



Comparison of Vegetation Structure in Texas Tortoise Habitats using LiDAR

Background and Methods

In 1847, the battle of Palo Alto was fought on an expanse of sacahuista prairie interspersed with shrub-covered ridges called lomas. Nearly 150 years later, the National Park Service acquired property in what is now Brownsville, Texas, to create Palo Alto Battlefield National Historical Park (NHP). Although this act ensured future preservation of the battlefield site, the acquired lands had already been severely altered. Portions had been cleared for dairy farming, crop production or cattle ranching; even today, some of the core battlefield is still privately ranched.

Twentieth century farming practices significantly degraded the park's natural resources, but since their cessation, there has been some recovery. Through natural and assisted revegetation, plowed fields and pastures have begun their transition back to shrubland and prairie, to benefit both the cultural landscape and the biological communities. The park has particular interest in its resident Texas tortoises, which are primarily found in the higher elevation loma shrublands and ecotones. Texas tortoises are listed as threatened in the state of Texas, and they are the subject of a long-term monitoring study since 2008, by the Gulf Coast Inventory and Monitoring Network. The network has tortoise study units on seven of the park's lomas, most of which are in the process of post-agricultural recovery (e.g., Figure 1A,B).

The structure and pattern of shrubland regrowth and maturation likely matters to Texas tortoises at Palo Alto Battlefield NHP. To better quantify this aspect of habitat change, we assembled and compared two spatial datasets from 12 years apart, 2006 and 2018. The datasets were derived using an airborne laser technology called LiDAR, which measures elevation at ground level and all strata above it (e.g., Figure 1C and Figure 2). These data were processed in 3 meter (m) pixels for the entire park in ArcGIS and then summarized as mean maximum canopy height and shrub density for the seven tortoise study units within each year. We used the following equation for shrub density, which includes taller cacti:

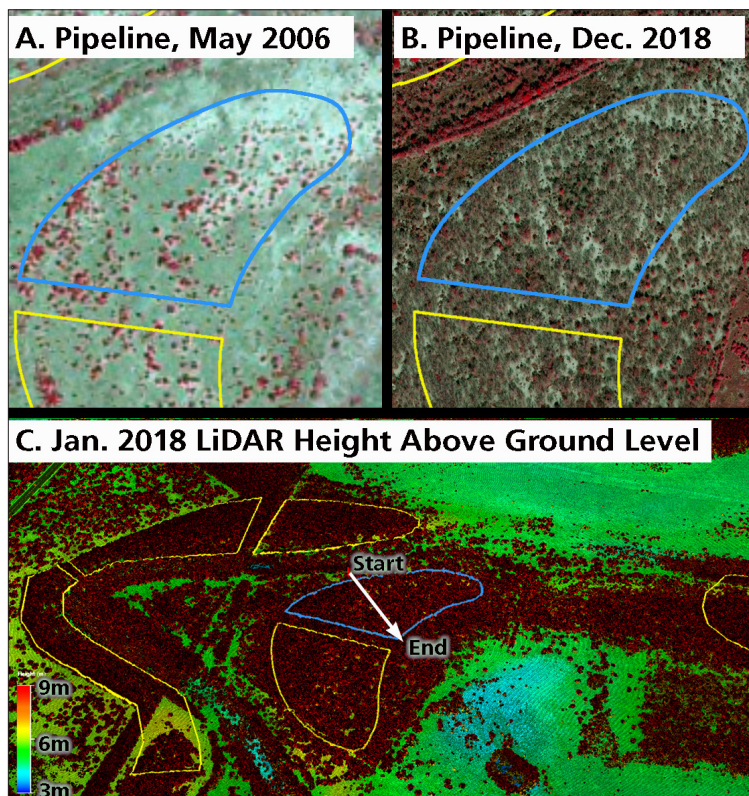


Figure 1. Imagery of a northern section of Palo Alto Battlefield NHP, focusing on the Pipeline study unit (blue outline) used in Texas tortoise monitoring. Other units are outlined in yellow. (A) Aerial imagery from May 2006; (B) Aerial imagery from Dec. 2018; (C) Oblique view of the Pipeline unit area from the 2018 LiDAR point cloud, as visualized in Quick Terrain Modeler. The white arrow shows the location of an example point-cloud transect, as depicted in Figure 2.

$$\text{Shrub Density} = \frac{(\text{Number of laser point intercepts between 0.5m and 1.5m})}{(\text{Total number of intercepts below 1.5m})}$$
 Project findings are presented in a table of per-unit averages of (1) maximum canopy height (2) shrub density and (3) change for each (2018 minus 2006 values). Change is also illustrated for the whole park with maps for change in canopy height and shrub density (Figure 3).

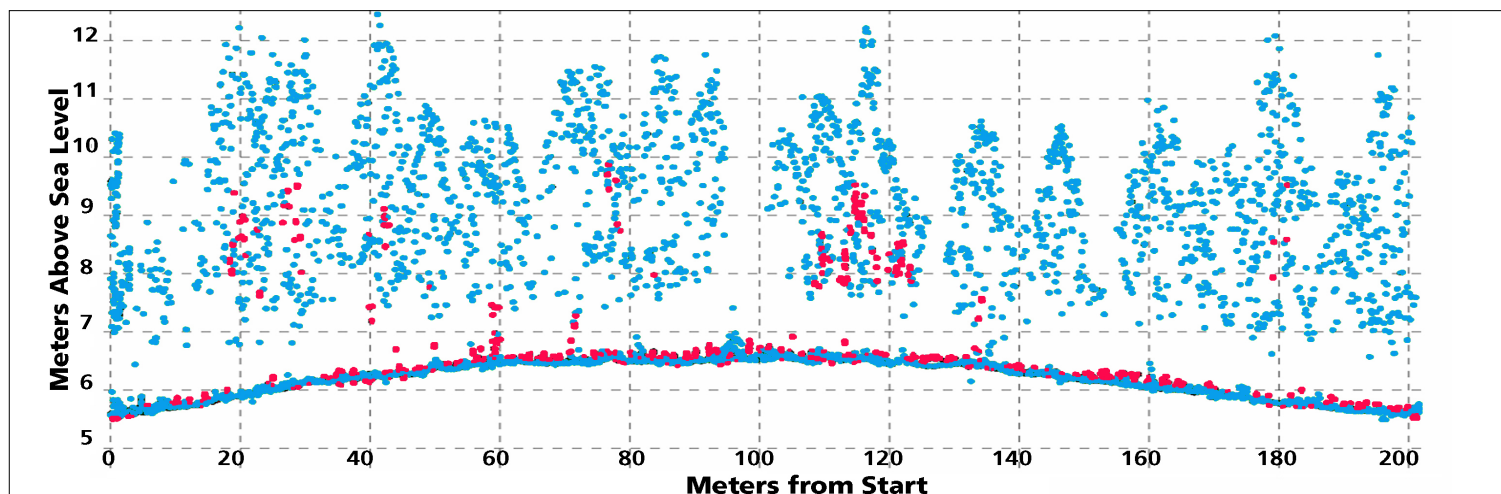


Figure 2. LiDAR point intercepts from ground level to maximum canopy height along a transect through Pipeline unit, for Jan./Feb. 2006 (red) and 2018 (light blue).

Results and Discussion

Vegetation structure changed markedly between 2006 and 2018, but the pattern of change was not consistent among tortoise study units (Table 1). The four northern-most units (4-7) increased the most in maximum canopy height, with 12-year growth rates ranging from 1.32 to 2.62 m (Figure 3A). The three southern units only increased slightly, by up to 0.63 m. For shrub density, in contrast, there was relatively little change within units over time (-0.08 to 0.01), as compared to differences between units within years (e.g., units 2 and 5 differed by 0.21 in 2006 and 0.17 in 2018; Table 1; Figure 3B).

The cross-unit differences in vegetation structure appear to be driven by their differing plant assemblages, which are in turn related to land use history. Northern units 4,5 and 7 were under cultivation until the early 2000s, and their explosive canopy growth between 2006 and 2018 was from fast-growing mesquite trees and limited shrubs and cacti. The southern units of 1, 2 and 3, in contrast, were never

cleared (unit 2) or had portions cleared only through the 1960s, which led to more consistently dense and rich shrub layers and smaller gains in canopy height. Unit 6 straddled the two groups, with canopy height increasing moderately and shrub density remaining stable and relatively high. This unit was last cleared in the 1980s, but apparently for cattle rather than for crops.

These diverse patterns of vegetation change have undoubtedly impacted Texas tortoises, although *how* is less obvious. In general, total available habitat has likely increased, as the post-cultivated north has regrown mesquite and in-filled with understory shrubs in some areas (e.g., b3 and b4 in Figure 3). Even so, the food and shelter found in mesquite-dominated lomas may be inferior relative to later-successional, shrub-rich lomas. Additionally, some gains in woody regrowth have been offset with brush clearing from the battlefield in the south. Through our continued long-term project, we aim to further clarify the links between changing vegetation structure and tortoise abundance throughout the park.

Table 1. Unit-wide averages for each LiDAR year and the change between years. Height is the mean maximum canopy height in meters (m). Density is shrub density, or the average point intercept density from 0.5 to 1.5m, standardized by the total number of point intercepts below 1.5m.

Unit	Height 2006	Height 2018	Height Change	Density 2006	Density 2018	Density Change
1, South Side	1.58	1.60	0.02	0.10	0.10	0.00
2, Visitor Center	2.75	3.21	0.46	0.25	0.22	-0.03
3, Maintenance	3.31	3.94	0.63	0.15	0.09	-0.06
4, Nilgai	2.55	4.26	1.71	0.06	0.06	0.00
5, Pipeline	1.73	4.34	2.62	0.04	0.05	0.01
6, Crescent East	2.52	3.84	1.32	0.19	0.11	-0.08
7, Northeast Boundary	2.40	4.48	2.07	0.09	0.08	-0.01

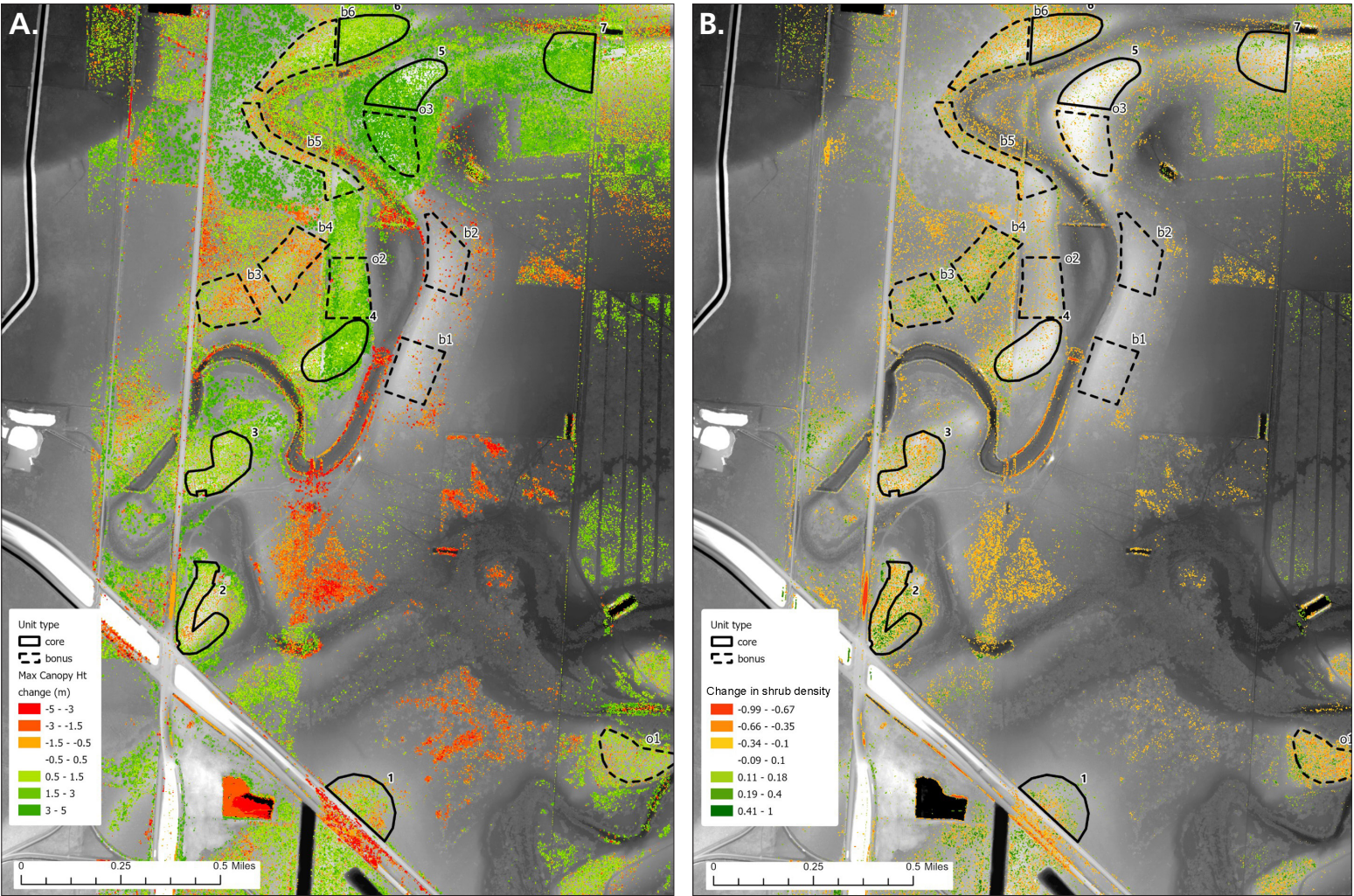


Figure 3. Change between 2006 and 2018 for (A) maximum canopy height and (B) shrub density from LiDAR data at Palo Alto Battlefield NHP. The black outlines are for the seven main tortoise study units, and the dotted outlines are for non-focal study areas that are under consideration for future supplemental surveys.