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Chronic Exclusion of Fire in Longleaf Pine Stands of an Urban Interface: The University of West Florida Campus Ecosystem Study

Frank S. Gilliam

Department of Biology, University of West Florida, Pensacola, FL 32514, USA; fgilliam@uwf.edu

Abstract: The dependence of longleaf pine (*Pinus palustris*) ecosystems on fire is well-understood, and the anthropogenic alteration of fire cycles within its natural range has contributed to its decline. This has been increasingly exacerbated in areas of urban interfaces, wherein the use of prescribed fire can be problematic. The purpose of this study—the University of West Florida Campus Ecosystem Study—was to examine the effects of fire exclusion on longleaf pine in the unique urban interface of a university campus. This was an interconnected series of investigations on the main campus and three associated natural areas that comprised remnant longleaf stands following the cessation of widespread longleaf pine harvesting—120 years ago. This period of chronic fire exclusion allowed for a distinct shift in the stand structure and composition. The open, savanna-like structure of fire-maintained longleaf stands has transitioned into closed-canopy forests with the increased prevalence of southern evergreen oaks (especially live oak—*Quercus virginiana*) and *Magnolia* spp., resulting in the complete absence of longleaf regeneration. Fire exclusion also appeared to decrease soil fertility. The significant variation in the mean age of longleaf pine stems on the main campus; natural areas suggest that these natural areas were likely under separate ownership with contrasting land-use history prior to its purchase by the State of Florida for campus construction in 1963.

Keywords: longleaf pine; urban interface; fire exclusion

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1. Introduction

Longleaf pine (*Pinus palustris*) is one of the better-known disturbance-maintained ecosystems, and its dependence on fire and tropical cyclones has been both well-studied and understood [1–4]. A phenomenological model has been developed that integrates both fire and tropical cyclones to influence the physiognomy of longleaf pine stands [5]. This model developed as an alternative strategy toward creating endpoints for longleaf restoration, views these two disturbance regimes as having contrasting impacts on vegetation strata based on their innate differences in disturbance frequency and intensity. Tropical cyclones are more sporadic and intense compared to fires. Tropical cyclones exert a direct impact on the overstory through wind damage and mortality, with indirect effects on the herb layer, primarily via changes in spatial patterns of the accumulation of detritus and shading, as well as adding spatial heterogeneity via the creation of tip-up mounds which increase biodiversity in the herb layer [6,7]. By contrast, fire affects the herb layer directly, including the juvenile stages of longleaf regeneration.

Forests, in general, have been referred to as comprising a paradox of biodiversity, with the most apparent vegetation stratum—the overstory—typically composed of the fewest number of species, with the diminutive herbaceous layer harboring 80–90% of forest plant species. An extreme example of this would be longleaf pine ecosystems. Under conditions of frequent fire, the savanna-like physiognomy of longleaf stands is simple—one species in the overstory and numerous species in the herb layer [6]. Synthesizing data from forest ecosystems throughout the United States, Gilliam [7] reported that there was a significant linear relationship between the species richness of the overstory and that of the herb layer, further noting that conifer forests more commonly occupied the low range of both strata in terms of species richness. A notable outlier in this summary was data from longleaf pine savannas. Indeed, working on the old-growth longleaf pine in southeastern Louisiana, Platt et al. [6] found, as expected, only longleaf pine in the overstory but 251 species in the herb layer. More specifically, they found more herb layer species—at least 20% more—in both recent and persistent canopy openings. They also found a notable variation among plant functional groups in response to these openings. For example, plants responding most sensitively to canopy openings were either short-lived, monocarpic perennial forbs or grasses arising from soil seed banks. There was a significant linear increase in the total numbers of all species with measured levels of light. Clearly, fire is important in maintaining high light levels that support the observed species richness of longleaf savannas.

Among numerous threats to the structure and function of the longleaf pine ecosystem is the chronic, widespread alteration of fire cycles that were once both part of the natural landscape and were a common land-use practice among indigenous human populations. These factors also intersect with current increases in human populations and associated land-use practices and resource demands [8].

Less studied is the effect of fire exclusion on soil fertility. This can be especially important in soils of longleaf pine stands which are typically acidic and low in fertility with aluminum mobility. It is possible that, because of the enhanced encroachment of hardwood species, chronic fire exclusion increases soil fertility via inputs of litter with high nutrient content. Conversely, an increased uptake by these species decreases soil fertility.

Additionally, related to human population growth in the southeastern United States is the increase in the degree of urban interface with longleaf pine sites [9]. Urban interfaces represent a unique juxtaposition of human populations and the natural systems that sustain them [10]. More specifically, college and university campuses comprise a distinctive urban interface, with their spatial patterns of permanent construction—dormitories, administrative buildings, classrooms, academic departments—combined with parking lots and green spaces, such as quadrangles, gardens, and arboreta [11,12]. Ultimately, all urban interfaces, especially those of campuses, typically necessitate a high degree of fire exclusion.

Several features of the campus of the University of West Florida in Pensacola have combined to provide an opportunity to study the ecology of longleaf pine—including the effects of fire exclusion—in a unique setting. Campus construction began in 1963 with 405 ha of longleaf pine stands recovering from extensive logging in the region [13]. The designer of the campus, John E. Jarvis, Jr., used a 'design with nature' approach that called for minimal tree removal during the construction of buildings and the establishment of paved areas [14]. Remnant campus trees were predominantly species native to the Florida Panhandle, including species of pine (*Pinus* spp.), oak (*Quercus* spp.), and magnolia (*Magnolia* spp.) [15,16]. In addition to his main campus directive, Jarvis called for the establishment of natural areas with an expansive network of low-impact, non-paved trails. The vision of Jarvis was borne out to be particularly fruitful, as there are numerous habitat types observable on the UWF campus, including a wetland and associated hammock, a cypress pond, and a freshwater stream with riparian plant species. Anecdotally, the campus of UWF has the highest number of vascular plant species (nearly 900) of any university campus in the eastern United States (specimens of each species held in the UWF Michael I. Cousens Herbarium).

In the summer of 2019, these distinctive features of the UWF campus were recognized for their innate value in investigating the ecology of longleaf pine in the urban interface of a university campus [17,18]. Thus, the UWF Campus Ecosystem Study (CES) was established as an interconnected series of research projects. To date, there have been five investigations, with four as part of the original focus on the ecology of longleaf pine [19–22] and one study [23] that monitored the freshwater stream that flows through the campus and joins the Escambia River (Figure 1).

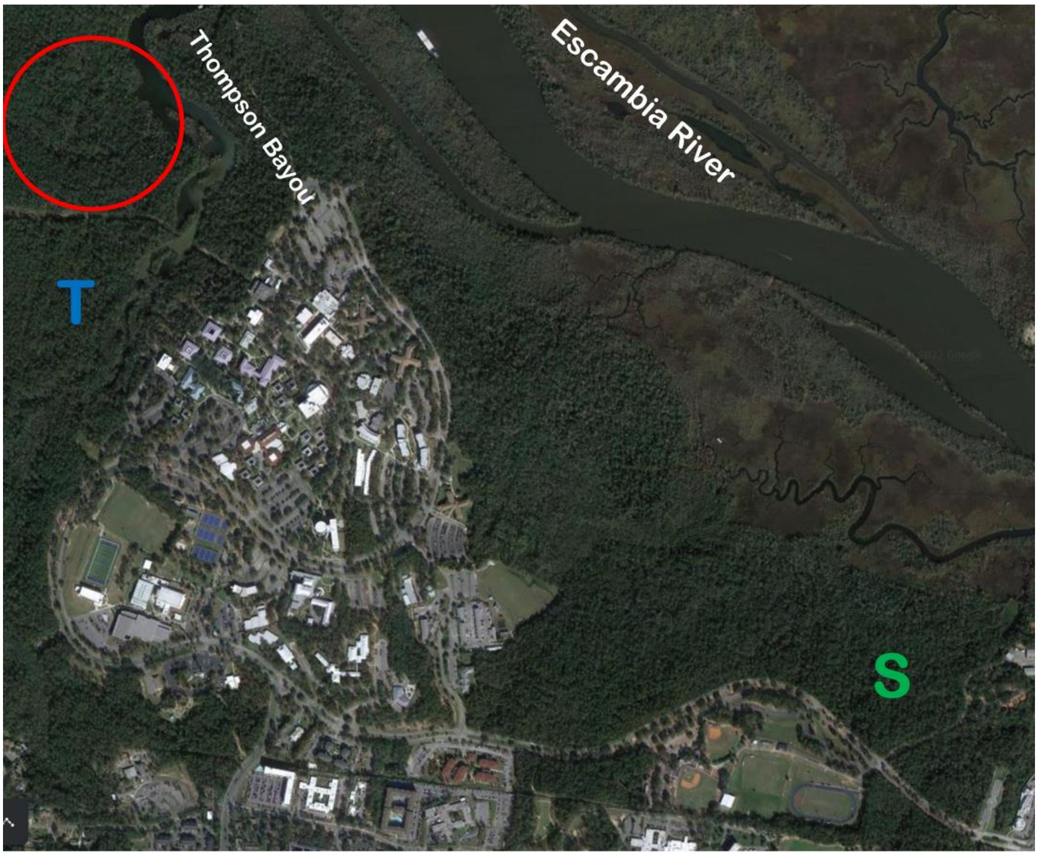

Figure 1. The campus of the University of West Florida, Pensacola, Florida (30.5102° N, 87.2125° W). The main campus is composed of all roads, parking lots, and permanent structures; university property extends beyond this to wooded areas. In the summer of 2019, all longleaf pines of the main campus ≥2.5 cm diameter at breast height (DBH) were measured for DBH—a total of 2165 stems [19]. In the summer of 2020, sample plots were established and sampled in two of the UWF campus' natural areas: Ball Trails (T) and Baars-Firestone Wildlife Sanctuary (S) [20]. The most recent study [22] is indicated by the red circle.

Most forest stands along the UWF campus nature trails are typical of second-growth longleaf pine forests that have experienced chronic fire exclusion [6,20,24–28]. These comprise stands of widely-space longleaf stems primarily 50–100 yrs in age [21] with an otherwise fire-maintained open matrix [2,29,30] filled with hardwood species, especially numerous southern oaks, e.g., live oak (*Quercus virginiana*), water oak (*Q. nigra*), blackjack oak (*Q. marilandica*), and laurel oak (*Q. laurifolia*).

The purpose of this paper was to provide a synthesis review of all the work carried out as part of the UWF CES. Additionally, we further added a novel analysis of soil fertility and forest stand composition and structure to understand current conditions in the context of past land-use history, with a focus on the effects of chronic fire exclusion on longleaf pine composition and soil fertility. The following questions were addressed: (1) what is the effect of chronic fire exclusion on species composition and the structure of longleaf pine stands? (2) how does the longleaf age structure vary across the urban interface of the UWF campus? (3) what is the effect of fire exclusion on soil fertility?

2. Materials and Methods

2.1. Study Site

The UWF CES is an ongoing study that comprises the main campus and the forested stands from low-impact, unpaved sandy trails in several natural areas in Pensacola, Florida (30°33′ N, 87°11′ W, Figure 1). The natural areas included the Edward Ball Nature Trails (hereafter 'Ball Trails'), the Baars-Firestone Wildlife Sanctuary (hereafter 'Sanctuary'), and the Campus Side Trails (hereafter 'Side Trails'). The soils of these sites are dominated by the Troup series, which consists of deep, well-drained soils that originate from marine sediments of a sandy, loamy nature [31]. The Troup soils are loamy, kaolinitic, thermic Grossarenic Kandiudults with a chronically high seasonal water table below 2 m in depth [32]. Previous works have shown these soils to be acidic and infertile [22].

2.2. Field Sampling

The initial investigation of the UWF CES began in the summer of 2019. Although that study examined two complementary aspects of the longleaf pine ecosystem that are associated with the campus, i.e., (1) the effects of gopher tortoise burrowing on herbaceous plant communities and soil fertility and (2) the size structure of longleaf pines on the main campus, only data from the longleaf pine sampling are covered here. These data were obtained by measuring all longleaf stems $\geq$2.5 cm diameter at breast height (DBH) on the main campus for DBH.

In the summer of 2020, longleaf stands of the Ball Trails and Sanctuary sites were studied to determine the response of longleaf pine stands to chronic fire exclusion. For this part of the study, 15 $\times$ 400-m^2 circular plots were established in each site to characterize the composition and structure and sample mineral soil. All living stems that were $\geq$2.5 cm DBH were identified in each sample plot to species and were measured for DBH. Mineral soil was taken to a 5 cm depth at five locations per plot and combined to yield a single composite sample per plot. These data were transcribed to a yield basal area and density for each species per sample site for the construction of important value tables, as well as serving as an input for canonical correspondence analysis (CCA—see Section 2.3). Following the removal of organic material, mineral soil was sampled to a depth of 5 cm and analyzed for pH, organic matter (OM), cation exchange capacity (CEC), extractable macro- and micronutrients, and Al.

On 16 September 2020, Hurricane Sally—a Category 2 tropical cyclone—impacted the region around and including the UWF campus with a 12 h eyewall and winds reaching 49 m/s. This resulted in numerous trees, especially longleaf pines, being windfallen, including the main campus and the stands along the nature trails. In the summer of 2021, the UWF CES was able to take advantage of longleaf pine windthrows by Hurricane Sally to obtain cross-sections for age determinations, which were sampled primarily in the Ball Trails and Sanctuary areas. Sections were taken at 1.5 m from the base of each stem. A total of 50 sections were taken for this study, with 40 trees that were windthrown and 10 live-tree harvests to provide for an adequate low-end range of diameters, as small, young longleaf pines tended to be unsusceptible to windthrow. For each stem section sampled, DBH and the number and width of annual rings (to the nearest 0.01 mm) were recorded.

Sampling was expanded in the summer of 2022 to include the Side Trails area, which was composed of hardwood stands to compare with adjacent longleaf pine stands to assess variation in stand composition/structure, soil fertility, and soil microbiome. For this study, 12 circular sample plots (400 m^2 ha) were established per stand type. Stand and soil sampling was carried out as in previous UWF CES investigations. Longleaf pine and soil data from only the longleaf pine stands were included in this analysis.

2.3. Data Analysis

The size structure of longleaf pine was determined by constructing size-class frequency distributions based on DBH. To assess the possible effects of fire exclusion on soil fertility, *t*-tests were used to compare the mean soil data between soils from adjacent canopy openings (pre-fire exclusion) versus soils from forest stand plots (post-fire exclusion) [33]. Linear regression was used to compare the age of longleaf stems to the measured DBH for 50 stems to yield a model allowing an estimation of the stem age based on DBH. The age of each measured longleaf pine stem was estimated from DBH with the following model based on this analysis [22]:

$$\text{Age} = 1.76 \times \text{DBH} + 0.83\ (r^2 = 0.82;\ p < 0.00001)$$

where Age is the stem age in years; DBH is in cm. The mean age of longleaf pine was compared among the main campus, Ball Trails, Sanctuary, and Side Trails sites via an analysis of variance and Least Significant Difference tests [33]. Age-class frequency distributions were also constructed for the longleaf pine populations of these sites.

Stand composition was compared among natural area sample sites using CCA with Canoco 5.11, Windows release [34]. As previously stated, the input data for tree species were the basal areas for each species in each sample plot. Soil data were used as environmental variables. Among numerous ordination techniques, CCA has the advantage of providing a direct gradient analysis of environmental (i.e., soil) variables and species composition [35,36].

3. Results and Discussion

The inaugural effort of the UWF CES in the summer of 2019 determined the DBH of all main campus longleaf pine stems: a tally that totaled 2165 stems. When this number was adjusted for the estimated sample area, stem density was ~64 stems/ha: a value clearly lower than that of the natural stands (e.g., 120–140 stems/ha) [6,24]. On the other hand, it was well within the range of tree densities in other urban settings, i.e., 40 to 100 stems/ha [11]. Given the chronically unburned state of urban interfaces [8], it was also unsurprising that the distribution of the stem size resembled fire-excluded longleaf pine stands and was in sharp contrast to frequently burned stands [18].

The two natural areas—Ball Trails and Sanctuary—sampled in the summer of 2020 displayed interesting patterns of both similarities and contrasts, ultimately suggesting that these two areas were tracts/parcels of land under separate ownership prior to the initiation of the construction of the UWF campus in 1963. Regarding similarities, both sites had live oak as the species with the highest importance value (45.4 and 35.6% at Ball Trails and Sanctuary, respectively) as a result of high density, with longleaf pine being of secondary importance, even with its much higher basal area, because of its low density (29.3 and 25.3%, respectively). These sites were of an essentially identical stand structure, with a total basal area of 30.3 and 29.6 m^2/ha for the Ball Trails and Sanctuary, respectively, and a total density of 1225 and 1197 stems/ha, respectively [20].

There were also, however, notable contrasts between these sites regarding the size structure of longleaf pine. In the Sanctuary site, more than 30% of longleaf stems were found in classes >30–40 cm, but only ~10% were >30–40 cm for the Ball Trails. Furthermore, the Sanctuary site was more similar to the main campus than the Ball Trails site. The median DBH was 35.0 and 37.1 cm for the main campus and Sanctuary, respectively, and 31.2 cm for the Ball Trails (Figure 2). The mean DBH of longleaf pine stems was not significantly different between the main campus and Sanctuary (34.4 $\pm$ 0.2 and 35.9 $\pm$ 1.1 cm, respectively), but the means for both were significantly higher ($p < 0.05$) than the Ball Trails (30.9 $\pm$ 0.8 cm).

Two conclusions arose from these observed patterns. The overall similarity confirmed that the longleaf pines of the UWF campus represented the remaining stems from a time when extensive logging in northwest Florida ceased >100 years ago [13]. Sharp contrasts between the Sanctuary and Ball Trail sites, however, suggested that these two sites likely had different ownership and contrasting land-use history prior to the construction of the UWF campus in 1963. Indeed, these areas are ~2 km apart and occur on opposite sides of the main campus.

As already discussed, the work of summer 2021 was to sample windthrown longleaf stems resulting from Hurricane Sally in September 2022. This resulted in the linear model presented in the Methods (see Section 2.3), which allowed for the estimation of the age of all measured longleaf trees, including the main campus and all-natural areas, based on DBH.

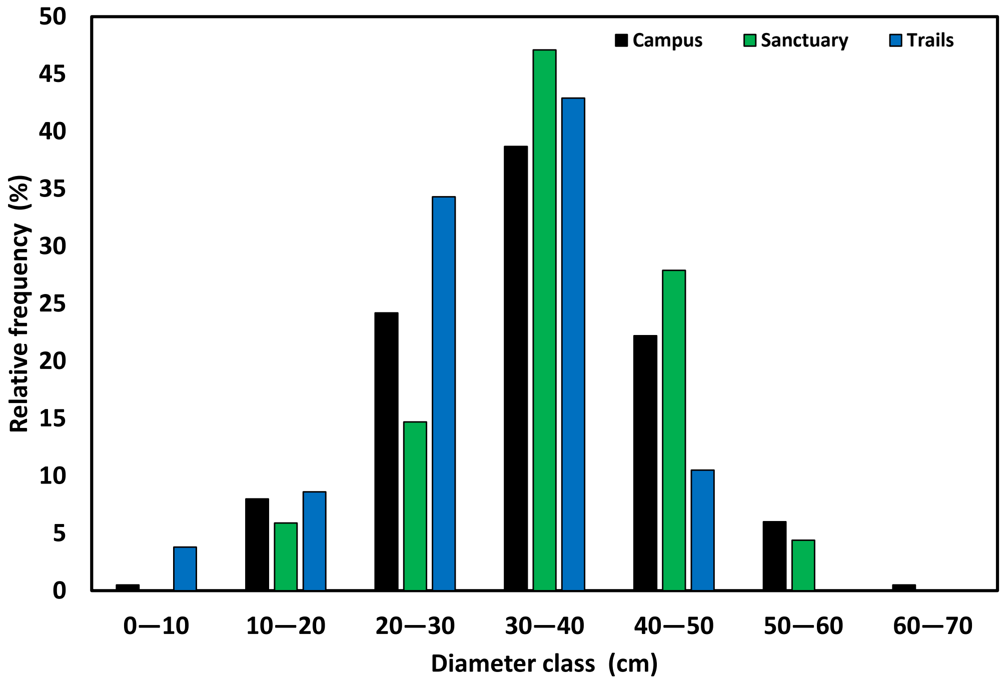

Figure 2. Diameter size-class frequency distributions for longleaf pine for two UWF natural areas (Ball Trails and Wildlife Sanctuary) and the UWF main campus. Figure used with permission from [20].

The scope of the UWF CES was expanded in the summer of 2022 to include two new facets: (1) the comparative analysis of an additional longleaf-dominated stand with an adjacent hardwood-dominated stand, and (2) the determination of the soil microbiome of these stands. Sampling took place on the Side Trails site (see Section 2). The component of this work that proved relevant for this review comprised the DBH data of longleaf pine stems in the pine-dominated Side Trails stand, with a specific focus on the stem age and age-class distribution of all sampled areas, including the main campus, Sanctuary, Ball Trails, and Side Trails. Data from the Side Trails place, a site more in line with the Ball Trails site, showed that the mean age of the pine-dominated stand was also significantly lower than the main campus and Sanctuary (Figure 3).

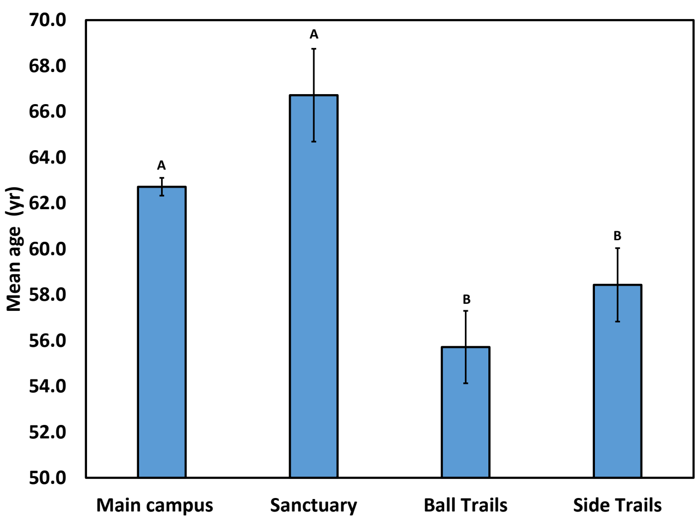

Figure 3. Mean age of longleaf pine for four areas at UWF: main campus, Baars-Firestone Wildlife Sanctuary, Edward Ball Trails, and pine-dominated stands of the current study (see Figure 1 for locations). Values shown are means ± 1 SE. Means with the same superscript are not significantly different at $p < 0.05$.

Age class distributions further revealed contrasts in the age structure among campus longleaf populations, confirming earlier conclusions that these areas were likely of different ownership under contrasting land use at the time of purchase by the State of Florida for the construction of the UWF campus [19,20]. Most longleaf stems were between 60 and 70 yrs for the main campus and Trails but between 70 and 80 yrs for the Sanctuary (Figure 4). Of even sharper contrast was the longleaf-dominated stand of the Side Trails site. That is, not only were most stems of this stand 40–50 yrs but stems <50 yrs were virtually absent (Figure 4). The median stem age was 64, 69, 58, and 55.3 yrs for the main campus, Sanctuary, Ball Trails, and Side Trails, respectively.

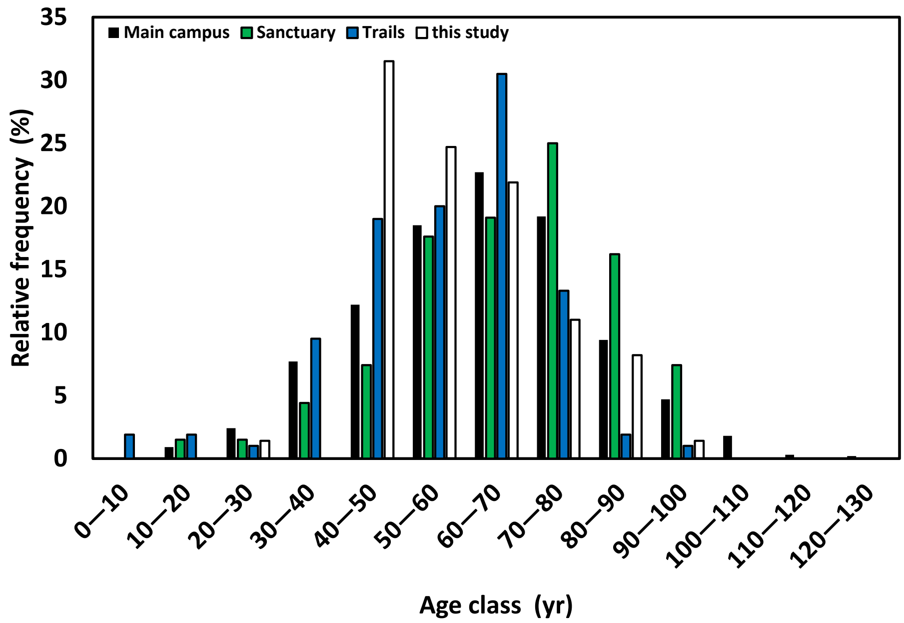

Figure 4. Frequency age class distributions for four areas at UWF: main campus, Baars-Firestone Wildlife Sanctuary, Edward Ball Trails, and pine-dominated stands of the current study (see Figure 1 for locations).

Despite the sharp contrasts in stand age and longleaf age structure among these three natural areas, they were generally quite similar with respect to the species composition, as evidenced by the results of canonical correspondence analysis (CCA) (Figure 5). The distribution of sample plots in the CCA ordination space revealed no patterns that were consistent with this site. These data support previous findings of close similarities between Ball Trails and Sanctuary stands [20], wherein live oak and longleaf pine were co-dominant species at both sites (to emphasize this, these two species are highlighted in bold, green font). Appropriately, they were found at the center of ordination space, owing to their ubiquitous nature, as they were generally found in all plots.

It merits restating that this high diversity of hardwood species was the direct result of chronic fire exclusion. Although these were second-growth stands, this phenomenon has also been described for old-growth longleaf stands [6,8,25]. Of particular importance is the success of live oak with their importance in all stands, regardless of the stand age of longleaf pine. More specifically, the age structure for longleaf pine at UWF (e.g., Figure 4) closely approximates the region's land-use history, wherein the wide-spread logging extended from 1870 to 1930 [13].

To assess the potential changes in soil fertility in response to chronic fire exclusion in the UWF sample sites, Gilliam et al. [20] compared soil data from the Ball Trails and Sanctuary sites to the open matrix used for the gopher tortoise study on the UWF campus and was immediately adjacent to the forest stands [19]. This was admittedly based on an assumption that could not be tested empirically, i.e., that soils from these open areas represent pre-exclusion conditions. Despite this, two observations supported the veracity of this assumption. First, the open matrix displayed the patterns of longleaf regeneration, which were typical of the period prior to fire exclusion. Second, the soils of all sites (open matrix and three longleaf pine sites) were of the same series—the Troup series (see Section 2).

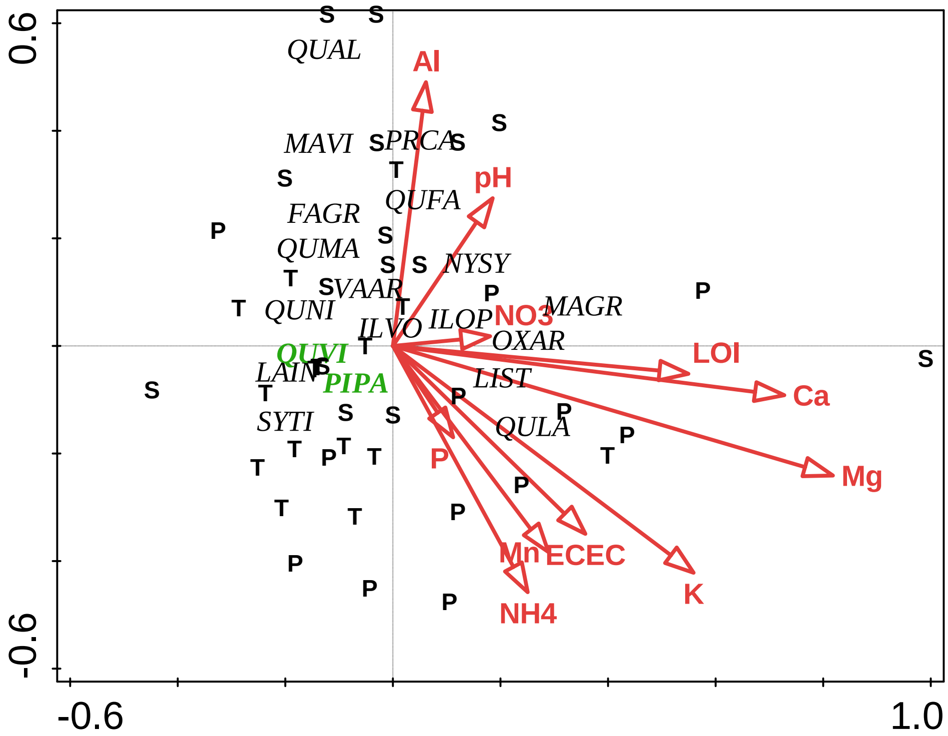

Figure 5. Canonical correspondence analysis of overstory species in Ball Trails (T), Sanctuary (S), and Side Trails (P) sites. For vectors, element symbols are extractable concentrations of the stated elements: 'CEC' is cation exchange capacity, 'OM' is organic matter, 'pH' is H_2O-extractable soil pH, and 'C' and 'N' are total C and N, respectively. Species are indicated by four-letter codes: *Fagus grandifolia* (FAGR), *Ilex opaca* (ILOP), *Ilex vomitoria* (ILVO), *Lagerstroemia indica* (LAIN), *Liquidambar styraciflua* (LIST), *Magnolia grandifolia* (MAGR), *Magnolia virginiana* (MAVI), *Nyssa sylvatica* (NYSY), *Oxydendrum arboreum* (OXAR), *Pinus palustris* (PIPA), *Prunus caroliniana* (PRCA), *Quercus alba* (QUAL), *Quercus falcata* (QUFA), *Quercus laurifolia* (QULA), *Quercus marilandica* (QUMA), *Quercus nigra* (QUNI), *Quercus virginiana* (QUVI), *Symplocos tinctoria* (SYTI), *Vaccinium arboretum* (VAAR).

Direct studies on the effects of chronic fire exclusion on soils are underrepresented in the literature. The comparisons presented here suggest that fire exclusion resulted in an overall decline in soil fertility, much of which could be related to increases in the acidity of already acidic soils, as the pH of post-exclusion soil was ~0.7 units lower than the pre-exclusion soil (Table 1). On the other hand, this response varied among nutrients, as N and P availability increased with fire exclusion (Table 1). This could have arisen because of the higher N and P concentrations in hardwood litter [37].

Table 1. *T*-test comparisons of pre- vs. post-fire exclusion soil variables. All nutrients/Al are extractable (see Section 2). OM is organic matter; CEC is cation exchange capacity.

Status	pH	OM %	NO_3-N µg/g	NH_4-N µg/g	Ca µg/g	K µg/g	Mg µg/g	CEC meq/100 g	*p* µg/g	Al µg/g
Pre (*n* = 32)	5.37 ± 0.08	2.09 ± 0.13	0.23 ± 0.05	2.60 ± 0.43	175.2 ± 36.1	16.8 ± 1.9	22.0 ± 2.5	1.51 ± 0.17	0.37 ± 0.03	52.0 ± 3.8
	****	*	NS	*	****	****	****	NS	**	****
Post (*n* = 42)	4.67 ± 0.03	1.66 ± 0.10	0.30 ± 0.02	3.77 ± 0.25	26.9 ± 4.1	8.2 ± 0.5	6.5 ± 0.5	1.47 ± 0.10	0.49 ± 0.01	113.3 ± 3.5

NS = not significant at $p < 0.05$; * = significant at $p < 0.05$; ** = significant at $p < 0.01$; **** = significant at $p < 0.0001$.

This likely resulted from two acidifying processes that occurred interactively and simultaneously. First, litter from longleaf pine and live oak were acidic, and as acidic litter built up on the forest floor, organic acids were leached and accumulated in the A horizon. Furthermore, Moore et al. [38] demonstrated that throughfall from canopies of a live oak was acidified, with precipitation pH decreasing by as much as 0.5 as it passed through live oak canopies. Additionally, trees had a far higher nutrient demand than herbaceous plants [39], and the uptake of cations by plant roots acidified the rhizosphere from the exchange of H^+ for nutrient cations from exchange sites [39]. Because chronic fire exclusion has allowed extensive hardwood establishment, it is likely that nutrient cations, such as Ca, Mg, and K, have been taken up in great amounts during fire exclusion. Additionally, hardwoods, which represent up to 60% of the basal area of the longleaf sites, have a higher demand for base cations, particularly Ca and Mg, than conifers [40]. Patterns of significantly lower Ca, Mg, and K in post- versus pre-exclusion soil (Table 1) support this second mechanism.

Adding to fire exclusion-mediated declines in soil fertility was the contrast in soil organic matter (OM). Soils of all sampled areas were composed of deep, coarse-textured sands that had low OM (~2%) and CEC (~1.5 meq/100 g), typical of this region, with OM appearing lower compared to the soils observed in old-growth longleaf pine (~4%) [25]. Organic matter in post-exclusion soil was significantly lower than that in pre-exclusion soil (Table 1). Although this may seem counterintuitive (i.e., it may have been expected that fire exclusion increased in soil OM from the increased litterfall of trees), OM was probably higher in pre-exclusion soils because, in these coarse-textured soils, OM is derived from the fine-root turnover of dominant grass species, such as broomsedge (*Andropogon virginicus*), wiregrass (*Aristida stricta*), and bluegrass (*Poa* spp.) [41]. These grasses are predominant in open areas, but they exhibit a rapid decline because of insufficient light during canopy closure.

In acidic mineral soils below 5.5, cation exchange sites were increasingly occupied by Al [39]. Enhanced acidity associated with base cation uptake likely increased Al mobility, as Al was significantly higher in post- versus pre-exclusion soil (Table 1).

4. Conclusions

The University of West Florida Campus Ecosystem Study, initiated in the Summer of 2019, was conceived as a series of interconnected investigations on the main campus and associated natural areas that comprised remnant longleaf stands following the cessation of widespread logging ~120 years ago. This has allowed an assessment of the effects of chronic fire exclusion on longleaf pine in the unique urban interface of a university campus. The data presented here offer a compelling picture that fire exclusion has resulted in profound changes in the stand structure and composition of these trees. The savanna physiognomy of fire-maintained longleaf stands has become closed-canopy forests with numerous hardwood species. Live oak has been particularly ubiquitous in these stands, which inhibits longleaf regeneration. Indeed, it is notable that this was found in all stands, regardless of the presence of longleaf pine [22]. The data also suggest that soil fertility declined significantly with chronic fire exclusion. A significant variation in the mean age of longleaf pine stems of the main campus and the three natural areas suggested that these natural areas were likely under separate private ownership prior to the construction of the UWF campus in 1963.

A further implication for the research reviewed here is the essential value of campuses t higher education as sites for ecological study. As already established, college and university campuses comprise a unique type of urban interface with various buildings, paved areas, and lawns [11,12,18]. Indeed, Gilliam et al. [20] identified several institutions within the natural range of longleaf pine. In Georgia, these were Berry College and Valdosta State University. In Florida, these were Stetson University, Florida A&M University, Florida State University, University of Central Florida, and Rollins College. There are numerous others beyond these, all with a wide land cover of longleaf pine. In many, restoration and research projects are either planned or underway [17,42,43].

More specifically, regarding the investigations of the UWF CES, such efforts have involved the work of undergraduate students, providing them with the invaluable and unique opportunity to extend their education and learning through research. To date, the results of the research carried out by these students have provided deeper insights into longleaf pine ecology, especially regarding the effects of chronic fire exclusion on the structure and function of longleaf pine ecosystems, including species composition and soil resources. Consistent with the aims of the UWF CES, future investigations could build further on the results presented herein, including measurements of photosynthetically active radiation and the characterization of the soil seed banks among hardwood-dominated versus longleaf pine-dominated stands.

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