

1 Responses of Florida scrub vegetation to water additions from a groundwater treatment
2 project and to hurricane disturbance

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6 **ABSTRACT**

7 Florida scrub is a fire-maintained shrub vegetation of well-drained, sandy soils;
8 dominant species include several species of *Quercus* and *Serenoa repens*. In a
9 remediation project, treated groundwater was distributed through an exfiltration gallery
10 into intact scrub. We established eight permanent line-intercept transects (15 m length)
11 in the site in April 2002, four close to the exfiltration gallery and four more distant from it.
12 We sampled vegetation, < 0.5 m and ≥ 0.5 m, along each transect and measured
13 vegetation height at four points (0, 5, 10, 15 m) annually through 2019. The initial phase
14 of the project operated from October 2002 to early March 2004 (494 days) and
15 distributed 1.74 x 10⁸ L of water. The final phase of the project occurred from March
16 2005 through August 2008 (1251 days) and distributed 1.90 x 10⁸ L of water. Pumping
17 raised the water table near the exfiltration gallery. Vegetation height did not differ
18 between the near and far transects initially. Vegetation height increased in the near
19 transects by 2004 with the greatest percent change in 2003 and 2004 as did total cover
20 ≥ 0.5 m. Total cover < 0.5 m and bare ground were similar initially in the near and far
21 transects and declined in the near transects by 2004. Scrub species, particularly the
22 dominant scrub oaks, increased height and cover in response to water additions with no

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23 loss of dominant scrub species and no establishment of mesophytes. Hurricane
24 Frances (September 2004) reduced cover ≥ 0.5 m the following year. Hurricane
25 Matthew (October 2016) and Hurricane Irma (September 2017) caused greater damage
26 including breaking limbs as reflected in reduced height and total cover ≥ 0.5 m probably
27 because the older, taller scrub was more vulnerable to wind damage.
28 Key words: Florida scrub, Groundwater, Hurricane impacts, *Quercus*, Water availability

29 INTRODUCTION

30 Water is frequently limiting to plant growth (Kozlowski et al. 1991). Soil moisture
31 is a major determinant of plant growth and productivity and is related to the amount and
32 seasonal distribution of precipitation. The amount and seasonality of precipitation
33 influences vegetation distribution at global and continental scales (Walter 1979,
34 Woodward 1987, Bailey 2014). Water stress affects most aspects of plant physiology,
35 reduces photosynthesis and growth, causes premature shedding of leaves, and may
36 result in plant death (Kozlowski et al. 1991, Brodribb et al. 2020). Adaptations to avoid
37 or tolerate water stress include extensive and deep root systems, sclerophyllous and
38 heavily cutinized leaves, stomatal control of water loss, water storage in stems or other
39 organs, and physiological tolerances to dehydration (Kozlowski et al. 1991, Gupta et al.
40 2020).

41 Climatic change is expected to increase water stress through increased
42 frequency of drought (Ault 2020). Woody vegetation is vulnerable to water stress from
43 drought particularly as combined with rising temperatures (Brodribb et al. 2020), and
44 increasing atmospheric CO₂ concentrations may not ameliorate these effects (Peñuelas
45 et al. 2017, Sperry et al. 2019, Yuan et al. 2019). In coastal areas, sea level rise from

46 climate change is a stress not only from coastal erosion and inundation but also from
47 rising water tables (A. Saha et al. 2011, S. Saha et al. 2015, Xiao et al. 2016, 2018). For
48 upland vegetation, saturation of the rooting zone by an extended high water table
49 reduces O₂ supply to the roots and redox potential of the soil; this results in reduced
50 photosynthesis, mineral uptake, and growth and may lead to mortality (Kozlowski et al.
51 1991).

52 Here we examine effects of water additions to a Florida scrub community. Florida
53 scrub is a shrub community on well-drained, infertile sandy soils where scrub oaks
54 (*Quercus geminata* Small, *Q. myrtifolia* Willd., *Q. chapmanii* Sarg., *Q. inopina* Ashe),
55 Florida rosemary (*Ceratiola ericoides* Michx.), repent palms (*Serenoa repens* (W.
56 Bartram) Small, *Sabal etonia* Swingle ex Nash), and ericaceous shrubs predominate
57 (Myers 1990). A pine canopy may be present or absent. Scrubby flatwoods occur on
58 sites intermediate between mesic flatwoods and xeric Florida scrub (Abrahamson et al.
59 1984, Abrahamson and Hartnett 1990). Florida scrub and scrubby flatwoods are
60 characterized by periodic, intense fire (Myers 1990, Abrahamson and Hartnett 1990).
61 Scrub vegetation is primarily xeromorphic with sclerophyllous leaves (Abrahamson and
62 Hartnett 1990, Myers 1990). In addition, most of the dominant species of scrub are
63 evergreen or brevideciduous (Cavender-Barres et al. 2004). This physiognomy
64 suggests adaptation to periodic drought and low available nutrients (Monk 1966, Chabot
65 and Hicks 1982). Depth to the water table decreases across the landscape gradient
66 from sandhill through scrub, scrubby flatwoods, to mesic flatwoods. Water and nutrient
67 availability generally increase along this gradient, but seasonally high water tables limit

68 the occurrence of scrub oaks in mesic flatwoods (Abrahmson et al. 1984, Huck 1987,
69 Schmalzer and Hinkle 1992, Menges 1999, Boughton et al. 2006).

70 Peninsular Florida receives substantial annual precipitation, but about 60% falls
71 within the summer (May - October) rainy season and only 40% in the remainder of the
72 year. There is high year-to-year variability in precipitation, and extreme precipitation
73 events (tropical storms, hurricanes) may mask seasonal deficits. Spring drought can
74 occur particularly in Central and South Florida (Chen and Gruber 1990). Soil moisture in
75 scrub tracks precipitation being lowest in the spring dry season and highest in the
76 summer rainy season (Weekley et al. 2007, Bracho et al. 2008).

77 The sandy soils of scrub do not retain water making water stress from periodic
78 drought a recurring event in scrub vegetation (S. Saha et al. 2008). However, much of
79 the biomass of scrub is belowground in extensive root and rhizome systems (Geurin
80 1993, Stover et al. 2007), and at least some of the dominant scrub species obtain much
81 of their water from the water table (Hungate et al. 2002, Bracho et al. 2008) or deep in
82 the soil profile (Ellsworth and Sternberg 2015). In addition, stomatal control of water loss
83 (Bracho et al 2008), and the low osmotic potentials of scrub oaks compared to other
84 North American oaks (Abrams and Menges 1992) allow scrub species to persist and
85 grow through the dry season.

86 Even under normal precipitation growth of scrub vegetation may be limited by
87 water availability (Hungate et al. 2002, Hymus et al. 2003). Scrub vegetation is
88 photosynthetically active throughout the year (Hymus et al. 2003, Powell et al. 2006),
89 but carbon assimilation and leaf and stem growth are concentrated in the spring dry
90 season (Abrams and Menges 1992, Powell et al. 2006). Water stress from spring

91 drought may therefore have substantial effects on scrub vegetation (Li et al. 2007a, S.
92 Saha et al. 2008) and reduce radial growth of *Q. chapmanii* and *Q. myrtifolia* (Foster et
93 al. 2014, 2015).

94 Here we consider the response of a Florida oak-saw palmetto community to
95 water additions over two time periods. Water additions came from a groundwater
96 remediation project. The purpose of the remediation project was to clean groundwater
97 previously contaminated with organic compounds. Cleaned groundwater was then
98 returned to the environment through an exfiltration system located in scrub vegetation.
99 We examine whether additional water changed height growth, vegetation cover, and
100 species composition. Given the sensitivity of scrub vegetation to water supply, adding
101 water might increase growth of scrub species. If the height of the raised water table
102 exceeded the tolerances of scrub species, then replacement of scrub species by those
103 more tolerant of wetter conditions might occur. Annual sampling of permanent transects
104 also allowed us to evaluate effects of several hurricanes.

105 METHODS

106 Study Site

107 This study was conducted in the central section of Kennedy Space Center/Merritt
108 Island National Wildlife Refuge (KSC/MINWR). The site was typical of oak scrub on
109 KSC/MINWR (Schmalzer and Hinkle 1992). Site soils were mapped as Immokalee sand
110 (Arenic Alaquod) and Pomello sand (Oxyaquic Alorthod), both Spodosols (Huckle et al.
111 1974); these soils are commonly associated with oak-saw palmetto scrub on acidic soils
112 on KSC/MINWR (Schmalzer and Foster 2020). The site had been cut and burned for
113 restoration in 1996, six years prior to initiation of the groundwater remediation project.

114 The climate of KSC/MINWR is warm and humid; precipitation averages 134
115 cm/yr (Foster et al. 2015), but year-to-year variability is high (Mailander 1990). The wet
116 season extends from May to October (Figure 1). The mean annual air temperature from
117 1920 to 2011 was 22.3° C with high temperatures occurring in July (28.0° C) and low
118 temperatures occurring in January (15.5° C) (Figure 1) (Foster et al. 2015).

119 **Remediation Project**

120 NASA operated a Component Cleaning Facility (CCF) on KSC near the Vehicle
121 Assembly Building from 1962-1992. Contamination of the shallow, surficial aquifer
122 around this facility with volatile organic compounds including trichloroethylene (TCE)
123 occurred. Groundwater treatment of this site included pumping and treating of
124 groundwater as well as an air sparge system with soil vapor extraction. Treated
125 groundwater was disposed of through an exfiltration gallery (HSW Engineering 2003,
126 2004). The exfiltration gallery was placed in scrub vegetation near the CCF remediation
127 site. It consisted of three legs each ca. 122 m in length (Figure 2).

128 The remediation project operated in two phases: Interim project - October 2002-
129 March 2004, 494 days, (HSW Engineering 2004); Final project – March 2005-August
130 2008, 1251 days, (Jacobs Engineering 2006-2009). During the interim project the depth
131 to the water table near the exfiltration gallery was monitored by 6 piezometers (HSW
132 Engineering 2004) (Figure 2). Several interruptions to operations of the remediation
133 system occurred due to equipment problems and hurricanes during both project phases.

134 **Vegetation Sampling**

135 We established and sampled eight line-intercept transects (15 m length)
136 (Mueller-Dombois and Ellenberg 1974) in May 2002 five months prior to the initiation of

137 pumping treatment. Four transects were near the water exfiltration gallery and four were
138 more distant from it (Figure 2). Cover was measured to the nearest 5 cm by species in
139 two height strata, ≥ 0.5 m and < 0.5 m. We determined vegetation height at four points
140 (0, 5, 10, 15 m) along each transect. Transect locations were recorded with a
141 differentially corrected GPS system (Trimble; Sunnyvale, CA). Vegetation transects
142 were sampled annually from 2002 through 2019. Nomenclature follows Wunderlin and
143 Hansen (2011).

144 **Data Analysis**

145 We summarized species composition by strata and vegetation height separately
146 for transects near and more distant from the exfiltration gallery (IBM SPSS, ver. 26;
147 www.ibm.com). For vegetation height and total cover ≥ 0.5 m, we calculated the annual
148 percent change. We compared vegetation height, total cover ≥ 0.5 m, total cover < 0.5
149 m, and bare ground for the near and far transects from 2001-2016 using repeated
150 measures analysis of variance (IBM SPSS, ver. 27; www.ibm.com). We conducted
151 nonmetric multidimensional scaling (NMS) ordination (Kruskal 1964a, 1964b) (PCORD,
152 ver. 7; MjM Software Design, Gleneden Beach, Oregon) of the ≥ 0.5 m strata of
153 transects using the Sorenson distance measure to examine changes in community
154 composition along spatial gradients and with time. NMS is considered the most
155 generally effective method for the ordination of community data (McCune and Grace
156 2002).

157 We compiled data on amount of water pumped through the exfiltration system for
158 the interim project (HSW Engineering 2004) and for the final project (Jacobs

159 Engineering 2006-2009) as well as groundwater piezometer data from the interim
160 project (HSW Engineering 2004).

161 **RESULTS**

162 During the interim project from October 2002 to March 2004, 494 days, $1.74 \times$
163 10^8 L of treated water was distributed through the exfiltration system, mean rate = 3.52
164 $\times 10^5$ L/day (Figure 3A). Exfiltration of treated groundwater decreased the depth to the
165 water table in scrub near the exfiltration gallery during the interim project as shown by
166 data from the four piezometers adjacent to the gallery leg in scrub (Figure 4). Depth
167 declined steadily with pumping from October 2002 through March 2003 (0-150 days)
168 when it stabilized for ca. 40 days (Figure 4). Depth increased from May through June
169 2003 (ca. 190-250 days). This corresponded with a lower rate of pumping (Figure 3A).
170 Depth declined with some variability for the remainder of the interim project (July 2003-
171 February 2004); however, it remained > 1 m below the surface at all piezometers
172 (Figure 4). In the final project from March 2005 through August 2008, 1251 days, $1.90 \times$
173 10^8 L of water was distributed, mean rate = 1.52×10^5 L/day (Figure 3B). Depth to water
174 table data were not collected in the final project.

175 Mean height of transects near and farther from the water distribution system was
176 generally similar before treatment with the near transects slightly shorter (Figure 5A).
177 Height did not differ by May 2003 (Figure 5A), although the percent increase of the near
178 transects was greater (Figure 5B). By May 2004, height of the near transects exceeded
179 that of the far transects and that difference has been maintained (Figure 5A). The
180 percent increase of height of the near transects was much greater in 2004 (Figure 5B).
181 Repeated measures analysis of variance (ANOVA) indicated significant effects of time,

182 time x position (near, far) interactions, and position (Table 1). Greenhouse-Geisser
183 corrections for violation of sphericity (Field 2018) were used for time and time x position
184 interactions. The significant interaction term reflected the switch of near transects that
185 were initially shorter than far transects to taller after water additions.

186 Total cover ≥ 0.5 m followed the same pattern. Cover was similar before
187 treatment with near transects slightly lower (Figure 6A). Cover of the near transects
188 increased to a greater extent in 2003 and to a much greater extent in 2004 than in the
189 far transects (Figures 6B). Total cover ≥ 0.5 m for 2001 - 2016 differed with time, time x
190 position interactions, and position (Table 1), and as with height, the interaction term
191 reflected the switch of initial lower cover of near transects relative to far transects to
192 greater cover after water additions.

193 Total cover < 0.5 m (Figure 7A) declined to a greater extent in the near transects
194 by 2004. Repeated measures analysis indicated that total cover < 0.5 m for 2001 - 2016
195 differed with time (Table 1), but time x position and position effects were not significant.
196 Near and far transects had nearly identical bare ground values initially; percent bare
197 ground (Figure 7B) declined to a greater extent in the near transects by 2004. Time and
198 position effects were significant but not the interaction term in the repeated measures
199 analysis (Table 1). Detailed species composition of the near and far transects is given in
200 Tables S1-S4.

201 Hurricane Frances (September 2004) reduced cover ≥ 0.5 m the following May
202 (Figure 5), but it recovered by the next year. Hurricane Matthew (October 2016) caused
203 canopy damage including downed and broken limbs, dead limbs in the canopy, and leaf
204 cover loss (personal observation). Hurricane Irma (September 2017) caused similar

205 damage. Hurricane effects in 2017 and 2018 included reduction in height (Figure 5),
206 reduction in total cover ≥ 0.5 m (Figure 6), increased total cover < 0.5 m (Figure 7A),
207 and increased bare ground (Figure 7B).

208 Non-metric multidimensional scaling ordination (NMS) of the ≥ 0.5 m strata of the
209 transect data suggested a gradient of greater scrub oak cover in the near transects and
210 greater cover of scrubby flatwoods species (e.g., *Befaria racemosa* Vent., *Lyonia lucida*
211 (*Lam.*) K. Koch) in the far transects (Figure 8A, 8B). Successional vectors indicated
212 similar patterns over time in both the near and far transects (Figure 8A). These vectors
213 reflect an increase in the cover of scrub oaks (*Q. chapmanii*, *Q. geminata*, *Q. myrtifolia*)
214 from 2002-2016 with declines in 2017 and 2018 from hurricane impacts. Cover of saw
215 palmetto (*Serenoa repens*) also increased over much of this period.

216 DISCUSSION

217 The groundwater table rose (depth to water table decreased) rapidly after the
218 beginning of pumping into the exfiltration system (Figure 4). Pumping began in October
219 of 2002, the beginning of the dry season when water tables would be expected to be
220 declining; however, water additions overrode the expected seasonal trend. Dynamics of
221 the water table generally corresponded to the rate of pumping (Figure 3A, Figure 4).
222 Other studies have shown that the water table in scrub responds to precipitation
223 (Weekley et al. 2007, S. Saha et al. 2008, Foster unpublished).

224 Height and total cover ≥ 0.5 m increased in transects close to the water
225 distribution system five months (May 2003) after pumping began and most dramatically
226 in the second growing season (May 2004) (Figure 5, Figure 6). This is consistent with
227 studies indicating that growth in scrub increases with greater water availability,

228 particularly in the spring, but is limited by drought. Elevated CO₂ in scrub decreased
229 evapotranspiration through decreased stomatal conductance, while carbon uptake and
230 growth increased (Hymus et al. 2003). Reduced evapotranspiration increased surface
231 soil water content (Hungate et al. 2002). Carbon assimilation rates were greatly reduced
232 by a severe drought (Powell et al. 2006), and severe drought reduced leaf net
233 photosynthetic rate for *Q. myrtifolia* (Li et al. 2007a). Spring drought caused leaf loss,
234 stem dieback, and decreased height growth rate, but only minor mortality of scrub
235 species (S. Saha et al. 2008). Radial growth of *Q. chapmanii* and *Q. myrtifolia* was
236 reduced by spring drought and increased with high spring precipitation (Foster et al.
237 2014, 2015).

238 During the final project (March 2005-August 2008), scrub near the distribution
239 system showed modestly greater percent increase in height (Figure 5B). Percent
240 increase in total cover in the near transects exceeded that of the far transects in 2006
241 and 2007 (Figure 6B). Several factors may contribute to the less marked growth
242 responses to the final project. One is that pumping rates were lower in the final project
243 than in the interim project (Figures 3A, 3B). A second is the sharp increase in height
244 and total cover ≥ 0.5 m during the interim project; mean height of the near transects
245 increased from 68.3 cm in 2002 to 150.1 cm in 2004, and total cover ≥ 0.5 m increased
246 from 94.3% to 152.0% (Figure 5A, Figure 6A, Table S1). The rate of increase of height
247 and total cover ≥ 0.5 m decreases with time (Schmalzer and Hinkle 1992, Schmalzer
248 2003). A third is that another factor, such as nutrient availability, became limiting as
249 water became more available. In an 11-year elevated CO₂ experiment located near this
250 study site, net primary production was elevated most in the first two years and after

251 hurricane disturbance (Hungate et al. 2013b). Nutrient limitations and root closure
252 limited the further response of scrub vegetation to reduced water stress from elevated
253 CO₂ (Day et al. 2013, Hungate et al. 2013a, 2013b). Some additional growth may have
254 occurred in the diameters of scrub oaks or in belowground biomass; neither of which we
255 measured, rather than height.

256 Total cover < 0.5 m (Figure 7A) and bare ground (Figure 7B) declined more
257 rapidly in the near transects consistent with the more rapid height growth and increased
258 total cover ≥ 0.5 m. Decline in cover < 0.5 m and in bare ground are commonly
259 observed as scrub grows after fire (Schmalzer 2003), due to increased cover in the ≥
260 0.5 m strata and height.

261 Three hurricanes affected this site during this study. Hurricane Frances impacted
262 the site in September 2004. Near and far transects showed a decline in total cover ≥ 0.5
263 m (Figure 6A) but not height (Figure 5A) in May 2005. Li et al. (2007b) reported
264 defoliation and reduction in leaf area index but negligible stem damage from Hurricane
265 Frances at an 8-year postburn scrub site not far from our site. Menges et al. (2011)
266 found minimal hurricane impacts to rare scrub plants that were of small stature,
267 primarily herbaceous or small shrubs.

268 In contrast, the 2016 and 2017 hurricanes had greater impact on scrub height
269 (Figure 5A) and total cover ≥ 0.5 m (Figure 6A) than in 2004. In 2004, 8 years postburn,
270 mean height was 150.1 cm, near and 92.2 cm, far. In 2016, 20 years postburn, mean
271 height was 284.9 cm, near and 177.0 cm, far. Taller oaks appear more vulnerable to
272 limb breakage than do shorter ones as we have observed on other scrub sites after
273 hurricanes (Schmalzer and Foster unpublished data). Cover < 0.5 m (Figure 7A)

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466 coastal east-central Florida. *Science of the Total Environment* 630: 211-221.

467

468 Table 1. Repeated measures analysis of variance (ANOVA) for vegetation height, total
 469 cover ≥ 0.5 m, total cover < 0.5 m, and bare ground as a function of time (repeated
 470 factor) and position (near, far) to the water distribution system. Time period is from 2002
 471 (pretreatment) to 2016 (pre-Hurricane Michael). Significance values for time and time x
 472 position interactions are corrected for violation of sphericity using Greenhouse-Geisser
 473 corrections; this correction works by adjusting degrees of freedom. Values for position
 474 do not require correction as there are only two classes.

Variable	Effect	n	df	F	Significance (<i>p</i>)
Height	Time	15	2.032	37.765	< 0.001
	Time x Position	15	2.032	8.114	0.006
	Position	8	1	15.814	0.007
Total Cover > 0.5 m	Time	15	3.773	21.414	< 0.001
	Time x Position	15	3.773	3.107	0.038
	Position	8	1	33.164	0.001
Total Cover ≤ 0.5 m	Time	15	2.793	8.351	0.002
	Time x Position	15	2.793	2.836	0.07
	Position	8	1	5.355	0.06

Bare	Time	15	2.743	3.535	0.041
Ground					
	Time x Position	15	2.743	0.590	0.62
	Position	8	1	22.565	0.003

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List of Figures

Figure 1. Climate of Central Florida. Shown are mean monthly precipitation (bars) and temperature (points) for Division 3 in Florida from the National Climatic Data Center, Asheville, NC, for the period 1920-2011. Error bars indicate standard error.

Figure 2. Location of exfiltration gallery, six piezometers (PZ-2 – PZ-7), and eight vegetation sampling transects in scrub near the groundwater treatment site. The exfiltration gallery consisted of three legs each ca. 122 m in length. Four vegetation transects (R191 - R194) were close to the central leg of the water exfiltration system and four transects (R195 – R197) were more distant from it.

Figure 3. Cumulative amount of water (L) pumped through the exfiltration gallery. A. Interim project. Pumping started in October 2002 and ended in March 2004. Data from HSW Engineering (2004). B. Final project. Pumping started in March 2005 and ended in August 2008. Data from Jacobs Engineering (2006 – 2009).

Figure 4. Changes in depth to the water table during the interim project (October 2002 – March 2004) as recorded by four piezometers located near the central leg of the exfiltration gallery. Data from HSW Engineering (2004).

Figure 5. A. Mean height of vegetation on transects near and far from the exfiltration gallery. Error bars show standard error. B. Annual percent change in mean vegetation height of transects near and far the exfiltration gallery. Transects were sampled annually in May. The interim project ran from October 2002 to March 2004 and the final project from March 2005 to August 2008. Vegetation was affected by Hurricane Frances (September 2004), Hurricane Matthew (October 2016), and Hurricane Irma (September 2017).

500 Figure 6. A. Mean total cover ≥ 0.5 m of vegetation on transects near and far from the
501 exfiltration gallery. Error bars show standard error. B. Annual percent change in mean
502 total cover ≥ 0.5 m vegetation of transects near and far the exfiltration gallery. Transects
503 were sampled annually in May. The interim project ran from October 2002 to March
504 2004 and the final project from March 2005 to August 2008. Vegetation was affected by
505 Hurricane Frances (September 2004), Hurricane Matthew (October 2016), and
506 Hurricane Irma (September 2017).

507 Figure 7. A. Mean total cover < 0.5 m of vegetation on transects near and far from the
508 exfiltration gallery. B. Mean percent bare ground on transects near and far from the
509 exfiltration gallery. Error bars show standard error. Transects were sampled annually in
510 May. The interim project ran from October 2002 to March 2004 and the final project
511 from March 2005 to August 2008. Vegetation was affected by Hurricane Frances
512 (September 2004), Hurricane Matthew (October 2016), and Hurricane Irma (September
513 2017).

514 Figure 8. Non-metric multidimensional scaling (NMS) ordination of vegetation near (N =
515 4) and far (N = 4) from the exfiltration gallery using mean species cover ≥ 0.5 m from
516 2002 – 2019. Included are 21 species. The final solution had two dimensions after 54
517 iterations with a final stress of 7.85, a final instability < 0.00001 , and comparisons to
518 Monte Carlo tests indicated that the reduction in stress was significant ($P = 0.02$). A.
519 Transects and successional vectors. B. Species. Codes are: Br *Bejaria racemosa*, Cm
520 *Clitoria mariana*, Ge *Galactia elliottii*, Gv *Galactia volubilis*, Lf *Lyonia fruticosa*, Lfe
521 *Lyonia ferruginea*, Ll *Lyonia lucida*, Mc *Myrica cerifera*, Pa *Pteridium aquilinum*, Qc
522 *Quercus chapmanii*, Qg *Quercus geminata*, Qm *Quercus myrtifolia*, Rc *Rhus*

523 *copallinum*, Rm *Rhynchospora megalocarpa*, Sa *Smilax auriculata*, So *Solidago odora*,

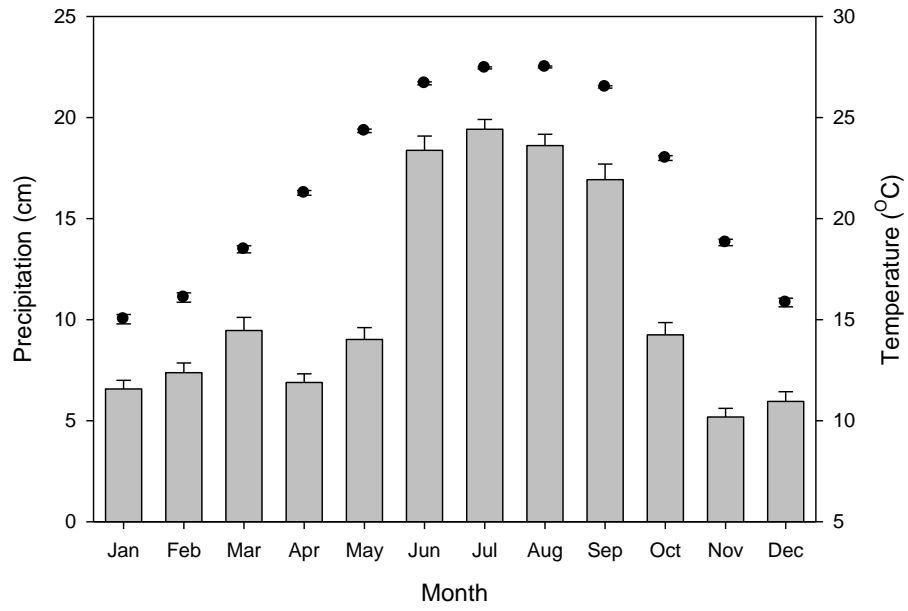
524 Sr *Serenoa repens*, Vm *Vaccinium myrsinites*, Vr *Vitis rotundifolia*, Vs *Vaccinium*

525 *stamineum*, Xa *Ximenia americana*.

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528 Figure 1.



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530 Figure 2

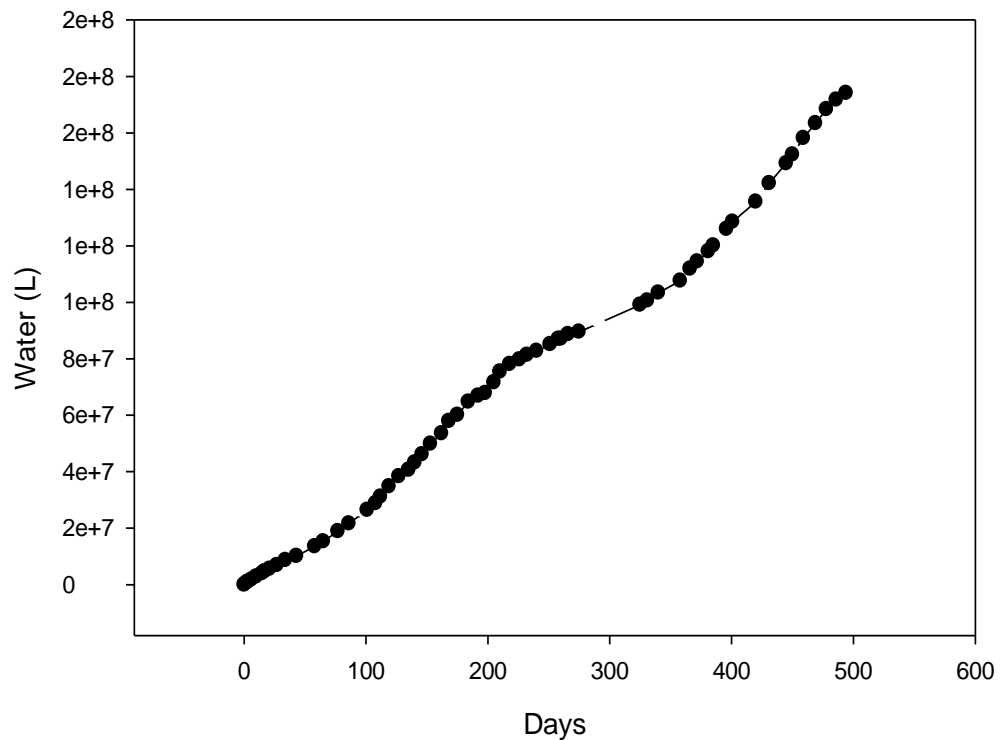


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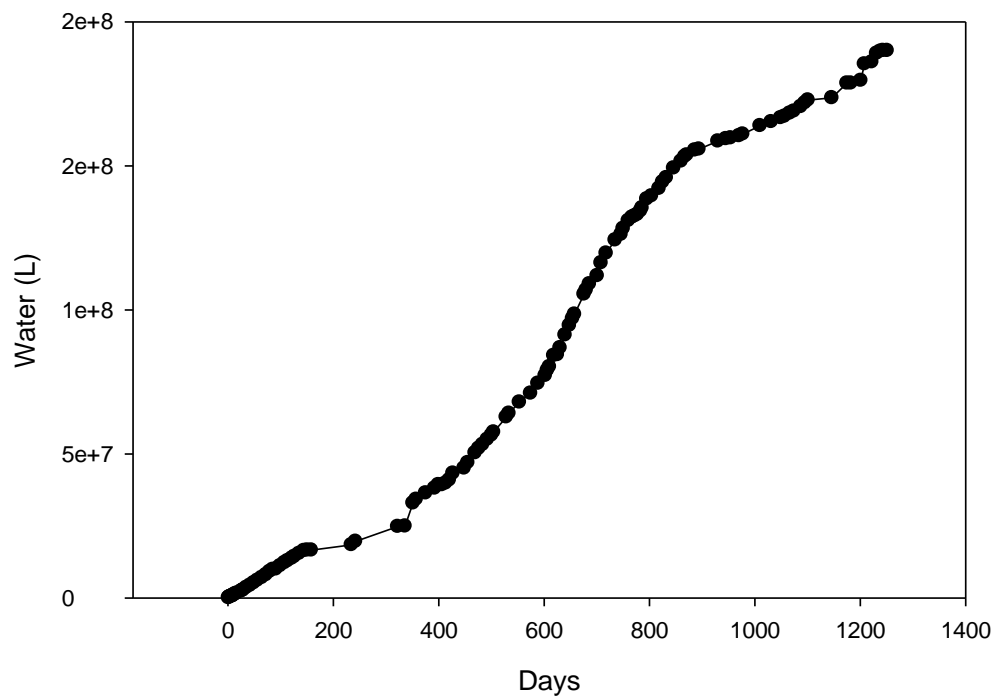
533 Figure 3.

A. Interim Project



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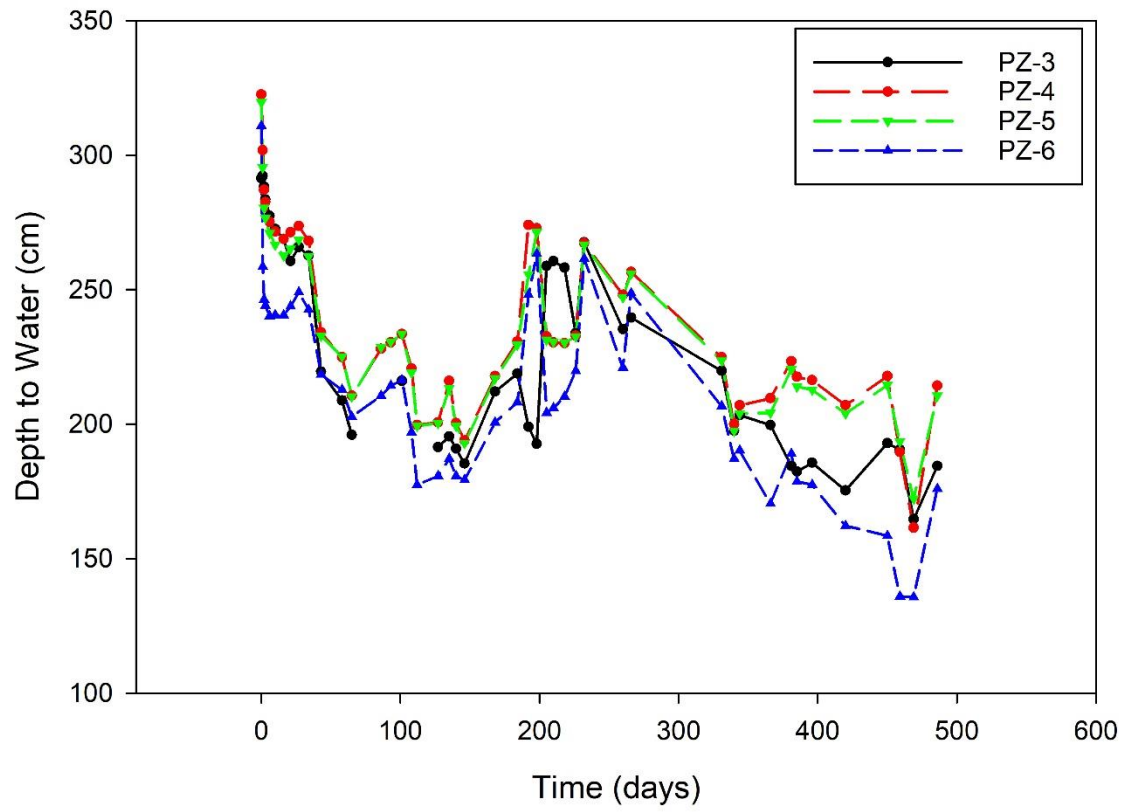
B. Final Project



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536 Figure 4.

Change in Depth to Water

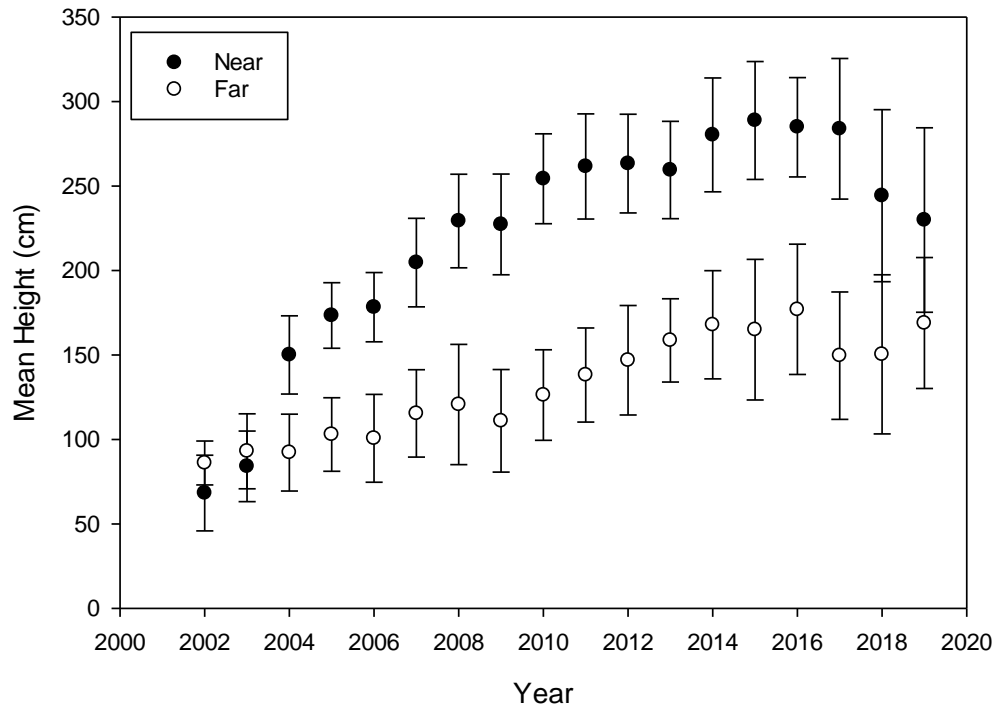


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Figure 5.

A. Height



B. Annual Height Change

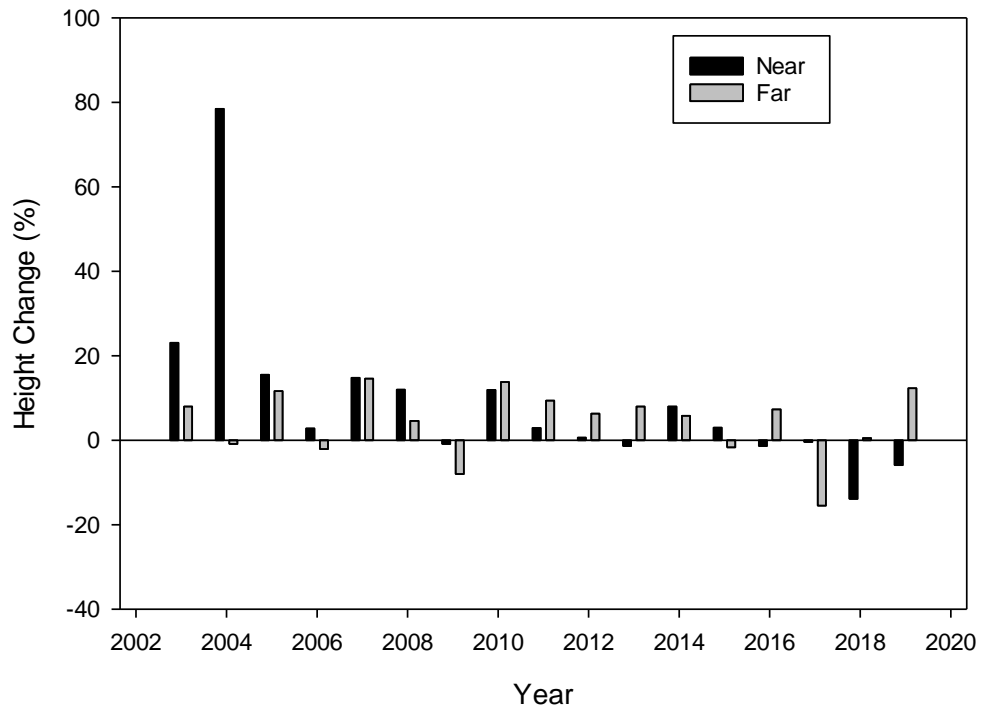


Figure 6.

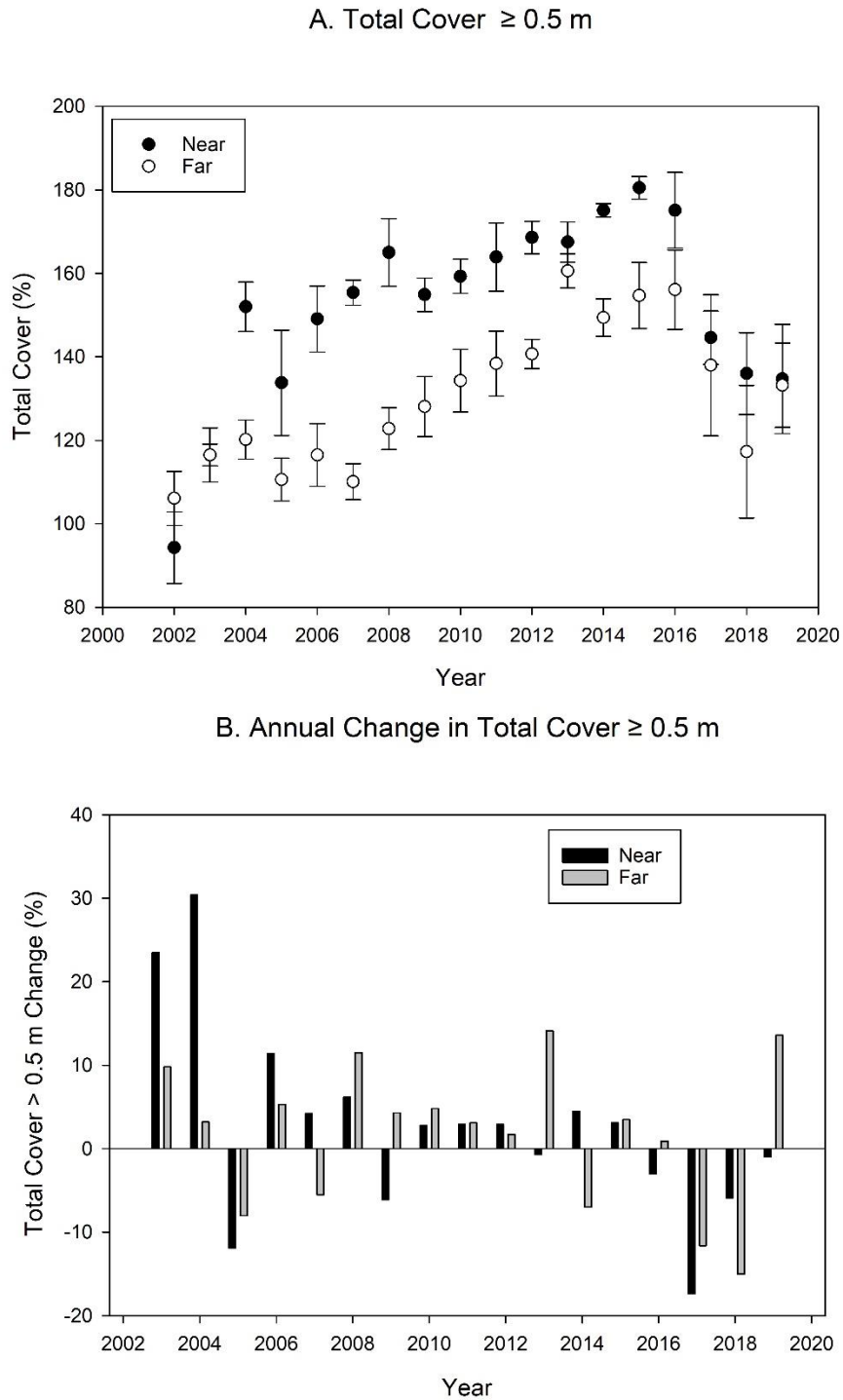
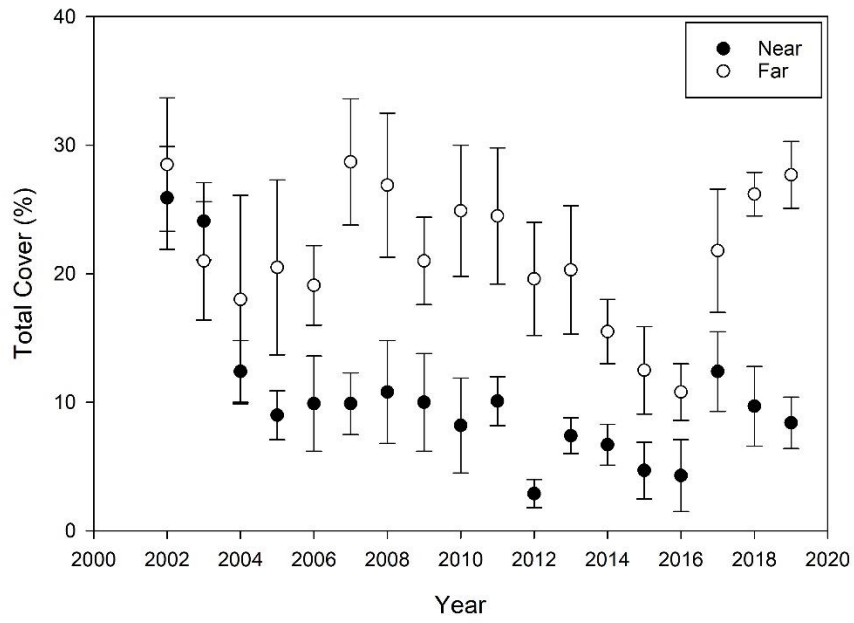


Figure 7.

A. Total Cover < 0.5 m



B. Bare Ground

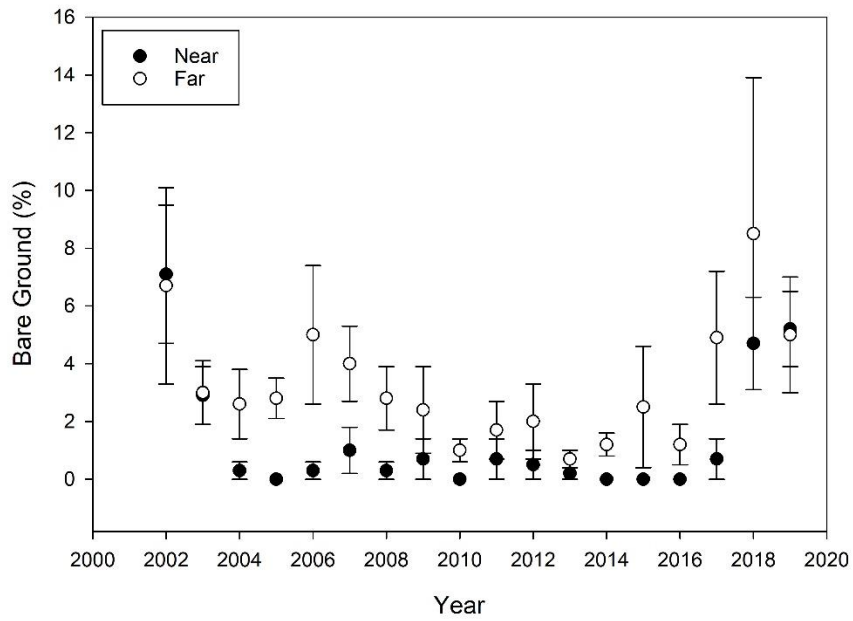


Figure 8.

