>Morus indica</i>	Non-Native	Perennial	Tree	Moraceae	UPL
MORU2	<i>Morus rubra</i>	Native	Perennial	Tree	Moraceae	FACU
MORUS	<i>Morus spp.</i>	Native	Perennial	Shrub	Moraceae	FACU

USDA Plant Code	Plant Species Name	Plant Status	Plant Cycle	Plant Structure	Plant Family	USACE Wetland Class
MOVE	<i>Mollugo verticillata</i>	Native	Annual	Forb	Molluginaceae	FAC
MUCA2	<i>Muhlenbergia capillaris</i>	Native	Perennial	Bunchgrass	Poaceae	FACU
MULI	<i>Muhlenbergia lindheimeri</i>	Native	Perennial	Bunchgrass	Poaceae	FACW
NAJA	<i>Nama jamaicense</i>	Native	Annual	Forb	Hydrophyllaceae	FACW
NALE3	<i>Nassella leucotricha</i>	Native	Perennial	Bunchgrass	Poaceae	UPL
NEPU3	<i>Neptunia pubescens</i>	Native	Perennial	Forb	Fabaceae	FAC
OECI	<i>Oenothera curtifolia</i>	Native	Annual	Forb	Onagraceae	UPL
OEGA	<i>Oenothera gaura</i>	Native	Biennial	Forb	Onagraceae	FACU
OELA	<i>Oenothera laciniata</i>	Native	Perennial	Forb	Onagraceae	FACU
OESP2	<i>Oenothera speciosa</i>	Native	Perennial	Forb	Onagraceae	UPL
OESU4	<i>Oenothera suffulta</i>	Native	Annual	Forb	Onagraceae	UPL
OXDI2	<i>Oxalis dillenii</i>	Native	Perennial	Forb	Oxalidaceae	FACU
PAAN	<i>Panicum anceps</i>	Native	Perennial	Bunchgrass	Poaceae	FAC
PADI3	<i>Paspalum dilatatum</i>	Non-Native	Perennial	Bunchgrass	Poaceae	FAC
PAGL17	<i>Packera glabella</i>	Native	Annual	Forb	Asteraceae	FACW
PAHA	<i>Panicum hallii</i>	Native	Perennial	Bunchgrass	Poaceae	FACU
PAHY	<i>Parthenium hysterophorus</i>	Non-Native	Perennial	Forb	Asteraceae	FAC
PAPE5	<i>Parietaria pensylvanica</i>	Native	Annual	Forb	Urticaeae	FAC
PAPU5	<i>Paspalum pubiflorum</i>	Native	Perennial	Bunchgrass	Poaceae	FACW
PAQU2	<i>Parthenocissus quinquefolia</i>	Native	Perennial	Vine	Vitaceae	FACU
PASPA2	<i>Paspalum spp.</i>	Native	Perennial	Bunchgrass	Poaceae	UPL
PAUR2	<i>Paspalum urvillei</i>	Non-Native	Perennial	Bunchgrass	Poaceae	FACW
PAVI2	<i>Panicum virgatum</i>	Native	Perennial	Bunchgrass	Poaceae	FAC
PHAN5	<i>Physalis angulata</i>	Native	Annual	Forb	Solanaceae	FAC
PHCA6	<i>Phalaris caroliniana</i>	Native	Annual	Bunchgrass	Poaceae	FACW
PHNO2	<i>Phyla nodiflora</i>	Native	Perennial	Forb	Verbenaceae	FAC
PHPO3	<i>Phyllanthus polygonoides</i>	Native	Perennial	Forb	Euphorbiaceae	UPL
PHUR	<i>Phyllanthus urinaria</i>	Non-Native	Annual	Forb	Euphorbiaceae	FAC
PHVI17	<i>Physalis viscosa</i>	Native	Perennial	Forb	Solanaceae	UPL
PHYSA	<i>Physalis spp.</i>	Native	Perennial	Forb	Solanaceae	UPL
PICH4	<i>Pistacia chinensis</i>	Non-Native	Perennial	Tree	Anacardiaceae	UPL
PLHE2	<i>Plantago heterophylla</i>	Native	Annual	Forb	Plantaginaceae	FACW

USDA Plant Code	Plant Species Name	Plant Status	Plant Cycle	Plant Structure	Plant Family	USACE Wetland Class
PLOD	<i>Pluchea odorata</i>	Native	Perennial	Forb	Asteraceae	FACW
PLRH	<i>Plantago rhodosperma</i>	Native	Annual	Forb	Plantaginaceae	FACU
POAN	<i>Poa annua</i>	Non-Native	Annual	Bunchgrass	Poaceae	FACU
POOL	<i>Portulaca oleracea</i>	Native	Annual	Forb	Portulacaceae	FAC
POPI3	<i>Portulaca pilosa</i>	Native	Perennial	Forb	Portulacaceae	FACU
POTE	<i>Polytaenia texana</i>	Native	Perennial	Forb	Apiaceae	UPL
PYPA4	<i>Pyrrhopappus pauciflorus</i>	Native	Perennial	Forb	Asteraceae	UPL
QUFU	<i>Quercus fusiformis</i>	Native	Perennial	Tree	Fagaceae	UPL
RACO3	<i>Ratibida columnifera</i>	Native	Perennial	Forb	Asteraceae	UPL
RAMU2	<i>Ranunculus muricatus</i>	Non-Native	Perennial	Forb	Ranunculaceae	FACW
RARU	<i>Rapistrum rugosum</i>	Non-Native	Annual	Forb	Brassicaceae	UPL
RHMI4	<i>Rhynchosia minima</i>	Native	Perennial	Vine	Fabaceae	UPL
ROCR3	<i>Rostraria cristata</i>	Non-Native	Annual	Bunchgrass	Poaceae	UPL
RUCR	<i>Rumex crispus</i>	Non-Native	Perennial	Forb	Polygonaceae	FAC
RUELL	<i>Ruellia spp.</i>	Native	Perennial	Forb	Acanthaceae	UPL
RUHI2	<i>Rudbeckia hirta</i>	Native	Perennial	Forb	Asteraceae	FACU
RUHU	<i>Ruellia humilis</i>	Native	Perennial	Forb	Acanthaceae	FAC
RUPU3	<i>Rumex pulcher</i>	Non-Native	Perennial	Forb	Polygonaceae	FACW
RUTR	<i>Rubus trivialis</i>	Native	Perennial	Forb	Rosaceae	FACU
SAFA2	<i>Salvia farinacea</i>	Native	Perennial	Forb	Lamiaceae	UPL
SANI	<i>Salix nigra</i>	Native	Perennial	Tree	Salicaceae	FACW
SCDR2	<i>Scutellaria drummondii</i>	Native	Annual	Forb	Lamiaceae	UPL
SCSC	<i>Schizachyrium scoparium</i>	Native	Perennial	Bunchgrass	Poaceae	FACU
SEPA10	<i>Setaria parviflora</i>	Native	Perennial	Bunchgrass	Poaceae	FAC
SHAR2	<i>Sherardia arvensis</i>	Non-Native	Annual	Forb	Rubiaceae	UPL
SIAB	<i>Sida abutifolia</i>	Non-Native	Perennial	Forb	Malvaceae	UPL
SIAN2	<i>Silene antirrhina</i>	Native	Annual	Forb	Caryophyllaceae	UPL
SIAN3	<i>Sisyrinchium angustifolium</i>	Native	Perennial	Forb	Iridaceae	FACW
SOAS	<i>Sonchus asper</i>	Non-Native	Annual	Forb	Asteraceae	FAC
SODI	<i>Solanum dimidiatum</i>	Native	Perennial	Forb	Solanaceae	UPL
SOEL	<i>Solanum elaeagnifolium</i>	Native	Perennial	Forb	Solanaceae	UPL
SOHA	<i>Sorghum halepense</i>	Non-Native	Perennial	Bunchgrass	Poaceae	FACU

USDA Plant Code	Plant Species Name	Plant Status	Plant Cycle	Plant Structure	Plant Family	USACE Wetland Class
SONCH	<i>Sonchus spp.</i>	Non-Native	Perennial	Forb	Asteraceae	UPL
SONE	<i>Solidago nemoralis</i>	Native	Perennial	Forb	Asteraceae	UPL
SONU2	<i>Sorghatrum nutans</i>	Native	Perennial	Bunchgrass	Poaceae	FACU
SOSE2	<i>Soliva sessilis</i>	Non-Native	Annual	Forb	Asteraceae	UPL
SPOB	<i>Sphenopholis obtusata</i>	Native	Perennial	Bunchgrass	Poaceae	FAC
STHE9	<i>Strophostyles helvola</i>	Native	Annual	Vine	Fabaceae	FACU
STME2	<i>Stellaria media</i>	Non-Native	Perennial	Forb	Caryophyllaceae	FACU
STNI6	<i>Stenaria nigricans</i>	Native	Perennial	Forb	Rubiaceae	UPL
SYDI2	<i>Symphyotrichum divaricatum</i>	Native	Annual	Forb	Asteraceae	OBL
SYDRT	<i>Symphyotrichum drummondii</i>	Native	Perennial	Forb	Asteraceae	UPL
SYPR5	<i>Symphyotrichum praelum</i>	Native	Perennial	Forb	Asteraceae	FACW
TAOF	<i>Taraxacum officinale</i>	Native	Perennial	Forb	Asteraceae	FACU
TELI3	<i>Tetraneuris linearifolia</i>	Native	Annual	Forb	Asteraceae	UPL
THFI	<i>Thelesperma filifolium</i>	Native	Perennial	Forb	Asteraceae	UPL
TOAR	<i>Torilis arvensis</i>	Non-Native	Annual	Forb	Apiaceae	UPL
TONO	<i>Torilis nodosa</i>	Non-Native	Annual	Forb	Apiaceae	UPL
TORA2	<i>Toxicodendron radicans</i>	Native	Perennial	Vine	Anacardiaceae	FACU
TRAGI	<i>Tragia spp.</i>	Native	Perennial	Forb	Euphorbiaceae	UPL
TRAL2	<i>Tridens albescens</i>	Native	Perennial	Bunchgrass	Poaceae	FAC
TRBI2	<i>Triodanis biflora</i>	Native	Annual	Forb	Campanulaceae	UPL
TRDA3	<i>Tripsacum dactyloides</i>	Native	Perennial	Bunchgrass	Poaceae	FAC
TRRE3	<i>Trifolium repens</i>	Non-Native	Perennial	Forb	Fabaceae	FACU
TYLA	<i>Typha latifolia</i>	Native	Perennial	Forb	Typhaceae	OBL
ULAL	<i>Ulmus alata</i>	Native	Perennial	Tree	Ulmaceae	FACU
ULAM	<i>Ulmus americana</i>	Native	Perennial	Tree	Ulmaceae	FAC
ULCR	<i>Ulmus crassifolia</i>	Native	Perennial	Tree	Ulmaceae	FAC
URRE2	<i>Urochloa reptans</i>	Non-Native	Annual	Turfgrass	Poaceae	UPL
VARA	<i>Valerianella radiata</i>	Native	Annual	Forb	Valerianaceae	FACW
VEBR2	<i>Verbena brasiliensis</i>	Non-Native	Annual	Forb	Verbenaceae	UPL
VEHA	<i>Verbena halei</i>	Native	Perennial	Forb	Verbenaceae	UPL
VEPE3	<i>Veronica persica</i>	Non-Native	Annual	Forb	Scrophulariaceae	UPL
VIDE3	<i>Viguiera dentata</i>	Native	Perennial	Forb	Asteraceae	UPL

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VILU	<i>Vicia ludoviciana</i>	Native	Annual	Forb	Fabaceae	UPL
VIMU2	<i>Vitus mustangensis</i>	Native	Perennial	Vine	Vitaceae	UPL
WEAC	<i>Wedelia acapulcensis</i>	Native	Perennial	Forb	Asteraceae	UPL

Appendix B: Recommended Vegetation Species for Biofiltration SCMs

1. Switchgrass (*Panicum virgatum*)
2. Lindheimer's muhly (*Muhlenbergia lindheimeri*)
3. Sideoats grama (*Bouteloua curtipendula*)
4. Plateau goldeneye (*Viguiera dentata*)
5. Camphorweed (*Heterotheca subaxillaris*)
6. Western ragweed (*Ambrosia psilostachya*)
7. Straggler daisy (*Calyptocarpus vialis*)
8. Gulf muhly (*Muhlenbergia capillaris*)
9. Eastern gama grass (*Tripsacum dactyloides*)
10. Frog fruit (*Phyla nodiflora*)
11. Marsh elder (*Iva annua*)
12. Ponyfoot (*Dichondra carolinensis*)
13. Evening primrose (*Oenothera speciosa*)
14. Gray goldenrod (*Solidago nemoralis*)
15. Prairie petunia (*Ruellia humilis*)
16. Upright prairie coneflower (*Ratibida columnifera*)
17. Silverleaf nightshade (*Solanum elaeagnifolium*)
18. Prairie tea (*Croton monanthogynus*)
19. Carolina geranium (*Geranium carolinianum*)
20. Tievine (*Ipomoea cordatotriloba*)