A Geospatial Database of Tree Islands within the Mustang Corner Fire Incident of 2008

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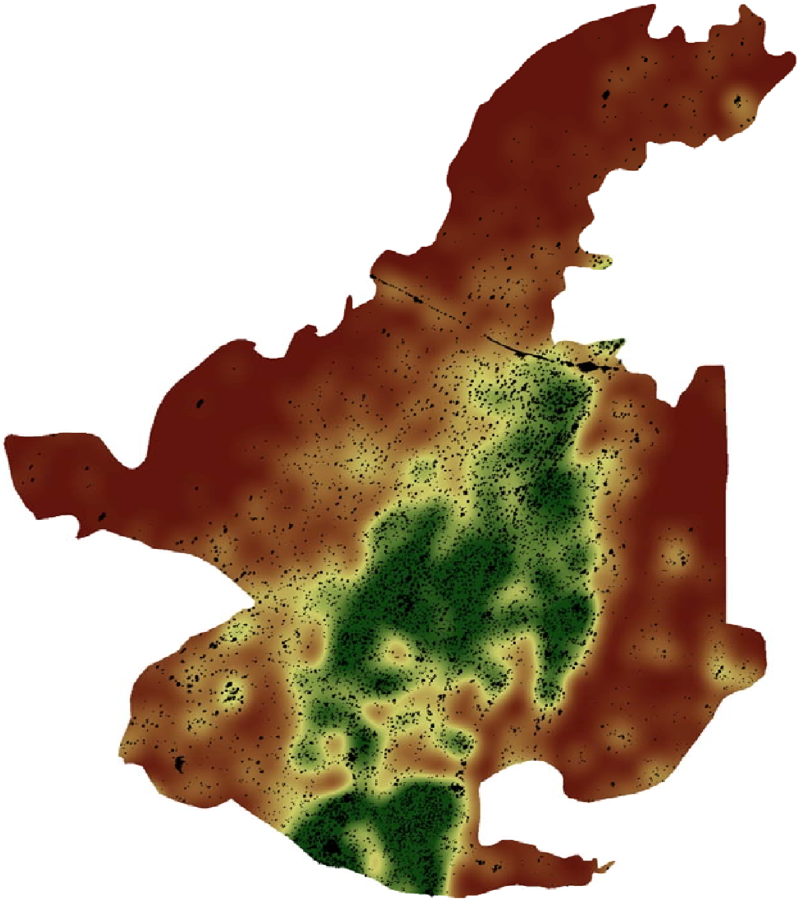

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Introduction:

Fire, which affects community structure and composition at all trophic levels, is an integral component of the Everglades ecosystem (Wade et al. 1980; Lockwood et al. 2003). Without fire, the Everglades as we know it today would be a much different place. This is particularly true for the short-hydroperiod marl prairies that predominate on the eastern and western flanks of Shark River Slough, Everglades National Park (Figure 1). In general, fire in a tropical or sub-tropical grassland community favors the dominance of C_4 grasses over C_3 species (Roscoe et al. 2000; Briggs et al. 2005). Within this pyrogenic graminoid community also, periodic natural fires, together with suitable hydrologic regime, maintain and advance the dominance of C_4 vs C_3 graminoids (Sah et al. 2008), and suppress the encroachment of woody stems (Hanan et al. 2009; Hanan et al. unpublished manuscript) originating from the tree islands that, in places, dominate the landscape within this community. However, fires, under drought conditions and elevated fuel loads, can spread quickly throughout the landscape, oxidizing organic soils, both in the prairie and in the tree islands, and, in the process, lead to shifts in vegetation composition. This is particularly true when a fire immediately precedes a flood event (Herndon et al. 1991; Lodge 2005; Sah et al. 2010), or if so much soil is consumed during the fire that the hydrologic regime is permanently altered as a result of a decrease in elevation (Zaffke 1983).

The general loss of tree islands in some parts of the Everglades due to flooding is well documented and understood (Patterson and Finck 1999; Avineon 2002; Hofmockel et al. 2003; Sklar et al. 2004). However, the loss of tree islands due to fires within the marl prairies of the Everglades has yet to be properly documented or studied. Anecdotal evidence suggests that tree islands within this pyrogenic landscape usually recover from a fire after several years. However, little is known about the successional sequence of tree islands following an intense fire and how that relates to the general distribution of woody species within this landscape and individual islands. At the same time, a paucity of information exists on how fires affect tree island biogenesis, if it occurs at all under current environmental conditions. To properly address these ecological questions, now or in the future, a comprehensive inventory of tree islands within this landscape is fundamentally necessary. The need for such inventory became abundantly clear following the Mustang Corner fire incident of 2008.

On May 14th, 2008 an arson fire was reported on the eastern boundary of Everglades National Park near an area known as the Mustang Corner (Figure 1). This fire, which burned for almost a month, consumed about 16,000 ha of environmentally sensitive lands within the breeding range of the Cape Sable seaside sparrow—a federally listed endangered species. Prior to the fire being extinguished on June 14th, 2008, aerial surveys indicated that significant portions of the landscape were devoid of all vegetation. In these areas, most tree islands experienced topkill of all trees, and were left with little or no standing live biomass (Plate 1). As a result of these post fire observations, Everglades National Park biologists recognized the need for a comprehensive inventory of tree islands within the Mustang Corner fire incident boundary prior to May 14th, 2008. This tree island inventory would then be used to document any net loss in the number and areal extent of tree islands within the affected area and to monitor tree island recovery.

As a result, a cooperative agreement between the National Park Service and Florida International University was signed to create a comprehensive geospatial database of all tree islands ($\geq 36 m^2$)

that existed within the Mustang Corner fire incident boundary prior to May 14th, 2008. In the pages that follow, the materials and methodologies used to create this geospatial tree island dataset are documented.

Methods:

A vector map of all tree island islands ($\geq 36\text{m}^2$) within and up to 500 m beyond the incident boundary of the Mustang Corner fire (Figure 2) were identified, digitized, and populated into a geodatabase using ESRI® ArcMap™ 9.3. The basemap used for the identification of these tree islands consisted of a set of 2004 1-m resolution multispectral, 3-band (NIR, Red, and Green) images. This image dataset corresponded to the regularly flown (about once every 5-years) National Aerial Photography Program (NAPP) Digital Ortho Quarter Quadrangles (DOQQs). These images, which were taken at 6,096 meters (20,000 feet) above mean seal level, had a scale of 1:40,000 and covered an area of approximately 64.8 km^2. A total of ten DOQQs were needed to map the entire study area. The native format for DOQQ imagery is a GeoTIFF. However, these images were only available as JPEG 2000 compressed images and, as such, were prone to ringing and blocking artifacts, which tend to minimize their overall usefulness. However, these compression artifacts were mitigated using a low pass 3x3 kernel filter in ERDAS Imagine 9.3. Once the images were enhanced, they were spectrally calibrated to ensure spectral consistency between all images.

Following the image enhancing process (i.e. 3x3 kernel filter & spectral calibration), the Normalized Difference Vegetation Index (NDVI), which has been shown to be an excellent predictor of photosynthetic activity & and productivity within a landscape (Wang et al. 2003; Warren and Metternicht 2005), was calculated for each DOQQ in ERDAS Imagine 9.3. NDVI is calculated by subtracting the Red spectral band from the NIR spectral band and then dividing this difference by the sum of the NIR and Red spectral bands (Equation 1).

Equation 1: $\text{NDVI} = (\text{NIR} - \text{Red}) / (\text{NIR} + \text{Red})$

The resulting 1-band raster consisted of pixels whose values ranged between -1 and 1 (Figure 3). In general, NDVI values > 0.3 tend to be associated with heavily vegetated areas with dense canopies, e.g. forests or agricultural fields. On the other hand, values between 0.1 and 0.2 are generally associated with bare soils or low productivity macrophyte communities while values <0 are typical of saturated soils or open water (see Jackson & Huete 1991).

Based on this general relationship, a minimum threshold NDVI value characteristic of a tree island community was determined to be approximately 0.35. Using this value as a cutoff, all raster pixels with an NDVI value < 0.35 were classified as Marsh while those with values ≥ 0.35 were classified as Tree Island. The resulting binary rasters were merged together and clipped to include all tree islands falling within the fire boundary and up to 500 m beyond it. After this mosaic was created, Tree Island objects whose NDVI values were ≥ 0.35 but whose total area was $< 36\ \text{m}^2$ were reclassified as Marsh since it was determined that 36 m^2 was the minimum resolution by which Tree Island objects could be identified as tree islands with a high degree of certainty. Next, the entire 22,528 ha tree island-marsh mosaic was given a final look over in order to identify improperly classified Tree Island objects $\geq 36\text{m}^2$ (e.g. agricultural fields, woody plants growing along roads, or sawgrass strands). During this QC/QA phase, Tree Island objects that exhibited gross boundary errors or other anomalies were manually edited. During this phase, some Tree Island objects were determined to be willow heads and were consequently dropped from the tree island feature class dataset. However, they were kept as a separated feature class within the geospatial database. Lastly, using the 25 and 75 percentiles as benchmarks, tree islands were categorized into three size classes: small (≤ 100 m^2), medium (101 to 625 m^2), and large (> 625 m^2).

Results:

Within the area mapped, a total of 9,025 tree islands and 224 willow heads were identified using this methodology (Figure 4). Of these totals, 7,453 tree islands and 153 willow heads were found exclusively within the Mustang Corner fire incident boundary. The total tree island area identified was 430 ha, which is approximately 2.7% of the total area affected by this fire. Tree island sizes varied from 36 m^2, the minimum mapping unit (mmu), to a maximum size of 63,827 m^2. The average tree island size was approximately 577 m^2 (~ 0.06 ha). Tree islands < 0.1 ha in size accounted for about 86% of the total number of tree islands mapped and, as a unit, accounted for 44% of the total tree island area within the Mustang Corner incident boundary (Figure 5a). In contrast, tree island > 1.0 ha were extremely rare (Figure 5a) and accounted for < 10% of the entire tree island area mapped (Figure 5b).

On average, most tree islands were within 63.4 meters of another island. Tree island density, expressed as a kernel density function, revealed a heterogeneous landscape where tree island density ranged from 0 to nearly 3 tree islands ha^{-1} (Figure 6). Tree island densities were greatest within a central, NE-SW running band. However, even within this high density band, tree island densities were quite heterogeneous.

Discussion:

The geospatial database described above is a distinctive dataset that documents the spatial distribution and extent of tree island resources within the Mustang Corner fire incident boundary. Because of its fine scale resolution (mmu of 36 m^2) this product supersedes previous tree island mapping efforts for this region and for the Everglades as a whole. As a result, this tree island database not only provides resource managers and ecologists with a toolset to monitor the effects of the Mustang Corner fire on tree island survival, biogenesis, and cessation but serves as a benchmark for the pre-fire density and extent of tree islands within the Mustang Corner fire incident boundary in 2004.

This database can be used along with historical imagery, which dates back to the 1940s, to monitor and ascertain the overall impact that repeated fires have had on the dynamics of tree islands within this region. Furthermore, if coupled with field efforts, it might be possible to determine if any or all of the sparsely-vegetated or barren bedrock outcrops (skeleton islands) that are present throughout this landscape were at one point tree islands themselves that have been lost as a result of fires and/or hydrologic modifications (Plate 2).

This database only covers the area affected by the Mustang Corner fire and 500 m buffer, and, as such, is an incomplete dataset of all the tree islands present within the marl prairies of the Everglades. The methods outlined in this report work extremely well with the imagery used and a complete tree island dataset for the marl prairies, using this imagery, could be done in a fairly short period of time. However, it is unclear, how well this methodology would work with other image datasets, particularly historical panchromatic image datasets As a result, if a comprehensive temporal tree island database is desired, the methodology outlined in this report could serve as a template from which new methodologies would be developed to handle the differences in the spectral and spatial resolution of each image dataset being analyzed.

Conclusion:

Tree islands within the short-hydroperiod marl prairies of the Everglades tend to be small but numerous, and are a major component of the landscape. While small, these tree islands contribute significantly to the biodiversity of the Everglades and serve as refugia for both plants and animals. At the same time, these wooded communities add the overall heterogeneity and physiography of this landscape by adding structure and bio-topographic relief to an otherwise featureless landscape. Furthermore, as functioning ecosystems, they are microcosms of the larger more productive forested communities typical of the Everglades, as a whole. As a result, any net loss in their density or areal extent could have significant repercussions on the overall ecological health of the Everglades and the species that coexist within this unique habitat type.

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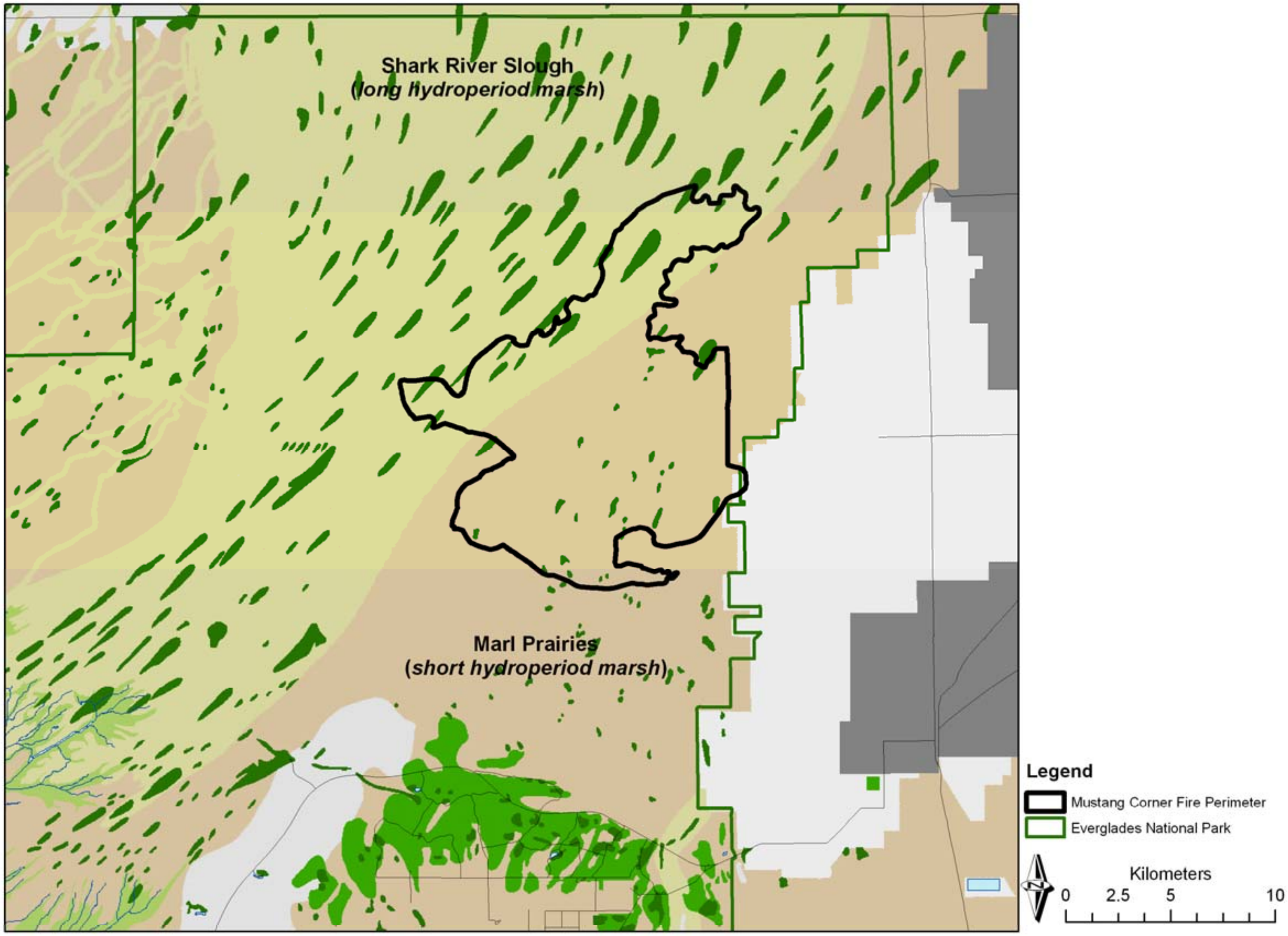

Figure 1: Mustang Corner fire incident boundary.

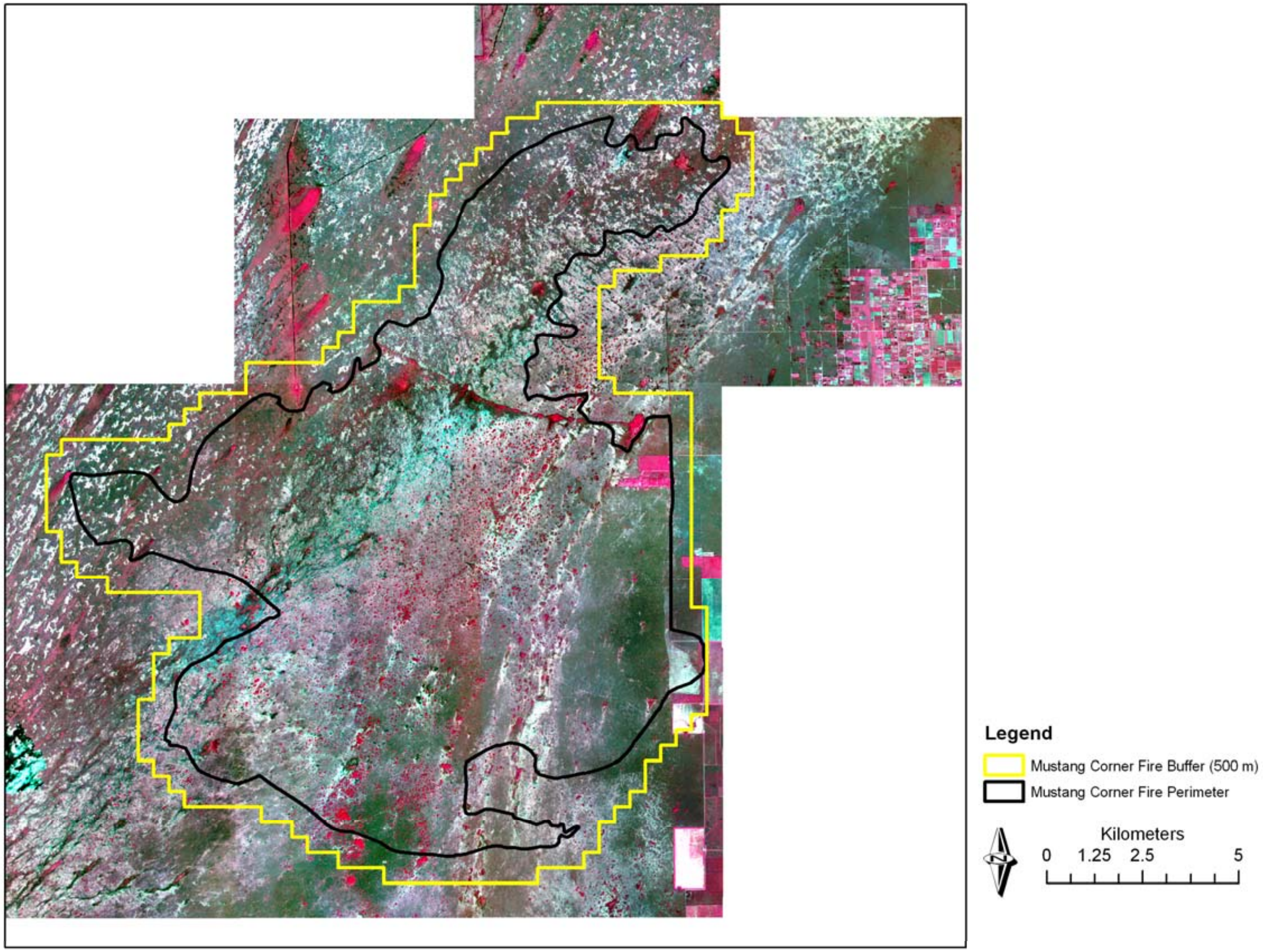

Figure 2: Mustang Corner fire incident boundary & buffer.

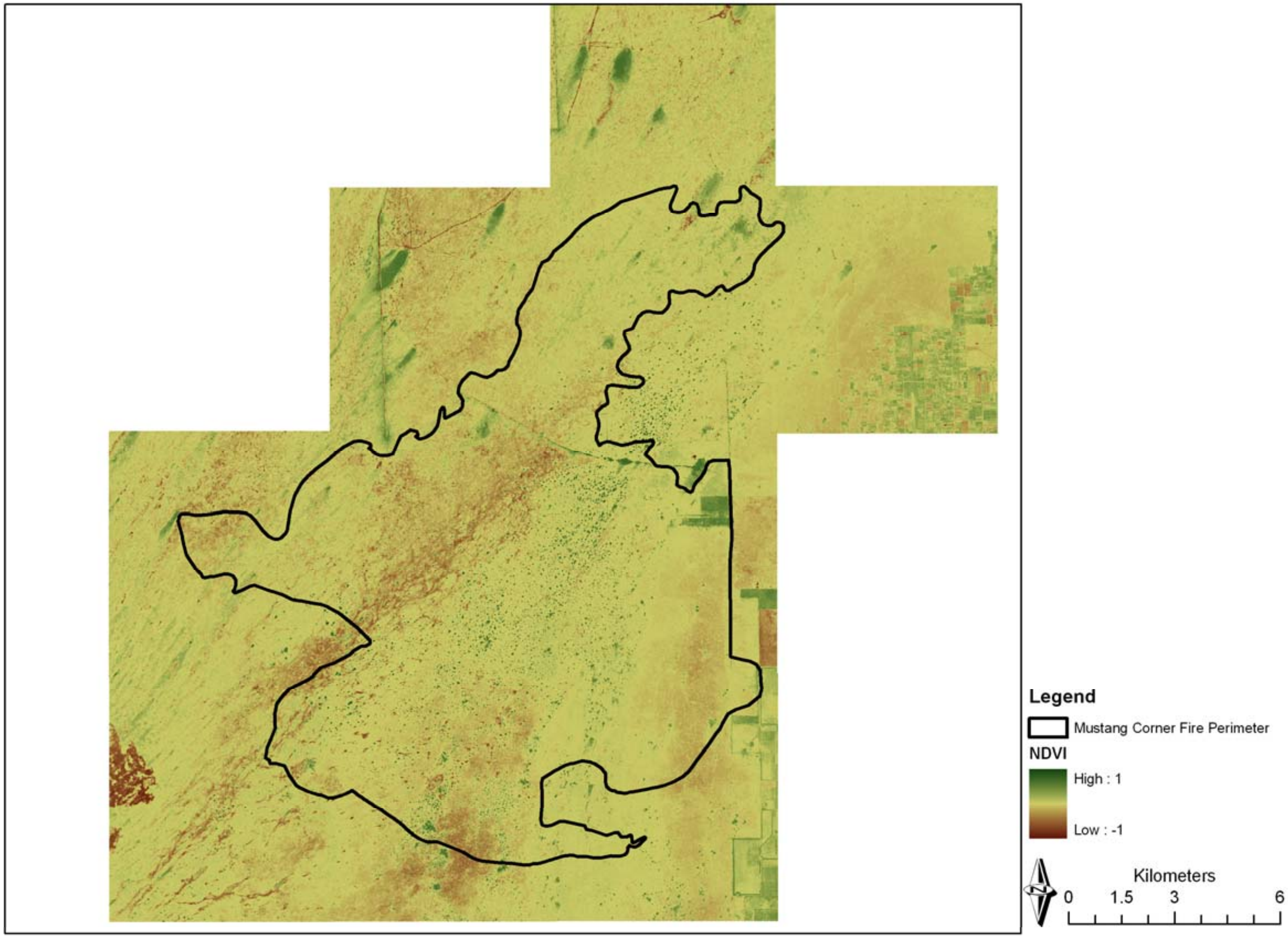

Figure 3: Normalized differnce vegetation index (NDVI) map used to indetify tree islands within the study area.

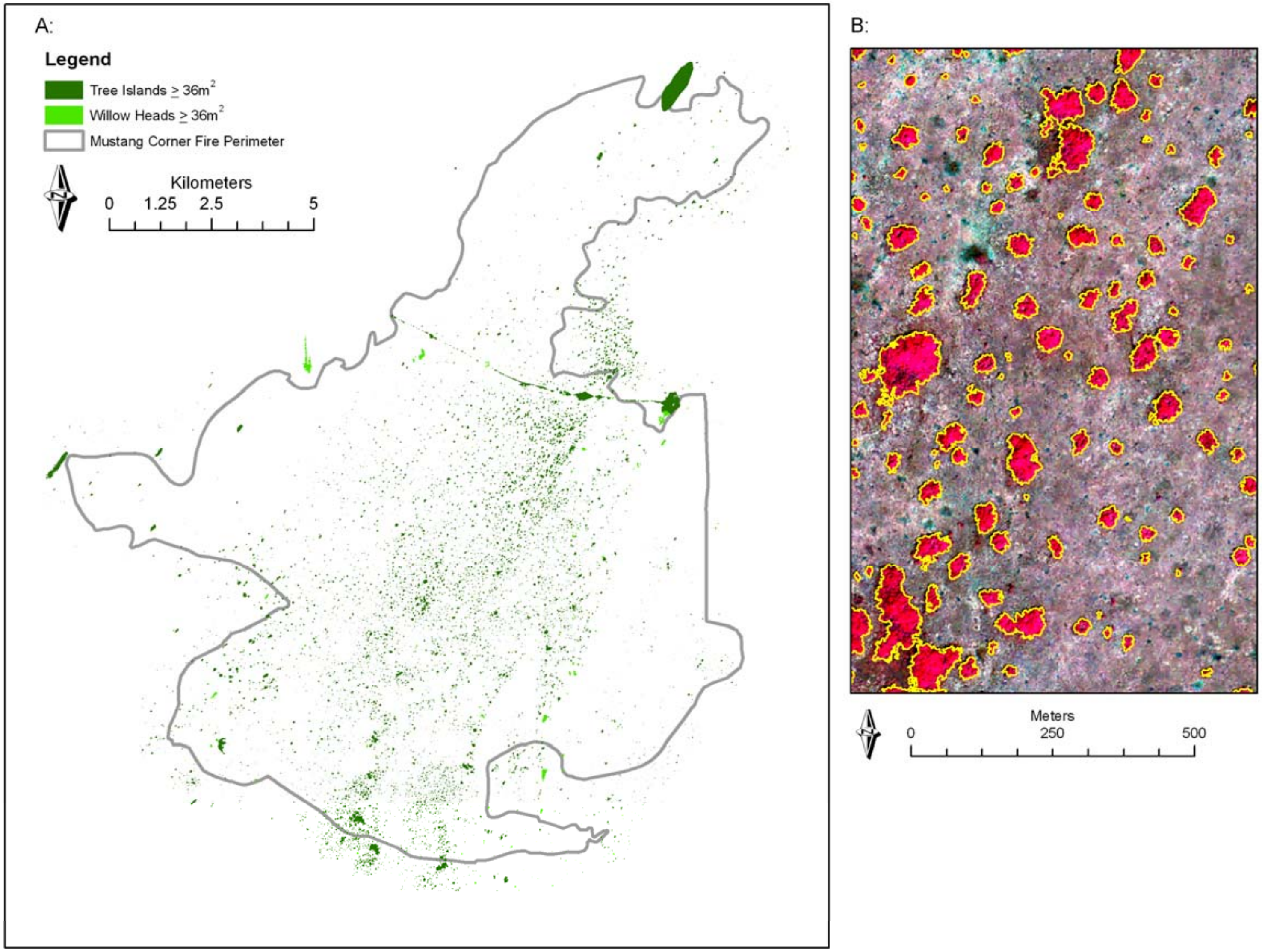

Figure 4: Map of tree islands and willow heads within the Mustang Corner fire incident (A) & close up of tree island deliniation (B).

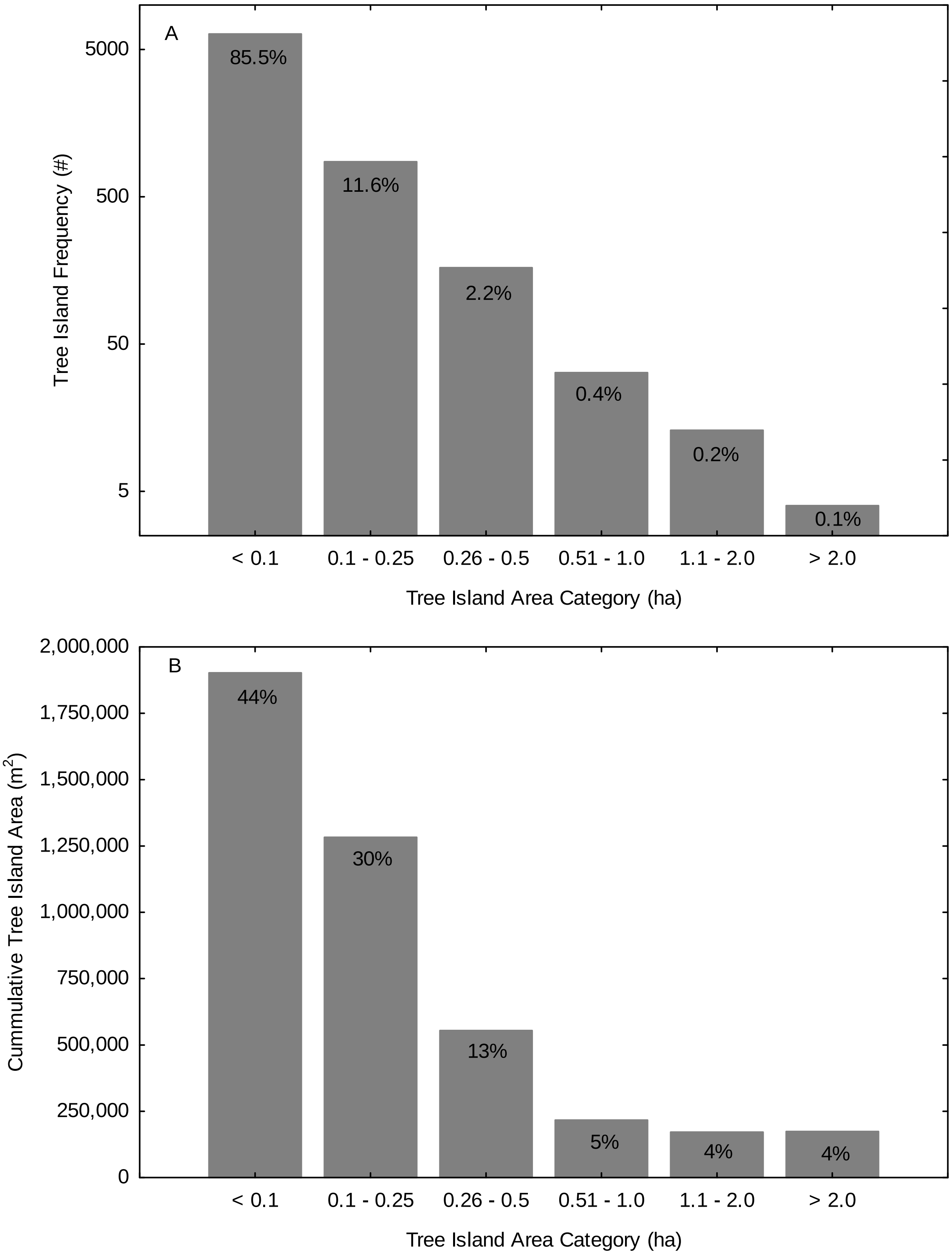

Figure 5: Frequency of tree islands (A) & cummulative area (B) by size classes within the Mustang Corner fire incident boundary

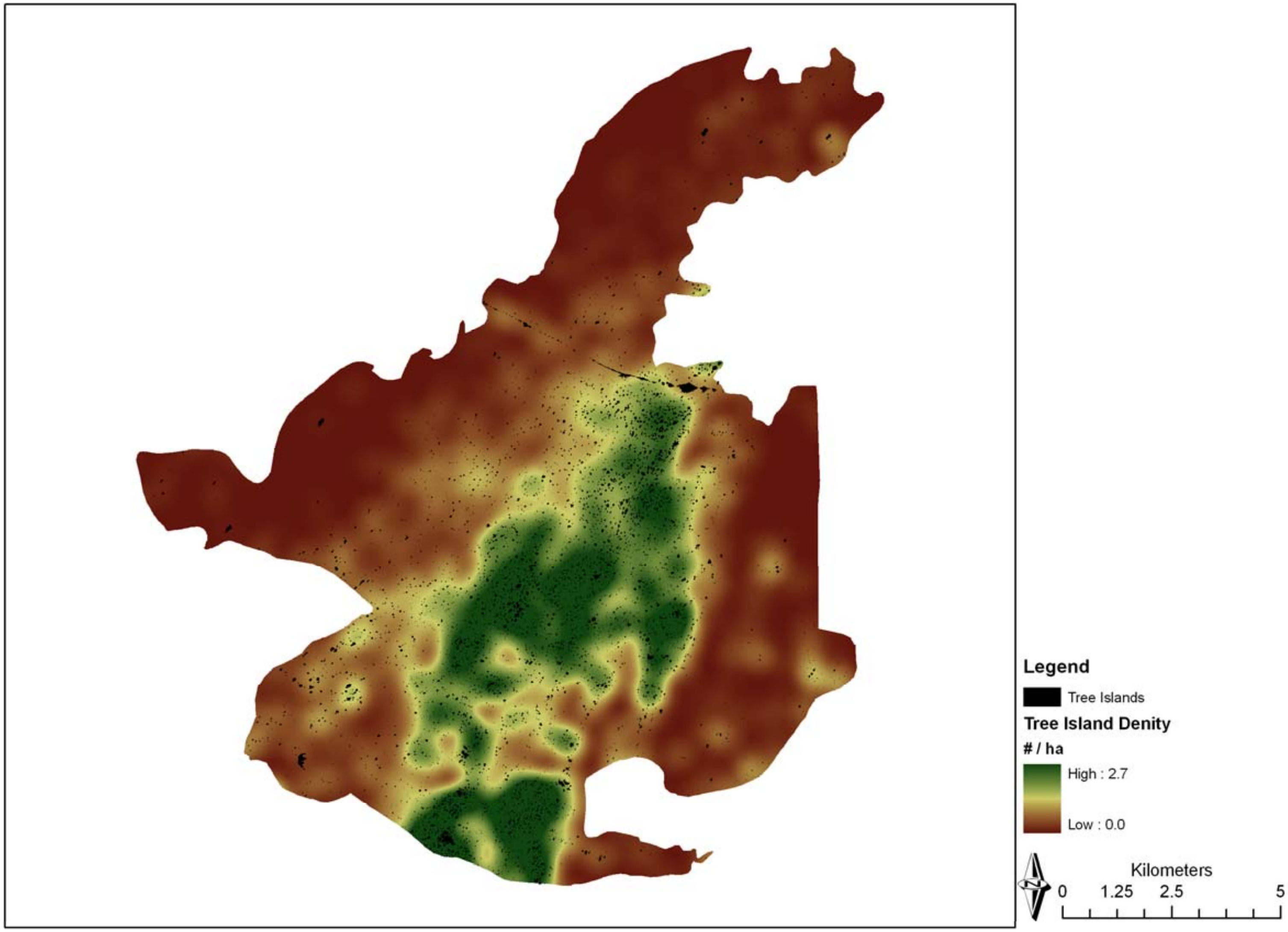

Figure 6: Tree island density (#/ ha) within the Mustange Corner fire incident boundary.

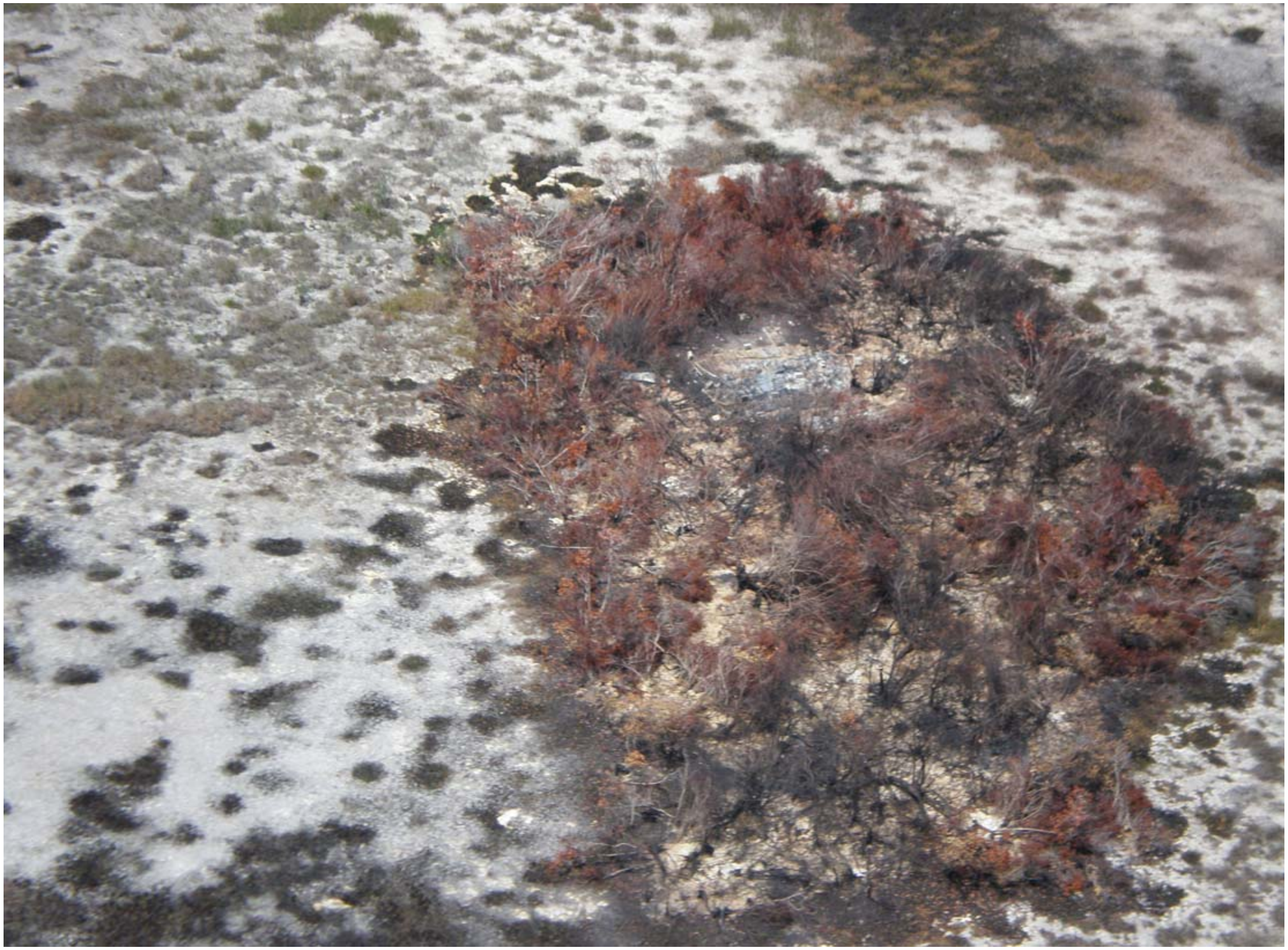

Plate 1: Aerial photo (June 2008) of burned out tree island within the Mustang Corner fire incident boundary.

Plate 2: Sparsely vegetated rock outcrop (skeleton island) within the marl prairie landscape.