Responses of Florida Scrub Vegetation to Water Additions from a Groundwater Treatment Project

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Introduction

- Florida scrub is a fire-maintained shrub vegetation of well-drained, sandy soils; dominant species include several species of *Quercus* and *Serenoa repens*. It is a rare and declining ecosystem and is habitat for threatened and endangered plants and animals.
- Many Florida scrub species are xeromorphic with adaptations to periodic drought.
- Climate of Central Florida is humid subtropical with a distinct rainy season (June-September)

Introduction (cont.)

- Several lines of evidence indicate that available water limits growth of scrub vegetation:
  - Radial growth of *Quercus chapmanii* and *Q*. *myrtifolia,* as indicated by tree rings, was related to spring precipitation – decreased by drought and increased by elevated spring precipitation (Foster et al. 2014, 2015)
  - Increment in aboveground oak biomass growth was reduced in severe drought. Elevated CO_2 ameliorated moderate but not severe drought (Li et al. 2007a).
  - Eddy flux studies in scrub showed that Net Ecosystem Exchange (NEE) was reduced by severe drought (Powell et al. 2006).
  - Scrub oaks access deep sources of water (Hungate et al. 2002, Bracho et al. 2008, Ellsworth & Sternberg 2015).
  - Severe drought resulted in physiological stress, leaf loss, and reduced growth, but only minor mortality of dominant scrub shrubs (Saha et al. 2008).

Introduction (cont.)

- In this study we examine the effects of adding water to an intact scrub ecosystem.
- Water was added through an underground exfiltration gallery during two periods (Oct. 2002-March 2004 and March 2005-Aug. 2008).
- We examined vegetation response from April 2002 (pretreatment) through May 2019.
- These data allow us to examine if scrub height growth, cover, and community composition changes with increased water.

Oak Scrub /Scrubby Flatwoods

Inland
Soils: leached, acid pH, low nutrient, well to moderately-well drained.

Vegetation: shrubland, oaks, saw palmetto, ericads, sometimes scattered pines.

Myrtle oak (*Quercus myrtifolia*)
Sand live oak (*Quercus geminata*)
Chapman oak (*Quercus chapmanii*)
Lyonia spp., *Vaccinium* spp.
Saw palmetto (*Serenoa repens*)
South Florida slash pine (*Pinus elliottii* var. *densa*)

Fire

Florida Scrub-Jay

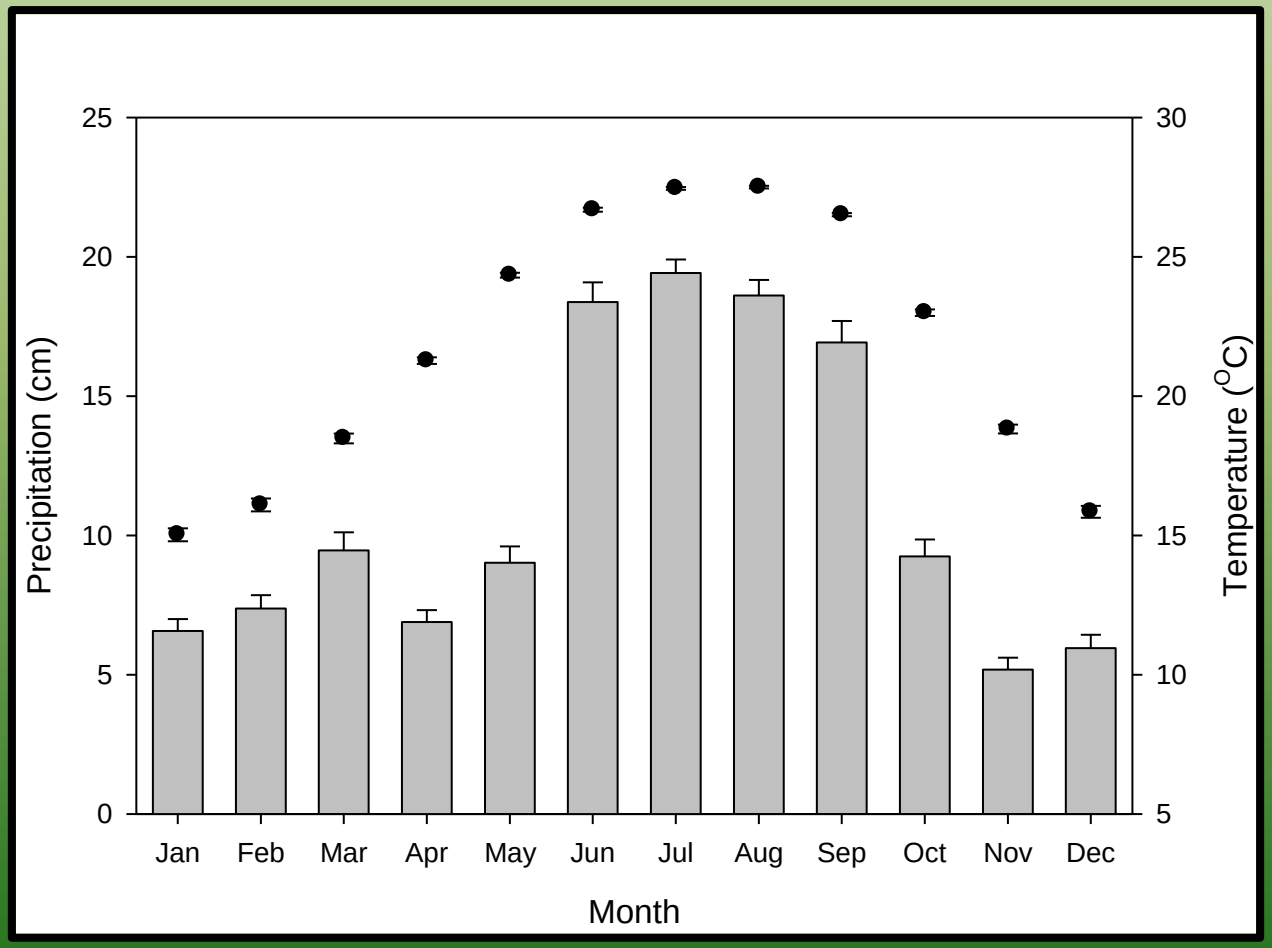
Listed as threatened by USFWS.

Habitat of scrub and scrubby flatwoods maintained by relatively frequent fire. Shrub height, low tree density, and sandy openings are important habitat features.

Scrub Fire

Prescribed burn in Happy Creek area of KSC/MINWR.

Central Florida Climate



CCF Remediation Project

- NASA operated a Component Cleaning Facility (CCF) on Kennedy Space Center near the Vehicle Assembly Building from 1962-1992.
- Groundwater contamination of the shallow, surficial aquifer around this facility with volatile organic compounds including trichloroethylene (= trichloroethene, TCE) occurred.
- Remediation of this site involved pumping and treating groundwater through an air sparging system as well as soil vapor extraction.
- Treated groundwater then was disposed of through an exfiltration gallery (HSW 2003, 2004).

CCF Remediation Project (cont.)

- The exfiltration gallery was placed in scrub vegetation near the CCF remediation site. It consisted of three legs each ca. 121.9 m in length.
- The remediation project operated in two phases:
  - Interim project - October 2002-March 2004, 494 days, 1.74 x 10^8 L treated water, mean rate = 3.52 x 10^5 L/day (HSW 2004).
  - Final project – March 2005-August 2008, 1251 days, distributed 1.9 x 10^8 L treated water, mean rate = 1.52 x 10^5 L/day (Jacobs 2006-2009).
  - During the interim project the depth to the water table near the exfiltration gallery was monitored by 6 piezometers (HSW 2004).
- Several interruptions to operations of the remediation system occurred due to equipment problems and hurricanes.

CCF Remediation and Scrub Site

The three legs of the water exfiltration gallery were each ca. 121.9 m in length.

Six piezometers were located near the exfiltration gallery to record depth to the water table.

The remediation site was to the lower right (southeast of the scrub site).

Methods

- We located 8 permanent line-intercept transects in the CCF scrub site in May 2002 five months before groundwater pumping began.
  - Transects were 15 m in length.
  - Four transects were near the water exfiltration gallery and four were more distant from it.
  - We sampled vegetation in two height strata, < 0.5 m and ≥ 0.5 m, along each transect and measured vegetation height at four points (0, 5, 10, 15 m).
  - This sampling was repeated annually through 2019.

- The site was typical of oak scrub on Kennedy Space Center/Merritt Island National Wildlife Refuge (Schmalzer & Hinkle 1992). It had been cut and burned for restoration in 1996, 6 years prior to initiation of the remediation project.

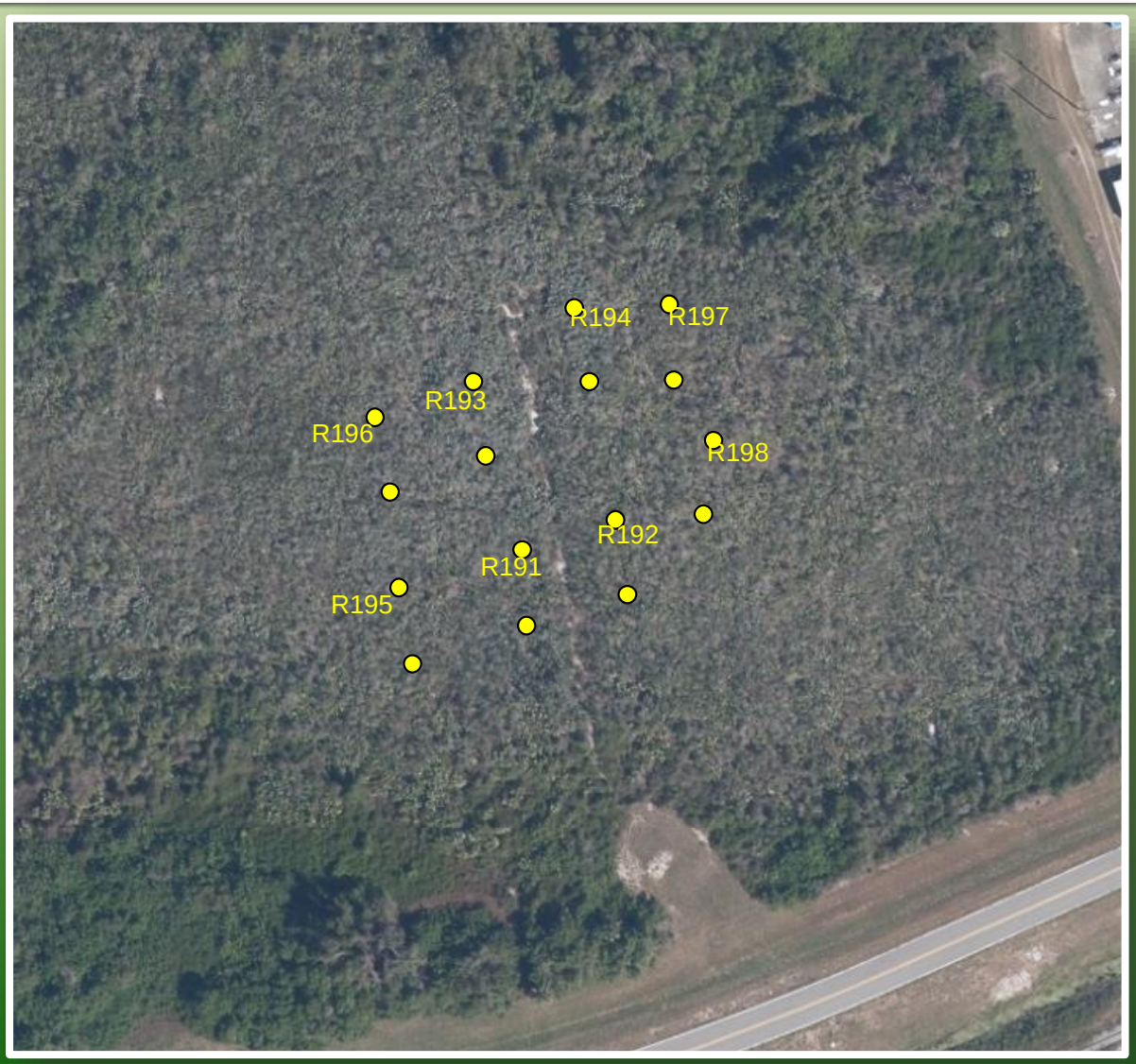
CCF Scrub Map

Location of 8 vegetation transects at the CCF scrub site

Four transects (R191-R194) were close to the central leg of the water exfiltration system.

Four transects (R195-R198) were more distant from the water exfiltration system.

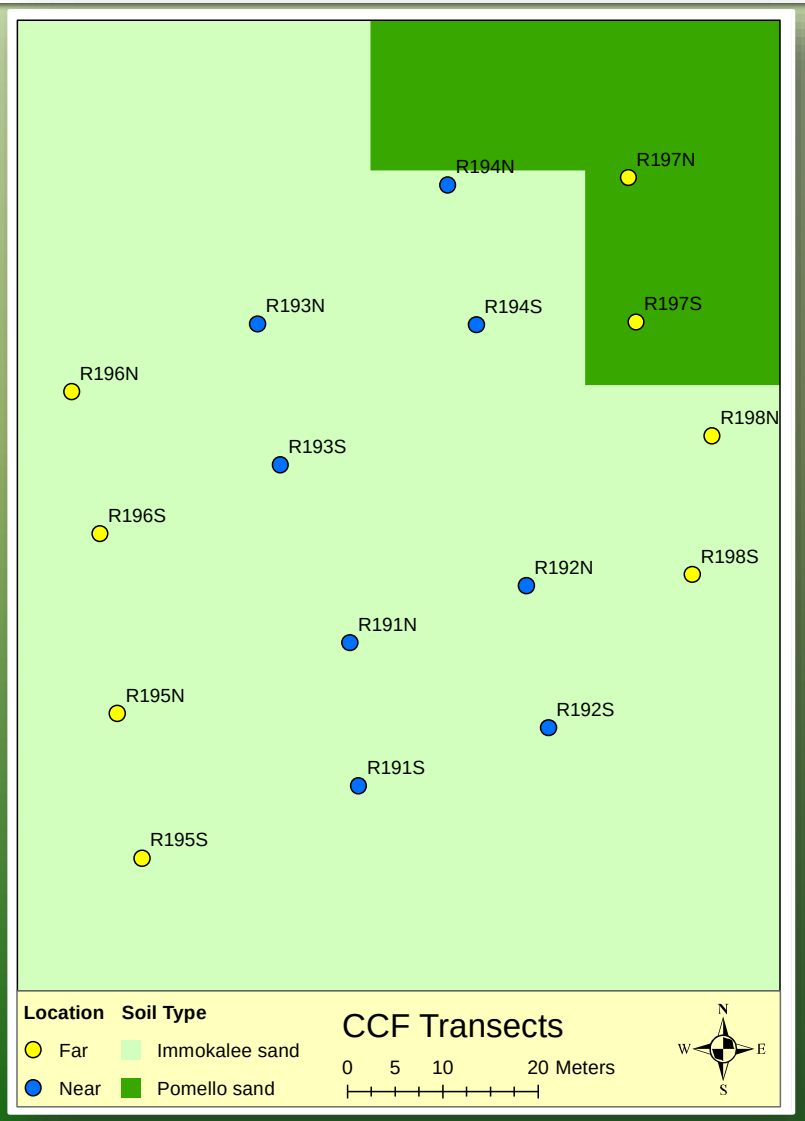
The Component Cleaning Facility was located south of the road shown at the bottom of the map.



Soil Map

Overlaying transects on the soil map (Huckle et al. 1974) indicated that seven of the transects were on Immokalee sand (Arenic Alaquod) and one on Pomello sand (Oxyaquic Alorthod), both Spodosols.

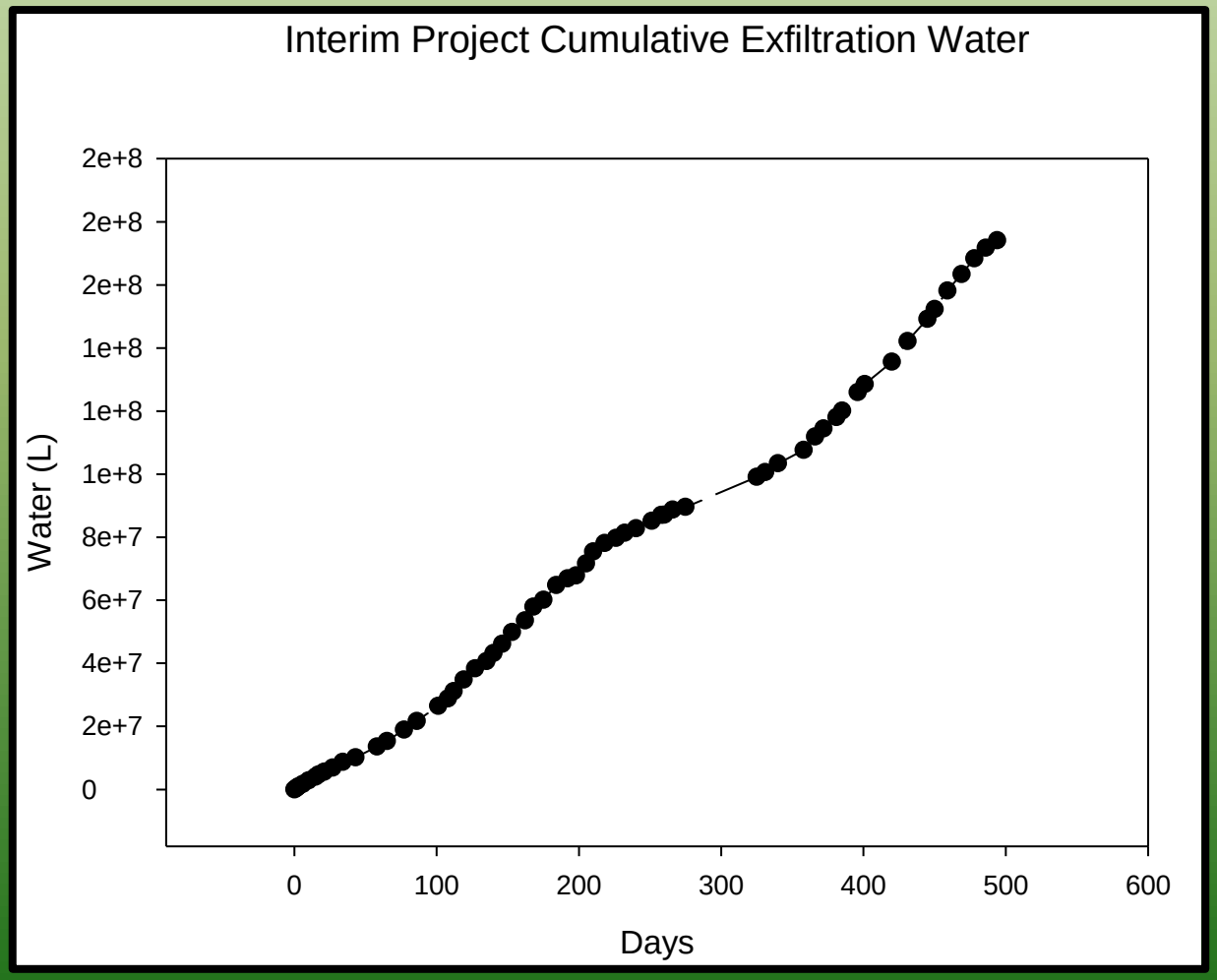
These are typical soils of oak-saw palmetto scrub on KSC/MINWR.



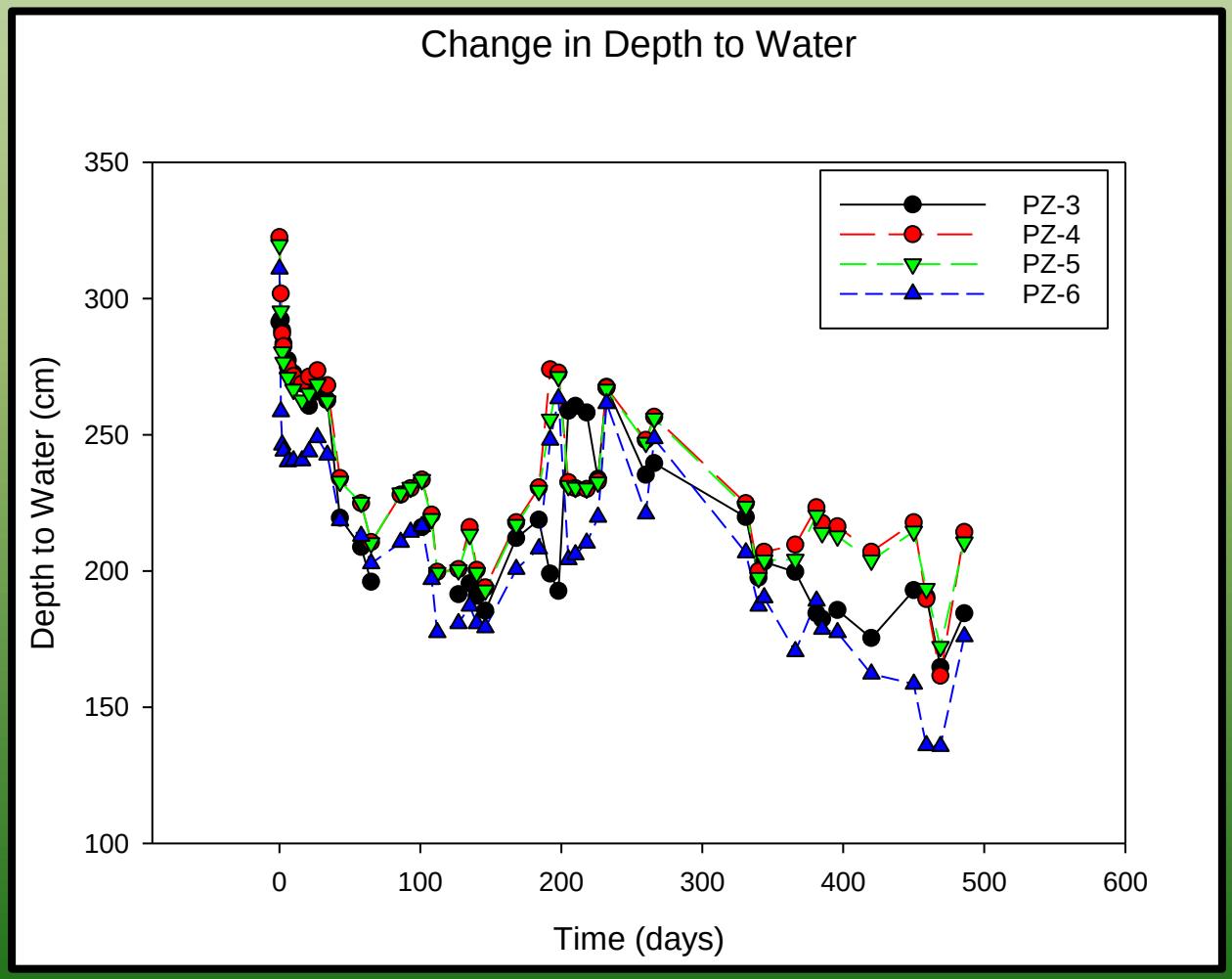
Results - Water

- During the interim project from October 2002 to March 2004, 494 days, 1.74 x 10^8 L of treated water was distributed through the exfiltration system.
- Exfiltration of treated groundwater decreased the depth to the water table in scrub near the exfiltration gallery during the interim project as shown by data from the four piezometers adjacent to the gallery leg in scrub.
  - Depth declined steadily with pumping from Oct. 2002 through March 2003 (0-150 days) when it stabilized for ca. 40 days.
  - Depth increased from May through June 2003 (ca. 190-250 days). This corresponded with a lower rate of pumping.
  - Depth declined with some variability for the remainder of the interim project (July 2003-Feb. 2004).
- In the final project from March 2005 through August 2008, 1251 days, 1.9 x 10^8 L of water was distributed. Depth to water table data were not collected in the final project.

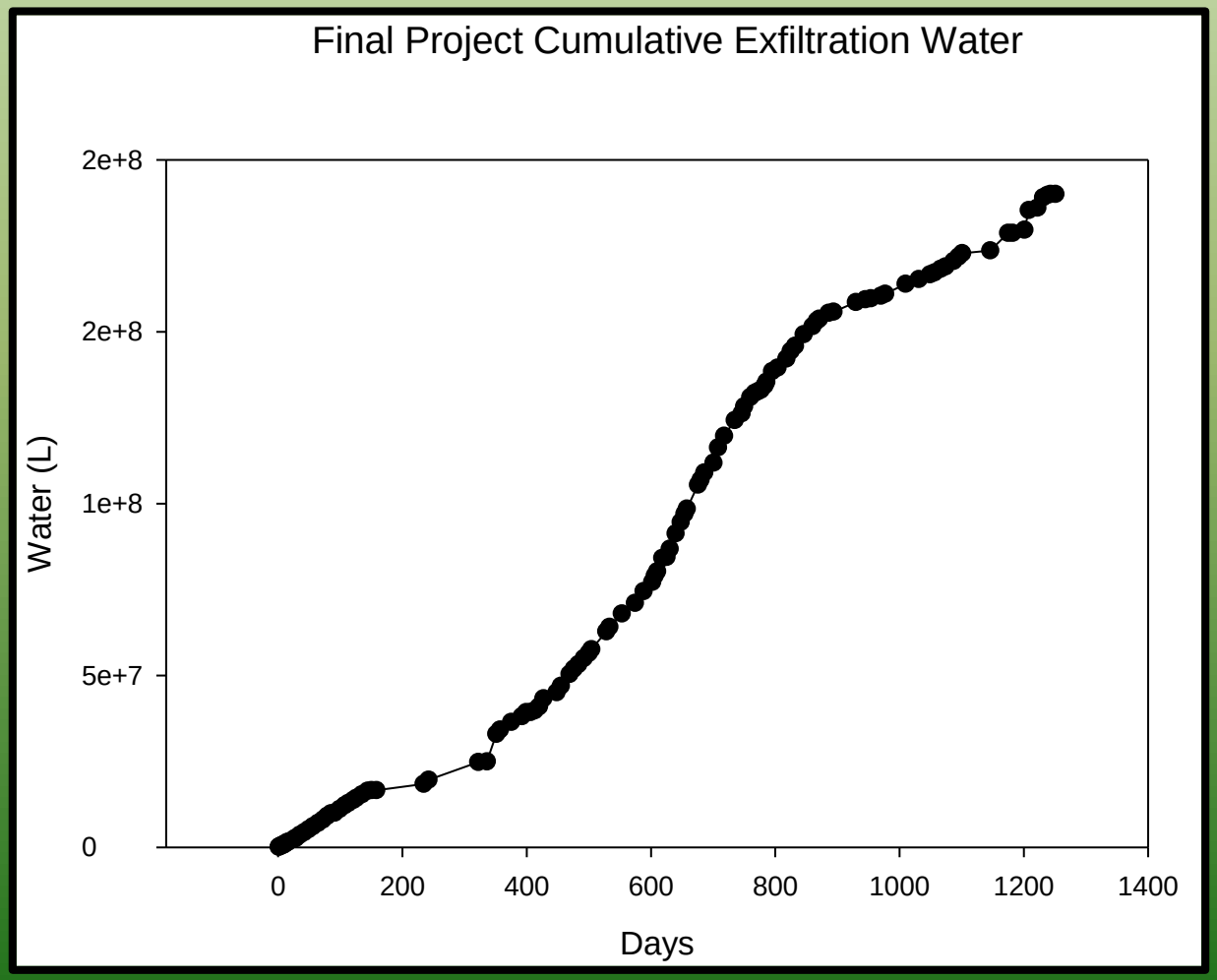
Water Added - Interim Project



Interim Project – Change in Depth to Water



Water Added – Final Project



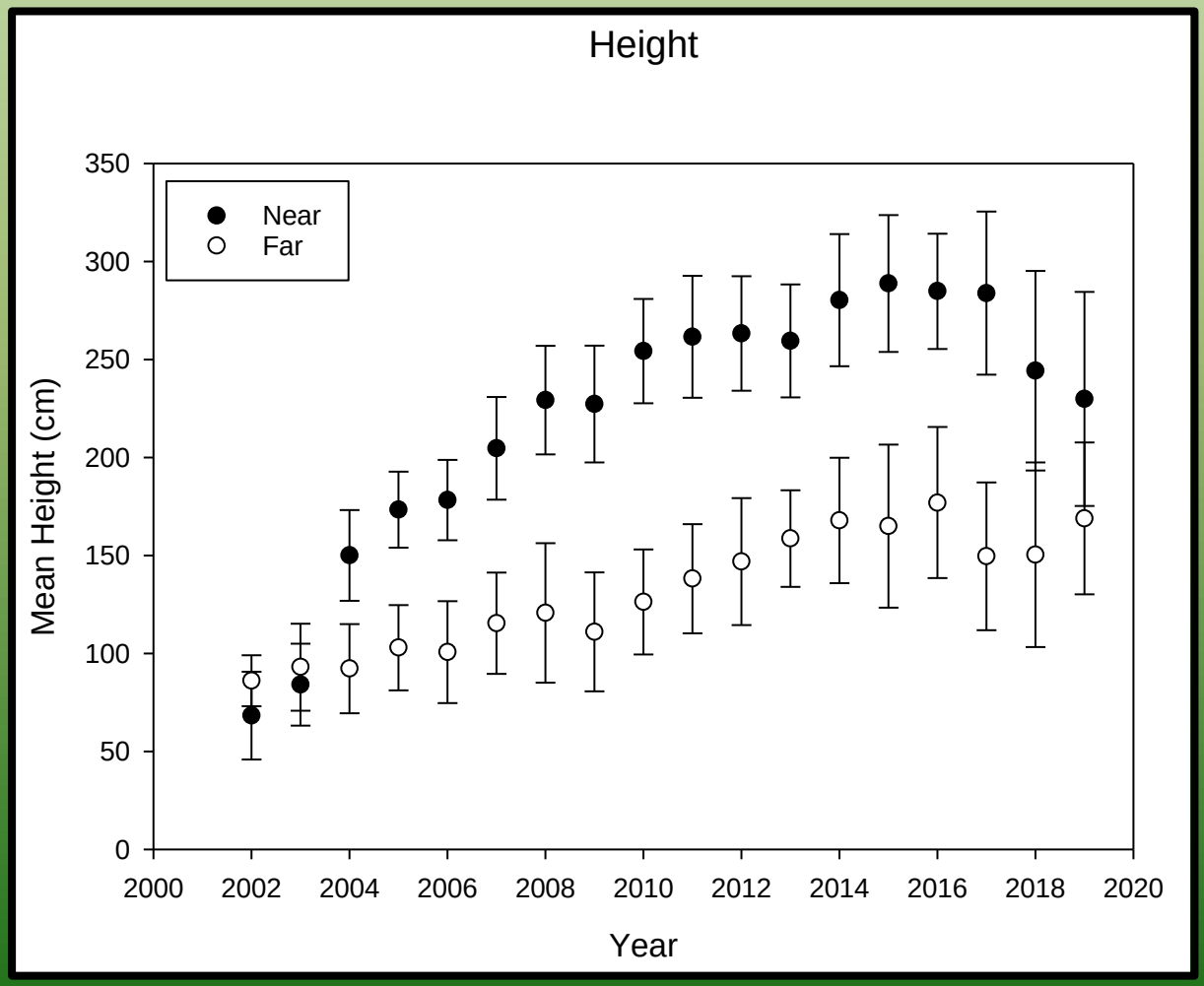
Results - Vegetation

- Mean height of transects near and farther from the water distribution system was similar before treatment. Height did not differ by May 2003, although the percent increase of the near transects was greater. By May 2004, height of the near transects exceeded that of the far transects and that difference has been maintained. The percent increase of height of the near transects was much greater in 2004.
- Total cover > 0.5 m followed the same pattern. Cover did not differ before treatment. Cover of the near transects increased to a greater extent in 2003 and to a much greater extent in 2004 than in the far transects.
- Total cover < 0.5 m and percent bare ground declined to a greater extent in the near transects by 2004.

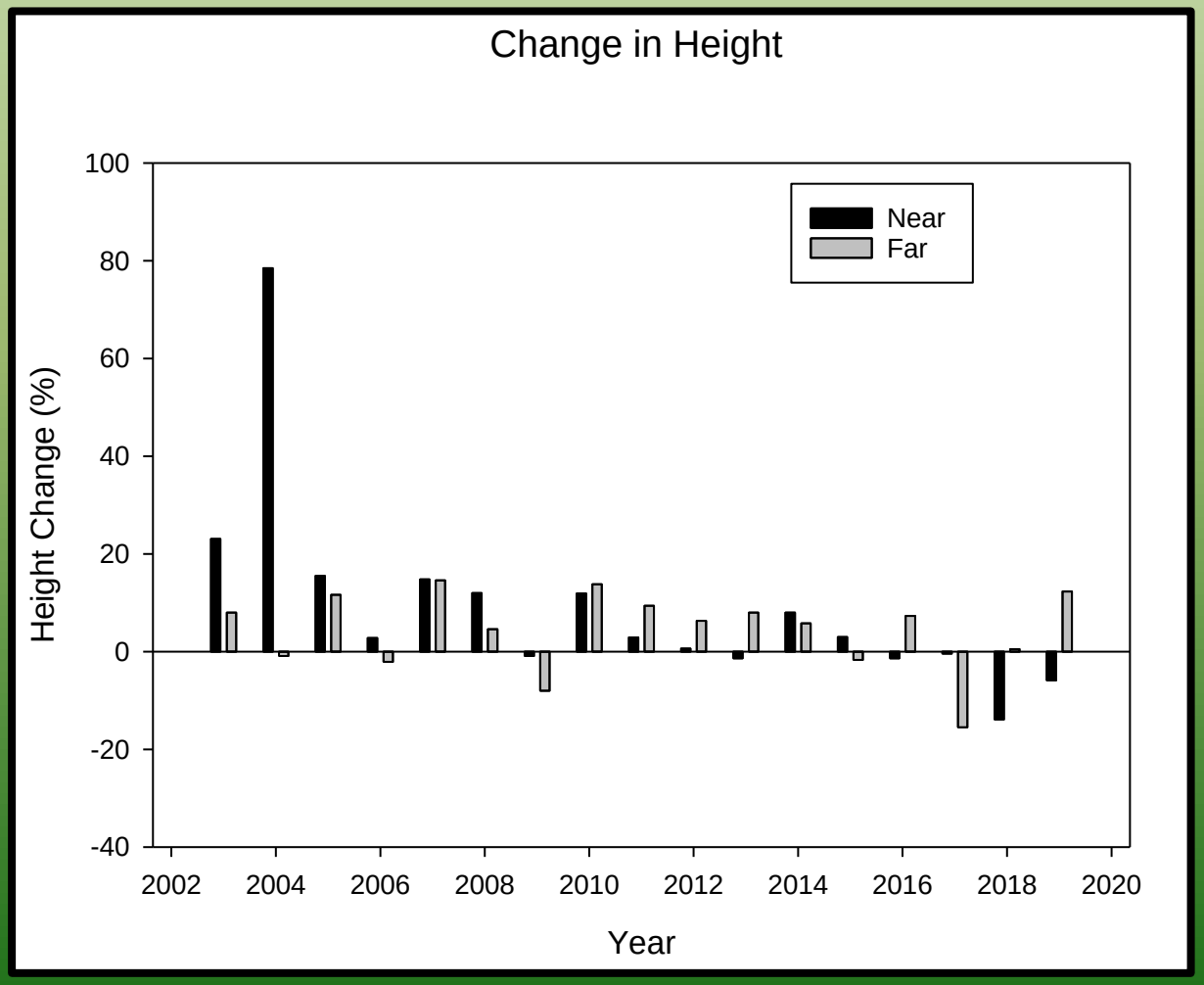
Results – Hurricane Impacts

- Hurricane Matthew (October 2016) caused canopy damage including downed and broken limbs, dead limbs in the canopy, and leaf cover loss.
- Hurricane Irma (September 2017) caused similar damage.
- Hurricane effects in 2017 and 2018 included:
  - Reduction in height
  - Reduction in total cover > 0.5 m
  - Increases in total cover < 0.5 m
  - Increases in bare ground

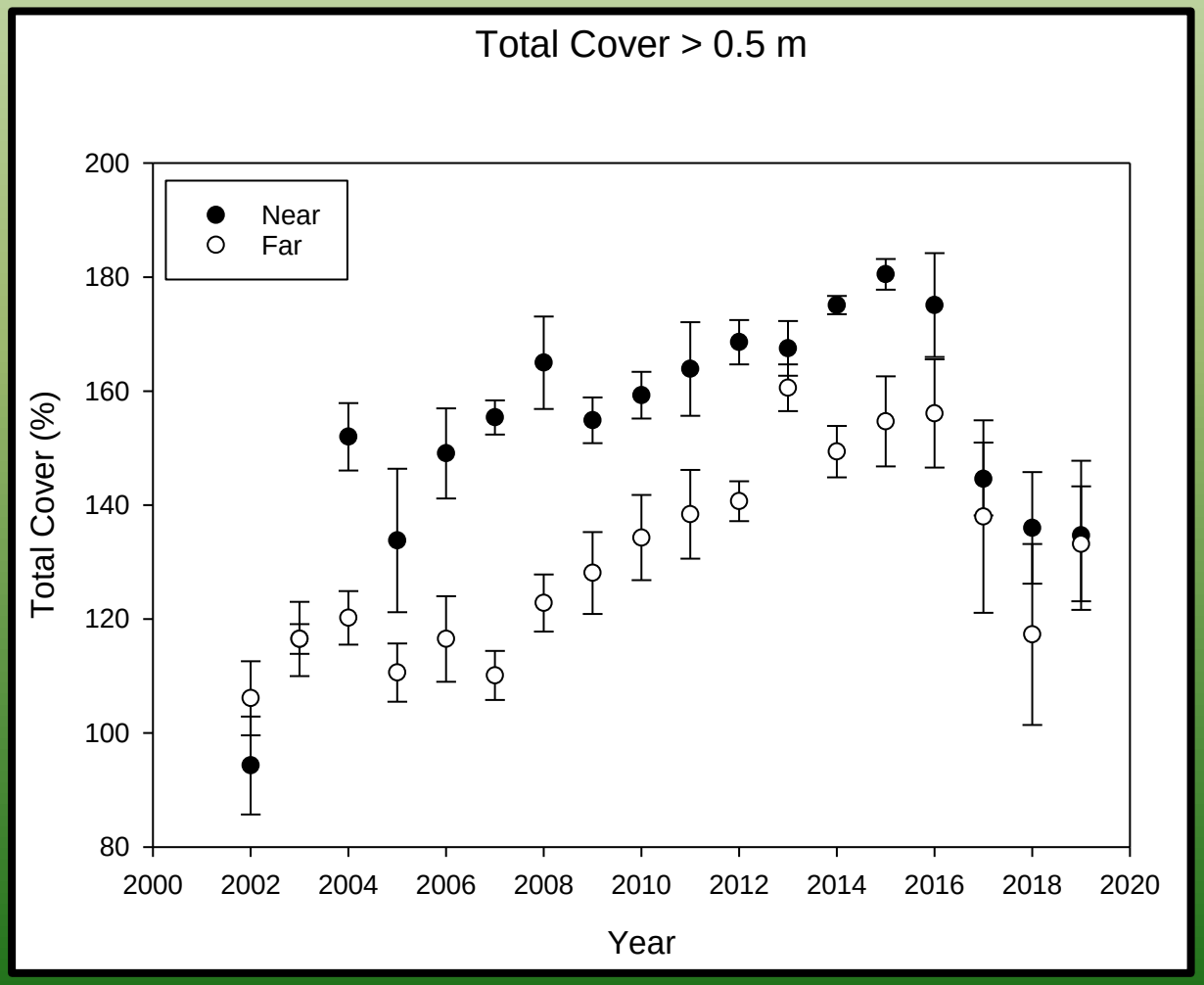
Height


Height
Near
Far
Mean Height (cm)
0
50
100
150
200
250
300
350
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018
2020
Year

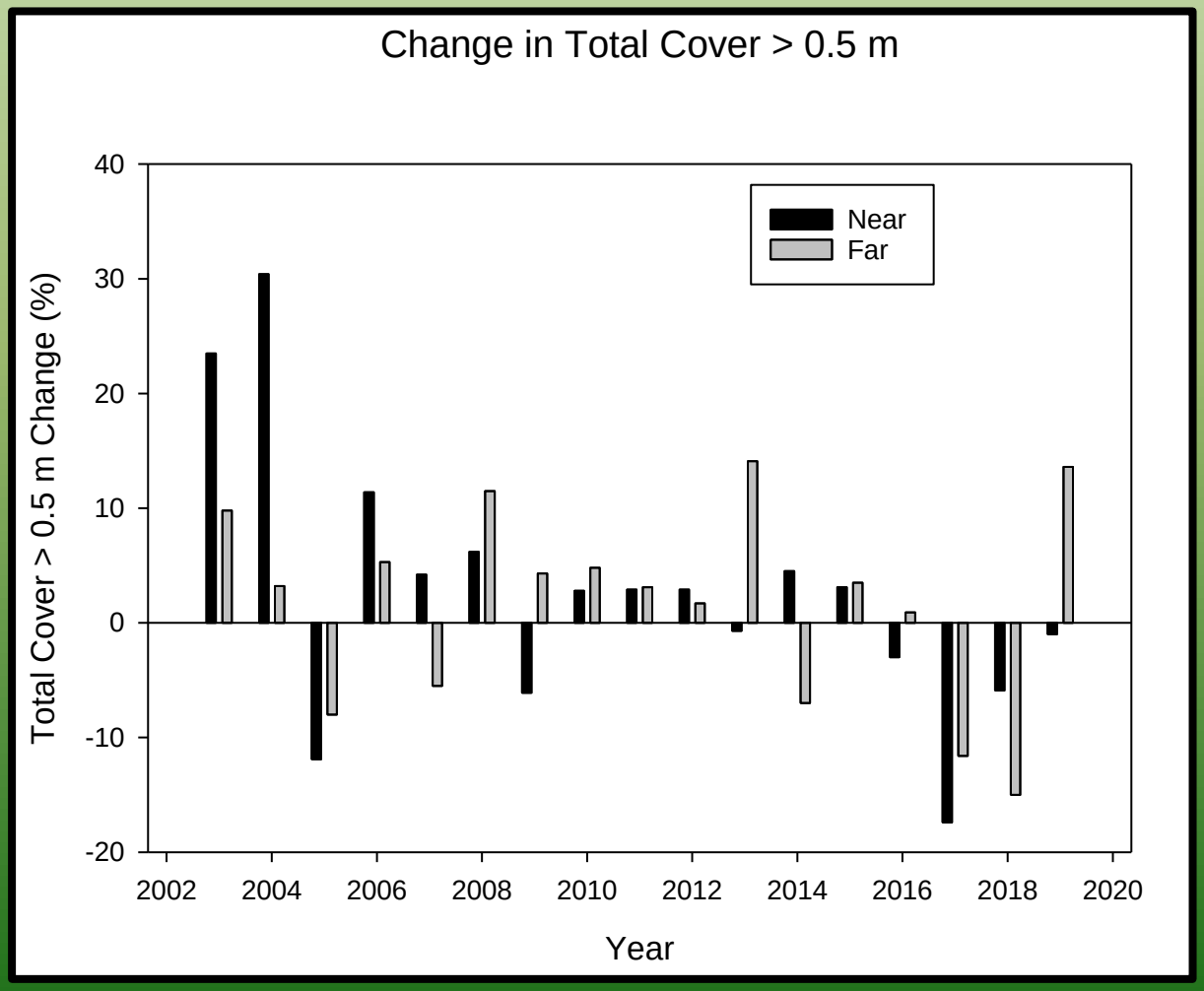
Height Change



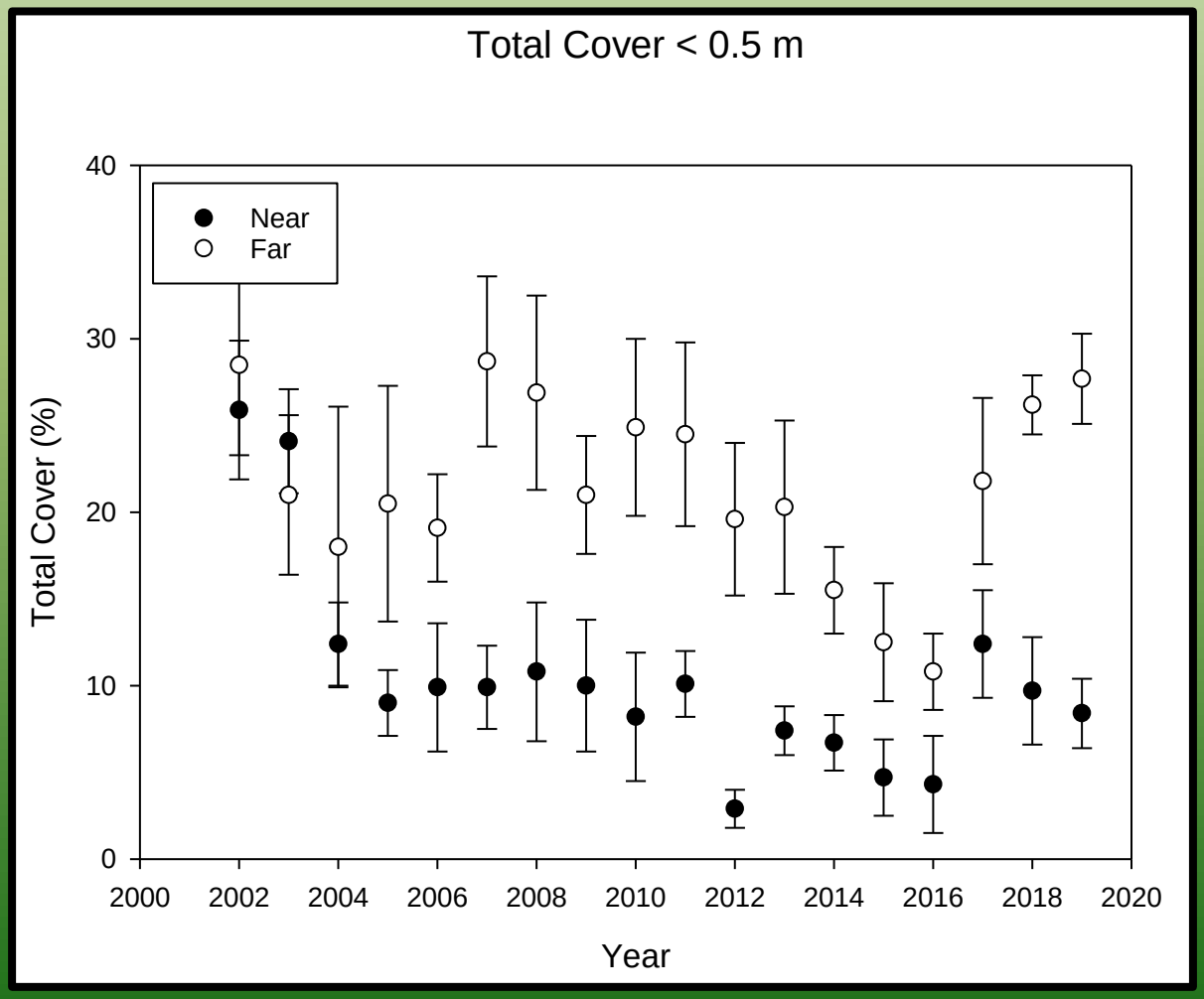
Total Cover > 0.5 m



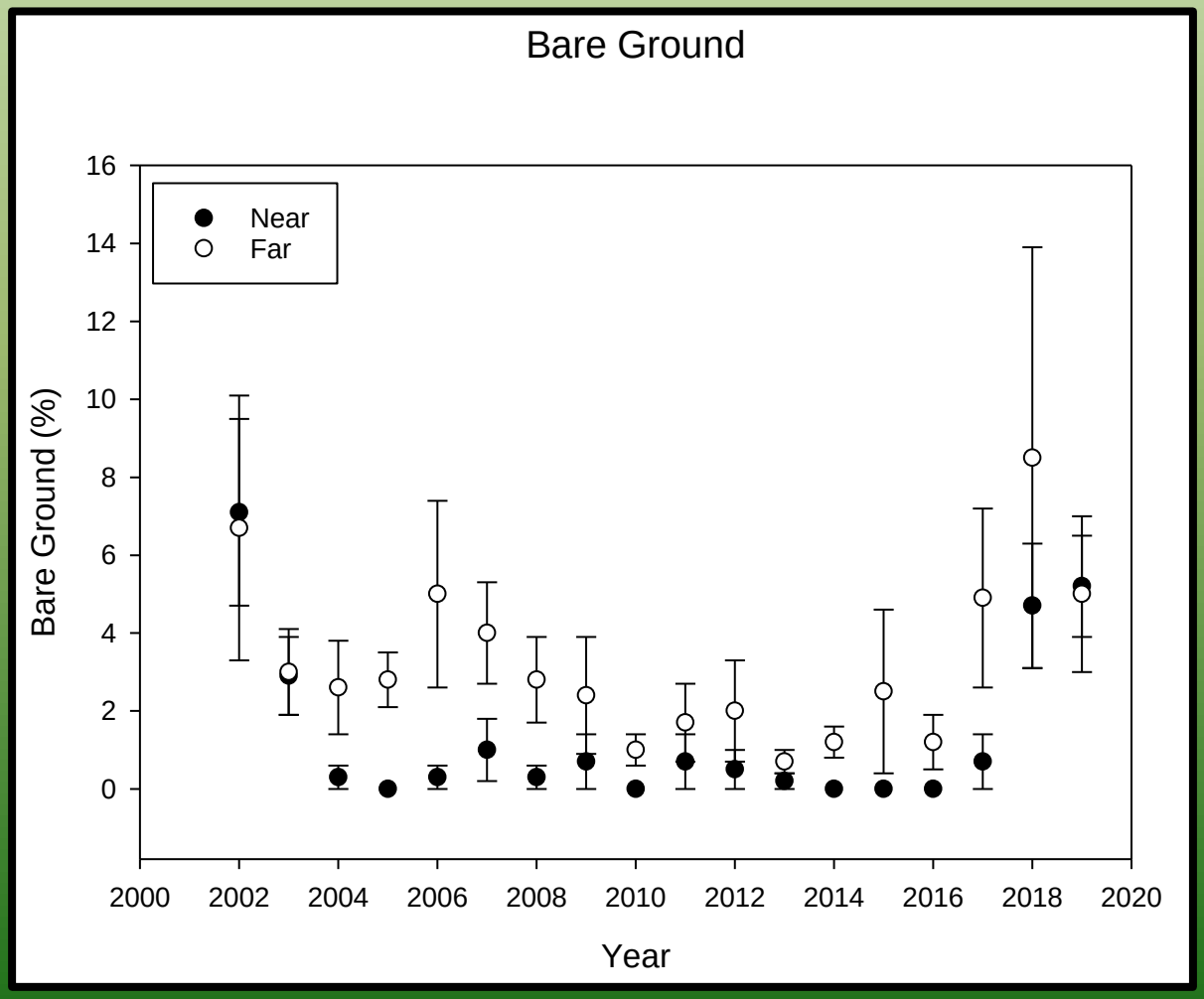
Change in Total Cover > 0.5 m



Total Cover < 0.5 m



Bare Ground

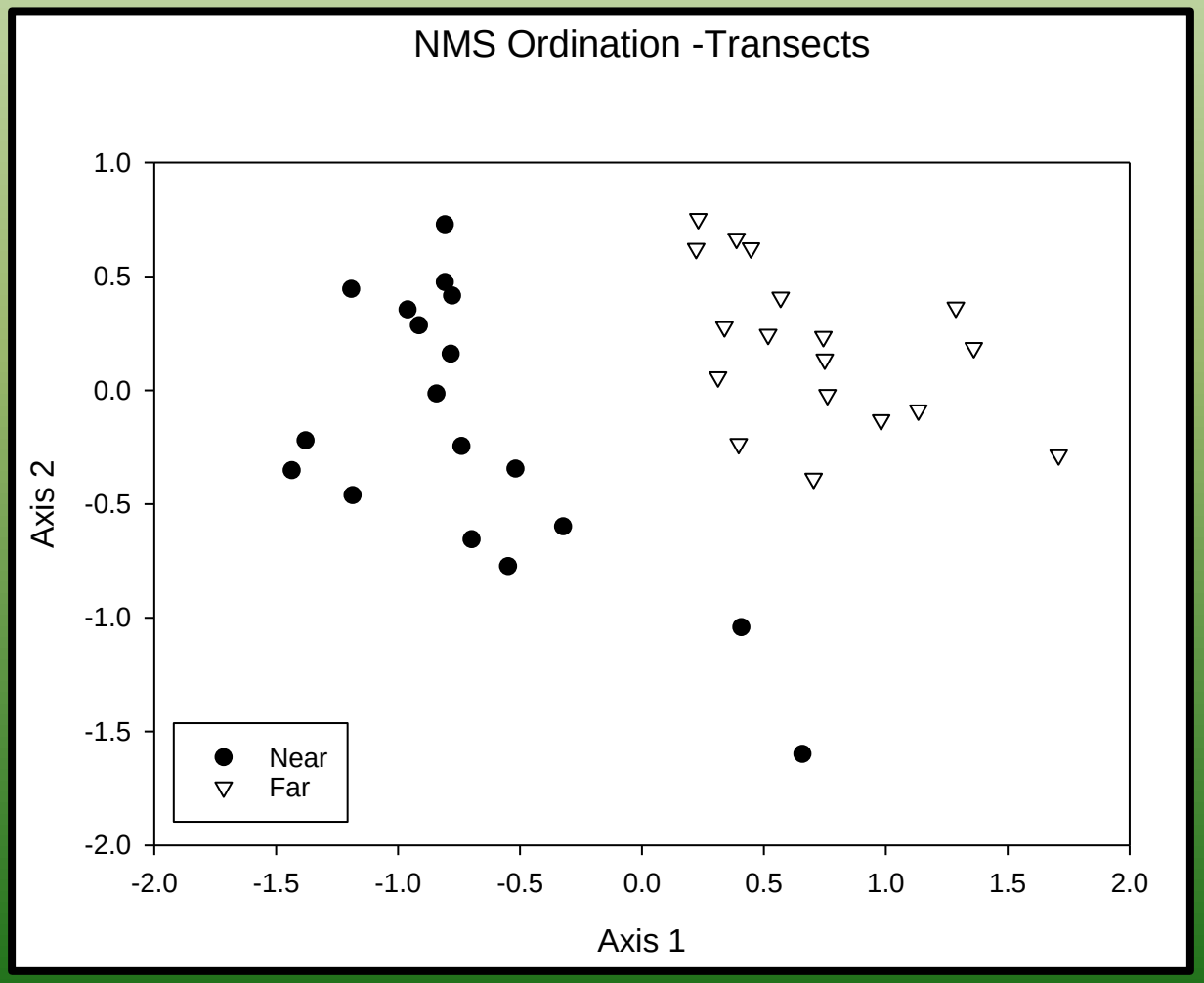

Bare Ground
Near
Far
Bare Ground (%)
16
14
12
10
8
6
4
2
0
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018
2020
Year

Results -Ordination

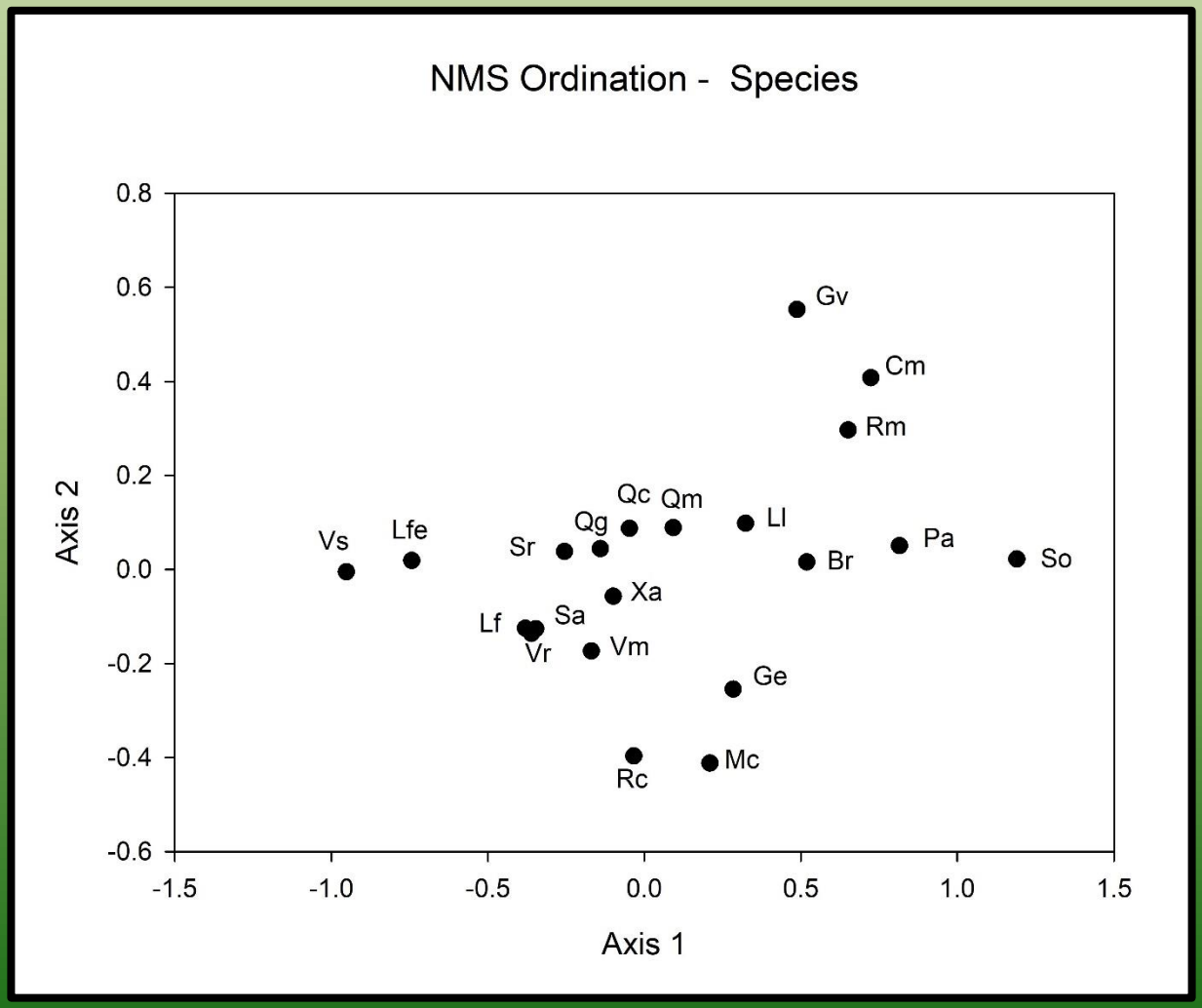
- Non-metric multidimensional scaling ordination (NMS) of the > 0.5 m strata of the transect data suggested a gradient of greater scrub oak cover in the near transects and greater cover of scrubby flatwoods species (e.g., *Befaria racemosa*, *Lyonia lucida*) in the far transects).

- Successional vectors indicated similar patterns over time in both the near and far transects. These vectors reflect an increase in the cover of scrub oaks (*Q. chapmanii, Q. geminata, Q. myrtifolia*) from 2002-2016 with declines in 2017 and 2018 from hurricane impacts. Cover of saw palmetto (*Serenoa repens*) also increased over much of this period.

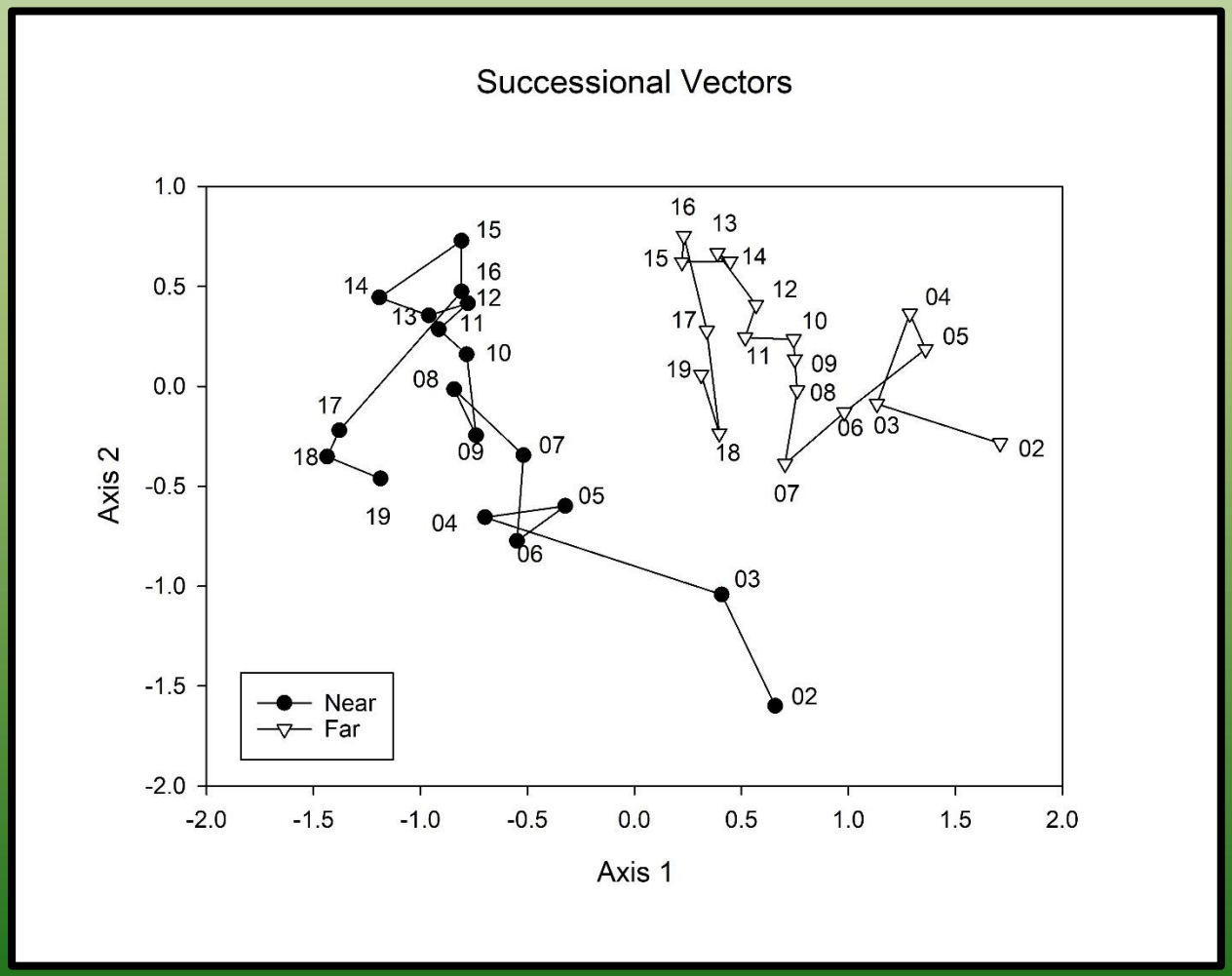
NMS Ordination of CCF Transects



NMS Ordination of CCF Species



NMS Ordination Successional Vectors



Discussion

- Height and total cover > 0.5 m increased in the transects close to the water distribution system five months (May 2003) after pumping began and most dramatically in the second growing season (May 2004). This is consistent with other studies indicating that growth in scrub decreases with drought and increases with greater water availability (Bracho et al. 2008, Ellsworth & Sternberg 2015, Foster et al. 2014, 2015, Hungate et al. 2002, Li et al. 2007a, Powell et al. 2006, Saha et al. 2008).

- Transects near the water system maintained greater height throughout the study period and maintained greater total cover > 0.5 m until impacted by hurricanes in 2016 and 2017.

- During the final project (March 2005-August 2008), scrub near the distribution system showed modestly greater percent increase in height. Percent increase in total cover in the near transects exceeded that of the far transects in 2006 and 2007.

Discussion (cont.)

- Near and far transects showed a decline in total cover in May 2005. This probably resulted from the three hurricanes (Charley, Frances, and Jeanne) that impacted the site in August and September 2004.
- Li et al. (2007b) reported defoliation and reduction in leaf area index from Hurricane Frances at a scrub site not far from the CCF scrub site.
- Growth responses to the final project were not as marked as from the interim project. Several factors may contribute to this.
  - Pumping rates were lower in the final project.
  - Height and total cover > 0.5 m increased sharply during the interim project, perhaps exerting some limits on the further increases that could occur.
  - Additional growth may have occurred in the diameters of scrub oaks or in belowground biomass; neither of which we measured.

Discussion (cont.)

- Water additions resulted in accelerated growth of scrub species – increased height growth and total cover > 0.5 m.
- No new species established and none of the characteristic scrub species were lost.
- The 2016 and 2017 hurricanes appeared to have greater impact on scrub height and cover than those in 2004.
  - In 2004, 8 years postburn, mean height was 150.1 cm, near and 92.2 cm, far.
  - In 2106, 20 years postburn, mean height was 284.9 cm, near and 177.0 cm, far. Taller oaks appear more vulnerable to limb breakage than do shorter ones.
  - Cover < 0.5 m increased with the partially opening of the canopy post-hurricane.
- Li et al. (2007b) reported leaf loss and reduction of leaf area index from Hurricane Frances but negligible stem damage in scrub that was 8 years postburn. Menges et al. (2011) found minimal hurricane impacts to rare scrub plants that were primarily herbaceous or small shrubs.

Summary

- Water additions from an underground exfiltration system increased height growth and increases in total cover > 0.5 m.
- Increases were greatest in younger, shorter scrub and with higher pumping rates.
- The extent of rise of the water table here did not exceed the tolerance of scrub species. No species were lost and no new species established.
- There are greater hurricane impacts in older, tall scrub including reductions in height and total cover > 0.5 m caused by limb breakage.

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