Final Deliverable
Project Report
Including
All Previous Deliverables In Full
and
Complete User Guide & Update Policies

Mapping Fires Across Florida:

Advancement of a Fire Spatial Database

April 2019

Tallahassee, FL

TALL TIMBERS

Principal Investigator/Project Manager

Joe Noble

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Casey Teske
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Kevin Robertson

Project ID

FWC-16/17-135 Spatial Database
A Proposal for Mapping Statewide Fire Occurrence, Fire History, and Ecological Outcomes
Submitted by Tall Timbers Research, Inc., June 20, 2017

Previous project deliverable reports, including the earlier workshop proceedings, video of expert presentations, summary report, and power point presentations are available free of charge from Tall Timbers Research, Inc. Please contact Joe Noble: jnoble@talltimbers.org

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Executive Summary

Tall Timbers Research, Inc. is pleased to present the final deliverable for the *Mapping Fires Across Florida* project. The overall purpose of the project is to develop a spatial database of prescribed fire extents in Florida with querying and reporting capabilities. Development of a comprehensive spatially explicit map of fire occurrence remains one of the most critical needs for conservation in the Southeastern US. Not only are the vast majority of Florida's endangered species and ecosystems reliant on frequent fire, but fire risk analysis, prescribed fire planning, and fire behavior modeling are sensitive to fire history. Fire occurrence in Florida is currently tracked by approximate location through the Florida Forest Service (FFS) open burn authorization (OBA) system using the Fire Management Information System (FMIS). While this system represents one of the most advanced prescribed fire planning datasets in the country, the system does not record perimeter data or include assessments regarding which burns are actually completed. Relying solely on this system results in documented data gaps when estimating the size, location and effectiveness of managed fires on a statewide scale. These "actual burned" areas are critical factors in analyses and models evaluating conservation success.

Tall Timbers Research, Inc. addressed this need by developing a robust spatial database for more precise mapping and tracking of all prescribed fire in Florida. We used advanced remote sensing techniques to identify spatial extents of prescribed fires and wild fires across the state using the USGS Burned Area (BA) products (Version 2, referred to as BA.v2; USGS 2019). We used ancillary data in the form of the FFS OBA data and select landowner-provided datasets to evaluate the remotely sensed products. We loaded the final remotely sensed spatial fire boundaries into a modified version of the U.S. Air Force Wildland Fire Database. In addition, we developed custom query tools to report on fire history (*e.g.,* frequency, time-since-burn, year last burned, etc.) including overlaps in specific fire dependent ecological systems or fire dependent species habitats and ownerships.

We have evaluated fire datasets from twenty-six sources for the period 2006-2016, and ultimately have updated the database with products current through 2018. The datasets include BA.v2-based fire extent maps, as well as species occurrence, landcover, and ownership datasets. We have updated summary reports and maps illustrating fire extent in Florida using the BA.v2 products (2019). We do not differentiate between prescribed fires and wildfires since both types of fire can meet management objectives and impact species habitats, and as such are both an important part of the fire regime evidence used to inform conservation-monitoring decisions.

We present the various phases of work on this project as chapters. Chapter 1 summarizes the kickoff workshop for the project; Chapter 2 highlights the data discovery process with the FFS authorization data and the first phases of converting the existing DoD database from Oracle to SQL Server. Chapter 3 describes the final SQL database structure and some desired queries that FWC and TTRS agreed upon; Chapter 4 provides a summary of a review of the various landowner provided fire atlas data and remotely sensed data sets. We evaluate fire extents derived from the USGS Burned Area (BA) version 1 products at 3 pilot areas (Chapter 5) and extend the work across the state (Chapter 6). Chapter 7 details tool and metric development, and includes a user guide and update protocol. Near the completion of each phase, we held update meetings with FWC partners to evaluate courses of action based on the discoveries made in each phase. These discussions are not explicitly detailed in any of the chapter write-ups, but they do explain the minor deviations from the original contract to the final products.

Glossary of Terms and Concepts

Broadcast Burn An open burn that is done for agricultural, silvicultural, or land clearing purposes and is not a pile

Burned Area Delineation Burned Area Delineation refers to the all-encompassing area within a fire perimeter; it includes burned and unburned areas.

Burned Area Essential Climate Variable (BAECV) refers to an algorithm that capitalizes on the long temporal availability of LANDSAT imagery to identify burned areas across the conterminous United States. Now referred to as Burned Area (BA) products, version 2 (BA.v2).

Burn Unit (Burn Compartment, Burn Block) Burn Unit refers to the area being burned, and generally has specific 'boundaries' defined in the form of roads/water/unburnable surfaces, etc. Other common synonymous usages include the terms Burn Compartment and Burn Block.

Continuation An authorization to continue a previously approved open burn authorization that was not completed for various reasons including late starts, poor weather conditions or lack of resources.

CONUS The Continental United States; this reference excludes Alaska and Hawaii.

Cooperative Land Cover (CLC) The Cooperative Land Cover Map is a project to develop an improved statewide land cover map from existing sources and expert review of aerial photography. The project is directly tied to a goal of Florida's State Wildlife Action Plan (SWAP) to represent Florida's diverse habitats in a spatially-explicit manner.

Environmental Protection Agency (EPA) The agency of the federal government which was created for the purpose of protecting health and environment.

Fire Frequency (Number of Times Burned) Fire frequency refers to the total number of times a specific location has burned in the period of record (or for a given period of interest if a subset of total fire record).

Fire Free Interval (Longest or Shortest) Fire Free Interval is the amount of time between two consecutive fires in a given area for a given period of time. In places where more than two fires have burned throughout time, the longest (or shortest) Fire Free Interval can be calculated as the maximum (or minimum) time period between two consecutive fires.

Fire Mapping Information System (FMIS) integrated set of applications that handle data input, processing and reporting needs for the Florida Division of Forestry (DOF).

Fire Perimeter (Burn Perimeter) Fire Perimeter refers to the perimeter delineating burned areas within a fire. It may or may not include unburned areas within a fire.

Fire Rotation an area-based estimate of fire frequency expressed in years. Specifically, fire rotation is a measure of the expected frequency of fire, calculated for large areas using past fire records, and is considered to be the relative expected interval between fires at regional scales.

Florida Forest Service (FFS) Agency whose mission is to protect and manage forest resources in Florida.

Florida Natural Areas Inventory (FNAI) Florida's state heritage program responsible for tracking occurrences of species and natural communities statewide.

Global Fire Emissions Database (GFED) Database combining satellite information on fire activity and vegetation productivity to estimate gridded monthly burned area and fire emissions.

GOES-16 previously known as GOES-R, is part of the Geostationary Operational Environmental Satellite (GOES) system operated by the U.S. National Oceanic and Atmospheric Administration and is the first spacecraft in NOAA's next-generation of geostationary satellites. The GOES-R series satellites will provide advanced imaging with increased spatial resolution and faster coverage, improving the detection of environmental phenomena.

Hazard Mapping Systems (HMS) NOAA product suite that provides both fire and smoke analysis products. It is an interactive processing system that allows analysts to manually integrate data from automated fire detection algorithms using GOES and polar (Advanced Very High Resolution Radiometer (AVHRR) and MODerate resolution Imaging Spectroradiometer (MODIS)) images. The result is a quality controlled display of the locations of fires and significant smoke plumes detected by meteorological satellites.

Interagency Fuel Treatment Decision Support System (IFTDSS) is a web-based software and data integration framework that organizes fire and fuels software applications to make fuels treatment planning and analysis more efficient. The effort was initiated by Joint Fire Science Program and the NWCG Fuels Management Committee in 2007.

Integrated Reporting of Wildland-Fire Information (IRWIN) This service is a Wildland Fire Information and Technology (WFIT) affiliated investment intended to provide an "end-to-end" fire reporting capability. IRWIN is tasked with providing data exchange capabilities between existing applications used to manage data related to wildland fire incidents.

LANDSAT The LANDSAT Program is a series of Earth-observing satellite missions jointly managed by NASA and the U.S. Geological Survey. Imagery is available since 1972 from six satellites in the LANDSAT series. These satellites have been a major component of NASA's Earth observation program.

Landscape Conservation Cooperative (LCC) self-directed partnerships between federal agencies, states, tribes, non-governmental organizations, universities, and other entities to collaboratively define science needs and jointly address broad-scale conservation issues.

Monitoring Trends in Burn Severity (MTBS) refers to an interagency program whose goal is to consistently map the burn severity and extent of large fires across all lands of the United States from 1984 to present.

Moderate Resolution Imaging Spectroradiometer (MODIS) is a key instrument aboard the Terra and Aqua satellites. Satellites view the entire Earth's surface every 1 to 2 days acquiring data in 36 spectral bands. These data improve our understanding of global dynamics and processes occurring on the land, oceans and lower atmosphere.

Pile Burn An open burn that is in the form of a pile that is larger than 8' diameter

PostGIS is a spatial database extender for PostgreSQL object-relational database. It adds support for geographic objects allowing queries to be run in SQL.

PostgreSQL is an open source object-relational database system.

Open Burn Authorization (OBA) refers to Florida Forest Service Open Burn Authorization Requests and is available to Certified Prescribed Burners.

QGIS is a free and open source professional Geographical Information System (GIS) that is built on top of Free and Open Source Software (FOSS)

QGIS Event Mapping Tool (EMT) (now known as the Fire Mapping Tool, FMT), a QGIS plugin for fire assessment developed by U.S. Geological Survey National Center for Earth Resources Observation and Science (EROS)

Seasonality Seasonality in this project refers to whether the burn occurred during growing season (March 15 - October 14) or dormant season (October 15 – March 14).

Southern Integrated Prescribed Fire Information System (SIPFIS) a Joint Fire Science Program initiative to design an integrated information system for fire and air quality data in the SE United States.

Spatial Database A database that is used to store and access spatial data or data that defines a geometric space.

Time of Year Time of Year refers to the season in which a burn occurred; it is the loose grouping of months into the four seasons (Spring, Summer, Fall or Autumn, and Winter).

Time Since Previous Fire (Time Since Last Fire, Time Since Last Burn) Time Since Previous Fire (or Time Since Last Fire; TSPF or TSLF) is the measure of time from a specific date back in time to the last date of a detected or known fire. Units can be months, weeks, days, or years.

Volatile Organic Compounds (**VOC)** refers to a large group of organic chemicals that include any compound of carbon (excluding carbon monoxide, carbon dioxide, carbonic acid, metallic carbides or carbonates, and ammonium carbonate).

Year Last Burned (Year First Burned) Year Last Burned (or Year First Burned) is the year of the last (or first) known fire/burn in a location; corresponds with the TSPF.

Project Background

For over a decade, resource managers in the state have recognized the importance of tracking and monitoring the use of prescribed fire. Many species in Florida are dependent on fire for maintenance of appropriate habitat conditions. Measurements, such as seasonality and years since last burn are important components in assessing the condition of these fire-maintained systems. For many species that are dependent on these systems, managing an appropriate fire return interval is critical. Differentiating those areas that have an appropriate fire return interval from those areas without an appropriate fire return interval would allow managers to focus resources on areas most in need of management actions, as well as serve as a means to measure and quantify the success of conservation and restoration efforts.

Cost effective and efficient management of conservation lands requires up to date detailed resource maps. The Peninsular Florida Landscape Conservation Cooperative (PFLCC) is working on a statewide Landscape Conservation Design. As part of this process, the PFLCC is identifying conservation targets (*i.e.,* indicators) for each priority resource. It became evident that fire return interval could be a critical indicator for these systems.

At present, Florida has a detailed (10m) land cover map, used by multiple entities (*e.g.,* Florida Fish and Wildlife Conservation Commission, FWC's State Wildlife Action Plan, Florida Natural Areas Inventory, and the PFLCC). However, there is a critical missing component from the existing land cover map - qualitative attributes regarding fire. One key qualitative attribute that has long been identified as a critical data gap pertains to prescribed fire. Addition of qualitative attributes based on fire regime characteristics, such as fire return interval, would increase the effectiveness of informing acquisition of conservation lands, supporting land and fire management, and tracking success and failure of conservation efforts. Assessment of the success of management actions will provide a valuable feedback loop to inform future management actions on conservation lands, both public and private.

Currently, a spatial database that tracks prescribed fire *extents* statewide does not exist, which means that there is not a comprehensive knowledgebase about fire regimes across the state. Managers recognized this data gap more than a decade ago. In 2006, they noted "…methods for monitoring the use of fire on public lands may be one of the greatest unmet needs in comprehensive wildlife management…" (*Monitoring Prescribed Burning on Public Lands in Florida, 2006).* This project aims to enhance our understanding of prescribed fire characteristics across the state of Florida for integration into further analyses specific to landscape conservation and monitoring. We list below specific project outcomes and accomplishments to date:

1. We address the data gap using a modified extension of the US Air Force Wildfire Database, a spatial database designed to track and analyze fire extents (Chapters 3 and 4).
2. We looked at methods to validate FFS burn authorization records by comparing authorized permits to known fire locations, and developed methods to use remote sensing techniques to record spatial fire boundaries (Chapters 3 and 5).
3. We populated our database with fire extents derived from the USGS BA.v2 (2019) products for the years 2006 to 2018, and other ancillary datasets (Chapters 6 and 7)
4. We developed custom query tools to evaluate fire regime characteristics and trends in landcover classes, fire-dependent species habitats, and ownerships, as well as provide guidance on procedures for updates moving forward (Chapter 8).

This document serves as the final report for the *Mapping Fires Across Florida* project; it includes all previous Deliverables in the form of chapters (unedited; *i.e.,* exactly as they were originally submitted). Each chapter details the processes and findings for that phase of the project, as well as recommendations for moving forward. Appendices specific to each phase are included at the end of each chapter. The final chapter includes the Final User Guide and Update Protocol for the database. A hard drive with all project data sets and a SQL database are included as part of the final deliverable.

Understanding fire regime characteristics across the state of Florida is important from a conservation perspective if the aim is to maximize conservation efforts and target conservation opportunities appropriately. However, until now, limited information about fire occurrence in the state existed, particularly in terms of a statewide spatial database that includes individual fire perimeters for prescribed fires and for many fires occurring on private lands.

Through the various phases of this project, we evaluated multiple sources of fire information and data. This was necessary to determine if the data met the needs of the FWC project in terms of spatial resolution, geographic extent, and time stamping for the study period of interest (2006-2016). In general, the datasets evaluated included prescribed fire information, wildfire information, or both. Data types included point, polygon, and raster data. The temporal characteristics of the data varied depending on the source. For this project, we initially only assessed fires occurring in the 2006-2016 timeframe for possible inclusion in the SQL geodatabase. The ability exists to upload any additional data as needed (*e.g.*, as available, pre-2006 or post-2016, if available from the original sources).

We expanded upon the data assessment by comparing spatial footprints of fires derived from the satellite-based BA.v1 products (Hawbaker *et al.* 2017; USGS 2019) against known locations of fires at Eglin Air Force Base, the Apalachicola National Forest, and Big Cypress National Preserve (Figure 1). We chose these pilot areas for multiple reasons. They all have active prescribed fire programs, have supported wildfires in the past, and have well documented burn records that detail fire sizes, types and dates – all things that would help us evaluate usefulness of BA, especially in places without fire records (e.g., private lands). Together, the three pilot areas span a large portion of the state, and encompass many fire-dependent systems and species habitats of interest to PFLCC and FWCC. We worked with fire managers at the three locations to get feedback on the products and gauge interest and usefulness of the products. Based on manager evaluations of these data and recommendations for moving forward, we extended the satellite-based mapping process to the entire state of Florida for the same period. Fire datasets in the final database were derived from the BA.v2 data (the most current USGS version being served), are up-to-date between 2006 and 2018, and extend across all ownerships in Florida.

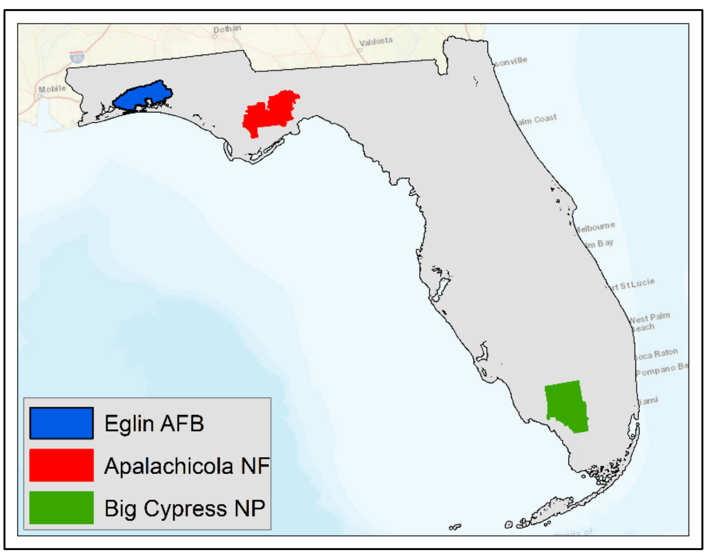

Figure 1: Three pilot area locations: Big Cypress National Preserve, Apalachicola National Forest, and Eglin Air Force Base.

Florida

Florida is a large state, encompassing nearly 66,000 square miles, approximately 70% of which is privately owned. It is largely a peninsular state bounded by both water (the Gulf of Mexico to the west and the Atlantic Ocean to the east) and land (Georgia to the north, and Alabama to the northwest; Myers and Ewel 1990). The climate can be described as a humid subtropical climate north of Lake Okechobee and a tropical climate south of Lake Okechobee, with an average annual precipitation amount of 59.2 inches (USCD 2018). The dry season is generally cool (*e.g.,* winter) and the warm season is typically rainy and marked by tropical storms and even hurricanes. The highest point in Florida is only 345 feet above sea level, although inland areas have rolling hills with elevations up to 250 feet above sea level. Variations in topography may be slight or occur over short distances, but can have large effects on the vegetation due to impacts on water, soil, and nutrient regimes. The biodiversity in Florida is quite high, with many species of flora and fauna, including fire-adapted species and threatened/endangered/rare species. Upland ecosystems in the state consist of the pine flatwoods and dry prairies, scrub, temperate hardwood forests and South Florida rocklands (Myers and Ewel 1990). Fire is a strong influence in the composition and structure of the Upland ecosystems, and many species that occur in these areas are considered 'pyrogenic', or having fire adaptations. In the wetlands of the state, which includes marshes and swamps, hydrology cycles and fire cycles have interchangeable impacts. Variations in hydroperiods, organic matter accumulation, and fire frequency all have important structural impacts on the wetlands. Fire frequencies and rotations vary across the state, and range from frequent low intensity surface fires to infrequent high intensity crown fires; prescribed burning is common and occurs throughout the entire year, much of it on private lands. However, exact spatial locations are largely unknown outside of state and federal (*i.e.,* the 30% public) ownership.

Fire Datasets Evaluated

Multiple landowner sources across the state provided fire information in the form of fire occurrence databases and fire perimeters for both prescribed and wild fires. Landowners included public (*i.e.,* USFS, FWC, Florida Park Service, etc.), and private landowners (*i.e.,* Tall Timbers, Archbold, etc.), as well as some nationally available datasets that span ownerships (*i.e.,* the National Fire Occurrence Database [Short 2017]). Refer to Chapter 5 (*i.e.,* Deliverable 4) for complete dataset descriptions. The fire data we currently possess from these sources can be uploaded into the database for use on an 'as-is' basis, or with some serious quality control, to supplement further analyses. The data were quite useful in helping us focus in on known fire areas for the evaluation of the annual BA products; however, we encourage further use with caution and a complete understanding of what the data represent.

LANDSAT Burned Area Products (BA)

The LANDSAT Burned Area products (BA.v2), formerly referred to as 'Burned Area Essential Climate Variable (BAECV)' products, are a recent product suite developed and validated by the USGS (Hawbaker *et al.* 2017; USGS 2019) that show promise for identifying geospatial extents of fires (Vanderhoof *et al.* 2017). This national product is independent of any type of fire reporting system. Hawbaker *et al.* (2017) document the methods used for automatic derivation of BA products using regression models and a combination of change detection algorithms, spectral indices, and reference conditions with LANDSAT imagery to produce a BA probability surface. Remote sensing techniques and tools can then be used to identify and delineate burned areas at a 30m pixel resolution for every LANDSAT image on record (*i.e.,* 1984-present), which is the longest consistent record of burned area information available. Vanderhoof *et al.* (2017) evaluated the BAECV products against known datasets (*e.g.,* MTBS) and against finer-resolution sensors (*e.g.,* QuickBird) with satisfactory results that suggest that the products are suitable for use in this project.

It is possible that BA.v2 products and derivations can provide additional/unknown burn locations and extents within Florida, including smaller fires or those not recorded in other national datasets. For example, fires smaller than a national standard (*e.g*., the 500ac used by MTBS in the southeastern US), or fires in those areas where reporting is not required (*e.g.,* on private property) may be detected in a standardized fashion. Given that more than a million acres of prescribed fire alone burn across the state annually, but many of these fires may be difficult to detect post-fire using traditional burn scar mapping protocols, it seems that the BA methods could be used to locate burned areas in an automated and systematic way. Currently, using BA products, one can identify locations (at a 30m pixel level) that have burned using the probability associated with the pixel having burned (burn probability; BP) and also derive the date the burn was first detected by satellite sensors (burn date; BD). These products have been used to identify fires as small as 10 acres, and we are assessing the ability to detect down to approximately 2.5 acres.

We acquired an updated version of BA-derived products from our USGS partners for the period 2006-2018 for Florida (*i.e.,* BA.v2). As mentioned previously, these data may not encompass all fires, but hold promise in terms of identifying fire extents in locations where mapped fires do not currently exist. We have imported data derived from the current BA.v2 datasets into the database, and describe the methods for deriving database-ready products – as well as updating datasets – in Chapter 8 (*i.e.,* Deliverables 6 and 7).

Fire Metrics

Once the BA.v2 data were fully processed, fire history and seasonality metrics were determined on an annual level (See Chapter 8; the metrics are defined in Appendix C and the derivations are detailed in Appendix D). For this project, we are interested in where and when fires have burned in the state between 2006 and 2018. Ultimately, the particular timing of the fires is important to assess things like effects due to seasonality and sub-annual burn characterizations; however, in the interest of timeliness for this project, we determined that an annual starting point was acceptable, and we are currently able to loosely associate time of year and seasonality based on satellite data timestamps in annual BD-based products. The methodologies described here for deriving the datasets are scalable and can be applied at the individual scene level as well as user-defined annual or seasonal composites. A complete 'User Guide' and 'Update Guide' are included in Chapter 8 (*i.e*, Deliverables 6 and 7 Appendices D and E).

Based on discussions with FWCC partners, we derived the following fire and seasonality metrics using the annual BP-based and BD-based burned area raster and polygon products:

- Fire Frequency (Number of Times Burned)
- Year Last Burned
- Time Since Previous Fire
- Longest Fire Free Interval
- Time of Year (Spring, Summer, etc.)
- Seasonality (Growing and Dormant)

These fire regime characteristics are important for managers in Florida, as they can inform planning and conservation efforts. Since they are in a spatial format, one has the ability to focus their efforts and identify where successes and/or issues may be located on the landscape. Because the data have a temporal component, one can also identify these locations and evaluate them at different times of the year as well as through the years. The information gathered from this process can further our understanding of the use of fire – or lack thereof – on the landscape through space and time for different purposes.

While the BA-based datasets are quite useful, it is important to highlight a couple limitations. The way we have portrayed the products in this database are based on a calendar year; thus, in terms of number of fires, if a pixel burns more than one time within a calendar year it is only counted one time. Additionally, values for time since previous fire are reported at an annual level, even if they may have actually been less than 12 months apart. Furthermore, late season misattribution is possible using this method – fires that occurred in November or December of a given year may not be detected until the following calendar year, in which case the 'year' of the burn would be misattributed. We also know that some fires may not be easily detected in Florida, where there is often a rapid green-up following fires, many cloudy days, and many low-intensity fires (see Chapters 5, 6, and 7). Additionally, more work needs to be done in the southeast to understand fire detection in water-dominated ecosystems (*e.g.,* the Everglades and various marsh ecosystems) that regularly burn by both wildfires and prescribed fires.

Finally, we would like to note that this project is regionally-based, and as such may not wholly represent fires – especially small fires – with appropriate details at a local level. Similar to many other national and regional products, the BA.v2 dataset represents a consistently mapped product across boundaries that is supported by scientific methods and documentation. As such, the data are useful for planning at the larger (regional) scale, but are not a complete substitute for local knowledge and datasets. Much can be gained by acquiring local datasets, interviews/meetings with local experts, and individual fire mapping efforts. We recommend these things especially for specific events or smaller scale fires where the coarse data methods may under represent fire events.

Recommendations

For the previous Deliverables, we explored various fire datasets for populating a spatial database. We expanded upon earlier work by comparing spatial footprints of fires derived from the satellite-based BA product (Hawbaker *et al.* 2017) against known locations of fires in three pilot areas. We selected the pilot areas based on having known fire location data, having large-scale prescribed fire programs, and having fire-maintained systems where species of greatest conservation need occur (to coincide with another project funded through a FWC State Wildlife Grant). A series of data derivation methods and protocols resulted in annual fire datasets that we evaluated with managers. Based on their recommendations and suggestions, we have extended this work to encompass the entire state of Florida. The 90-100%BP burned area footprints may under-predict fire in some instances; however, we feel that this is a step forward from the FFS permit point data for identifying fire location/extent in a spatial manner, and are continuing efforts to improve datasets and methodologies.

We continue to recommend that a standardized statewide data call with specific reporting requirements be developed and utilized to acquire individual landowner-based fire data; we additionally recommend a follow-up meeting with landowners who provide their fire data once the BA-based products exist for their land. This meeting serves multiple purposes; it allows us to understand the data they provided better, and it allows us to provide background information to the landowners on the BA data and product derivation. The managers then provide feedback on where the data products are capturing fire extent in an acceptable fashion and why. The managers can additionally isolate locations/types of fires/seasonal characteristics, which may cause data products to over/underperform, and it provides opportunities for them to help identify potential solutions. Having landowner buy-in is imperative for the success of these types of projects.

Chapter 6 Appendix B shows a complete list of comments and recommendations from the three pilot areas. Common to managers from all three areas was the notion that, overall, these annually-based datasets are doing an acceptable job of capturing actual fire footprints within areas where fire has been applied. However, the BA products' ability to identify these locations differs. Managers noted that in the Panhandle (*e.g.,* Eglin AFB and Apalachicola National Forest), the burns that were less likely to be captured in the annual 90-100% BP range had well-documented characteristics. For example:

- They occurred in grass-dominated locations;
- The actual fire did not burn very hot and did not alter canopy characteristics;
- The fire was at the end of prescribed fire season and beginning of wildfire season, where days are typically more often cloudy than clear at the time of sensor overpasses;
- Fires were set in units that did not have much fuel to begin with, so detection is normally difficult;
- Fires followed thinning or chemical treatments; and
- Fire was at the end of the calendar year so was perhaps captured in the following year's data.

In southern Florida (*e.g.,* Big Cypress and Everglades), while many of the same characteristics were noted, managers also suggested that lowering the BP threshold from 90% to somewhere in the range of 70-80% might produce better results in the ecosystems prevalent in that part of Florida. We considered those suggestions and evaluated protocols to determine when and where thresholding is appropriate, although were unable to improve detection rates. This is an ecosystem type where further work is necessary; perhaps hosting a workshop topic to address this with a larger audience to help us decide options would be useful. The data presently uploaded in the database captures 90-100% BP and the burn dates associated with those detected locations statewide.

The final SQL database contains fire datasets derived using the BA-based products, as well as other ancillary datasets (*i.e.,* species occurrence data, FFS OBA data, ownership and landcover data). Spatial and tabular queries are possible with the database. We presented this database, and all phases of its development – including examples of tools, queries, reports, etc. – at a workshop at the end of March 2019. To address the challenge of understanding spatial characteristics of burns and reconstructing burn histories, we discussed continued use of the BA dataset developed by Hawbaker *et al.* (2017; USGS 2019), data derived in-house using the fire mapping tools for smaller fires, and known fire perimeters for all areas statewide at our workshop. We also participated in a Southern Fire Exchange webinar in late April 2019. It is our hope with the workshop and webinar that we gain some insight and feedback on the final products and their intended uses, which we can address and incorporate into additional dataset improvements.

Next Steps

While this project is now complete, there is interest from land managers to continue this work. Further work may include testing outputs of new algorithms for BA-derived products in the southeast; adding supplementary datasets derived from other satellite sensors (*e.g.,* Sentinel 2A); extending the products in the database back through the LANDSAT record and updating through the current year (*i.e.,* 1984 through 2018). Additionally, we may create additional data-based queries in the SQL geodatabase to derive fire regime characteristics for this and other projects we are currently completing.

Summary

The overall aim of the *Mapping Fires Across Florida* project was to develop a spatial database of prescribed fire extents in Florida with querying and reporting capabilities. The fires in this spatial database range from less than ten acres to greater than 100 acres. To recap accomplishments so far on this project:

- A Partner Workshop was held at Tall Timbers in September 2017 to introduce the project and get ideas from partners about specific interests and needs; Deliverable #1 is a summary document about the workshop (Chapter 2).
- The exploratory data analysis performed for Deliverable #2 provided useful insights into the FFS OBA dataset, and its potential usefulness for assessing fire regime characteristics in the state of Florida (Chapter 3).
- For Deliverable #3.1 and 3.2 we focused on converting the existing DoD database from Oracle to SQL Server and importing the FFS OBA data (Chapters 3 and 4).
- In Deliverable #4, we explored multiple sources and types of fire extent information, including landowner-provided fire atlas datasets and satellite based detections and extent maps, and we reviewed literature about the sensors and datasets (Chapter 5).
- Deliverable #5.1 of the *Mapping Fires Across Florida* project focused on assessing the utility of the satellite-based BAECV product suite for identification of the spatial extents of fires in three pilot areas within Florida: Big Cypress National Preserve, Eglin Air Force Base, and the Apalachicola National Forest (Chapter 6).
- Deliverable #5.2 of the *Mapping Fires Across Florida* project focused on extending the methodology and products across the entire state (Chapter 7).
- Deliverables #6 and #7 were combined to include information on developing queries, fire metrics, and a general user guide, as well as maintenance and update procedures for moving forward (Chapter 8).

We expanded the BA-based fire products across the state based on previous evaluations of the products and derivatives within three pilot areas and facilitated meetings with fire managers at those locations. The methods used to develop these nationally scoped datasets are replicable, and we showed that it is possible to adapt them regionally to map the spatial extent of a range of fire sizes in Florida with some level of confidence. In addition, many smaller fires are mapped (~2.5 ac) as part of the protocols we developed for deriving the BA-based fire products. This is of benefit in Florida where many small fires prevail and where habitat-based analyses for those species with the greatest conservation needs are involved. We have determined that the BA-based datasets are quite useful as a first step for understanding fire regime characteristics in a spatial manner across the landscape within Florida, in spite of the known/documented limitations (see Chapters 5-7). We provide evaluations and suggestions for moving forward with identifying the spatial extents at a statewide level.

We believe that the automated portion of developing datasets and generating fire extents and perimeters using BA methodology can be useful for updating these datasets in a consistent fashion moving forward. As mentioned in previous Deliverables, we are exploring additional options to enhance this ability. The FFS OBA, BA, and landowner data combined can help focus and locate areas that have burned in prescribed fires and clarify fire characteristics across the state, perhaps better than any particular dataset alone – especially if there were simple standardized tracking and reporting options required that did not burden landowners with extra work.

Acknowledgements

We would like to acknowledge FWC and USFWS for providing the funding for this research/project. We would also like to acknowledge Todd Hawbaker and Melanie Vanderhoof the U.S. Geological Survey for assistance in processing and producing updated versions of the BAECV tiles for Florida. Josh Picotte, Stephen Laine, and Vince Sclafani provided guidance on coding, fire metric layer derivations, and database and query development. Additionally, we thank all the agencies, staff, and landowners that contributed data for this effort: Florida Forest Service; USFS Forests in Florida; Florida Park Service; US National Park Service; US Air Force Wildland Fire Center/Jackson Guard; US National Wildlife Refuge; Tall Timbers Research Station; Archbold Research Station; and The Nature Conservancy.

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Appendices

Appendix A: Fire Regime Derivatives

Appendix B: Data Sets Included and Data Field Description

Appendix A: Fire Regime Derivatives

The following pages contain examples of fire extent and fire regime derivatives from the current work for the three pilot areas. Any location identified in these maps can be considered to have burned at least once between 2006-2018, as indicated by BA.v2 annual burn probability products (90-100%BP). We have included these maps to highlight the utility of the BA.v2-based datasets. These images are for illustrative purposes only, and not intended for analyses.

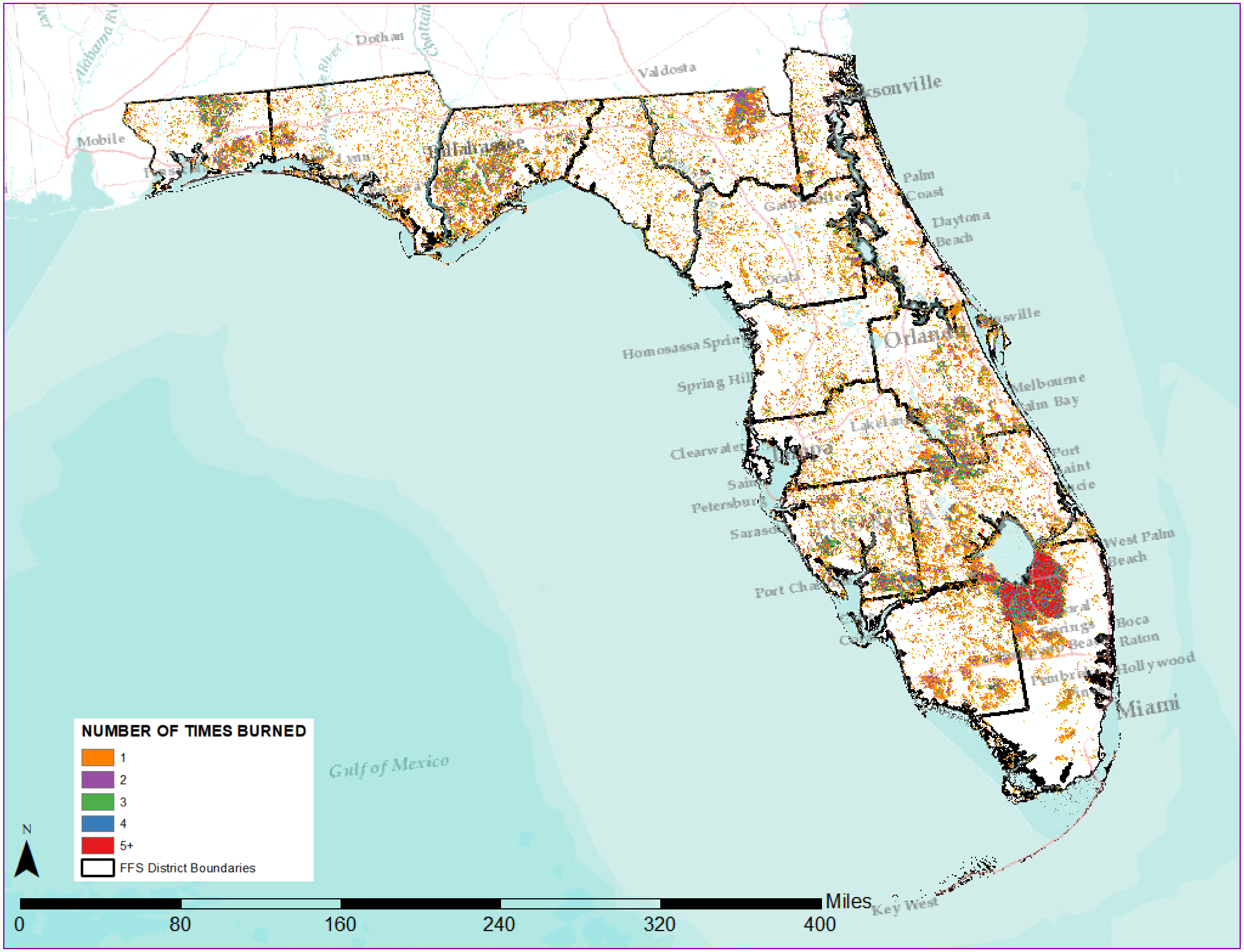


Figure A1: *Number of times burned between 2006 and 2018 across Florida based on BA.v2 annual composite 90-100% burn probability data.*

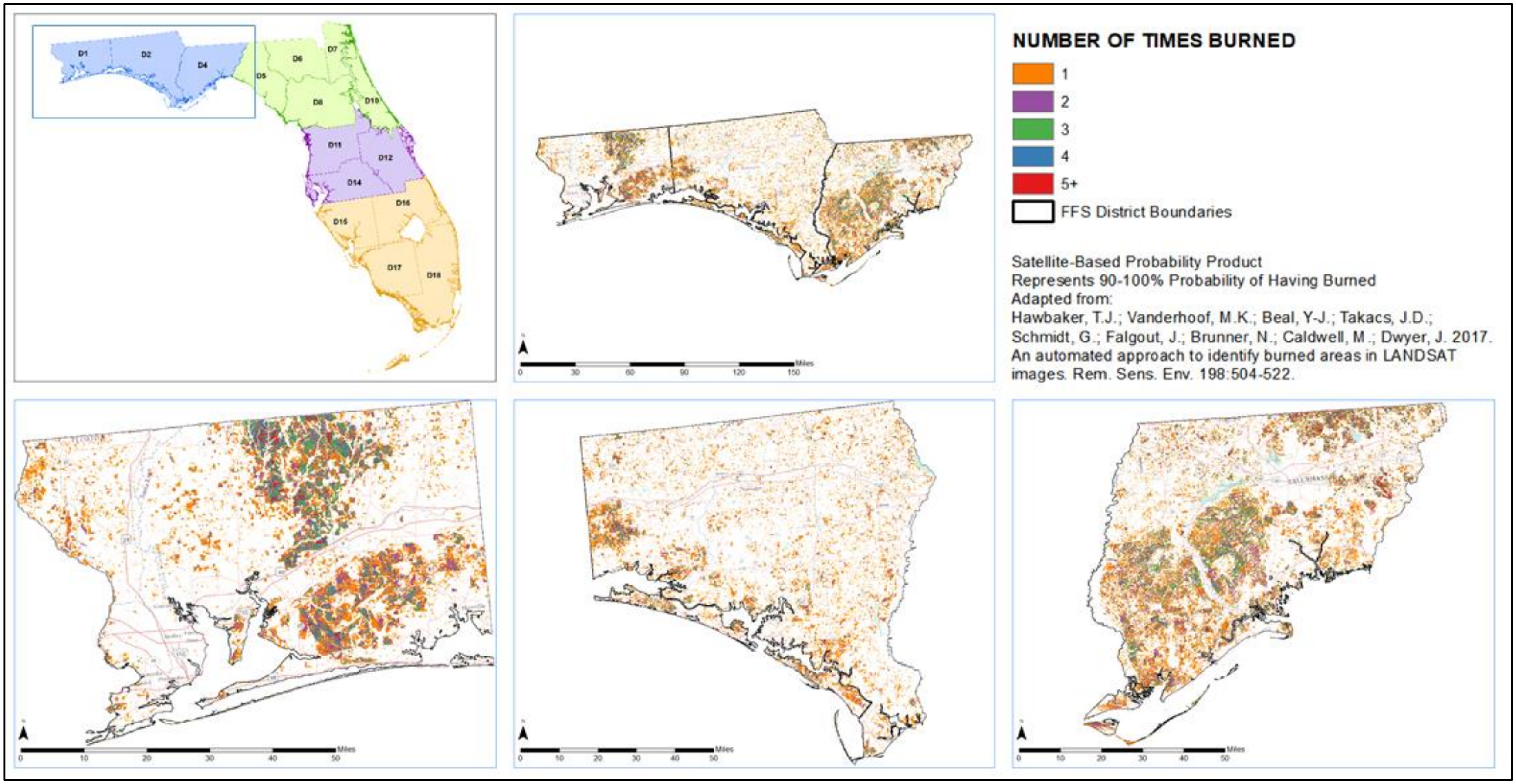


Figure A1.a: *Number of times burned between 2006 and 2018 based on BA.v2 annual composite 90-100% burn probability in FFS Districts 1-4.*

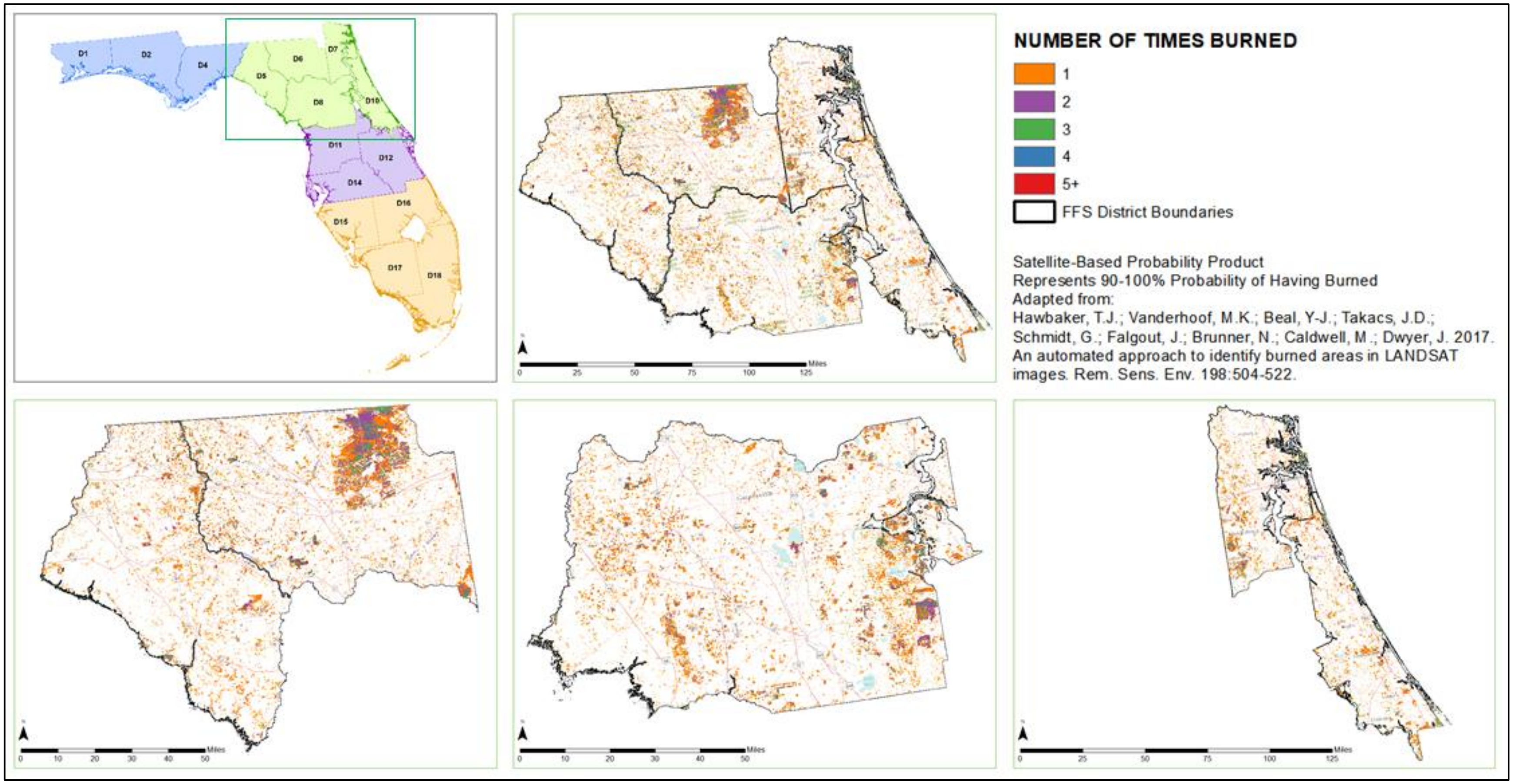


Figure A1.b: *Number of times burned between 2006 and 2018 based on BA.v2 annual composite 90-100% burn probability in FFS Districts 5-10.*

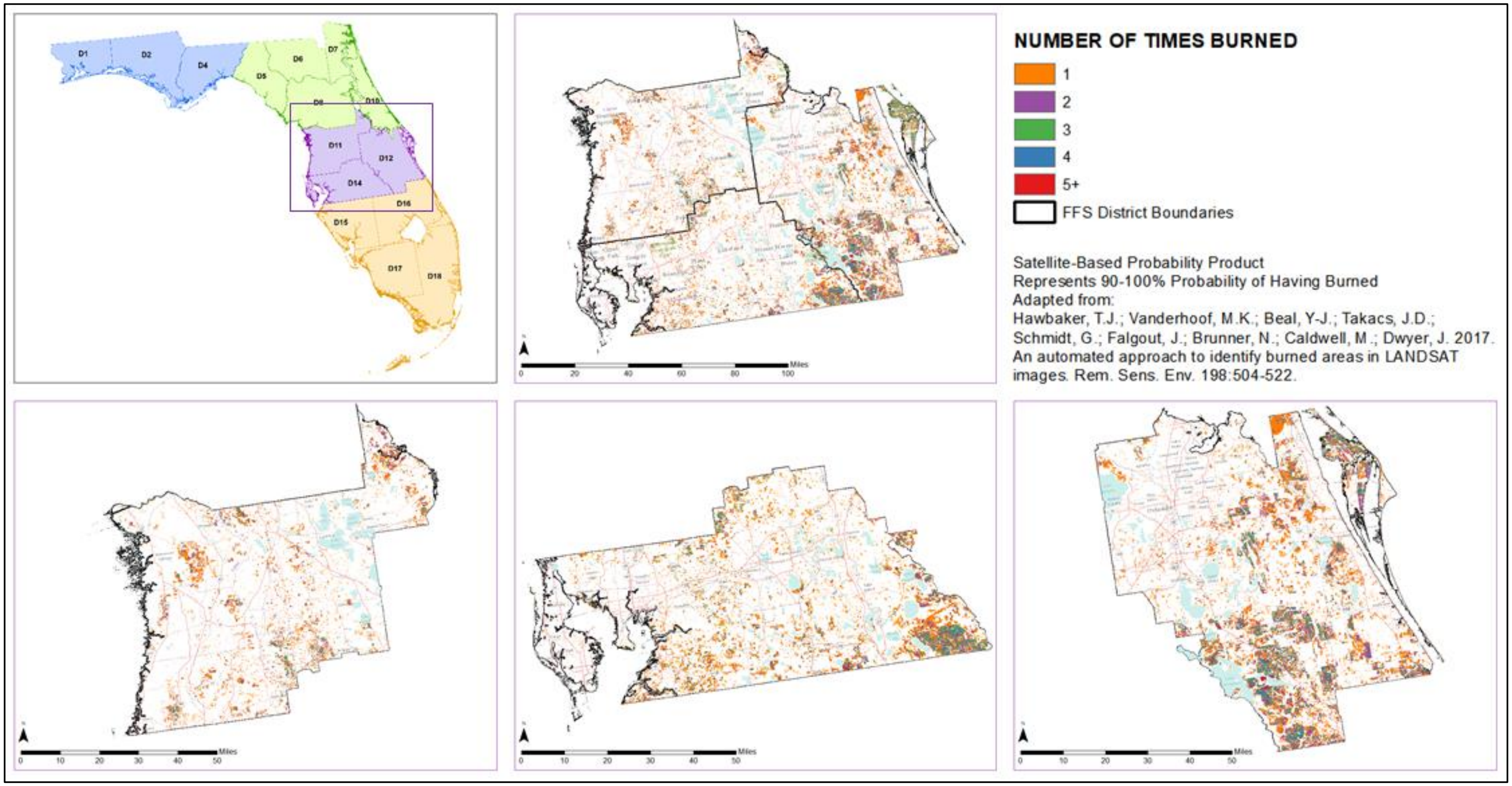


Figure A1.c: *Number of times burned between 2006 and 2018 based on BA.v2 annual composite 90-100% burn probability in FFS Districts 11-14.*

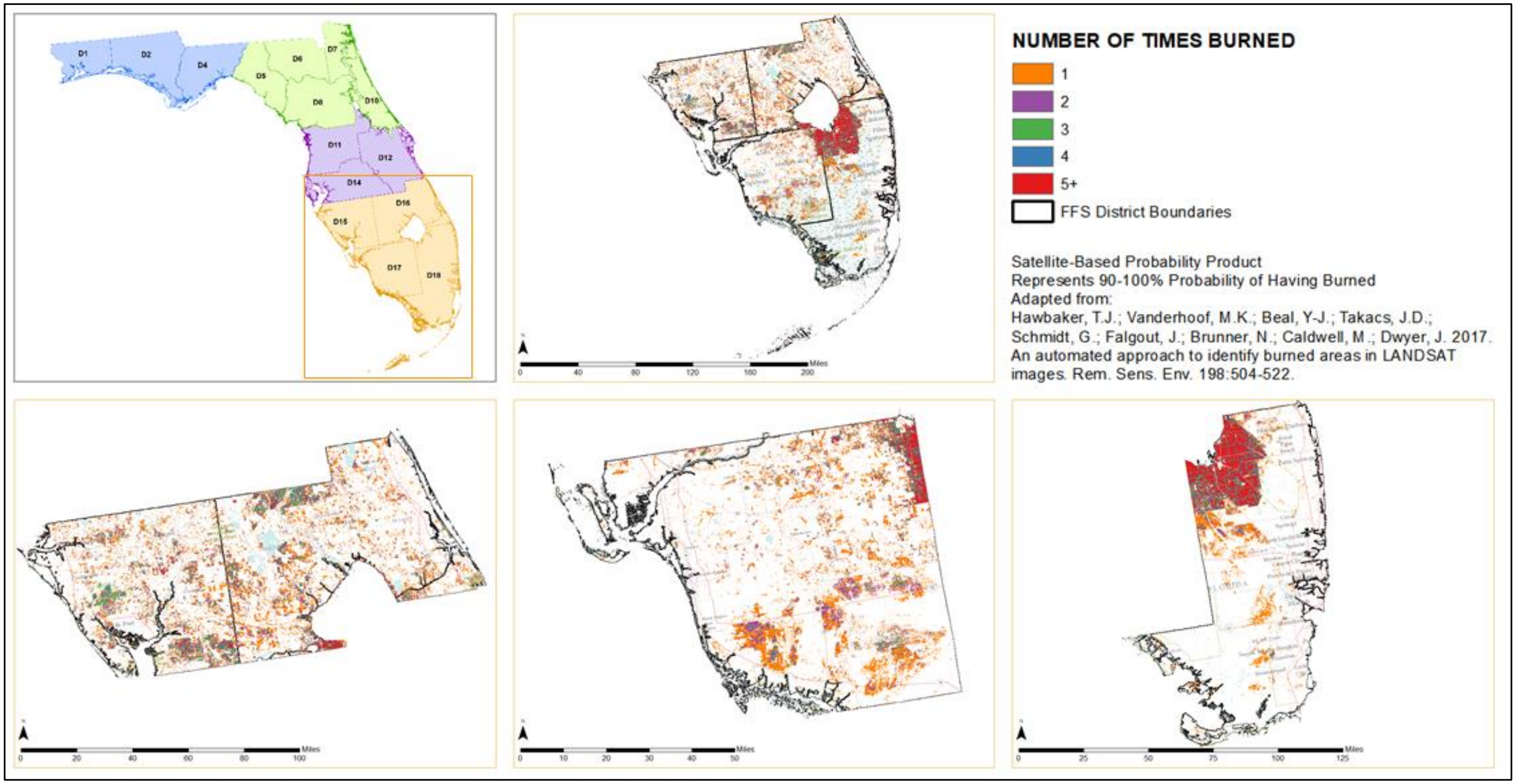


Figure A1.d: *Number of times burned between 2006 and 2018 based on BA.v2 annual composite 90-100% burn probability in FFS Districts 15-18.*

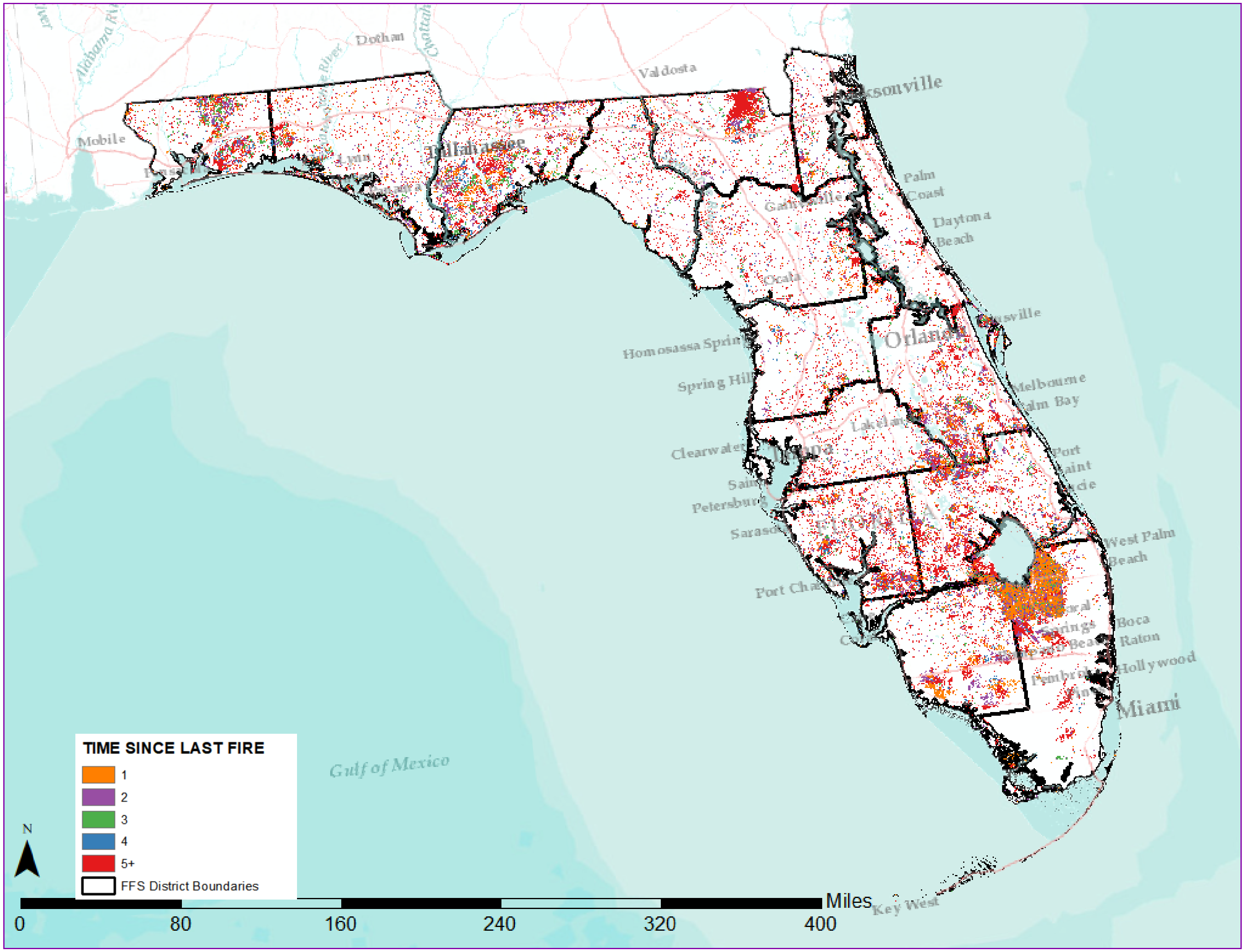


Figure A 2: *Number of years since last fire (as measured from 2019) for the time period 2006 - 2018 across Florida based on BA.v2 annual composite 90-100% burn probability data.*

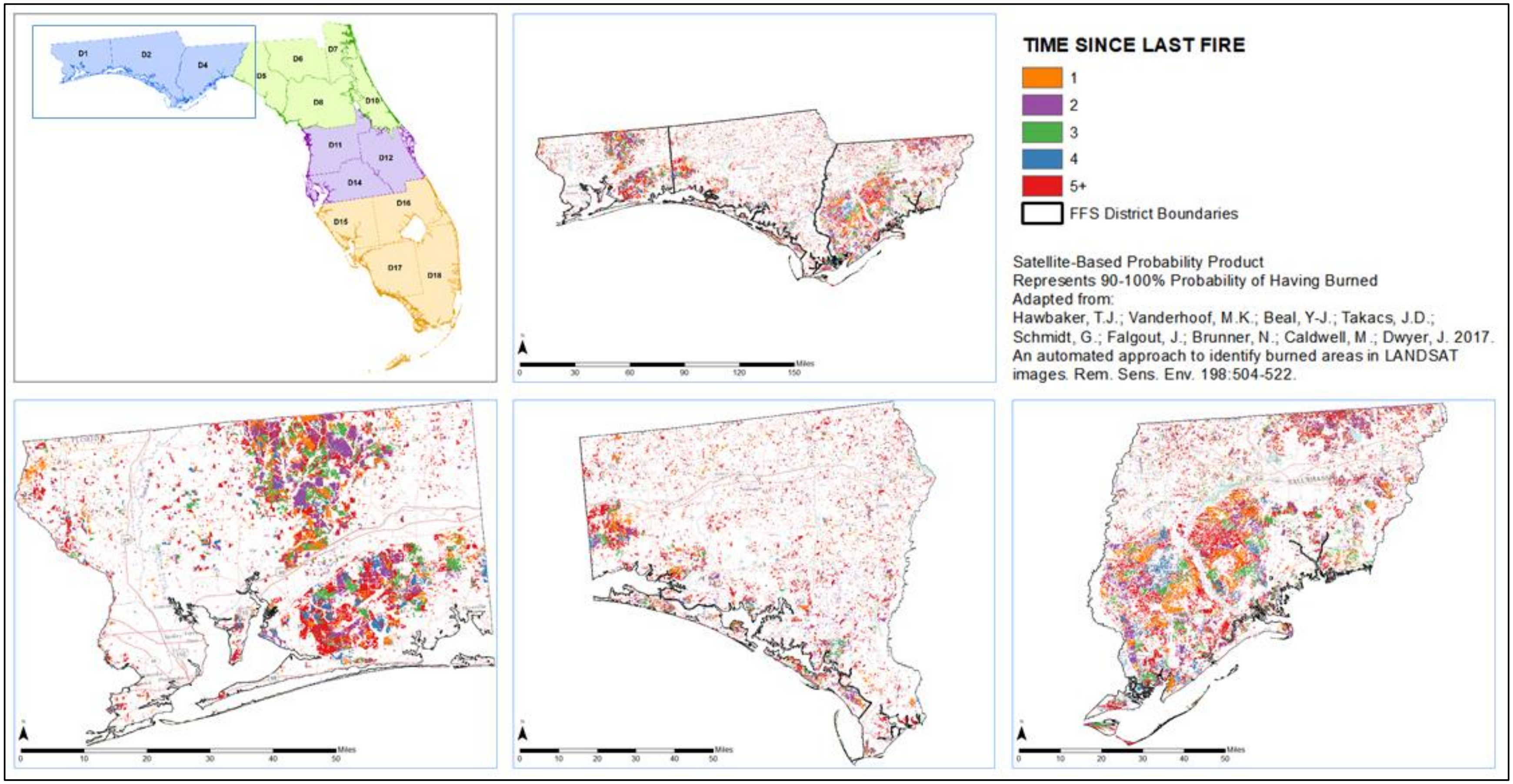


Figure A2.a: *Number of years since last fire (measured from 2019) for the time period 2006 - 2018 based on BA.v2 annual composite 90-100% burn probability, FFS Districts 1-4.*

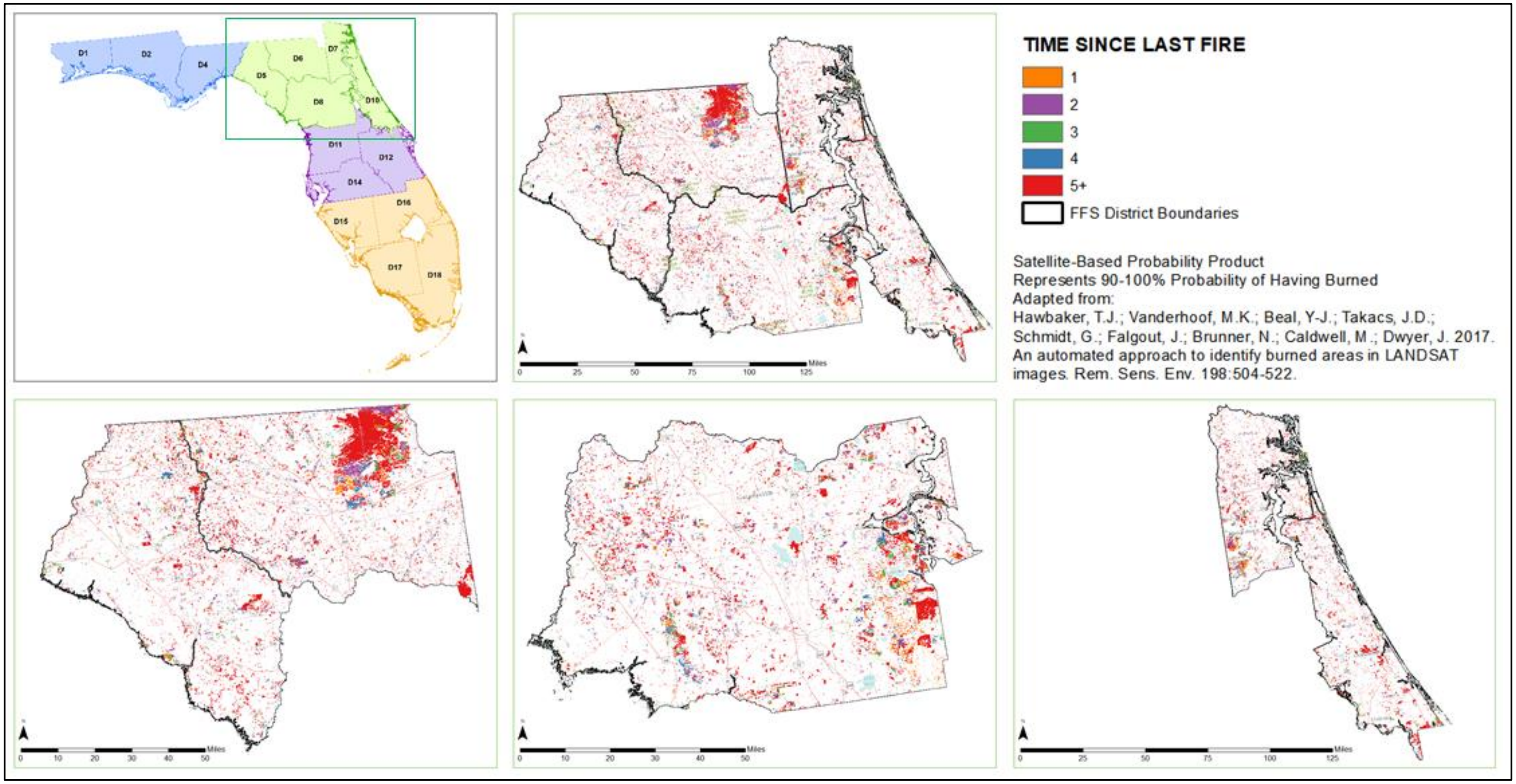


Figure A2.b: *Number of years since last fire (measured from 2019) for the time period 2006 - 2018 based on BA.v2 annual composite 90-100% burn probability, FFS Districts 5-10.*

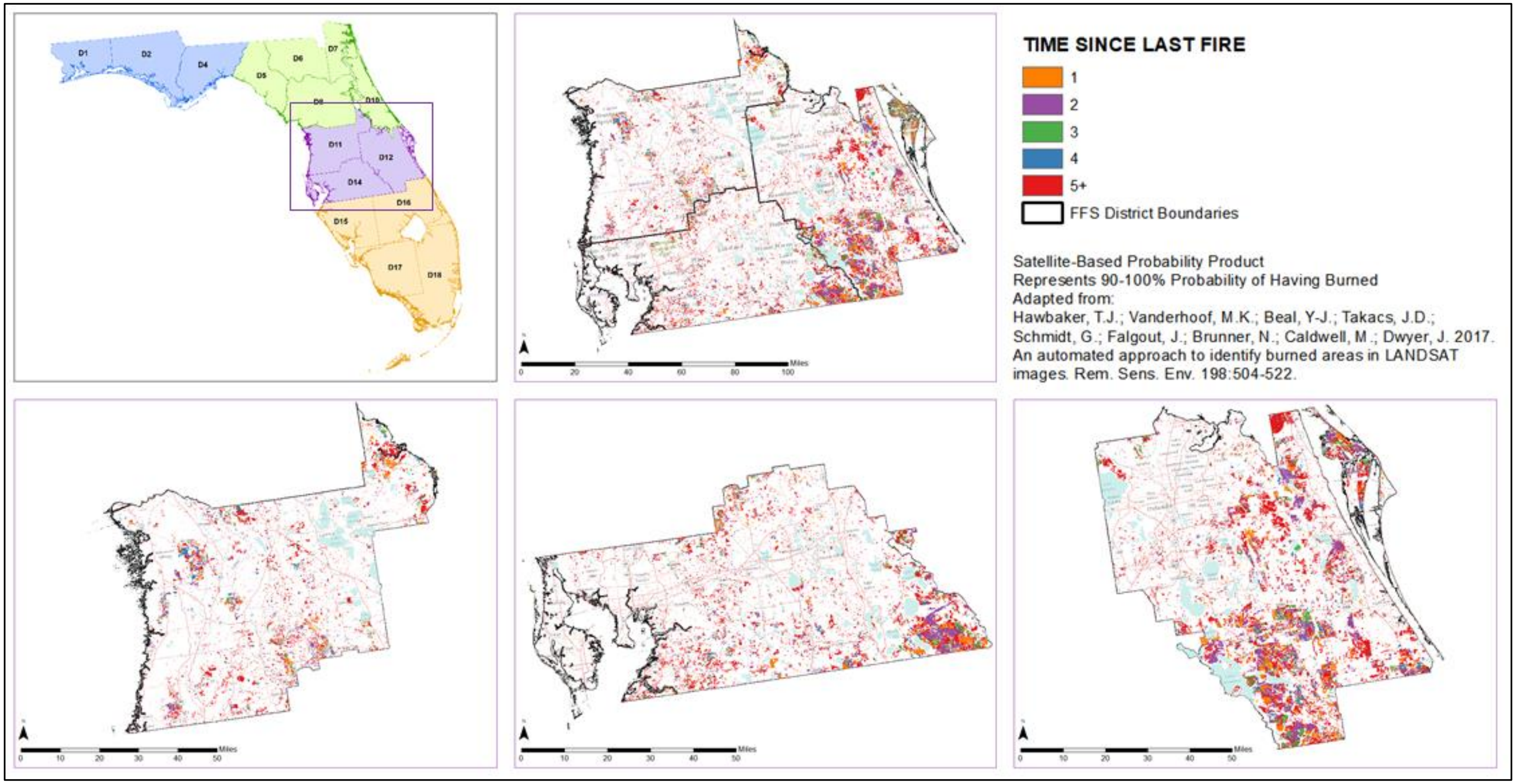


Figure A2.c: *Number of years since last fire (measured from 2019) for the time period 2006 - 2018 based on BA.v2 annual composite 90-100% burn probability, FFS Districts 11-14.*

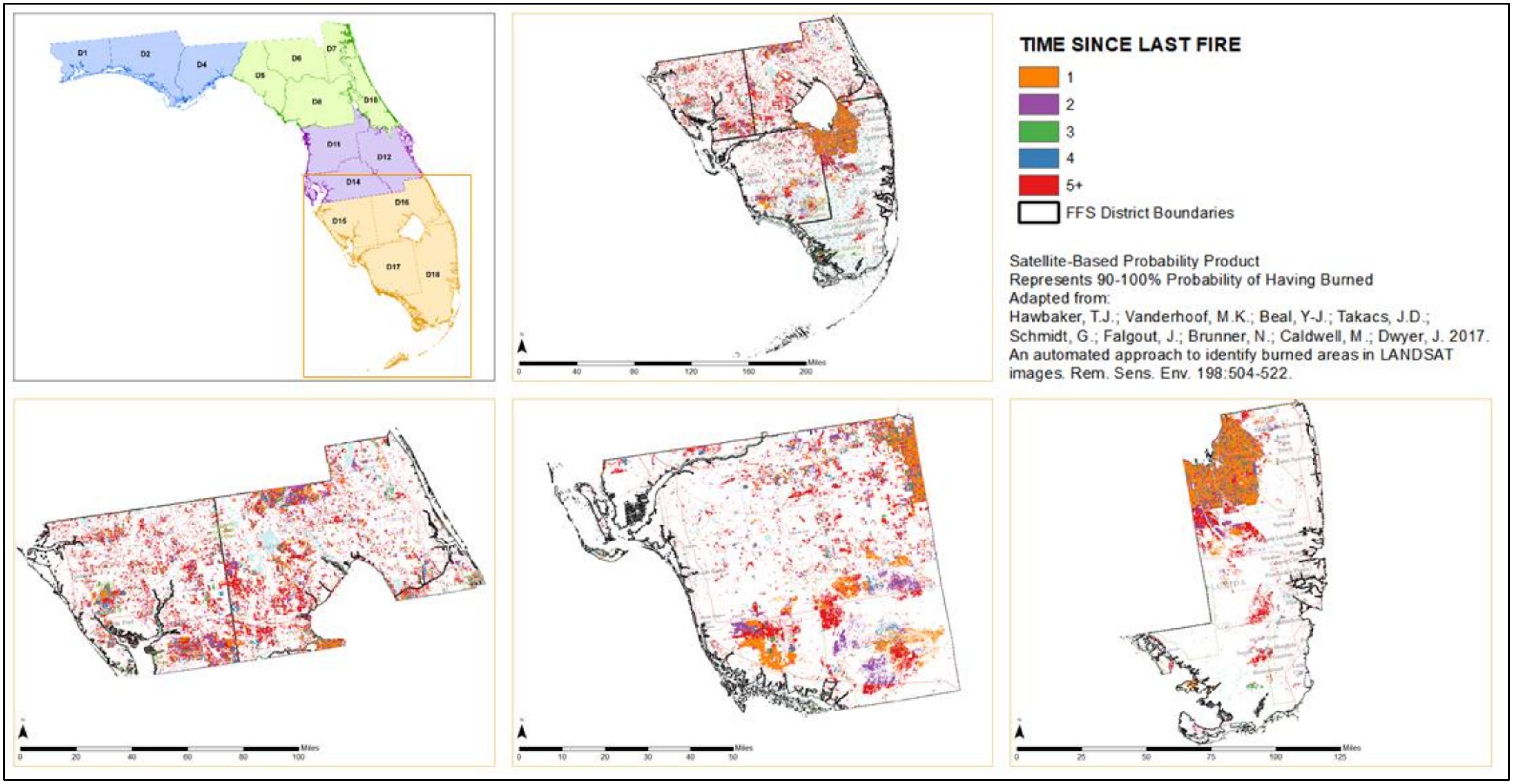


Figure A2.d: *Number of years since last fire (measured from 2019) for the time period 2006 - 2018 based on BA.v2 annual composite 90-100% burn probability, FFS Districts 15-18.*

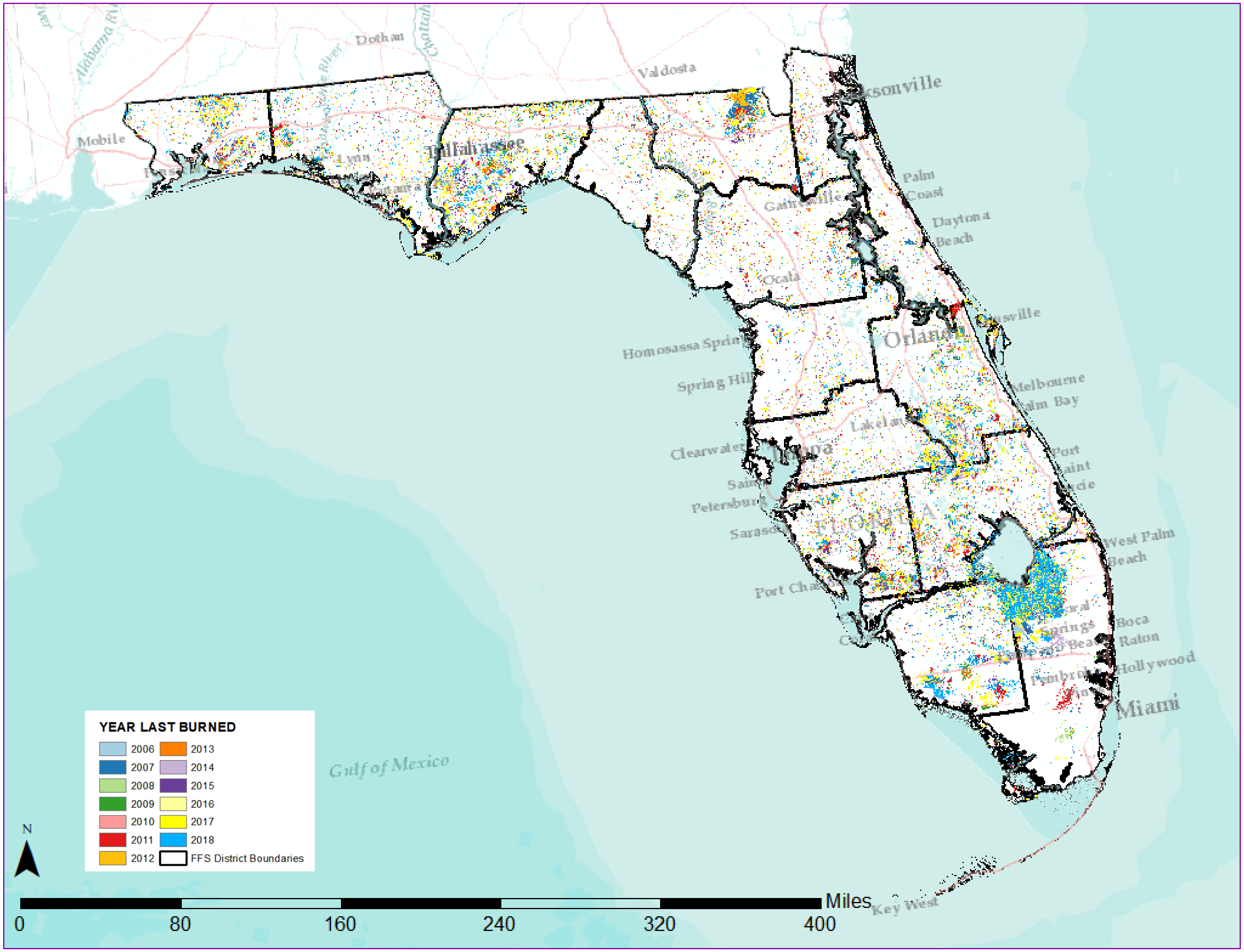


Figure A3: *Year last burned between 2006 and 2018 (as measured from 2019) across Florida based on BA.v2 annual composite 90-100% burn probability data.*

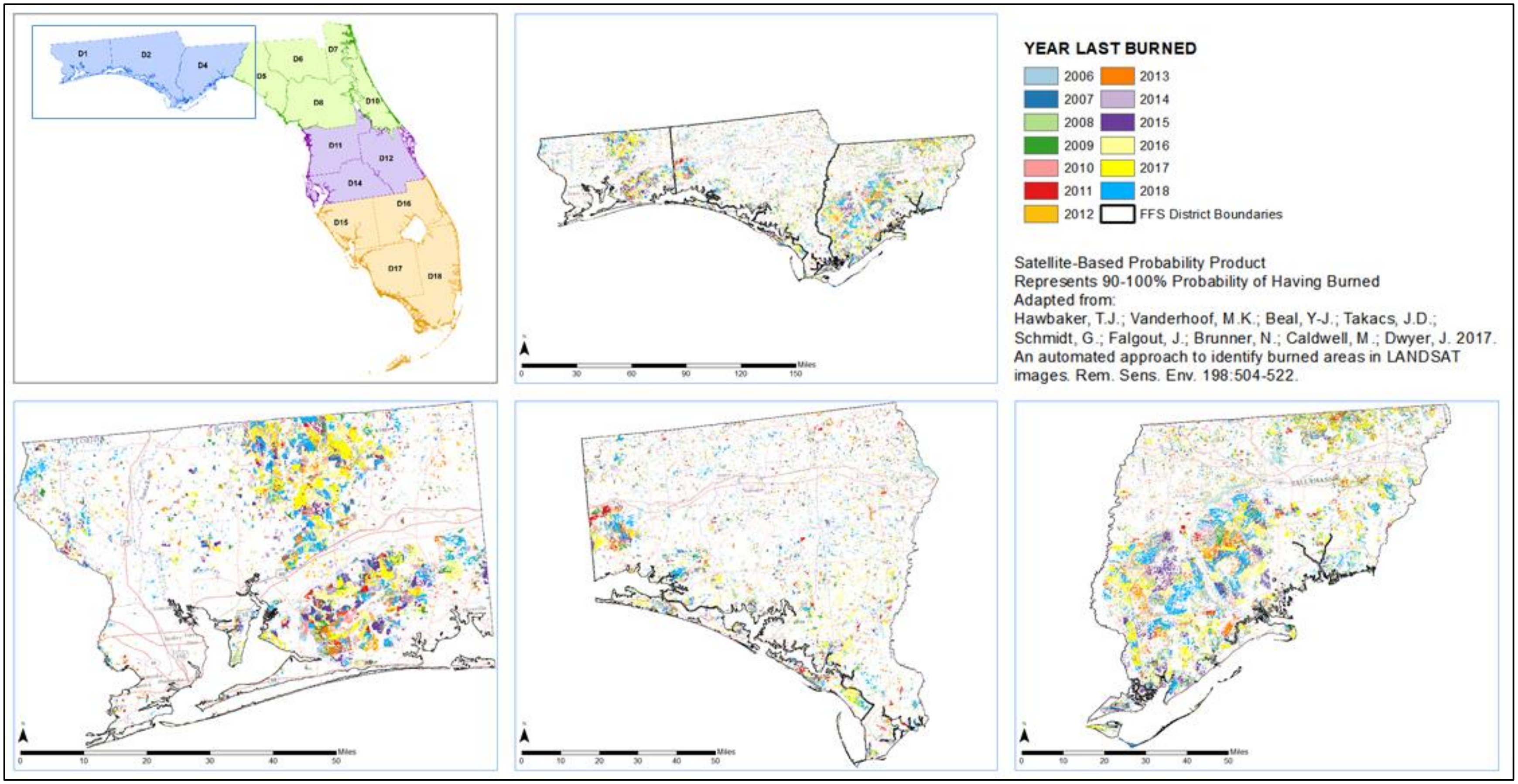


Figure A3.a: *Year last burned between 2006 and 2018 (as measured from 2019) based on BA.v2 annual composite 90-100% burn probability for FFS Districts 1-4.*

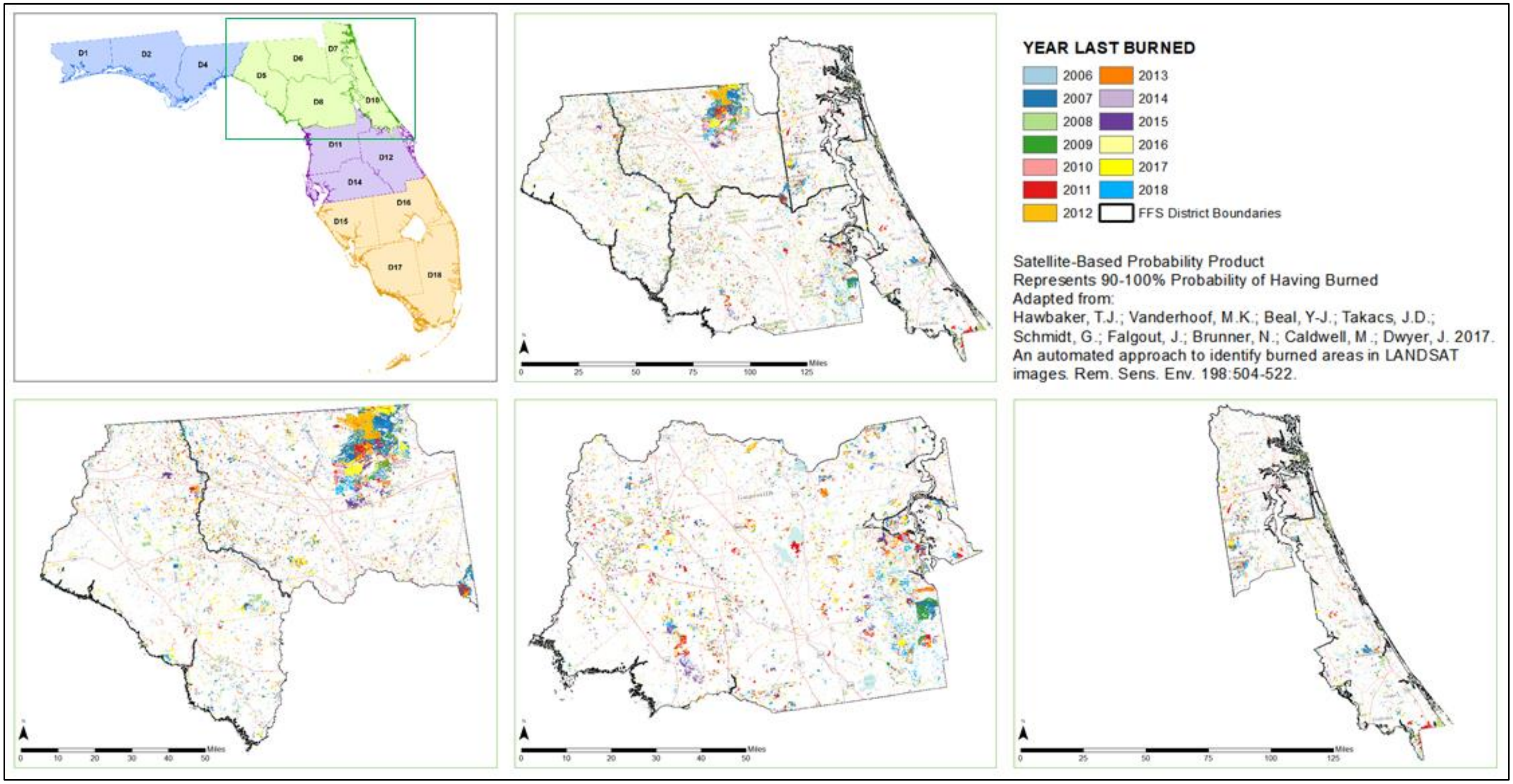


Figure A3.b: *Year last burned between 2006 and 2018 (as measured from 2019) based on BA.v2 annual composite 90-100% burn probability for FFS Districts 5-10.*

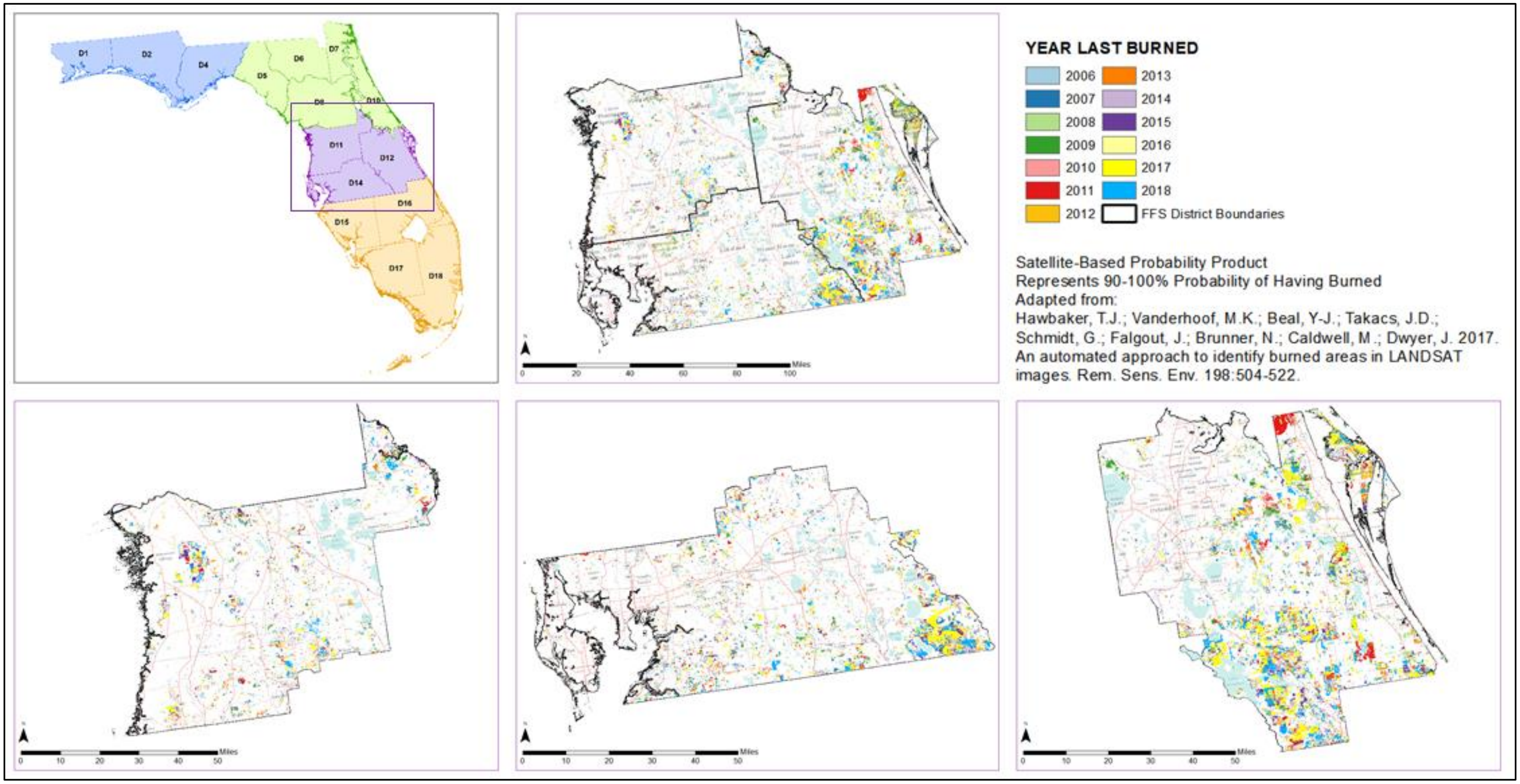


Figure A3.c: *Year last burned between 2006 and 2018 (as measured from 2019) based on BA.v2 annual composite 90-100% burn probability for FFS Districts 11-14.*

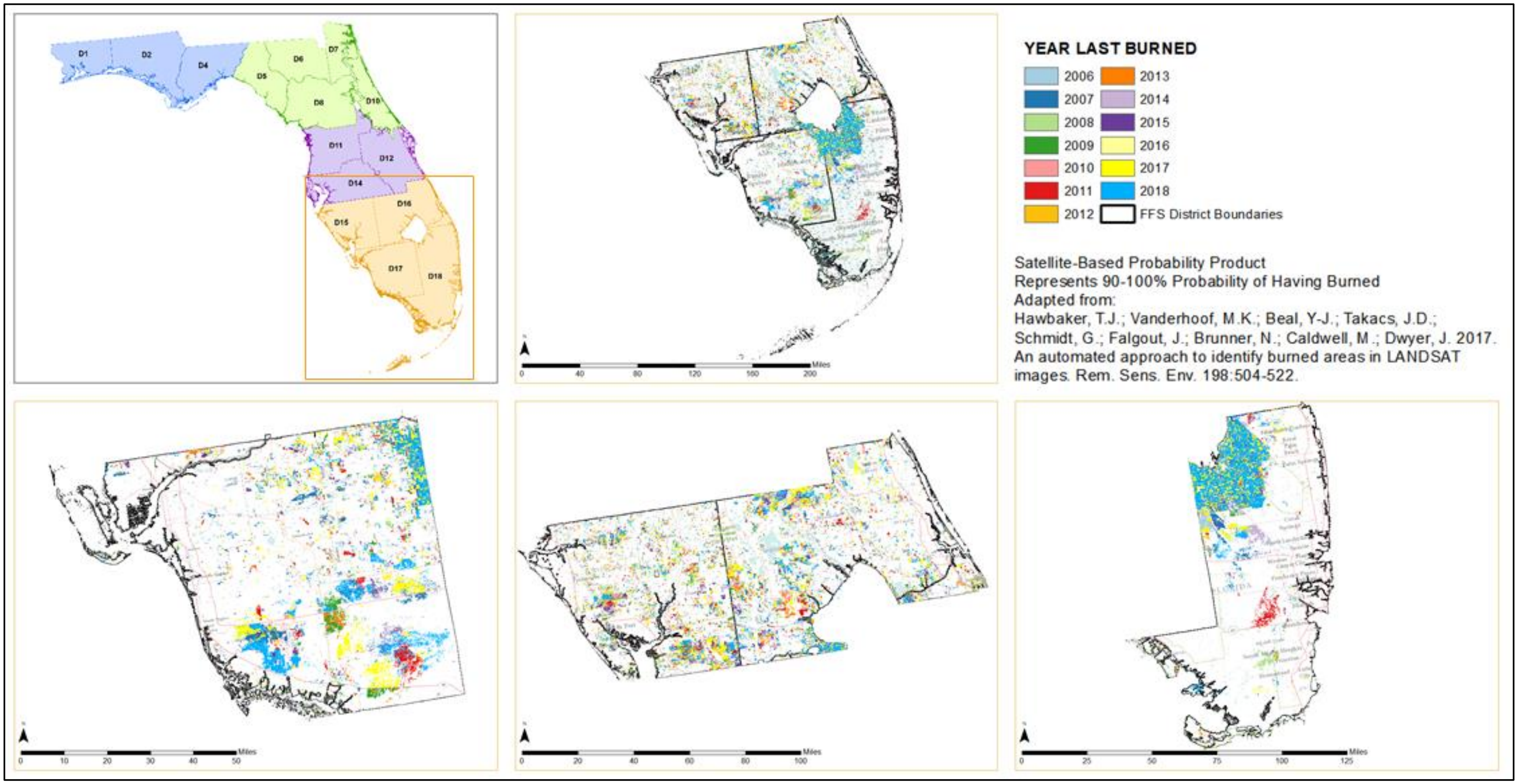


Figure A3.d: *Year last burned between 2006 and 2018 (as measured from 2019) based on BA.v2 annual composite 90-100% burn probability for FFS Districts 15-18.*

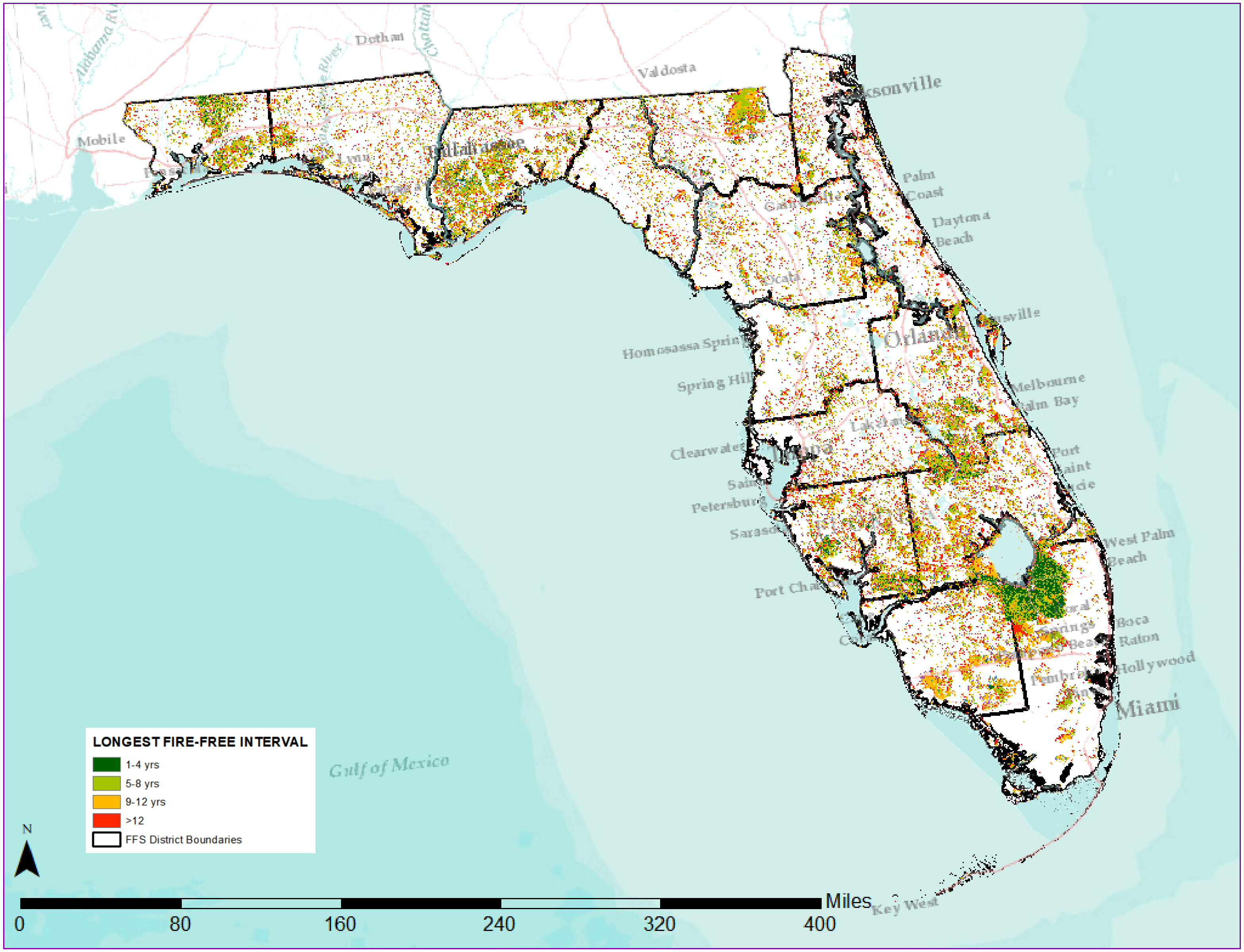


Figure A4: *Longest fire-free period (in years) between 2006 and 2018 across Florida based on BA.v2 annual composite 90-100% burn probability data.*

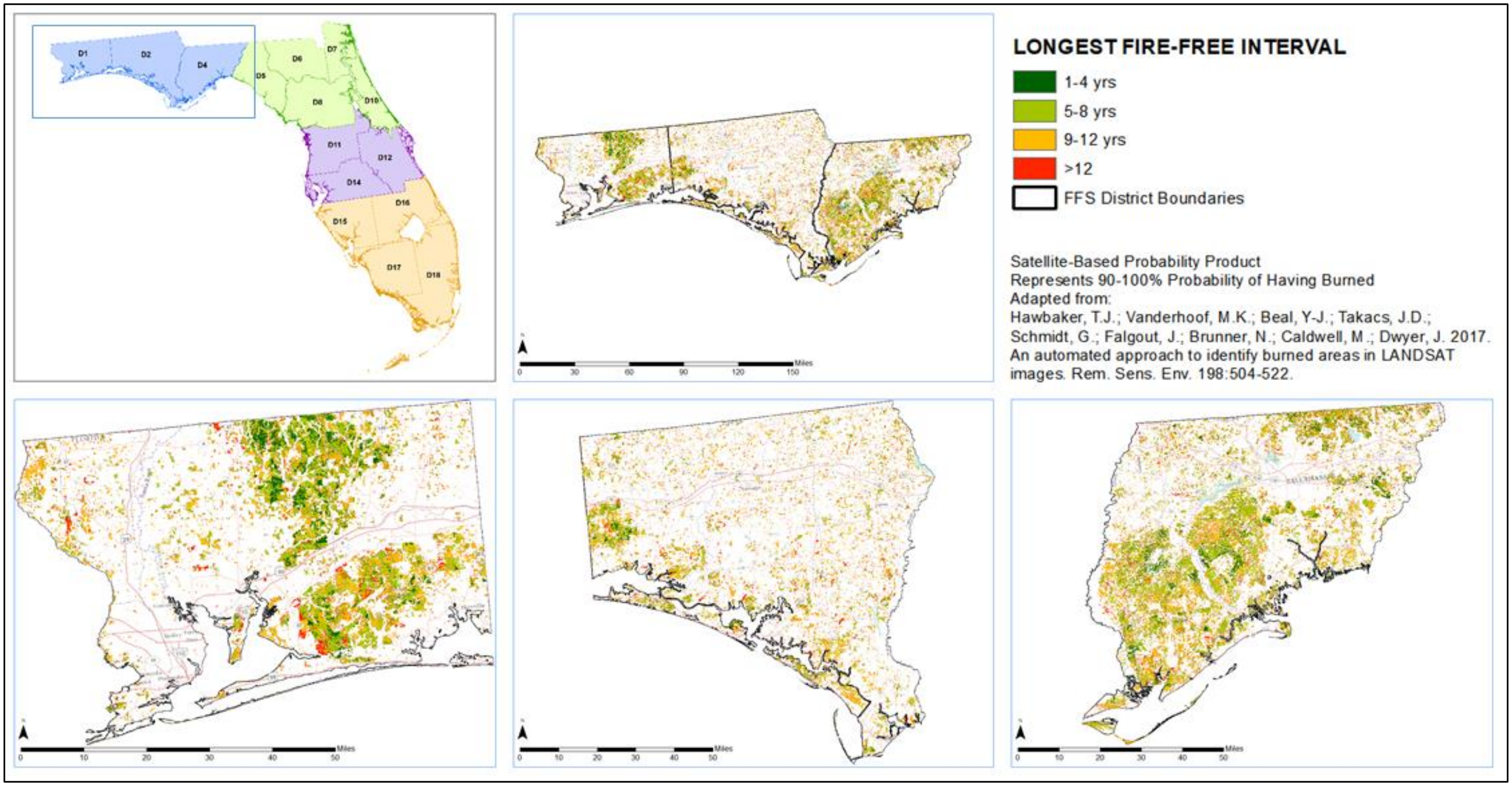


Figure A4.a: *Longest fire-free period (in years) between 2006 and 2018 based on BA.v2 annual composite 90-100% burn probability for FFS Districts 1-4.*

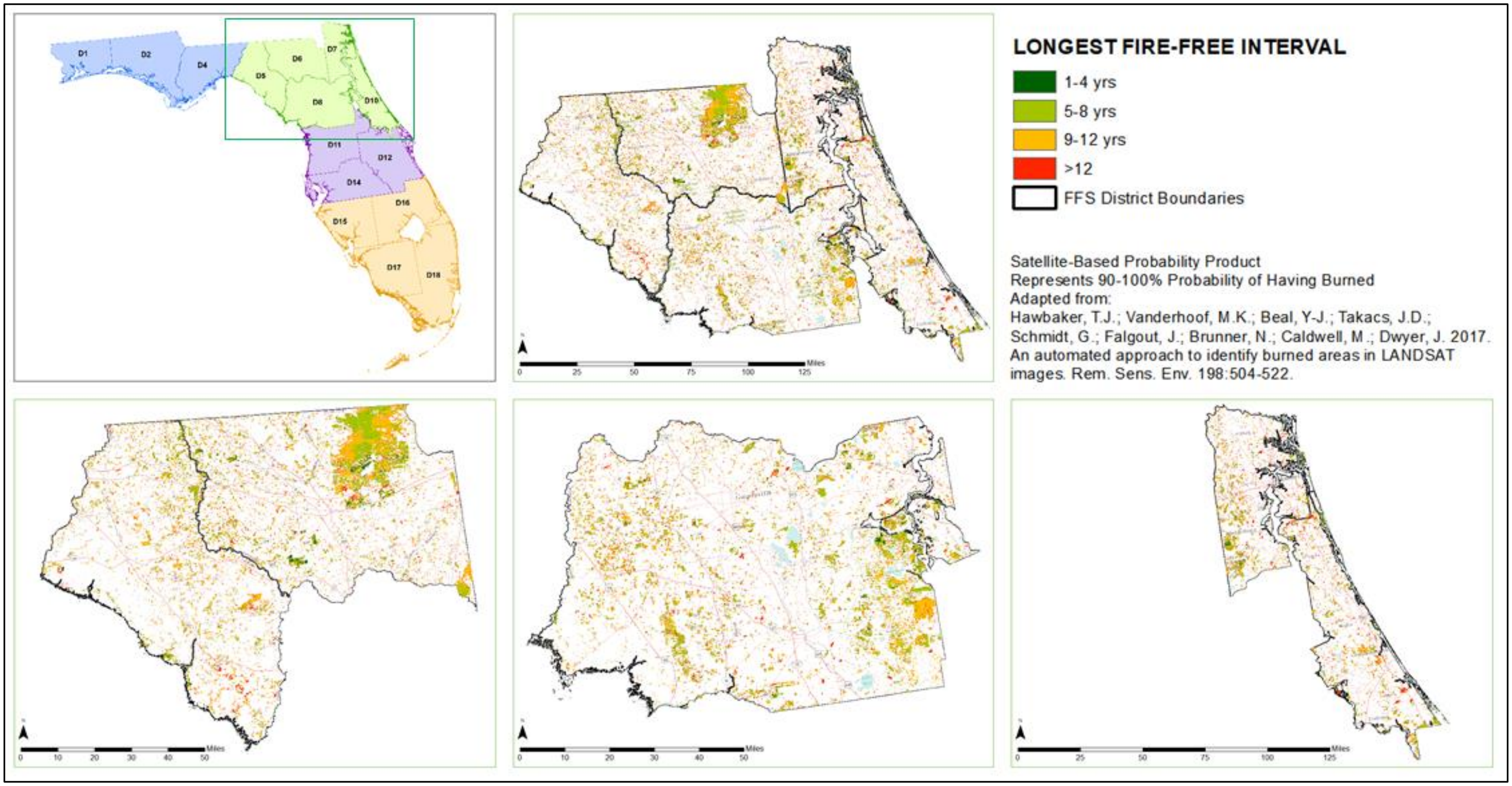


Figure A4.b: *Longest fire-free period (in years) between 2006 and 2018 based on BA.v2 annual composite 90-100% burn probability for FFS Districts 5-10.*

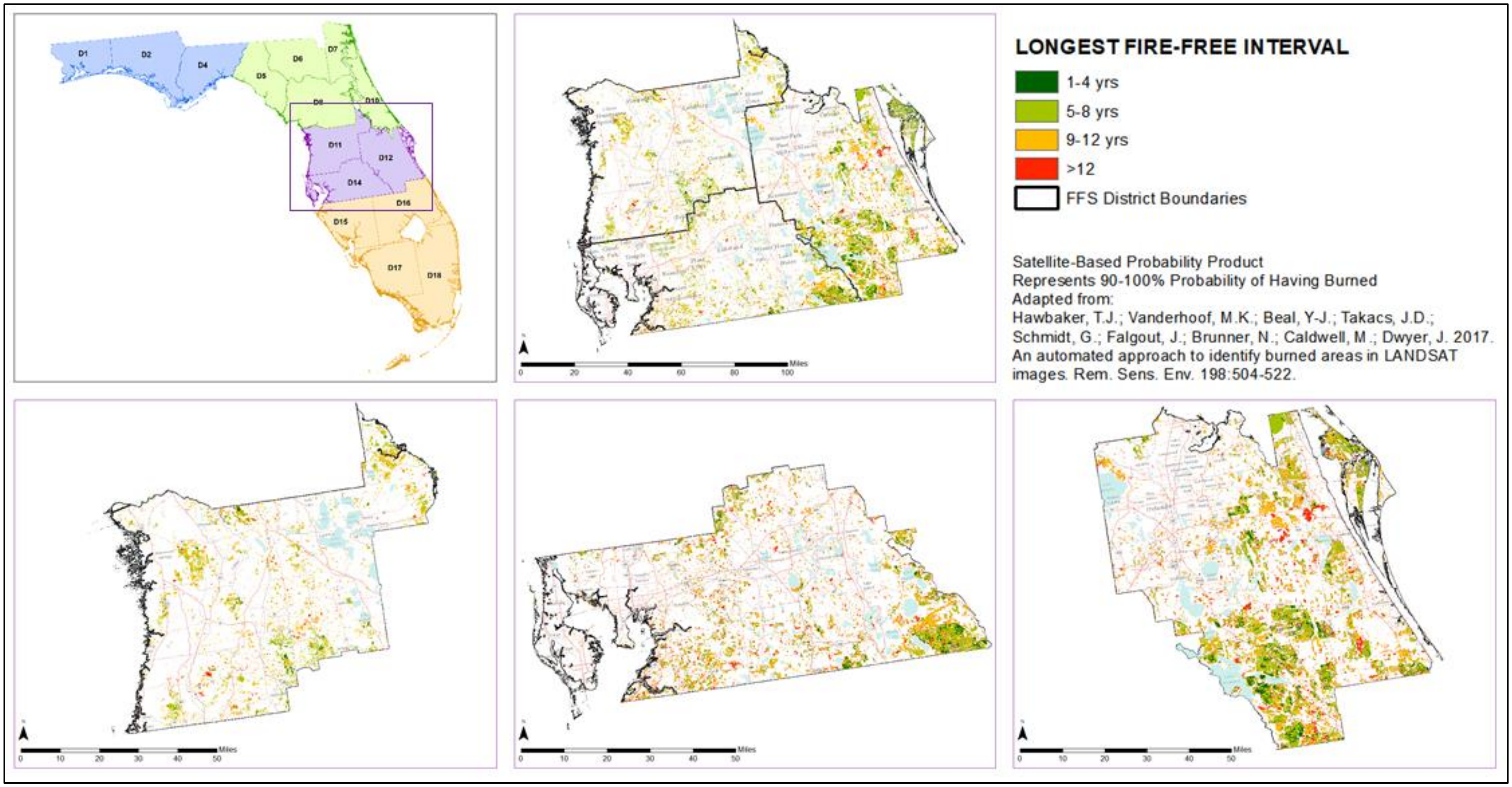


Figure A4.c: *Longest fire-free period (in years) between 2006 and 2018 based on BA.v2 annual composite 90-100% burn probability for FFS Districts 11-14.*

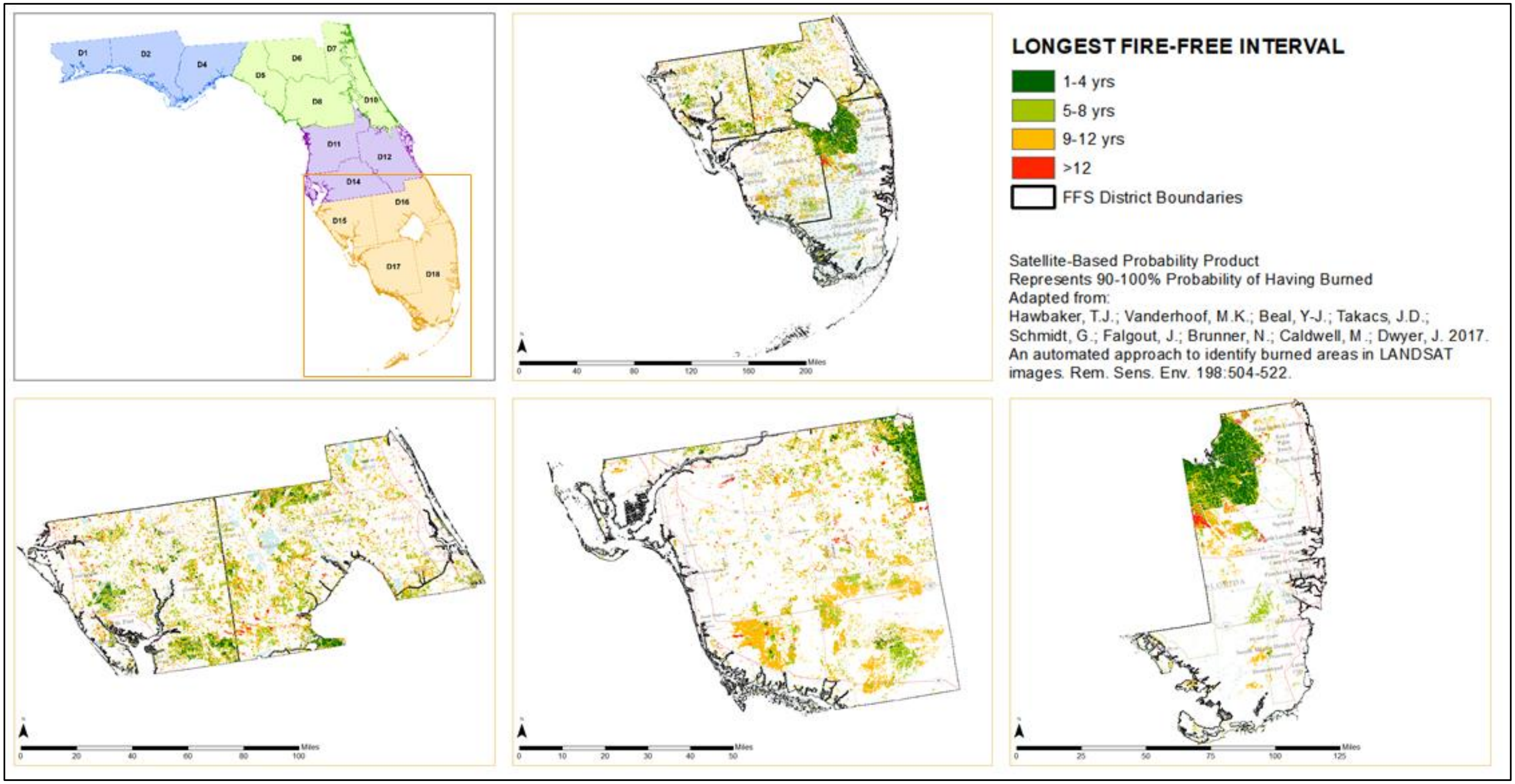


***Figure A4.d:** Longest fire-free period (in years) between 2006 and 2018 based on BA.v2 annual composite 90-100% burn probability for FFS Districts 15-18.*

Appendix A: Datasets Included

The following pages describe datasets included in the final database, including metadata text.

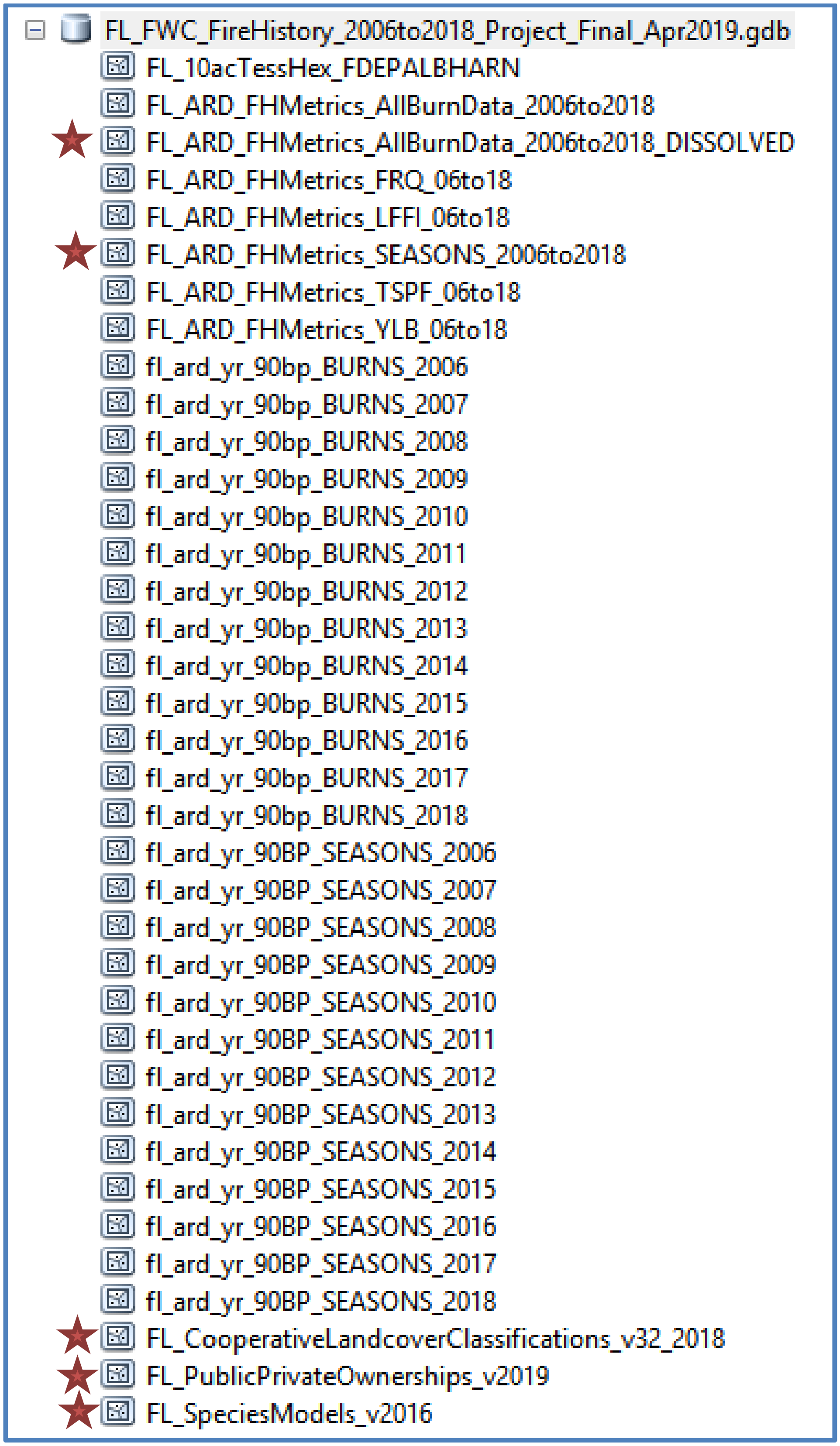
Feature Class Name	Description
FL_10acTessHex_FDEPALBHARN	10 acre Hexagon 'net' covering FL, with Fire Metrics Information (eg, so you can display a 'smoothed' map of any of the fire history data (*except seasonality) across the state for quickly identifying areas of interest)
FL_ARD_FHMetrics_AllBurnData_2006to2018 ***FL_ARD_FHMetrics_AllBurnData_2006to2018_DISSOLVED***	A "Flat file" layer that combines annual burn event data and fire history metric information calculated for the years 2006 to 2018. Binary datafields were calculated to return lists of years burned for easy queries. Dissolved dataset is the data with a reduced number of records in the table, based on a dissolve on the binary field.
FL_ARD_FHMetrics_SEASONS_2006to2018	Fire History Seasonality data for the years 2006 to 2018 based on a union of the annual seasonality layers. Seasons were attributed based on acquisition date of the first scene identifying a pixel with BP>90%. Binary datafields were calculated to return lists of years burned, and order of seasonality, for easy queries.
FL_ARD_FHMetrics_FRQ_06to18 FL_ARD_FHMetrics_LFFI_06to18 FL_ARD_FHMetrics_TSPF_06to18 FL_ARD_FHMetrics_YLB_06to18	Fire History Metric data (Frequency [FRQ; aka Number Times Burned]; Longest Fire Free Interval [LFFI]; Time Since Previous Fire [TSPF]; Year Last Burned [YLB]) calculated for the years 2006 to 2018 based on the annual burn event data. Not Dissolved.
FL_ARD_YR_90BP_BURNS_2006 FL_ARD_YR_90BP_BURNS_2007 FL_ARD_YR_90BP_BURNS_2008 FL_ARD_YR_90BP_BURNS_2009 FL_ARD_YR_90BP_BURNS_2010 FL_ARD_YR_90BP_BURNS_2011 FL_ARD_YR_90BP_BURNS_2012 FL_ARD_YR_90BP_BURNS_2013 FL_ARD_YR_90BP_BURNS_2014 FL_ARD_YR_90BP_BURNS_2015 FL_ARD_YR_90BP_BURNS_2016 FL_ARD_YR_90BP_BURNS_2017 FL_ARD_YR_90BP_BURNS_2018	Annual burn events for each year (2006 - 2018) based on the annual 90%BP BAECV layer (not dissolved)

Table A.1: Final datasets provided for ingestion into SQL database. The five ***bold italicized datasets*** contain all the information needed for the SQL database queries, views, tables, etc., but the others can be used individually if desired.

Feature Class Name	Description
[redacted]	
FL_ARD_YR_90BP_SEASONS_2006 FL_ARD_YR_90BP_SEASONS_2007 FL_ARD_YR_90BP_SEASONS_2008 FL_ARD_YR_90BP_SEASONS_2009 FL_ARD_YR_90BP_SEASONS_2010 FL_ARD_YR_90BP_SEASONS_2011 FL_ARD_YR_90BP_SEASONS_2012 FL_ARD_YR_90BP_SEASONS_2013 FL_ARD_YR_90BP_SEASONS_2014 FL_ARD_YR_90BP_SEASONS_2015 FL_ARD_YR_90BP_SEASONS_2016 FL_ARD_YR_90BP_SEASONS_2017 FL_ARD_YR_90BP_SEASONS_2018	Annual seasonality information for each year (2006 - 2018) based on the annual 90%BP BAECV layer (not dissolved)
FL_CooperativeLandcoverClassifications_v32_2018	Landcover Classifications (v3.2, 2018)
FL_PublicPrivateOwnerships_v2019	Ownership information (Public/private) based on FLMA (v2019) unioned with a FL state boundary layer.
FL_SpeciesModels_v2016	Species Models (v.2016) from J. Reddner

Table A.1: Final datasets provided for ingestion into SQL database. The five ***bold italicized datasets*** contain all the information needed for the SQL database queries, views, tables, etc., but the others can be used individually if desired.

Figure A.1: Final geodatabase/datasets provided for ingestion into SQL database. The five ***bold italicized datasets*** from table A.1 that contain all the information needed for the SQL database queries, views, tables, etc., are indicated with **red star symbols**. The other feature classes can be used individually if desired. The SQL final data structure can be found in Chapter 8.



METADATA TEXT

This dataset is derived from the USGS Burned Area Products (Hawbaker *et al.* 2017). We used Burned Area (BA) version 2 products (USGS 2019). We evaluated the *annual*BAECV Burn Probability (BP) datasets –which are raster datasets – for evidence of burns. The annual datasets span an entire calendar year (*e.g.,*Jan 1 through Dec 31) and indicate the maximum BP within the year (0-100%). For each year between 2006 and 2018, we combined the annual datasets of interest within individual ARD Tiles into a single annual raster dataset (*i.e.,* we mosaicked the tiles) for further processing. We performed all additional processing steps on the annual mosaicked datasets as this provided statewide consistency. We identified pixels as burned or unburned according to their probability value; initially, we retained all pixels with an annual BP between 85-100% based on Hawbaker *et al.* (2017). Values between 90-100% were then converted to presence/absence rasters and we used image processing methods to remove 'speckling' (*e.g.,*fill in small holes within a burned area and remove groups of pixels less than a specified size/amount). This process resulted in annual rasters and vectors indicating burn presence (with 90-100% probability) for groups of pixels greater than ~2.24 acres (*e.g.,*10 30m pixels, in any arrangement). We also assigned dates from the Burn Date (BD) dataset to these same pixels as a surrogate for seasonality. We evaluated these products against fire records for three pilot areas. For each area, we held a meeting with fire managers, either in person or via web conferencing methods. We invited managers to inspect the data with us to evaluate their thoughts on the products. Through this process, managers provided many explanations for why no burn was detected and where/why fire detection was performing very well, as well as some ideas and suggestions for moving forward (all of which we relayed to USGS). Many of these comments reflect known limitations previously documented (see Hawbaker *et al.* 2017, Vanderhoof *et al.* 2017). Based on these meetings, we have applied the processing "logic" across the entire state at 90-100%BP. Fire regime metrics such as number of times burned, year last burned, and time since previous fire (as measured from 2019) are included in the dataset upload, and were derived using these annual presence/absence rasters and vectors.

References:

Hawbaker, T.J.; Vanderhoof, M.K.; Beal, Y-J.; Takacs, J.D.; Schmidt, G.; Falgout, J.; Brunner, N.; Caldwell, M.; Dwyer, J. 2017. An automated approach to identify burned areas in LANDSAT images. Remote Sens. Environ., 198, 504–522.

United States Geological Survey [USGS]. 2019. Landsat Level-3 Burned Area Science Product. < https://www.usgs.gov/centers/eros/science/usgs-eros-archive-landsat-landsat-level-3-burned-area-ba-science-product?qt-science_center_objects=0#qt-science_center_objects>. Digital Object Identification: doi.org/10.5066/F77W6BDJ

Vanderhoof, M. K.; N. Fairaux; Y-J. G. Beal; T.J. Hawbaker. 2017. Validation of the USGS LANDSAT Burned Area Essential Climate Variable (BAECV) across the conterminous United States. Remote Sens. Environ., 198, pp. 393-406.

Contact:

Casey Teske (cteske at talltimbers dot org) or Joe Noble (jnoble at talltimbers dot org) for more information.

Fields in FL Burn data

FIELD NAME	VALUES	NOTES
B2006 – B2018	0 or 1	Presence/absence of a burn in a given year (e.g., if B2006 has a value of 1, there was a fire in 2006)
FRQ	1-13	Number of times burned between 2006-2018
YLB	2006-2018	Year last burned (measured from 2019) between 2006-2018 (actual year)
TSPF	1-13	Time since previous fire (measured from 2019) between 2006-2018 (yrs)
LFFI	1-13	Longest Fire Free Interval (2006-2018) in yrs
GIS_AC	**	Total Acres of polygon
FIRE_BIN	**	Binary string used for processing
FIRE_DEC	**	Code from binary string used for processing
FIRE_COUNT	**	Code from binary string used for processing
FIRE_LAYERS	**	List of years that a location burned
****<all other fields are for querying within database, but not given a value here>****		

Fields in FL SEASONS Data

FIELD NAME	VALUES	NOTES
Gridcode06 – Gridcode18	0 or 1	Presence/absence of a burn in a given year (e.g., if gridcode06 has a value of 1, there was a fire in 2006)
TOY_06-TOY_18	Spring, Summer, Autumn, Winter	Time of Year a fire was first recorded in a given year (from acquisition date of first image registering fire)
TOY_Code06 – TOY_Code18	1-4	Time of Year Code
DG_06 – DG_18	Dormant, Growing	Dormant or Growing season for a given year
DG_Code06 – DG_Code18	1, 2	Dormant/Growing Code
FYEAR06 – FYEAR18	2006 - 2018	Year that fire occurred
BYR06 – BYR18	0 or 1	Presence/absence of a burn in a given year (e.g., if gridcode06 has a value of 1, there was a fire in 2006)
FIRE_BIN	**	Binary string used for processing
FIRE_DEC	**	Code from binary string used for processing
FIRE_COUNT	**	Code from binary string used for processing
FIRE_LAYERS	**	List of years that a location burned
DG_SEAS_BIN	**	String of all DG_Code<YR> used for processing
TSEAS_Lyr	**	List of order of seasonality that a location burned
DG_Lyr	**	List of order of growing/dormant seasons that a location burned
****<all other fields are for querying within database, but not given a value here>****		

Species Names and Codes – the Species 6-Letter Field Code column indicates the ‘short’ code we used for each species model provided by FWC. This code is used in column headings of species datasets.

Layer Name	Species	Species 6-Letter Field Code
AMKE	American Kestrel	AMKE
BEAR	Bear	BEAR
CHBM	Choctawhatchee Beach Mouse	CHBM
CKMS	Cedar Key Mole Skink	CKMS
FLMOUSE	Florida Mouse	FLMOUS
FWSAL	Flatwood Salamander	FWSAL
GOPHTORT	Gopher Tortoise	GPHTRT
GPHRFRG	Gopher Frog	GPHFRG
GRSP	Grasshopper sparrow	GRSP
INDIGOSN	Indigo Snake	NDGSNK
NBOBWHITE	Northern Bobwhite	NBOBWT
PABU	Eastern Painted Bunting	PABU
PBTF	Pine Barren Tree Frog	PBTF
PINESNAKE	Pine Snake	PINSNK
RCW	Red Cockaded Woodpecker	RCW
RRCS	Rim Rock Crowned Snake	RRCS
SCJA	Scrub Jay	SCJA
SHFS	Sherman Fox Squirrel	SHFS
SHOGSNK	Southern Hognose Snake	SHGSNK
SSKINK	Sand Skink	SSKINK
STNEWT	Striped Newt	STNEWT
STSNAK	Short Tail Snake	STSNK
TIGERSAL	Tiger Salamander	TIGSAL
WILDTRK	Wild Turkey	WLDTRK

Florida Cooperative Landcover Classifications (site and state codes can be found online): https://myfwc.com/research/gis/applications/articles/cooperative-land-cover/

Land Cover Class Code	Land Cover Class	Description	Acres
1880	**Bare Soil/Clear Cut**	Areas of bare soil representing recent timber cutting operations, areas devoid of vegetation as a consequence of recent fires, natural areas of exposed bare soil (e.g., sandy areas within xeric communities), or bare soil exposed due to vegetation removal for unknown reasons	31494
1700	**Barren and Outcrop Communities**	Small extent communities in karst features or on exposed limestone	507
22132	**Basin Swamp**	Typically large basin wetland with peat substrate; seasonally inundated; still water or with water output; Panhandle to central peninsula; occasional or rare fire; forest of cypress/tupelo/mixed hardwoods; pond cypress, swamp tupelo	192634
2231	**Baygall**	Slope or depression wetland with peat substrate; usually saturated and occasionally inundated; statewide excluding Keys; rare or no fire; closed canopy of evergreen trees; loblolly bay, sweetbay, swamp bay, titi, fetterbush	111861
1214	**Coastal Scrub**	This scrub category represents a wide variety of species found in the coastal zone. A few of the more common components are saw palmetto, sand live oak, myrtle oak, yaupon, railroad vine, bay bean, sea oats, sea purslane, sea grape, Spanish bayonet and prickly pear. This cover type is generally found in dune and white sand areas.	19554
1640	**Coastal Strand**	Stabilized coastal dune with sand substrate; xeric; peninsula; rare fire; marine influence; primarily dense shrubs; saw palmetto in temperate coastal strand or seagrape and/or saw palmetto in tropical coastal strand.	6703
1600	**Coastal Uplands**	Mesic or xeric communities restricted to barrier islands and near shore; woody or herbaceous vegetation; other communities may also occur in coastal environments	16570
1850	**Communication**	Airwave communications, radar and television antennas with associated structures are typical major types of communication facilities that will be identified in this category. When stations are associated with a commercial or governmental facility, they will be included in either of those specific categories when located within their bounds and will not be listed as separate elements.	4084
18331	**Cropland/Pasture**	Agricultural land which is managed for the production of row or field crops and improved, unimproved and woodland pastures.	1038495
5300	**Cultural - Estuarine**	Communities that are either created and maintained by human activities, or are modified by human influence to such a degree that the physical conformation of the substrate, or the biological composition of the resident community is substantially different from the character of the substrate or community as it existed prior to human influence.	5366

Land Cover Class Code	Land Cover Class	Description	Acres
3200	**Cultural - Lacustrine**	Communities that are either created, and maintained by human activities, or are modified by human influence to such a degree that the trophic state, morphometry, water chemistry, or biological composition of the resident community are substantially different from the character of the lake community as it existed prior to human influence	414335
2400	**Cultural - Palustrine**	Communities that are both created and maintained by human activities, or are modified by human influence to such a degree that the physical conformation of the substrate, the hydrology, or the biological composition of the resident community is substantially different from the character of the substrate, hydrology, or community as it existed prior to human influence.	367976
4200	**Cultural - Riverine**	Communities that are either created and maintained by human activities, or are modified by human influence to such a degree that stream flow, morphometry, water chemistry, or the biological composition of the resident community are substantially different from the character of the stream community as it existed prior to human influence	79951
1800	**Cultural - Terrestrial**	Includes communities that are both created and maintained by human activities, or are modified by human influence to such a degree that the physical conformation of the substrate, or the biological composition of the resident community is substantially different from the character of the substrate or community as it existed prior to human influence.	19794
2211	**Cypress**	Dominated entirely by cypress, or these species important in the canopy; long hydroperiod.	637310
2210	**Cypress/Tupelo (incl Cy/Tu mixed)**	Dominated entirely by cypress or tupelo, or these species important in the canopy; long hydroperiod	92145
22131	**Dome Swamp**	Small or large and shallow isolated depression in sand/marl/limestone substrate with peat accumulating toward center; occurring within a fire-maintained community; seasonally inundated; still water; statewide excluding Keys; occasional or rare fire; forested, canopy often tallest in center; pond cypress, swamp tupelo.	48862
1310	**Dry Flatwoods**	Non-hydric flatwoods.	2459
1330	**Dry Prairie**	Flatland with sand soils over an organic or clay hardpan; mesic-xeric; central peninsula; annual or frequent fire (1-2 years); treeless with a low cover of shrubs and herbs; wiregrass, dwarf live oak, stunted saw palmetto, bottlebrush threeawn, broomsedge bluestem.	155891

Land Cover Class Code	Land Cover Class	Description	Acres
5000	**Estuarine**	Deepwater tidal habitats and adjacent tidal wetlands that are usually semi-enclosed by land but have open, partly obstructed, or sporadic access to the ocean, with ocean-derived water at least occasionally diluted by freshwater runoff from the land. The upstream and landward limit is where ocean-de rived salts measure less than .5 ppt during the period of average annual low flow. The seaward limit is (1) an imaginary line closing the mouth of a river, bay, or sound; and (2) the seaward limit of wetland emergents, shrubs, or trees when not included in (1)	1619174
7000	**Exotic Plants**	Upland and wetland areas dominated by non-native trees that were planted or have escaped and invaded native plant communities. These exotics include melaleuca, Australian pine, Brazilian pepper, and eucalyptus. This class includes sites known to be vegetated by non-native but for which the actual species composition could not be determined.	66089
1870	**Extractive**	Encompass both surface and subsurface mining operations. Included are sand, gravel and clay pits, phosphate mines, limestone quarries plus oil and gas wells. Industrial complexes where the extracted material is refined, packaged or further processed are also included in this category	256978
2123	**Floodplain Marsh**	Floodplain with organic/sand/alluvial substrate; seasonally inundated; Panhandle to central peninsula; frequent or occasional fire (ca. 3 years, much less frequent in freshwater tidal marshes); treeless herbaceous community with few shrubs; sawgrass, maidencane, sand cordgrass, and/or mixed emergents	49974
2215	**Floodplain Swamp**	Along or near rivers and streams with organic/alluvial substrate; usually inundated; Panhandle to central peninsula; rare or no fire; closed canopy dominated by cypress, tupelo, and/or black gum.	421270
2200	**Freshwater Forested Wetlands**	Floodplain or depression wetlands dominated by hydrophytic trees	2676694
2100	**Freshwater Non-Forested Wetlands**	Herbaceous or shrubby palustrine communities in floodplains or depressions; canopy trees, if present, very sparse and often stunted	138786
1822	**High Intensity Urban**	Residential density > 2 dwelling/acre, commercial, industrial, and institutional	2252895
1200	**High Pine and Scrub**	Hills with mesic or xeric woodlands or shrublands; canopy, if present, open and consisting of pine or a mixture of pine and deciduous hardwoods.	290829
2232	**Hydric Hammock**	Lowland with sand/clay/organic soil over limestone or with high shell content; mesic- hydric; primarily eastern Panhandle and central peninsula; occasional to rare fire; diamond-leaved oak, live oak, cabbage palm, red cedar, and mixed hardwoods.	240562

Land Cover Class Code	Land Cover Class	Description	Acres
183313	**Improved Pasture**	This category in most cases is composed of land which has been cleared, tilled, reseeded with specific grass types and periodically improved with brush control and fertilizer application. Water ponds, troughs, feed bunkers and, in some cases, cow trails are evident.	3056264
2121	**Isolated Freshwater Marsh**	--	276763
2213	**Isolated Freshwater Swamp**	--	74557
52111	**Keys Tidal Rock Barren**	Flatland with exposed limestone in supratidal zone; restricted to Keys; no fire; open, mainly herbaceous vegetation of upper tidal marsh species and stunted shrubs and trees; buttonwood, christmasberry, perennial glasswort, saltwort, seashore dropseed, shoregrass.	8519
3000	**Lacustrine**	Wetlands and deepwater habitats (1) situated in a topographic depression or dammed river channel; (2) lacking trees, shrubs, persistent emergents, emergent mosses, or lichens with greater than 30% areal coverage; and (3) whose total area exceeds 8 hectares (20 acres); or area less than 8 hectares if the boundary is active wave-formed or bedrock or if water depth in the deepest part of the basin exceeds 2 m (6.6 ft) at low water. Ocean- derived salinities are always less than .5 ppt.	388970
1821	**Low Intensity Urban**	Less than two dwelling units per acre. Areas of low intensity residential land use (generally less than one dwelling unit per five acres), such as farmsteads, will be incorporated into the rural structures category.	1302061
5250	**Mangrove Swamp**	Estuarine wetland on muck/sand/or limestone substrate; inundated with saltwater by daily tides; central peninsula and Keys; no fire; dominated by mangrove and mangrove associate species; red mangrove, black mangrove, white mangrove, buttonwood.	571710
6000	**Marine**	Open ocean overlying the continental shelf and coastline exposed to waves and currents of the open ocean shoreward to (1) extreme high water of spring tides; (2) seaward limit of wetland emergents, trees, or shrubs; or (3) the seaward limit of the Estuarine System, other than vegetation. Salinities exceed 30 parts per thousand (ppt).	7841740
1650	**Maritime Hammock**	Stabilized coastal dune with sand substrate; xeric-mesic; statewide but rare in panhandle and Keys; rare or no fire; marine influence; evergreen closed canopy; live oak, cabbage palm, red bay, red cedar in temperate maritime hammock; gumbo limbo, seagrape, and white or Spanish stopper in tropical maritime hammock.	29654
2120	**Marshes**	Long hydroperiod; dominated by grasses, sedges, broadleaf emergents, floating aquatics, or shrubs.	2435732

Land Cover Class Code	Land Cover Class	Description	Acres
1311	**Mesic Flatwoods**	Flatland with sand substrate; mesic; statewide except extreme southern peninsula and Keys; frequent fire (2-4 years); open pine canopy with a layer of low shrubs and herbs; longleaf pine and/or slash pine, saw palmetto, gallberry, dwarf live oak, wiregrass.	1325011
1120	**Mesic Hammock**	Flatland with sand/organic soil; mesic; primarily central peninsula; occasional or rare fire; live oak, cabbage palm, southern magnolia, pignut hickory, saw palmetto.	126285
1400	**Mixed Hardwood-Coniferous**	Mix of hardwood and coniferous trees where neither is dominant	1329657
3100	**Natural Lakes and Ponds**	Includes inland lakes and ponds in which the trophic state, morphometry, and water chemistry have not been substantially modified by human activities, or the native biota are dominant	550976
4100	**Natural Rivers and Streams**	Streams in which the stream flow, morphometry, and water chemistry have not been substantially modified by human activities, or the native biota are dominant.	80295
2300	**Non-vegetated Wetland**	Hydric surfaces on which vegetation is found lacking due to the erosional effects of wind and water transporting the surface material so rapidly that the establishment of plant communities is hindered or the fluctuation of the water surface level is such that vegetation cannot become established. Additionally, submerged or saturated materials often develop toxic conditions of extreme acidity. Intermittent ponds are the main components of this category	13828
18332	**Orchards/Groves**	This class is for active tree cropping operations that produce fruit, nuts, or other resources not including wood products	907991
18335	**Other Agriculture**	--	138533
2220	**Other Coniferous Wetlands**	Coniferous forested wetlands that are not dominated by cypress, tupelo, or a mix of cypress/tupelo	26800
2230	**Other Hardwood Wetlands**	Dominated by a mix of hydrophytic hardwood trees; cypress or tupelo may be occasional or infrequent in the canopy; short hydroperiod	23022
1340	**Palmetto Prairie**	These are areas in which saw palmetto is the most dominant vegetation. Common associates of saw palmetto in this cover type are fetterbush, tar flower, gallberry, wire grass and brown grasses. This cover type is usually found on seldom flooded dry sand areas. These treeless areas are often similar to the pine flatwoods but without the presence of pine trees.	21131
1300	**Pine Flatwoods and Dry Prairie**	Mesic pine woodland or mesic shrubland on flat sandy or limestone substrates, often with a hard pan that impedes drainage	105838
1320	**Pine Rockland**	Flatland with exposed limestone substrate; mesic-xeric; southern peninsula and Keys; frequent to occasional fire (3-7 years); open pine canopy with mixed shrubs and herbs in understory; south Florida slash pine, palms, mixed tropical and temperate shrubs, grasses, and herbs	16866

Land Cover Class Code	Land Cover Class	Description	Acres
2110	**Prairies and Bogs**	Short hydroperiod; dominated by grasses, sedges, and/or titi	1736441
4000	**Riverine**	All wetlands and deepwater habitats contained within a channel except those wetlands (1) dominated by trees, shrubs, persistent emergents, emergent mosses, or lichens, and (2) which have habitats with ocean-derived salinities in excess of .5 ppt.	164993
1130	**Rockland Hammock**	Flatland with limestone substrate; mesic; southern peninsula and Keys; rare or no fire; closed canopy of evergreen mixed tropical hardwoods; gumbo limbo, pigeon plum, stoppers.	19320
1830	**Rural**	--	1581448
5240	**Salt Marsh**	Estuarine wetland on muck/sand/or limestone substrate; inundated with saltwater by daily tides; statewide; occasional or rare fire; treeless, dense herb layer with few shrubs; saltmarsh cordgrass, needle rush, saltgrass, saltwort, perennial glasswort, seaside oxeye	378678
1670	**Sand Beach (Dry)**	Beaches are constantly affected by wave and tidal action. The fine clays and silts are washed away leaving sand. However, in protected bay and marsh areas, fine soil particles from surface drainage may settle out. The beach areas also are subject to water and wind erosion	24386
1213	**Sand Pine Scrub**	Found on ridges throughout the state; rare fire (20-80 years); canopy of sand pine and an understory of the three shrubby oaks, myrtle oak, Chapman's oak, sand live oak, or less commonly, Florida rosemary.	220967
1240	**Sandhill**	Upland with deep sand substrate; xeric; panhandle to central peninsula; frequent fire (1-3 years); open canopy of longleaf pine and/or turkey oak with wiregrass understory.	775755
1210	**Scrub**	Upland with deep sand substrate; xeric; statewide except extreme southern peninsula and Keys, mainly coastal in Panhandle; occasional or rare fire; open or dense shrubs with or without pine canopy; sand pine and/or scrub oaks and/or Florida rosemary.	159788
5252	**Scrub Mangrove**	Areas sparsely vegetated with small, stunted mangroves. Found in extreme south Florida only	42388
1312	**Scrubby Flatwoods**	Flatland with sand substrate; xeric-mesic; statewide except extreme southern peninsula and Keys; occasional fire (5-15 years); widely scattered pine canopy over saw palmetto and scrub oaks; longleaf pine, sand live oak, myrtle oak, Chapman's oak, saw palmetto, wiregrass.	93619

Land Cover Class Code	Land Cover Class	Description	Acres
1500	**Shrub and Brushland**	This association includes a variety of situations where natural upland community types have been recently disturbed through clear-cutting commercial pinelands, land clearing, or fire, and are recovering through natural successional processes. This type could be characterized as an early condition of old-field succession, and various shrubs, tree saplings, and lesser amounts of grasses and herbs dominate the community. Common species include wax myrtle, saltbush, sumac, elderberry, saw palmetto, blackberry, gallberry, fetterbush, staggerbush, broomsedge, dog fennel, together with oak, pine and other tree seedlings or saplings.	342184
1140	**Slope Forest**	Steep slope on bluff or in sheltered ravine within the Apalachicola drainage; sand/clay substrate; mesic-hydric; central panhandle; rare or no fire; closed canopy of mainly deciduous species; American beech, Florida maple, white oak, Ashe's magnolia, southern magnolia, spruce pine, Shumard's oak.	5875
2214	**Strand Swamp**	Broad, shallow channel with peat over mineral substrate; situated in limestone troughs; seasonally inundated; slow flowing water; vicinity of Lake Okeechobee southward in the central and southern peninsula; occasional or rare fire; closed canopy of cypress and mixed hardwoods; cypress, pond apple, strangler fig, willow, abundant epiphytes	44236
1833121	**Sugarcane**	--	618200
5220	**Tidal Flat**	A community of quiet waters, with substrates composed of silt or sand that is rich in organic matter and poorly drained at low tide. The substrate may be covered with algae	43950
1840	**Transportation**	Transportation facilities are used for the movement of people and goods. Highways include areas used for interchanges, limited access rights-of-way and service facilities. The Transportation category encompasses rail-oriented facilities including stations, round-houses, repair and switching yards and related areas. Airport facilities include runways, intervening land, terminals, service buildings, navigational aids, fuel storage, parking lots and a limited buffer zone and fall within the Transportation category. Transportation areas also embrace ports, docks, shipyards, dry docks, locks and water course control structures designed for transportation purposes. The docks and ports include buildings, piers, parking lots and adjacent water utilized by ships in the loading and unloading of cargo or passengers. Locks, in addition to the actual structures, include the control buildings, power supply buildings, docks and surrounding supporting land use (i.e., parking lots and green areas)	1610733
18333	**Tree Plantations**	--	4485132
9100	**Unconsolidated Substrate**	--	3050

Land Cover Class Code	Land Cover Class	Description	Acres
1720	**Upland Glade**	Upland with thin clay soils over limestone outcrops; hydric-xeric; central panhandle only; sparse mixed grasses and herbs with occasional stunted trees and shrubs that are concentrated around the edge; black bogrush, poverty dropseed, diamondflowers, hairawn muhly, Boykin's polygala, red cedar.	34
1110	**Upland Hardwood Forest**	Upland with sand/clay and/or calcareous substrate; mesic; Panhandle to central peninsula; rare or no fire; closed deciduous or mixed deciduous/evergreen canopy; American beech, southern magnolia, hackberry, swamp chestnut oak, white oak, horse sugar, flowering dogwood, and mixed hardwoods.	224388
1231	**Upland Pine**	Upland with sand/clay substrate; mesic-xeric; longleaf pine and/or loblolly pine and/or shortleaf pine.	164839
1860	**Utilities**	Include power generating facilities and water treatment plants including their related facilities such as transmission lines for electric generation plants and aeration fields for sewage treatment sites. Small facilities or those associated with an industrial, commercial or extractive land use are included within these larger respective categories.	113620
18334	**Vineyard and Nurseries**	Includes tree nurseries, sod farms, and three classes of ornamentals. Miscellaneous uses that would belong include vineyards and nurseries other than for trees.	135882
2221	**Wet Flatwoods**	Flatland with sand substrate; seasonally inundated; statewide except extreme southern peninsula and Keys; frequent fire (2-4 years for grassy wet flatwoods, 5-10 years for shrubby wet flatwoods); closed to open pine canopy with grassy or shrubby understory; slash pine, pond pine, large gallberry, fetterbush, sweetbay, cabbage palm, wiregrass, toothache grass.	761947
1150	**Xeric Hammock**	Upland with deep sand substrate; xeric; primarily eastern Panhandle to central peninsula; rare or no fire; closed canopy of evergreen hardwoods; sand live oak, saw palmetto.	24211

Landowner-provided datasets evaluated for mapping fires in Florida, and their spatial and temporal characteristics (this includes update availability, period of record, and data coverage timeframe) pertinent to this project. Unless otherwise noted, the data we used is bounded by the years 2006-2016.

Data Source (Fire Data by Landowner)	Data Type	Spatial Characteristics	Dataset Period of Record	Wildfire (W), Prescribed Fire (P), or Both (WP)	Source, notes, description
Archbold Research Station	Polygon	Varies depending on source	2006-2017		• Source: Archbold R.S. GIS Dept. • Rx Fires • Variability within fire mapped
Florida State Forests RX Fires	Polygon		2009-2017	P	• Source: FFS GIS Dept. • Details about seasonality, weather, fire behavior, ignition pattern, etc. included
FFS Wildfire	Point, Polygon		2006-2016	W	• Source: FFS GIS Dept. • Perimeters include ROS, cause, date/time • Points (FOD) include name, date/time, fire behavior metrics, etc. • FOD points link to existing perimeters
Florida Park Service	Polygon		2006-2016	WP	• Source: FPS GIS Dept. • Burn Unit perimeters; must be linked to .csv provided to derive fire history by year
FWC	Polygon		1998-2018	WP	• Source: FWC GIS Dept. • Includes date/time of burns, rx burn purpose, and notes on burn
US FWS	Point, Polygon		2002-2018 (points) 1963-2016 (SMNWR)	WP	• Source: WIMS Fire Occurrence Database (includes points outside of FL) • Source: Prescribed Fire Burn Units (St Marks NWR) • Polygon data includes ignition method, seasonality, date/time
National Fire Occurrence Database	Point		1992-2015	WP	• Source: Fire Occurrence Database (Short 2017) • Includes fires outside of Florida
Tall Timbers Research Station	Polygon		1990-2016	P	• Source: Tall Timbers R.S. GIS Dept. • Details include burn date, landcover

Data Source (Fire Data by Landowner)	Data Type	Spatial Characteristics	Dataset Period of Record	Wildfire (W), Prescribed Fire (P), or Both (WP)	Source, notes, description
NPS	Point, Polygon	Varies depending on source	1940-2017	WP	• Source: J.Shedd (NPS Fire Dataset) • Points (FOD) & Perimeters • Includes Wildfire and Prescribed Fire • Includes fires in SE Park Units (outside of FL)
NPS – BICY	Polygon		2006-2018	WP	• Source: BICY GIS Dept. • Includes wildfire & prescribed fire • Details about fire type, cause, ignition source, fire wx, fire effects, etc. included
TNC- Saddle Blanket Scrub	Polygon		2008-2016 (Intermittent)	P	• Source: TNC GIS Dept. • Rx Fires • Includes Burn Date
TNC – Tiger Creek Preserve	Polygon		2008-2018	P	• Source: TNC GIS Dept. • Rx Fires • Includes Burn Date
TNC – Disney Wilderness Preserve	Polygon		2008-2018	P	• Source: TNC GIS Dept. • Rx Fires • Includes Burn Date
USFS – Apalachicola NF Rx Fires	Point, Polygon		1970-2017 (Wildfire FOD) 1993-2017 (Rx FOD)	WP	• Source: USFS Forests in Florida GIS Dept. • Wildfires and Rx Fires • Rx Fires require relates/joins to derive history on annual basis • Separate FOD for wildfires and Rx Fires
USFS – Osceola NF Rx Fires	Polygon		2007-2018	P	• Source: USFS Forests in Florida GIS Dept. & Fire Planner • Rx Fires • Includes Burn Date
USFS – Ocala NF Rx Fires	Polygon		1962-2017 (intermittent ’62-’81)	P	
DoD – Eglin AFB	Polygon		1972-2016	WP	• Source: DoD WFMIS • Includes wildfires and Rx Fires • Details include Date, cause, comments
DoD – Avon Park	Polygon		1972-2016	WP	• Source: DoD WFMIS • Includes wildfires and Rx Fires • Details include Date, cause, comments
DoD – Tyndall AFR	Polygon		1972-2016	WP	• Source: DoD WFMIS • Includes wildfires and Rx Fires • Details include Date, cause, comments

Chapter 2: Deliverable #1

Project Kickoff Workshop Summary

WORKSHOP SUMMARY REPORT

Mapping Fires Across Florida:

Advancement of a Fire Spatial Database

September 22, 2017
Tallahassee, FL

TALL TIMBERS

Workshop Speakers

Dr. Bill Palmer, Joe Noble, Joshua Picotte, Dr. Holly Nowell, Dr. Kevin Robertson, Kevin Hiers, Vince Sclafani

Workshop Facilitator

Brian Branciforte

With special thanks to FWC and Peninsular Florida LCC personnel for assistance in organizing

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Kurt Haffner

Project ID

FWC-16/17-135 Spatial Database
A Proposal for Mapping Statewide Fire Occurrence, Fire History, and Ecological Outcomes
Submitted by Tall Timbers Research, Inc., June 20, 2017

The complete workshop proceedings, including video of expert presentations, this summary report, and power point presentations are available free of charge from Tall Timbers Research, Inc. Please contact Joe Noble: jnoble@talltimbers.org

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TALL TIMBERS

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Executive Summary

Tall Timbers Research, Inc., is pleased to present the proceedings of its September 2017 workshop, *Mapping Fires Across Florida: Advancement of a Fire Spatial Database*. Development of a comprehensive spatially explicit map of fire occurrence remains one of the most critical needs for conservation in the Southeastern US. Not only are the vast majority of Florida's endangered species and ecosystems reliant on frequent fire, but fire risk analysis, prescribed fire planning, and fire behavior modeling are sensitive to fire history. Fire occurrence in Florida is currently tracked by approximate location through the Florida Forest Service (FFS) burn authorization system, Fire Management Information System (FMIS). While this system represents one of the most advanced prescribed fire planning datasets in the country, the system does not record perimeter data or include assessments regarding which burns are actually completed. Relying solely on this system results in documented data gaps when estimating the size, location and effectiveness of managed fires on a statewide scale. These "actual burned" areas are critical factors in analyses and models evaluating conservation success.

Tall Timbers Research, Inc., is addressing this need by developing a robust spatial database for more precise mapping and tracking of all prescribed fire in Florida. Advanced remote sensing techniques will be applied to known locations of prescribed fires, as identified in the FFS system, to record actual spatial fire boundaries into a modified version of the U.S. Air Force Wildland Fire Database. In addition, custom query tools will be developed to report fire history (e.g., frequency, time-since-burn) in specific fire dependent ecological systems or fire dependent species habitats.

Tall Timbers' staff convened this workshop to gather input from project partners, identify connections to existing fire management efforts, and collect feedback on key ancillary data, required analyses, and research that would benefit project participants. Tall Timbers, FWC, and Peninsular Florida LCC personnel organized the workshop, and attendees represented a broad spectrum of fire practitioners and GIS data managers from federal, state, and private organizations.

The workshop participants were: 1) presented a suite of remote sensing approaches to fire mapping that will be leveraged for this statewide mapping effort; 2) shown existing datasets that will be used to validated FFS permitting data; and 3) introduced to the functionality and structure of the AF Wildland Fire Data Management System. Following lunch, participants focused on three broad questions that will guide data development and system reporting throughout the life of this project. These included: 1) existing spatial data; 2) analysis and expectations of this project; and 3) integration and limitations of data acquisition and reporting.

Glossary of Terms and Concepts

Burned Area Essential Climate Variable (BAECV) refers to an algorithm that capitalizes on the long temporal availability of Landsat imagery to identify burned areas across the conterminous United States.

CONUS The continental United States; this reference excludes Alaska and Hawaii.

Environmental Protection Agency (EPA) The agency of the federal government which was created for the purpose of protecting health and environment.

Florida Forest Service (FFS) Agency whose mission is to protect and manage forest resources in Florida.

Florida Natural Areas Inventory (FNAI) Florida's state heritage program responsible for tracking occurrences of species and natural communities statewide.

Fire Mapping Information System (FMIS) integrated set of applications that handle data input, processing and reporting needs for the Florida Division of Forestry (DOF).

Global Fire Emissions Database (GFED) Database combining satellite information on fire activity and vegetation productivity to estimate gridded monthly burned area and fire emissions.

GOES-16 previously known as GOES-R, is part of the Geostationary Operational Environmental Satellite (GOES) system operated by the U.S. National Oceanic and Atmospheric Administration and is the first spacecraft in NOAA's next-generation of geostationary satellites. The GOES-R series satellites will provide advanced imaging with increased spatial resolution and faster coverage, improving the detection of environmental phenomena.

Interagency Fuel Treatment Decision Support System (IFTDSS) is a web-based software and data integration framework that organizes fire and fuels software applications to make fuels treatment planning and analysis more efficient. The effort was initiated by Joint Fire Science Program and the NWCG Fuels Management Committee in 2007.

Integrated Reporting of Wildland-Fire Information (IRWIN) This service is a Wildland Fire Information and Technology (WFIT) affiliated investment intended to provide an "end-to-end" fire reporting capability. IRWIN is tasked with providing data exchange capabilities between existing applications used to manage data related to wildland fire incidents.

LANDSAT The Landsat Program is a series of Earth-observing satellite missions jointly managed by NASA and the U.S. Geological Survey. Imagery is available since 1972 from six satellites in the Landsat series. These satellites have been a major component of NASA's Earth observation program.

Landscape Conservation Cooperative (LCC) self-directed partnerships between federal agencies, states, tribes, non-governmental organizations, universities, and other entities to collaboratively define science needs and jointly address broad-scale conservation issues.

Monitoring Trends in Burn Severity (MTBS) refers to an interagency program whose goal is to consistently map the burn severity and extent of large fires across all lands of the United States from 1984 to present.

Moderate Resolution Imaging Spectroradiometer (MODIS) is a key instrument aboard the Terra and Aqua satellites. Satellites view the entire Earth's surface every 1 to 2 days acquiring data in 36 spectral bands. These data improve our understanding of global dynamics and processes occurring on the land, oceans and lower atmosphere.

Hazard Mapping Systems (HMS) NOAA product suite that provides both fire and smoke analysis products. It is an interactive processing system that allows analysts to manually integrate data from automated fire detection algorithms using GOES and polar (Advanced Very High Resolution Radiometer (AVHRR) and MODerate resolution Imaging Spectroradiometer (MODIS)) images. The result is a quality controlled display of the locations of fires and significant smoke plumes detected by meteorological satellites.

PostGIS is a spatial database extender for PostgreSQL object-relational database. It adds support for geographic objects allowing queries to be run in SQL.

PostgreSQL is an open source object-relational database system.

Open Burn Authorization (OBA) refers to Florida Forest Service Open Burn Authorization Requests and is available to Certified Prescribed Burners.

QGIS is a free and open source professional Geographical Information System (GIS) that is built on top of Free and Open Source Software (FOSS)

QGIS Event Mapping Tool (EMT) a QGIS plugin for fire assessment developed by U.S. Geological Survey National Center for Earth Resources Observation and Science (EROS)

Southern Integrated Prescribed Fire Information System (SIPFIS) a Joint Fire Science Program initiative to design an integrated information system for fire and air quality data in the SE United States.

Volatile Organic Compounds (**VOC)** refers to a large group of organic chemicals that include any compound of carbon (excluding carbon monoxide, carbon dioxide, carbonic acid, metallic carbides or carbonates, and ammonium carbonate).

Agenda

Mapping Fires Across Florida

E.V. Komarek Education Center
Tall Timbers Research Station
Tallahassee, FL
22 September 2017

The purpose of the workshop is to share information on the Mapping Fires Across Florida project and to gather input from partners in the development of the spatial fire database.

10:00 – 10:10	Welcome to Tall Timbers	Dr. Bill Palmer
10:15 - 10:25	Project Overview	Joe Noble
10:30 - 10:55	Burn Mapping Processes and Tools developed at USGS	Joshua Picotte
11:00 - 11:20	Assessing Areal and Spatial Accuracy of FFS Burn Authorizations	Dr. Holly Nowell
Break		
11:30 - 11:40	Update: Southern Integrated Prescribed Fire Information System	Dr. Kevin Robertson
11:45 – 12:05	USAF Database: The Power of Landscape Analysis of Fire Regime	Kevin Hiers
12:10 - 1230	Database Design and Customized Spatial Queries for Project Requirements	Vince Sclafani
Lunch		
1:30 – 3:00	Moderated Discussion	Brian Branciforte
~4:00	Informal Social and Further Discussion	

Workshop Themes

Presentations and discussions at the workshop were divided into two thematic sessions. The morning session (*Session 1: Relevant and Complementary Technology*) consisted of six speakers addressing the project goals and leveraged data, research, and technology. The afternoon session (*Session 2: Moderated Group Discussion*) was a facilitated brainstorming session and discussion revolving around three main subject areas. The sessions are all summarized below.

Session 1: Relevant and Complementary Technology *Brian Branciforte*

The morning session focused on state-of-the-art technologies for remote sensing research and analyses, as well as current research and findings with regard to the existing datasets that will be feeding the spatial fire database.

Session 1.1
Mapping Fires Across Florida: Project Overview *Joe Noble*

This was a brief introduction to the project, including project purpose and goals. Additionally, the Project Team and collaborators were introduced.

Session 1.2
Burn Mapping Processes and Tools developed at USGS *Joshua Picotte*

This presentation highlighted a partner project that developed a system of automated fire identification and mapping procedures that will be leveraged by this Florida project. LANDSAT datasets are used in conjunction with Monitoring Trends in Burn Severity (MTBS) algorithms in an automated environment to identify and/or locate fire events, and then derive perimeters and severity characteristics. This automated platform will be used in conjunction with prescribed fire permitting data to mine for the additional spatial information that is not currently captured in the permitting process. Examples of the process were shown and participants had opportunities to ask questions.

Session 1.3
Assessing Areal and Spatial Accuracy of FFS Burn Authorizations *Dr. Holly Nowell*

Dr. Nowell presented findings from a complementary validation/accuracy assessment project by FSU and Tall Timbers in which researchers explored the accuracy of the Florida Forest Service burn permit/authorization dataset compared to known burn perimeters from participating land managers and satellite detections. Point data representing burn locations were compared to known perimeters for the same burns. Results highlighted differences between satellite detections and reported locations, although in many cases the FFS permitted locations were located in the fire area. This project showed how partner data could be used to validate FFS and satellite fire detections. Participants had opportunities to comment and ask questions.

Session 1.4
Update: Southern Integrated Prescribed Fire Information System *Dr. Kevin Robertson*

This presentation showcased a Joint Fire Science Project (JFSP) investigation of the relationships between air quality and prescribed fire emissions. The goal of the research was developing a system that compiled prescribed burn and air quality data to inform model simulation of air quality impacts of prescribed burning, and associated health effects of smoke exposure. This team confirmed existing satellite detection of fires was not sufficient for the needs of this project, but that burn authorization data closely tracks area burned using a call-back survey methodology. Online systems for reporting recent burns and for predicting prescribed fire activity were developed. Information needs were also identified by project participants. Workshop participants had the chance to comment and ask additional questions. The Florida fire mapping effort will enhance this JFSP-funded research through integration of higher resolution spatial fire data and could provide methods for filling gaps in states with poor permitting records.

Session 1.5
USAF Database: The Power of Landscape Analysis of Fire Regime *Kevin Hiers*

Mr. Hiers presented the spatial database that Eglin Air Force Base (AFB) utilizes to track their burns. The Oracle database was developed with spatial queries, flexible user interfaces, and real-time web-based reporting in mind. Mr. Hiers discussed the background of the project and its development. Hiers showed useful summary reporting tools and comparisons (including queries, table and graphing capabilities). He also discussed user roles and access and administration of the database, and the spatial outputs of fire characteristics. Partners discussed linkages between how the Eglin AFB system informs the framework for the Mapping Fires Across Florida project. Workshop attendees were able to comment and have their questions answered.

Session 1.6
Database Design and Customized Spatial Queries for Project Requirements *Vince Sclafani*

Mr. Sclafani presented his recent work which involved converting the Eglin AFB Oracle database into a SQL database for the Mapping Fires Across Florida project. He presented the status of the project, including ability to map perimeters, submit queries, and return reports, as well as provide insight into future possibilities for adapting the database. Mr. Sclafani discussed the similarities and differences between the Eglin system and the Mapping Fires Across Florida system. Workshop participants were able to comment and have their questions answered.

Session 2: Moderated Group Discussion *Brian Branciforte, Beth Stys*

Following lunch, this session focused participants on three major topics related to gathering information about existing spatial data and on group engagement in the project. Participants used MeetingSphere online workshop technology to discuss and capture key themes as categorized by the three sub-topics below. This technology is similar to automated note-taking: it facilitates discussion on multiple threads at once while simultaneously allowing anonymous interactions between users. MeetingSphere notes as well as a summary of those notes can be found in the Appendix (see Appendix B and C).

Session 2.1: *Spatial Data*

This discussion focused on the role of collating existing spatial data by agencies and organizations within the state for integration into the Fire Mapping project. Participants were asked to discuss the spatial data/types/formats that they use or possess, their willingness to share the data for this project, main contacts/data stewards for the various entities, and whether or not participants (or their respective organizations) would be willing to help assess/validate our products. Data supplied by partners would be used in a similar validation process as presented by Dr. Holly Nowell, and validated perimeters would be returned to partnering organizations as a quality control check of their spatial data. Summary tables of this discussion can be found in Appendix C.

Session 2.2: *Analysis and Expectations*

This session encouraged participants to identify: how the opportunity to customize output from this project would benefit their organization; repetitive tasks for which the data will used (e.g., reports, tables, graphs); types of reporting/querying of interest; and what is important to them in terms of fire data. Referencing the functionality of the Eglin AFB fire database presented by Kevin Hiers, participants were challenged to articulate their vision of the system's uses and analysis. Key insights from this session are listed below and summary tables and notes can be found in Appendix C.

Key insights from Session 2.2

- Types of analyses and reporting that participants would like to see can be categorized into roughly six broad categories:
    - Fire Effects
    - Fire History
    - Management Objectives
    - Species of Concern
    - Weather
    - Scale-Dependence
- Types of enhancements that participants would like to see include:
    - Data Submission Options
    - Data Request/Query Options
    - Mobile App Development
    - Reporting Options
    - Ability to access/ingest 'outside' data (weather, landcover, species, etc.)
- Reporting requirements differ between organizations

Session 2.3: *Integration and Limitations*

The focus of this discussion was to identify participant recommendations for integration to other data systems and discuss any concerns about system limitations. This discussion included identification of core data fields needed; future merging of databases; non-fire related data needs; and privacy/access concerns. Participants identified three broad categories of integration opportunities and five categories of limitations and concerns. These are summarized below and full breakouts of these categories can be viewed in tables in Appendix C.

Key insights from Session 2.3

- Integration Opportunities:
    - Disturbance Data
    - Fire Data
    - Non-Fire Data
- Limitations/Concerns:
    - Accounting/Analysis
    - Privacy
    - Long-Term Vision
    - Data (Validity/Accuracy/Errors/Metadata)
    - Planning Effort Collaborations

Recommendations

In addition to the details captured in MeetingSphere, presentations and discussions at the workshop led to the following overarching recommendations for moving forward with the Mapping Fires Across Florida spatial database project.

1. Create focus group from workshop participants and others to continue collaborative efforts.
2. Use focal group to perform ecological spatial analyses throughout the development life of the project as fire data are compiled in different regions of Florida.
    a. FNAI and NatureServe have expressed interest in utilizing database and query tools for SALCC burn data.
3. Center reports on Eglin AFB standard analyses of time since burn and fire frequency (keep it simple and focused).
4. Create blog or similar forum for communicating project progress sharing of information.
5. Work with FFS to obtain complete FFS burn authorization records with all tabular data to map into the Fire SQL Database. Current records are not complete (e.g., missing coordinates, need all burn types, duplicates eliminated, etc.).
6. Work with FFS during upcoming revisions of FMIS in 2018; request FFS collect Lat/Long (rather than township/range/section) for location of fires and also gather more accurate burn objectives, etc.
7. Make data easily accessible from SQL for downloads of fire history data by partner organizations.
8. Look to address concerns of how the system will be updated after the life of the project or will it be a one-time thing?

Summary

The workshop successfully provided a project overview, introduction to tools that would be leveraged for project completion, and an opportunity for participants to have a voice in project design moving forward. The open format for dialogue provided meaningful input for data needs and end user requirements and considerations. Discussions, comments, concerns, and suggestions from the workshop will be used to inform the project moving forward. A couple of participants (or their respective organizations) were interested in helping to validate the project and outputs for accuracy. A list of recommendations was compiled by Tall Timbers' staff following the workshop. Workshop presentations, videos, and summaries are available from Tall Timbers.

Appendices

Appendix A: *Workshop Announcement*
Appendix B: *List of Invitees and Attendees*
Appendix C: *MeetingSphere Notes*
Appendix D: *Summary Tables for MeetingSphere Notes*
Appendix E: *Presentations*

Appendix A: *Workshop Announcement*

Tall Timbers Research Station

Mapping Fires Across Florida

Advancement of a Fire Spatial Database

Workshop Date: 22 September 2017

Start Time: Friday @ 10:00 am

Lunch Friday @ 12:00 pm

Adjourn Time: Friday @ 3:00 pm

**Casual Social and discussion* *Friday @ 4:00 pm*

Registration Deadline: Friday, September 15, 2017

Location: Tall Timbers Research Station– *E.V. Komarek Education Center*

Workshop Leads: Joe Noble, Kevin Hiers, Kevin Robertson and Casey Teske

Cost: No cost, snacks/drinks and lunch will be provided.
****** Limited*** *On-Site Lodging is Available:*
Contact Lisa Baggett at or 850-893-4153 Ext. 241

Registration Limit (max): **30**

Meeting Purpose: To share information on the Mapping Fires Across Florida project and to gather input from partners in the development of the spatial fire database.

Project Description: Development of a comprehensive spatially explicit map of fire occurrence remains one of the most critical needs for conservation in the Southeastern US. Not only are the vast majority of Florida's endangered species and ecosystems reliant on frequent fire, but fire risk analysis and fire behavior modeling are sensitive to fire history. Fire occurrence in Florida is currently tracked by approximate location through the Florida Forest Service (FFS) burn authorization system, Fire Management Information System (FMIS). While this system represents one of the most advanced tracking datasets in the country, the system does not record perimeter data or include assessments regarding which burns are actually completed. These data gaps result in errors estimating the size, location and effectiveness of managed fires on a statewide scale. These "actual burned" metrics are critical factors in analyses and models evaluating conservation success.

Tall Timbers Research, Inc., is extending the development of a robust spatial database for more precise mapping and tracking all prescribed fire in Florida. Advanced remote sensing techniques will be applied to known locations of prescribed fires, as identified in the FFS system, to record actual spatial fire boundaries into a modified version of the U.S. Air Force Wildland Fire Database, complete with spatial footprints of all burns. In addition, custom query tools will be developed to report fire history (e.g., frequency, time-since-burn) in specific fire dependent ecological systems or fire dependent species habitats. To tap the potential of this effort, input is required to identify connections to existing fire data management efforts as well as input on key ancillary data, required analysis, and reports that would benefit our partners.

Organized by: Joe Noble, Kevin Hiers, FWC and Peninsular Florida LCC personnel.

Tall Timbers Research Station

***Laptops are highly recommended in order to fully participate**

Mapping Fire Across Florida

Advancement of a Fire Spatial Database

Application Form

Name:________________________________Agency/Organization: ________________________

Address: ____

City:____________________________________State:________________Zip: ______________

Primary Phone:______________________________Cell Phone: __________________________

**Email Address[1]: ____

Will you be bringing a laptop? __________________________

Registration is due by Friday, 15 September 2017
For more information: call (850) 510-9248 or E-mail Jnoble@talltimbers.org

Send this registration to:

Joe Noble,
13093 Henry Beadel Drive, Tallahassee, FL 32312
***or* …. fax it to: (850) 906 - 0837**
***or* …. E-mail: jnoble@talltimbers.org**

***If you can't attend and feel someone else would be appropriate to represent your organizations interest, please ask them to register in your place.*

[1] Email will be the primary means of correspondence for this workshop and dissemination of updates, etc.

Appendix B: *List of Invitees and Attendees*

List of Invitees and Attendees. ***Attendees*** and *remote attendees* are denoted by bold/italic or italic fonts below.

First	Last	Organization	Email
Scott	Goodrick	USFS	sgoodrick@fs.fed.us
Mike	Housh	USFWS	mike_housh@fws.gov
Steve	Laine	Eglin AFB	stephen.c.laine@gmail.com
James	Furman	USFS AF Liaison	jameshfurman@fs.fed.us
David	***Godwin***	***UF***	***drg2814@UFL.EDU***
Talat	Odman	Ga Tech	talat.odman@ce.gatech.edu
Zach	Prusak	TNC	zprusak@tnc.org
Jason	Drake	USFS	jasondrake@fs.fed.us
Dan	Frisk	USFWS	dan_frisk@fws.gov
Rickie	White	Natureserve	rickie_white@natureserve.org
Carl	***Nordman***	***Natureserve***	***Carl_Nordman@natureserve.org***
David	***Johnson***	***FWC***	***David.johnson@myfwc.com***
Brian	***Camposano***	***FFS***	***Brian.Camposano@freshfromflorida.com***
Amy	***Knight***	***FNAI***	***aknight@fnai.fsu.edu***
John	Fish	FFS	John.Fish@freshfromflorida.com
Caroline	Noble	USFS	cnoble@firenet.gov
Caroline	***Gorga***	***PFLCC***	***caroline.gorga@myfwc.com***
Jenny	***Redner***	***FWC***	***jennylyn.redner@myfwc.com***
Steve	Traxler	PFLCC	steve_traxler@fws.gov
Rua	Mordecai	SALCC	rua@southatlanticlcc.org
Heather	Hitt	FWC	heather.hitt@myfwc.com
John	Sadler	FFS	John.Saddler@FreshFromFlorida.com
Josh	Picotte	EROS	joshua.picotte.ctr@usgs.gov
Vince	***Sclafani***		***vince.sclafani@gmail.com***
Steve	Coates	TNC	steve.coates@tnc.org
Jim	Smith	TNC/LANDFIRE	Jim_Smith@tnc.org
Internal			
Brian	***Branciforte***	***FWC- Facilitator***	***brian.branciforte@myfwc.com***
Beth	***Stys***	***FWC***	***beth.stys@myfwc.com***
Kevin	***Hiers***	***TTRS***	***jkhiers@talltimbers.org***
Kevin	***Robertson***	***TTRS***	***krobertson@ttrs.org***
Casey	***Teske***	***TTRS***	***cteske@talltimbers.org***
Bill	***Palmer***	***TTRS***	***bpalmer@talltimbers.org***
Joe	***Noble***	***TTRS***	***jnoble@talltimbers.org***
Suggested			
Justin	Shedd	NC State	justin_shedd@ncsu.edu
Susan	***Kett***	***USFS***	***skett@fs.fed.us***
Lane	***Green***	***Retired***	***lanegreen44@gmail.com***
Holly	***Nowell***	***FSU***	***hak07@my.fsu.edu***
Jana	***Mott***	***TNC***	***jmott@tnc.org***
Greg	***Seamon***	***PFTC***	***gseamon@talltimbers.org***
Monica	***Rother***	***Tall Timbers***	***mrother@talltimbers.org***
Other			
Ivor	***Kincaide***	***Alachua Conservation Trust***	***act.landmanager@gmail.com***
Lucas	***Furman***	***Longleaf Alliance***	***lucas@longleafalliance***
Travis	***Pollard***	***USFWS St. Marks***	***travis_pollard@fws.gov***
Daniel	***Sullivan***	***FWC***	***daniel.sullivan@myfwc.com***
Remote			
Andrew	*Bailey*	*USFS*	*andrew_bailey@nps.gov*
Todd	Hawbaker	EROS	tjhawbaker@usgs.gov
Caroline	*Noble*	*USFS*	*cnoble@firenet.gov*

Appendix C: *MeetingSphere Notes*

Report Florida Fire Database Partner Workshop
- summary -

Date	September 22, 2017
Location	TTRS
Facilitator	Beth Stys

Participants

Beth Stys
Dan Sullivan
David Johnson
Caroline Noble
Amy Knight
Brian Camposano
Kevin Hiers
Lucas Furman
Monica Rother
Joshua Picotte
David Godwin
Joe Noble
Holly Nowell
Travis Pollard
Jennylyn Redner
Caroline Gorga
Carl Nordman
Ivor Kincaide
Jana Mott

1.1 Presentation (Presentation)

Presenter

Beth Stys

Spatial Data

- What kind of fire data do you have (e.g. blocks, format, fire history, GIS, etc.)?
- Would your organization be willing to share fire data to assist us in the project?
- If so, who is your organizational contact?
- Would you review draft products we produce for quality assurance?

Analysis and Expectations

- How would a project as presented today benefit your organization?
- What are examples of repetitive tasks that you use your fire data for (e.g. burn prioritization, smoke, accomplishment reporting, etc.)?
- Are fire data used in decision making at your organization?
- What are your reporting requirements?
- What reporting would you use (e.g. acres by habitat type, number of fires by type, prescribed vs. wildfire acres, acres by species of concern, etc.)?
- Does fire severity matter?

Integration and Limitations

- Do you see the potential for products produced by this effort to integrate into a larger operating structure?
- What are the absolute core data fields for burn events that should be common across the state?
- What non-fire data are necessary to associate with burn events (e.g. weather, wind, transportation networks, etc.)?
- How should this system work long-term with the FFS permitting data?

2.1 Spatial Data (Brainstorm)

Number of participants: 17

Participant instructions:

Please add information regarding spatial data about fires in Florida
Provide type of data, contact information (person, phone/email), or website
All contributions are anonymous.

Not categorized (29)

- **1. we have a geodatabase of treatment data that includes prescribed fire.**
  - National Forests (#15)
- **2. spatial data representing partnership RX fire activity often require digitization from jpg/map form when recieved from private landowners.**
  - How large a partnership? (#10)
  - yes will help with validation (#13)
  - Local Implementation Teams (17 within the longleaf range) range from several hunder thousand to over 6 million acres (#40)
- **3. Contct person for FWC is Dan Sullivan**
  - or David Johnson (#4)
- **5. TNC has spatial data on Rx fire from our properties throughout the state. Initial contact would be Zach Prusak - zprusak@tnc.org. Amount of data associated with each burn varies.**
- **6. We have some data on unburned areas within burn perimeters (Tall Timbers). Do other organizations have this type of data?**
- **7. How large a partnership?**
- **8. Water Management Districts have land management databases that include fire. NWF and SJR use similar database so would have consistent data across their lands. Challenge may be getting data out into format for the TTRS fire database. Contact: NWF Danny Layfield**
  - Fl Water Management districts also have landcover data to give an idea of what vegetation types are present. Good for large scale land management. (#22)
- **9. We will be willing to share whatever spatia data have to help populate the various data fields you are targeting. Private landowner partner information will have to be with thier permission. (ACT)**
- **11. offering an APP allowing for easy submission of burn parameters/spatial location accessible via mobile device could facilitate capturing private RX (Ex: ED Maps/I've got one)**
  - Would love to see Florida Burn Tools App include things like this. IT needs some work (#39)
- **12. We have FMIS and would be happy to share data, despite its limitations. John Saddler would be the POC. On the individual property level, each area (should) have a geodatabase tracking burns, though what is recorded might be somewhat limited. That data should be able to be shared as well - but is not in a centralized location (yet)**
  - I (Brian) can be a POC as well, especially for state forests. (#33)
- **14. NRCS and NFWF cost share program records**
- **16. Florida Rec and Parks has fire data - contact = Sasha Ernst; brand new to job....may take awhile**
- **17. What about future potential to use drones to document fires post-burn? Imagery processing could readily extract fire polygon. Are any agencies/groups considering drones in land management?**
  - This is something that Tall Timbers is actively pursuing with both academic and government partners. Casey is a registered pilot. (#23)
  - According to Florida State Law (presently) any agency with law enforcement responsibilities are prohibited from drone use without a warrant. At least that's what I understand. Because we are missing opportunities to use for aerial ignition as well (#24)
- **18. University of Florida properties Austin Cary Forest and Ordway Swisher Biological Station have extensive fire history records. Andy Rappe (OSBS) and Scott Sager (ACF) have those data.**
- **19. One of the questions was: Would you review draft products we produce for quality assurance?**
  - Yes FWC will help with reviews. (#27)
  - I want to say yes to this (FFS), at least for state forest burns. But would be very hard to do for each forest from the state level and not sure the workload it would put on the field staff. (#29)

- **20. Counties with active land management programs?**
- **21. Contact for Nationa Forests is Susan Kett skett@fs.fed.us**
- **25. Working with agency contacts involved in prescribed burn associations (PBAs) could be an avenue for encouraging engaged private landowners to submit supplemental data on prescribed fires on private lands.**
- **26. Florida's Wildlife Legacy Initiative provides grants to fire strike teams, and there could be data from the actions of these teams.**
  - The FFS Strike Team should have this data from their work (#34)
  - The FFS team has shapefiles, but the other SWG-funded strike teams may not...we might be able to get Google Earth files from WRI. Habitat type data is reported by the FFS Team. (#43)
- **28. Archbold Biological Station - contact Burt Crawford or Eric Menges**
- **30. Pebble Hill burn units from 1994 to 2008. Also Allan Tucker has been keeping track but without GIS. Could get info from other local landowners as well in the Red Hills Region. We have Disney Wildernesrs Preserve burned areas for several years. We have within-unit GPS data for several burns on Tall Timbers.**
- **31. Ask partnerships (Ex: LIT's) to compare records with working knowledge of the landscape. This would help identify data "holes" and capture outliers**
- **32. Tim Elder has burn boundaries (vector) for fires >2ac in the Okeechobee field unit going back several yrs. Tim.Elder@FreshFromFlorida.com.**
- **35. Corkscrew Swamp Sanctuary - Scott Svec is the Resource Manager. Or try Jason Lauritsen, the Sanctuary Director.**
- **36. Does PFTC have records on where they have conducted burns statewide?**
- **37. PFTC answer to question 36 - yes, PFTC has records but they are extremely limited and better data are probably available from the host sites.**
- **38. Sue Wilder is a regional contact for USFWS for burned areas data.**
  - Josh O'Connor as well (#44)
- **41. This may be way too much to hope for, but if there was a way to see or access your own data, that would encourage participation**
- **42. Tall Timbers is considering using drone data to get within-unit burned area.**

3.1 Database Expectations (Brainstorm)

Number of participants: 17

Participant instructions:

Provide comments/suggestions

What do you want to see included in the database, what type of queries would be useful, other suggetions.

All contributions are anonymous.

Not categorized (35)

- **1. It would be great to have better fire history information to ask research questions regarding fire-vegetation feedbacks.**
- **2. Use in conjunction with other ecological data to help establish restoration priorities, locally or on a larger landscape scale.**
  - Habitat type, burn severity, burn intensity would be helpful for this query when available. (#4)
  - offer the option for more in depth data submissions to support proactive management objectives. (#11)
  - I second the burn severity and burn intensity (if possible). This would be helpful to determine the likelihood of satellite detection for a given fire. (#23)
- **3. management objective - specifically related to species/ecotype and whether site prep/maintenance etc.**
- **5. the ability to see not only years since last fire but also the fire frequency (how many fires over last X period of time). Ability to sort by natural community/landcover would be necessary.**
  - Cooperative Land Cover Map - show burns based on the land cover classes used by the CLC (at least Tier II). Species - not just the federally listed species. (#15)
- **6. It would be valuable for researchers to be able to export and download spatial and attribute data within defined AOIs and for specific time periods, ecoystem types, etc.**
- **7. PFTC reporting requirements: land manager of property being burned, date, acreage, WUI acreage, fuel model, trainees on the burn and position, and ptb tasks accomplished.**
- **8. cost/benefit could be a potential use - would need fields to track personnel and equipment.**
  - These functions are native to the current system, but just need to be activated in a way that meets user goals (#24)
- **9. Summary reports based on criteria and AOI similar to the Eglin database presented earlier.**
  - I agree. Providing an easy way to access/download data for a specific AOI to support conservation planning and assesment projects. (#34)
- **10. LANDFIRE maintains a database of all disturbances on a yearly basis. A centralized database of fires in Florida would greatly improve LANDFIRE's disturbance products, in showcasing fire events (i.e. prescribed fires) that are difficult to map using LANDFIRE's current methodologies.**
  - Perhaps include Landfire representative on this project, with goal of compatibility. (#38)
- **12. I am interested in fire history information in the distant past (i.e., many decades ago). If this type of information, regardless of its inaccuracies and limitations, might be available, that would be great. Encouraging folks to digitize their old paper files would be great.**
- **13. Ability to include spatial precision of source data, for example is burn data for an entire management unit vs burn block vs actual burn perimeter.**
- **14. As many agencies have spent consderable resources developing their databases, it would be important for this program to be flexble to allow for import of data fom different data sources/types (have script that standardizes variable names, etc).**
  - i agree! what other systems are out there that we should be thinking about trying to link to/access? (#19)
- **16. Our data is used by area managers to help inform management decisions, provide context for habitat condition assessments, review and monitoring of fire programs progress, numerous reports both internal and external.**

- **17. RX fire data used internally to track accomplishments at state level (acres burned). Field staff use RX fire data locally to look at things like time since fire, date of last burn/seasonality. But beyond that, not a ton of data is collected. In order to get people to buy in to collecting more data, they need a way to collect it quickly and more importantly, need to understand why it's being requested and why it's important.**
  - A mobile app connected to the burn authorization system could address this issue? (#21)
  - this would faciliate data entry from field staff lacking access to other spatial products (#25)
  - There is a mobile app currently, but it does not do what I think people in the group want it to do. (#32)
- **18. Any ground/person-truthed data could help with error analyses of National Datasets (e.g. BAECV).**
- **20. An API for data to be called upon by future 3rd party web apps and mobile apps.**
  - should there be a mobile app for this? burn permitting? (#22)
  - I was thinking for use in other programs like IFTDSS. (#28)
- **26. Query - current ecosystem type and historical ecosystem type. It would be interesting, for example, to pull up all current upland longleaf sites and also all sites that were once upland longleaf.**
- **27. At Tall Timbers we use our fire data for planning burns and recording burn history for wildlife management as well as research, including effects of fire regime, scale of burn effects on wildlife, and validation of remote sensing of fire and burn authorizations.**
- **29. Useful queries would be by fire intervals, landcover / habitat class, intesity**
- **30. At Tall Timbers I am conducting an analysis that is relating weather to completeness of burn, based in part on our GPS data of area burned within units but also based on post burn evaluations which used**
  - Perhaps some inclusion of fields such as temperature, humidity, and cloud cover during the burn could be helpful. This could be pulled historically from reanalysis data. (#35)
- **31. GPS points within the units, about one per acre, describing fire effects.**
- **33. Interface/App for managers to enter/upload burn data**
  - ArcCollector app (#37)
- **36. A way to track weather data associated with burn events could be useful data - link to spot weather forecast, and ability for site-specific staff to provide burn day weather obs. (not many would do this, but could be useful for research oriented organizations or properties.)**
  - Could also call up PDSI, KBDI, or other drought / fire weather indices for the geographic area. (#40)
- **39. Spatial query such as the example shown for flatwoods salamander areas would be useful for many applications.**
- **41. Site condition and current management objective would help cost-share and other support mechanisms identify support targets**
- **42. I just think it is important to remind that any data you want should be justifiable, especially if you want good data. Many different burn/manageent objectives, ownerships, etc. Data just for the sake of data has its pitfalls.**
- **43. Time since burn by agency lands, conservation ownerships, public vs. private, teasing out public and private burn trends**
- **44. Need to be able to use the FNAI habitats types.**
- **45. Habitat analysis: silviculture vs. ecological burning; burning by objective. Plant community associations.**
- **46. different landcover maps -- what are they if you don't use the cooperative landcover map?**
  - If lat/long are present, you could always extract the landcover from whatever landcover map was deemed the most useful. (#47)
- **48. biggies that we should be tracking statewide against: wildlife species of concern (Gopher toroise habitat, RCW, panther, black bear, etc....), habitat types, etc..... do we need to go down this track? stay focussed!! private landowners may be reluctant to list spp of concern...**
- **49. have some optional fields so that folks can answer without changing integrity of data**

- **50. coarse goal for this project: knowing dominant pine spp of an area would be useful for a lot of people**
  - any opportunity to look at Long Leaf seems to have a big pot of $$$ (#51)
- **52. How do you want to access the data? (options you would like to see??? user friendly!!!!!! easy summaries for an owner.**
- **53. view vs. download of data.... research q's vs mgmt q's.... etc.**
  - I would like to have an easy to find way to get data for a specified date range for the whole state (or a subset) into a geodatabase or at least a shapefile. Some sites make it difficult to find how to do this and often require manipulation of a map/GUI for subsetting. (#54)

4.1 Integration and Limitations (Discussion)

Number of participants: 13

Participant instructions:

Provide input on known or potential integration opportunities and limitations/concerns

All contributions are anonymous.

Integration opportunities

- Non-fire data: management activities such as herbiciding, tree planting, mowing, thinning, storm damage, etc. - - - anything that affects fuels (#2)
  - This is particulartly important as the effects of herbicide look similar to fire detections using TM. Need some good herbicide treatment boundaries to help interpret probability of false detections. (#8)
    - not all entities collect the same data (ex. fire severiy data). As such, the system will need flexibility to allow people to enter the data they have, but skip fields they do not have. (#28)
  - Could use the disturbance categories used by Landfire, which could ease the integration of data on these non-fire disturbances which Landfire is interested in. (#20)
- I think the system could be expanded for use by other organizations if it is online, slick, and user friendly. (#3)
  - Agreed - recording if the burn was performed under specific private landowner assistance program etc. (#14)
- Need to ensure database collects information provided when authorization is received. (#4)
- Core information needed: location, date, acres burned (#5)
- Need to provide clear instructions for collection of geospatial data. E.g. Where should the lat/long be collected/appoximated for each fire? (#6)
- I agree. with comment on collecting data when authorization is received or immediately after burn. If the time since fire is too long, folk's memories and records are likely to be weaker. (#7)
- Need to ensure data from existing databases can be integrated. (#9)
- Time since last fire also very important for estimating fuel load, consumption, fire behavior, and emissions. Timber type and stand density or basal area would be very helpful for estimating fuel type and loading. (#10)
- integration regionally with data fire spatial data from other states. (#11)
- Could potentially try to make sure that the database contains fields necessary for integration with National Databases. (#16)
  - Such as Landfire disturbance data for wildland fire (#50)
- Non fire data to pull: parcel, soils, waterbodies, wetlands, roads, natural community type etc. (#17)
- Most of the fileds that are required legally in Florida for a burn prescription should be included. (#19)
- Requirements for providing location of burn as part of authorizations could be stricter. Either a LAT LONG within the unit or ability for the requester to draw his or her own point or unit online real time while talking to the dispatcher would be ideal. I think there is this capacity with online burn authorization requests in Florida. (#21)

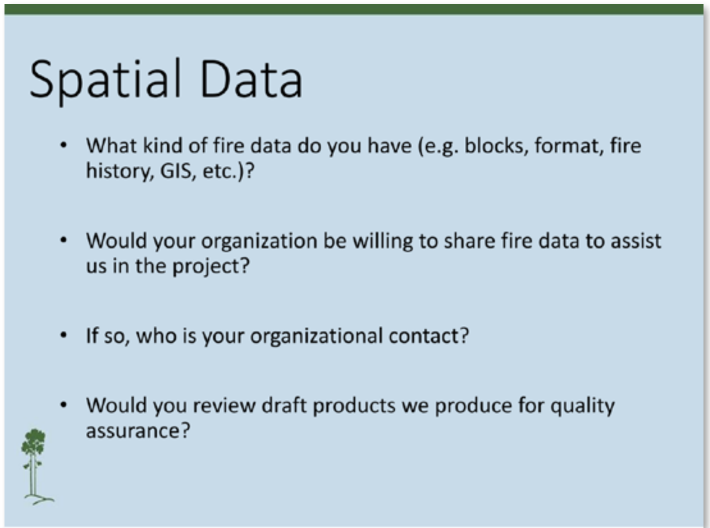
- FFS could randomly call back people, or subcontract this to an interested non-profit or grant-funded project, to at least calibrate the accuracy of data. Odman et al. did this as part of their SIPFIS project but more could be done. (#27)
  - YES!!! (#30)
  - Should then also ask about patchiness of burn and other fire effects type questions that aren't known at time of authorization (#34)
  - I can say this would be a VERY HARD sell to FFS upper management. Stretched way too thin already and concerns about invasion of privacy to private landowners. I would love to see more information collected and/or what is suggested here, but it can start feeling like a "big brother" type thing, regardless of the intentions. (#48)
- It seems like property parcel data are unutilized, even though they are public domain and exist as GIS data for most if not all counties. It seems like they should be a layer in fire databases to make better guesses about the perimeters of fires. (#37)
- An address and acres to be burned could serve as a general location for data providers that are not able to map the locations, or are not famiiar with TRS land surey location. Points could be derived from addresses. (#44)
- National Landcover Dataset (NLCD) is updated every 5 years, and uses a standard nationwide legend, it is broad, but would be good to include, for instance 2001, 2006, 2011, 2016, etc. The eBird data includes a set of envirnmental variables, which would be worth looking at, if you want to use anillary environmental or vegetation data. (#49)

Limitations/concerns

- What will be the long term plan to keep the system functioning? (#1)
- There are some fires detected by satellites and reported in datasets that do not have an associated burn authorization. These may be fires occuring with no authorization, an authorization that was not reported, or a false signal. How should these cases be handled? What is an efficient way to do this? (#12)
  - FFS burn authorizations are likely capturing most true RX burns. False positives are probably more of an issue from satellite data (small heat sources, pile burns, bonfires/campfires). Most illegal burns get reported. (#31)
    - Is there a way to get access to the illegally reported burns for inclusion? This may not be an issue depending on how many acres are illegally burned compared to those that are burned with a permit. (#41)
      - FMIS tracks not only RX burns, but wildfires and any "response" FFS takes (Smoke complaint, on site inspection, illegal burn, etc.). Not sure, but believe it is all public record and should be obtainable upon request. (#46)
- With rangewide interest in longleaf restoration this would be a great tool to tie in those planning efforts. Consider how this can integrate across the southeast. Example: coordination with Landfire, etc (#13)
  - Coordination with National products would really help the quality of National products and potentially provide more impetus for the projects continuation. (#26)
- this system must consider what data already exists (actually review example data from entities willing to share), and use that to determine what core atributes CAN be in the statewide dataset, and what it would take to make these existing data compatible. (#15)
- Concern: Who has access to raw data? Worried about bean counters looking at cost per acre for other entities and basing funding on those numbers. (#18)
- What data can be shared and what is private? E.g. some data owners may only share data if they know it will not be part of the public (e.g. geospatial) record. (#22)
  - This is big reason that FMIS is limited in what is collected (#36)
  - FL has a high acreage of public lands whose information is already part of public record. Starting with lands that have fewer privacy concerns would help to provide examples to private landowners and give accurate recommendation on privacy. (#39)
  - If necessary maybe offer a "granularized" dataset if privacy becomes an issue? Who would be asking for data beyond planning/management organizations willing to sign data privacy agreements? (#40)
- It would be helpful to collect metadata about where each data point comes from and tracking its estimated accuracy - whether from burn authorizations, remote sensing, etc. (#23)
- Are burn authorizations on private lands already publicly available information? (#24)
- Its not clear right now how much of the database is expected to be confirmed burn perimeters vs burns derived from remotely-sensed data. How will database handle various types of fire representation? (#25)
- Need some sort of validation for remotely-sensed burned areas. (#29)
- Concerned that data will be used to decide on what is being managed appropriately based solely on fire records. True determination of condition of habitats requires measurement of vegeation parameters over time. (#32)
- Is project operating in phases? For example might there be a roll-out based on integration & crosswalk of existing burn data, followed by remotely-sensed outputs? (#33)
- If burns are on private lands, ownership contact information may need to be protected or scrubbed from the database for privacy concerns. (#35)
- We should not pretend to get all the fires all the time, but focus on ways to make better statisical approximations for geographic units at a scale of interest. (#42)
- Promote database in very clear terms of benefits. Use language that is straightforward, non-technical to get buy-in, support so managers will want to participate. (#43)
  - YES (#45)

- At Tall Timbers we have our own habitat maps, including things like "upland pine" which is burned at least biennially, "field", "drain" (bottomland or other hardwood area that does not burn well), "water/wetland", and research plots. (#47)

Appendix D: *Summary Tables for MeetingSphere Notes*



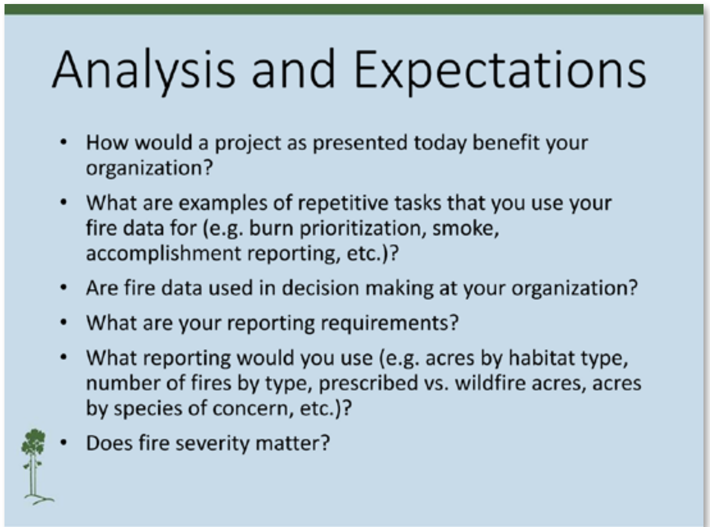
Who has geospatial data, type, contact, etc.? Or, who else should we consider contacting?

Agency/Organization	Type of data	Contact	Notes
USFS	Treatment Geodbase	Susan Kett skett@fs.fed.us	Includes rx
FWC		Dan Sullivan, David Johnson	
TNC	Geospatial rx data	Zach Prusak zprusak@tnc.org	
TTRS	Unburned area w/in perim	Kevin/Kevin/Joe	GPS data w/in unit on TTRS also
Partnerships	Jpg/map of rx		Need to digitize
Water mgmt. districts (NWF, SJR)	Land mgmt. dbase	Danny Layfield	Includes fire and landcover
State Forests (?)	FMIS, geodbase	John Saddler, Brian	Each property has various states of geodb of rx fires
Florida Rec & Parks	Fire data	Sasha Ernst	
UF (Austin Cary Forest, Ordway Swisher BS)	Fire history	Andy Rappe (OSBS) Scott Sager (ACF)	
FFS Strike Team	.shp		Habitat type recorded
WRI	.kml/.kmz		
Archibold Bio Station		Burt Crawford, Eric Menges	
Okechobee Field Unit	Burn boundaries (vector)	Tim Elder Tim.Elder@FreshFromFlorida.com	>2ac
Corkscrew Swamp Sanctuary		Scott Svec, Jason Lauritsen	
USFWS		Josh O’Connor, Sue Wilder	

Other considerations to contact for possible data			
Prescribed Burn Assocations			
ACT	Misc		
Fl Wildlife Legacy Initiative			
PFTC			Probably better data from the host sites
Pebble Hill		Alan Tucker	Rx units 1994-2008; other info from landowners in the Red Hills possible; Disney Wilderness Preserve burned areas possible
NRCS, NFWF			Cost share program records

The following offered to QA/QC draft products:

- FWC
- FFS



Types of analyses particpants would like to be able to do include:

Major Category	**Sub Category**	**Notes**
Fire Effects Questions		Need post-fire data/points/descriptions
Fire History Questions		Fire/vegetation feedbacks
	Habitat Type/class	Need ability to use FNAI habitat types
	Burn Severity	
	Burn intensity	
	Time since previous fire	
	Fire Frequency (# of fires)	Ability to set 'time window' of interest
	Land cover	Cooperative landcover map -- show burns based on the land cover classes used by the CLC (at least Tier II)
	Natural community	Include plant community associations
	Fire history as far back as it goes	Even if it means digitized data, encouraging folks to enter/digitize old data
	seasonality	
	Fire intervals	
	Completeness of burn	
Species of concern		Wildlife species, plant species, habitat types
Management Objectives		
	Species	Not just federally listed species
	Ecotype	
	Site Prep vs. Site Maintenance	
	Public v. private	
	Silvicultural vs ecological	
	Maintenance vs restoration	

Weather Questions		
	Temperature	
	RH	
	Cloud Cover	
Scale-dependence questions	Fire effects	effects of fire regime, scale of burn effects on wildlife, and validation of remote sensing of fire and burn authorizations

Types of reporting requirements include:

Participant/Agency	Notes
PFTC	reporting requirements: land manager of property being burned, date, acreage, WUI acreage, fuel model, trainees on the burn and position, and ptb tasks accomplished
Others	Summary reports based on criteria and AOI similar to the Eglin database
	Providing an easy way to access/download data for a specific AOI to support conservation planning and assessment projects.
	help inform management decisions, provide context for habitat condition assessments, review and monitoring of fire programs progress, numerous reports both internal and external
	Accomplishment Tracking (acres burned x type [rx, wildfire, etc.])
	Trends through Time

Types of “enhancements” particpants would like to be able to do include:

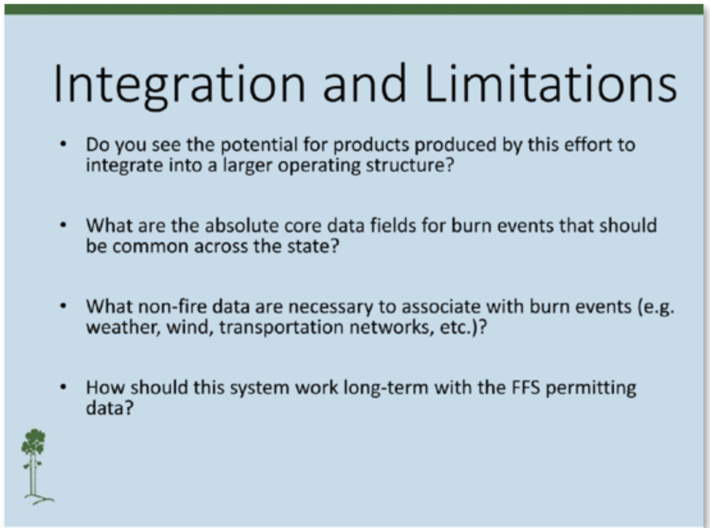
Major Category	Notes
In Depth Data Submission options	to get people to buy in to collecting more data, they need a way to collect it quickly and more importantly, need to understand why it's being requested and why it's important
Research accessibility	Export/download spatial and attribute data within defined AOIs and for specific time periods, ecosystem types, etc.; easy-to-find way to get data for a specified date range for the whole state (or a subset) into a geodatabase or at least a shapefile. Some sites make it difficult to find how to do this and often require manipulation of a map/GUI for subsetting.
Spatial precision options for source data	is burn data for an entire management unit vs burn block vs actual burn perimeter?
Apps	Mobile compatible; ArcCollector App; submit burn parameters/data (ex: ED Maps); Florida Burn Tools App compatabilty/integration; enter/upload burn data. A mobile app connected to the burn authorization system must be quick, explain *why* data are needed/how to be used; this would facilitate data entry from field staff lacking access to other spatial products; There is a mobile app currently, but it does not do what I think people in the group want it to do.
UAS	Data push/pull
Cost/Benefit Reporting	Need to track personnel/equipment/acres/etc.; Site condition and current management objective would help cost-share and other support mechanisms identify support targets

Import/ingest data from other formats	Scripts, Apps, APIs
Different 'levels' to choose from for reporting out	State, region, local unit, subunit, etc.
APIs	for data to be called upon by future 3rd party web apps and mobile apps (e.g. IFTDSS)
Queries	Current v. historical (ecosystems, fires, etc.); spatially defined (boxes, points, radius, etc.); species defined (flatwoods salamander area; RCW habitat; longleaf pine historic area, etc.)
Weather	link to spot weather forecast, and ability for site-specific staff to provide burn day weather obs (see FireWeather Calculator, other apps); Could also call up PDSI, KBDI, or other drought / fire weather indices for the geographic area (LANDFIRE provides 'daily' KBDI grid for SE, would need to be 'truthed').
Landcover	Multiple options, depending on organization – ability to choose which one to use
Optional fields	User-defined 'notes', etc.
Easy summary options	e.g., reports

OTHER:
LANDFIRE maintains a database of all disturbances on a yearly basis. A centralized database of fires in Florida would greatly improve LANDFIRE's disturbance products, in showcasing fire events (i.e. prescribed fires) that are difficult to map using LANDFIRE's current methodologies.

- Perhaps include Landfire representative on this project, with goal of compatibility

Any ground/person-truthed data could help with error analyses of National Datasets (e.g. BAECV)



Integration Opportunities

System or Type of Data	Category	Notes
Disturbance Data		Need Boundaries of treatments; need flexibility for entering data as not all entities have same requirements for collection/reporting
	Herbicide	
	Planting	
	Mowing	
	Thinning	
	Storm Damage	
	LANDFIRE Disturbance Categories	Could ease integration with other systems
Fire Data		Core info req'd: location, date, acres burned; NEED CLEAR INSTRUCTIONS FOR DATA (e.g., where should lat/long be collected for each fire?); time limits for reporting 'accomplishment' or 'completion' of burn
	Burn Authorization Info	When received, #, if completed, etc.
	"stricter" location info requirements	Either a LAT LONG within the unit or ability for the requester to draw his or her own point or unit online real time while talking to the dispatcher would be ideal. I think there is this capacity with online burn authorization requests in Florida
	Time since last fire	Can help estimate fuel load, consumption, fire behavior, emissions

	Regional fire data	For regional integration w/ other states
	“Field Compatability”	Ensure database contains fields necessary for integration with National Databases
	“Required by Florida” fields	Fields required legally for burn prescription should be included
	Calibration/Accuracy	FFS could randomly call back people, or subcontract this to an interested non-profit or grant-funded project, to at least calibrate the accuracy of data; Should then also ask about patchiness of burn and other fire effects type questions that aren't known at time of authorization; this would be a VERY HARD sell to FFS upper management. Stretched way too thin already and concerns about invasion of privacy to private landowners. I would love to see more information collected and/or what is suggested here, but it can start feeling like a "big brother" type thing, regardless of the intentions
Non-Fire Data	Timber type/stand density/basal area	Helpful for estimating fuel type/model and loading
	Property/Parcel	It seems like property parcel data are unutilized, even though they are public domain and exist as GIS data for most if not all counties. It seems like they should be a layer in fire databases to make better guesses about the perimeters of fires; An address and acres to be burned could serve as a general location for data providers that are not able to map the locations, or are not familiar with TRS land survey location. Points could be derived from addresses
	Soils	
	Waterbodies	
	Wetlands	
	Roads	
	Natural communities	

	National Landcover Database	updated every 5 years, and uses a standard nationwide legend, it is broad, but would be good to include
	e-Bird	data includes a set of environmental variables, which would be worth looking at, if you want to use ancillary environmental or vegetation data

Limitations/Concerns

<table>
<tr><th>Category</th><th>Notes</th></tr>
<tr><td>Accounting/Analysis</td><td>o Who has access to raw data? Worried about bean counters looking at cost per acre for other entities and basing funding on those numbers.
o Concerned that data will be used to decide on what is being managed appropriately based solely on fire records</td></tr>
<tr><td>Privacy</td><td>o Who has access to raw data?
o What data can be shared and what is private? E.g. some data owners may only share data if they know it will not be part of the public (e.g. geospatial) record.
▪ Starting with lands that have fewer privacy concerns would help to provide examples to private landowners and give accurate recommendation on privacy.
▪ If burns are on private lands, ownership contact information may need to be protected or scrubbed from the database for privacy concerns
o If necessary maybe offer a "granularized" dataset if privacy becomes an issue? Who would be asking for data beyond planning/management organizations willing to sign data privacy agreements?</td></tr>
<tr><td>Long-term Vision of / for System</td><td>o What is plan to keep it functioning?
o Is project operating in phases? For example might there be a roll-out based on integration & crosswalk of existing burn data, followed by remotely-sensed outputs?
o We should not pretend to get all the fires all the time, but focus on ways to make better statisical approximations for geographic units at a scale of interest
o Promote database in very clear terms of benefits. Use language that is straightforward, non-technical to get buy-in, support so managers will want to participate</td></tr>
<tr><td>Data Validity/Accuracy/Errors/ Metadata</td><td>o How to handle Omission/Comission errors (e.g., satellite detect without corresponding burn authorization #.)
• FFS burn authorizations are likely capturing most true RX burns. False positives are probably more of an issue from satellite data (small heat sources, pile burns, bonfires/campfires). Most illegal burns get reported
• Is there a way to get access to the illegally reported burns for inclusion? This may not be an issue depending on how many acres are illegally burned compared to those that are burned with a permit
• FMIS tracks not only RX burns, but wildfires and any "response" FFS takes (Smoke complaint, on site inspection, illegal burn, etc.). Not sure, but believe it is all public record and should be obtainable upon request
o Collect metadata about where each data point comes from and tracking its estimated accuracy - whether from burn authorizations, remote sensing, etc.
o It’s not clear right now how much of the database is expected to be confirmed burn perimeters vs burns derived from remotely-sensed data. How will database handle various types of fire representation?
• Need some sort of validation for remotely-sensed burned areas</td></tr>
</table>

Planning Effort Collaborations	o Range wide interest in longleaf restoration—this would be a great tool to tie in those planning efforts. Consider how this can integrate across the southeast o Coordination with National products would really help the quality of National products and potentially provide more impetus for the projects continuation o what data already exists (actually review example data from entities willing to share), and use that to determine what core attributes CAN be in the statewide dataset, and what it would take to make these existing data compatible

Appendix E: *Presentations*

Mapping Fires Across Florida Workshop

Advancement of a Fire Spatial Database

22 September 2017

TALL TIMBERS

FLORIDA FISH AND WILDLIFE CONSERVATION COMMISSION

PENINSULAR FLORIDA LANDSCAPE CONSERVATION COOPERATIVE

Agenda

10:00 – 10:10	Welcome to Tall Timbers	Dr. Bill Palmer
10:15 - 10:25	Project Overview	Joe Noble
10:30 - 10:55	Burn Mapping Processes and Tools developed at USGS	Joshua Picotte
11:00 - 11:20	Assessing Areal and Spatial Accuracy of FFS Burn Authorizations	Dr. Holly Nowell
Break		
11:30 - 11:40	Update: Southern Integrated Prescribed Fire Information System	Dr. David Godwin and Dr. Kevin Robertson
11:45 – 12:05	USAF Database: The Power of Landscape Analysis of Fire Regime	Kevin Hiers
12:10 - 1230	Database Design and Customized Spatial Queries for Project Requirements	Vince Sclafani
Lunch		
1:30 – 3:00	Moderated Discussion	Brian Branciforte
~4:00	Informal Social and Further Discussion	

Mapping Fires Across Florida

- Develop a spatial database to track prescribed burns conducted in Florida
- Database will be a modified extension of US Air Force Wildland Fire Database
- Remote sensing techniques will be applied to known locations of fires to record actual spatial fire boundaries
- Populate database spatial boundaries with a minimum of 10 years of FFS FMIS burn permitting data
- Develop custom query tools (e.g. fire frequency, time-since-burn) in specific fire dependent ecological systems or fire dependent species habitats.
- Develop procedures for annual updates to database

Team

Joe Noble	GIS/ Information Technology Program Director
Dr. Casey Teske	Geospatial Fire Ecologist
Kevin Hiers	Wildland Fire Scientist
Dr. Kevin Robertson	Fire Ecology Program Director
Joshua Picotte	Fire Specialist USGS EROS
Vince Sclafani	Vice President and Geospatial Applications Developer Woolpert Corporation

MeetingSphere

WiFi:

TTGUEST Password: talltimbersguest

Use this link: https://us30.meetingsphere.com/51332307/ttrs

Enter your name in the first box and your email in the second.

Click “OK” to join the session.

Spatial Data

- What kind of fire data do you have (e.g. blocks, format, fire history, GIS, etc.)?
- Would your organization be willing to share fire data to assist us in the project?

- If so, who is your organizational contact?
- Would you review draft products we produce for quality assurance?

Analysis and Expectations

- How would a project as presented today benefit your organization?
- What are examples of repetitive tasks that you use your fire data for (e.g. burn prioritization, smoke, accomplishment reporting, etc.)?
- Are fire data used in decision making at your organization?
- What are your reporting requirements?
- What reporting would you use (e.g. acres by habitat type, number of fires by type, prescribed vs. wildfire acres, acres by species of concern, etc.)?
- Does fire severity matter?

Integration and Limitations

- Do you see the potential for products produced by this effort to integrate into a larger operating structure?
- What are the absolute core data fields for burn events that should be common across the state?
- What non-fire data are necessary to associate with burn events (e.g. weather, wind, transportation networks, etc.)?
- How should this system work long-term with the FFS permitting data?

ASSESSING AREAL AND SPATIAL ACCURACY OF FFS BURN AUTHORIZATIONS

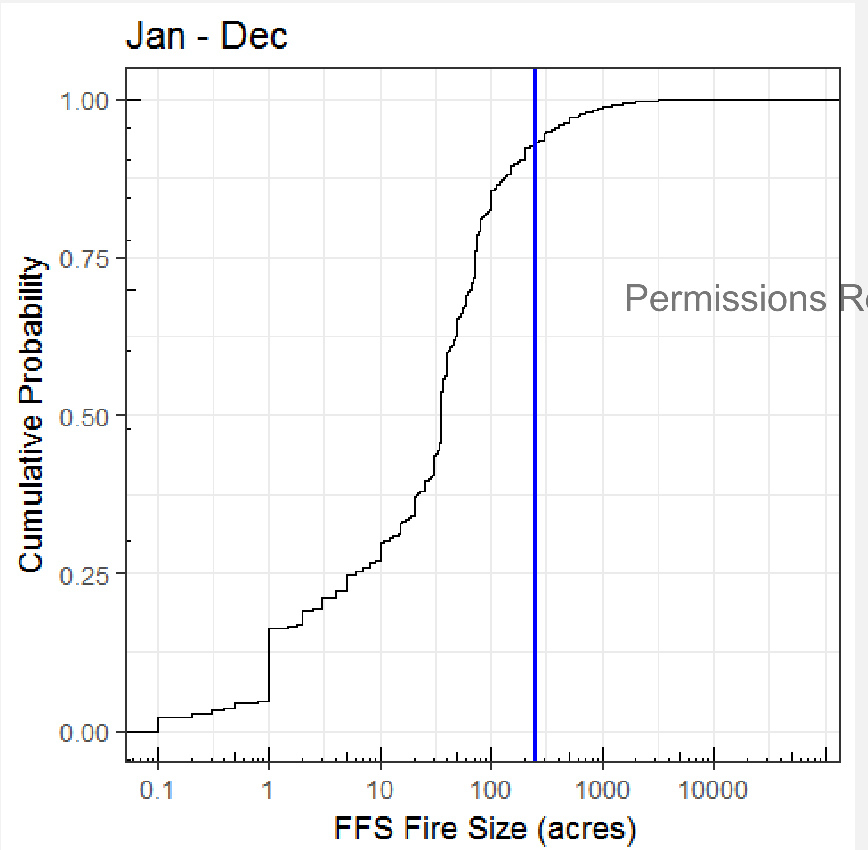
Dr. Holly Nowell

9/22/2017

BIAS RATIO

Year	FFS Burn Area (km^2)	GFED Burn Area (km^2)	Burn Area Difference (km^2)	Bias Ratio
2004	8,800	3,000	5,800	3
2005	8,400	2,500	5,900	3
2006	9,900	2,800	7,100	3.5
2007	9,100	4,100	5,000	2
2008	9,700	2,300	7,400	4
2009	9,600	2,800	6,800	3
2010	10,800	2,900	7,900	4
2011	9,600	2,700	6,900	3.5
2012	9,700	2,000	7,700	5
2013	9,500	2,200	7,300	4
2014	10,500	2,500	8,000	4

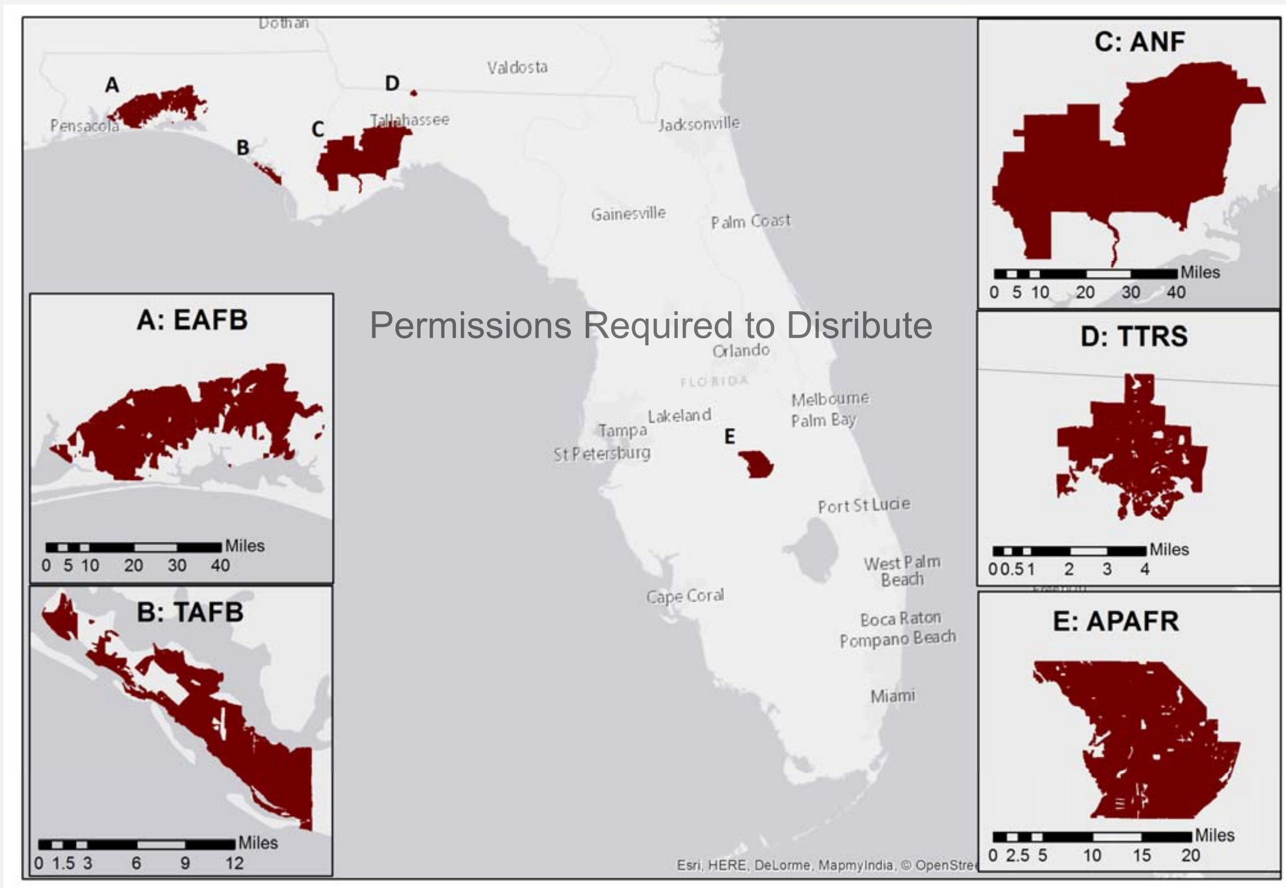
FIRE SIZE DISTRIBUTION IN FLORIDA



- Median fire size in Florida: 35 acres
- Quantiles of fire size

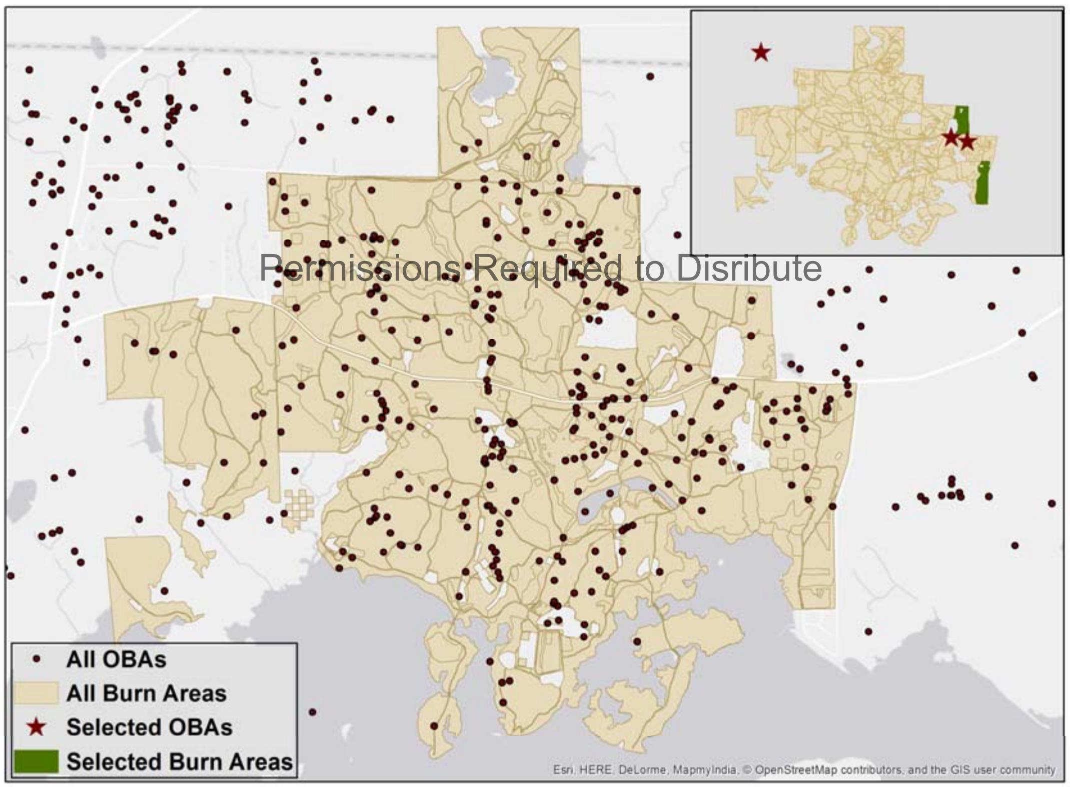
0%	25%	50%	75%	100%
0.1	6	35	72	68,295

TEST SITE LOCATIONS

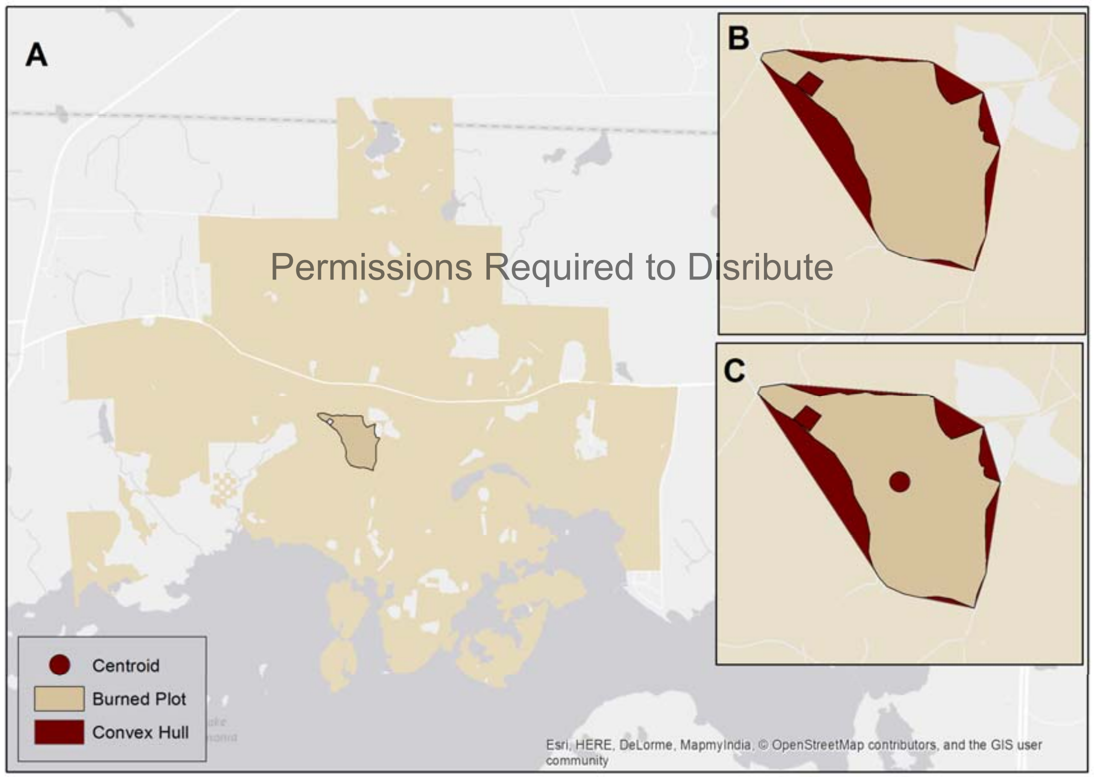


INPUT DATA

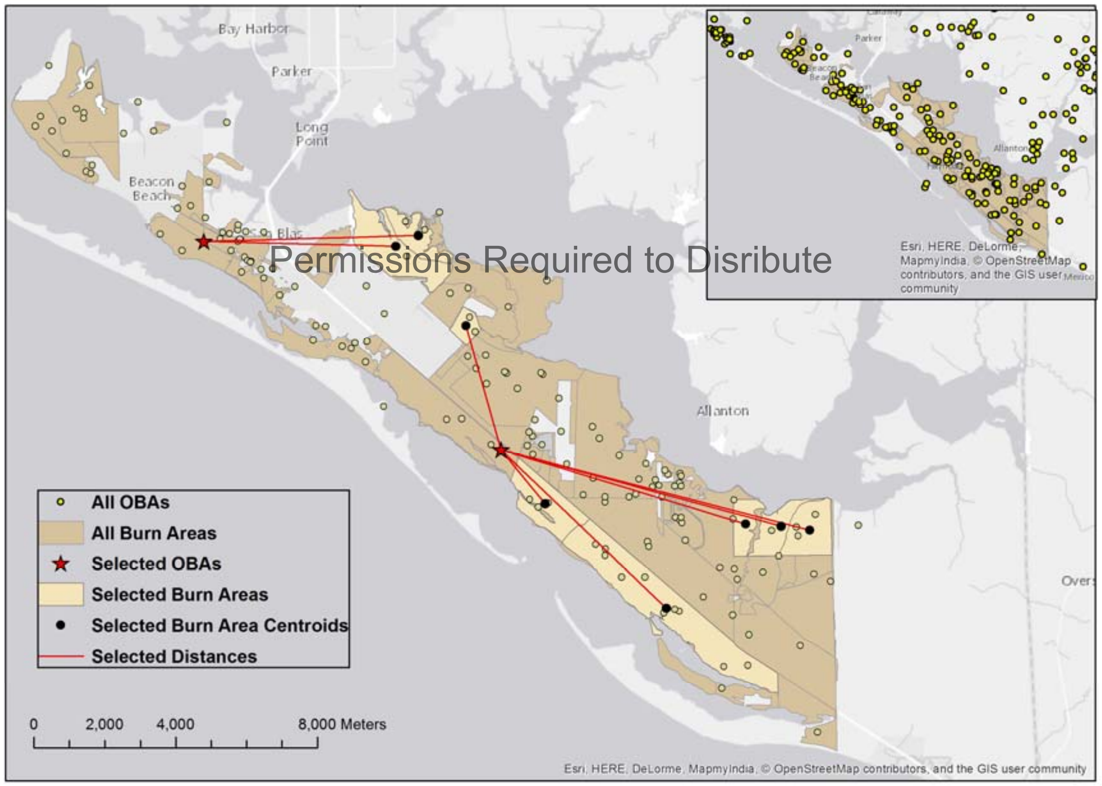
TTRS: Selected Data



SELECTING CENTROID



MATCHING TO OBA

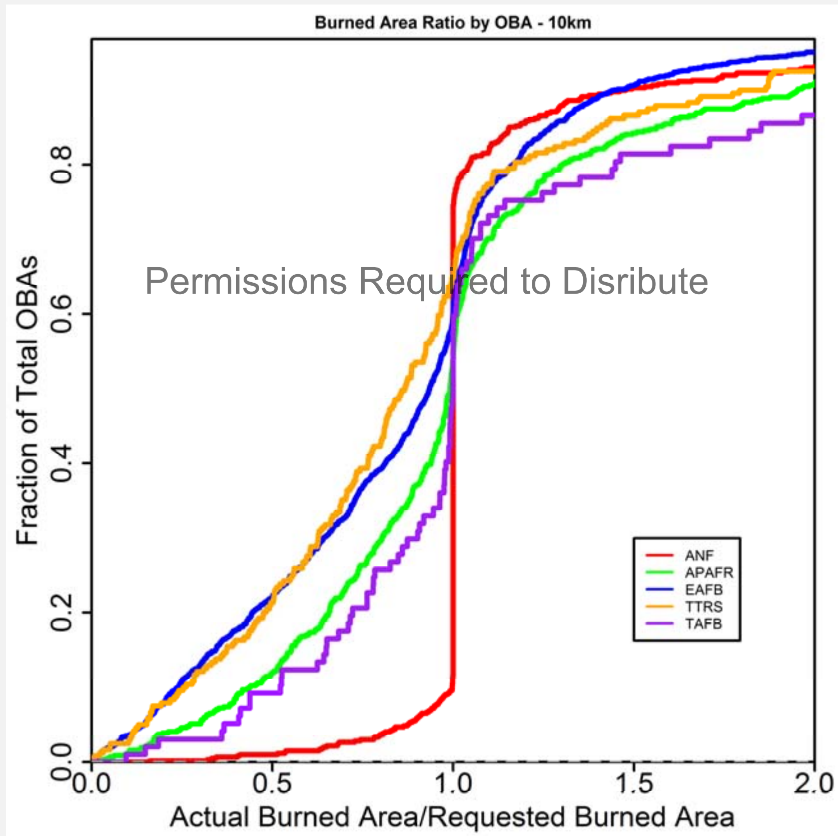


AREAL DIFFERENCES

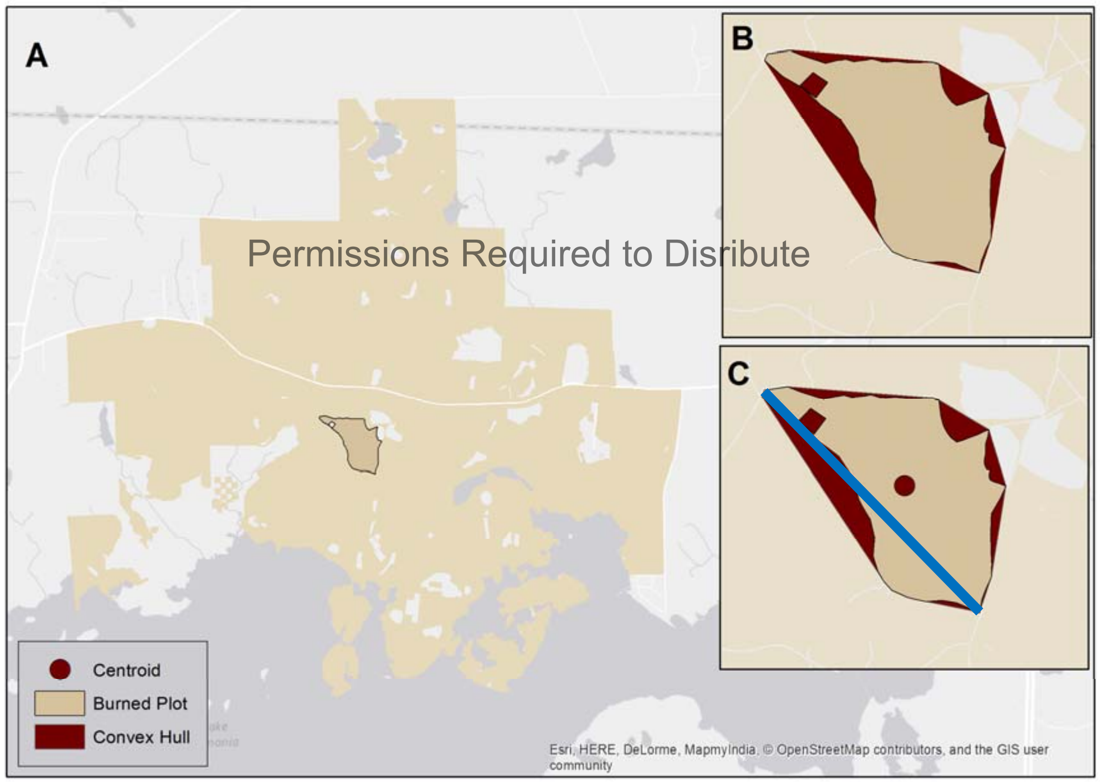
1 km buffer

Location	Burn Events	Acres Burned	Num OBA	OBA Acres
ANF	653	990,400	588	885,400
APAFR	681	251,200	557	217,000
EAFB	1,458	1,062,700	1,385	1,228,800
TAFB	130	50,800	92	43,200
TTRS	2,031	16,800	232	19,000
Totals	4,953	2,371,900	2,854	2,393,400

CDF BURN VS. REQUESTED AREAS

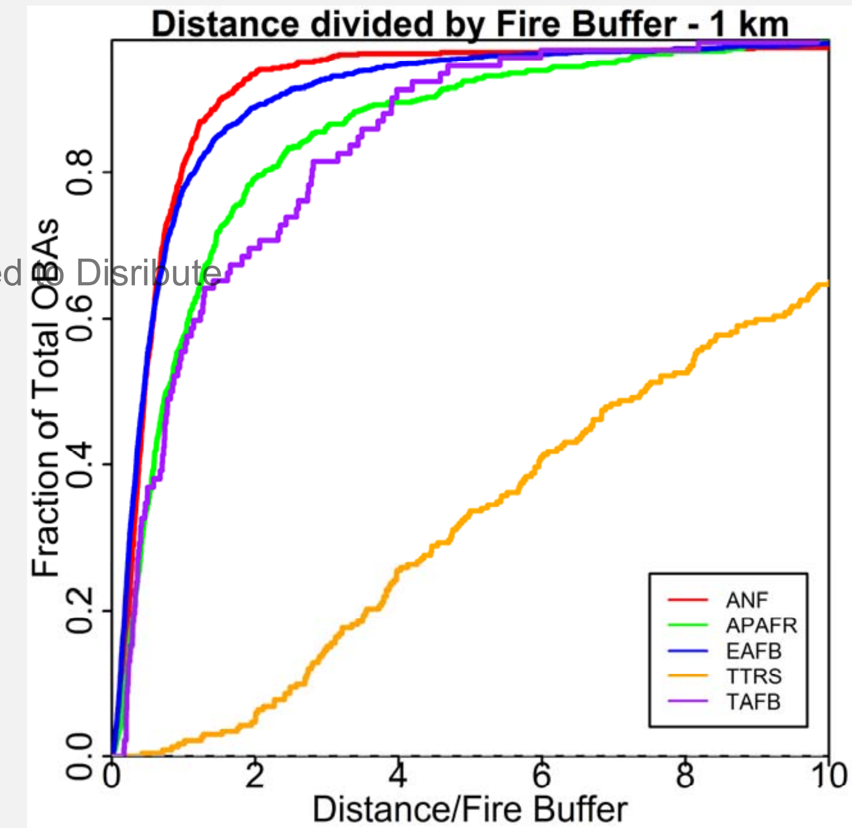


SPATIAL DIFFERENCE

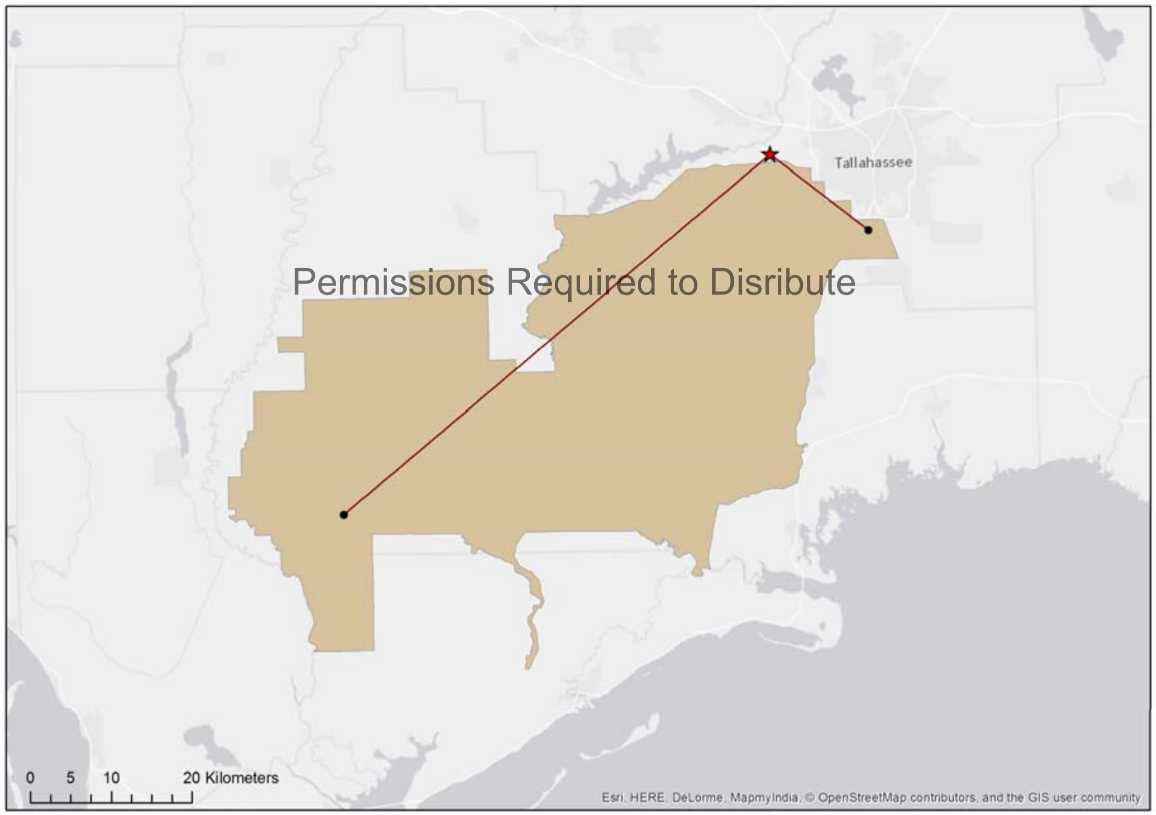


SPATIAL QUANTILES

Location	Median fire buffer	1x	2x	5x	10x
ANF	1,340	81%	94%	96%	97%
APAFR	960	58%	79%	92%	98%
EAFB	1,440	78%	89%	96%	98%
TAFB	940	55%	70%	95%	99%
TTRS	130	2%	5%	34%	65%



ANF MAX DISTANCE



CONCLUSIONS

- FFS areal accuracy well below satellite detection bias ratio
  - Roughly ± 16% for 1 km buffer, and -13% to 19% for 10 km buffer
- FFS is within fire buffer the majority of the time for most sites
- Are all entities as accurate?

Southern Integrated Prescribed Fire Information System (SIPFIS)

- Dr. Talat Odman, Georgia Tech (odman@gatech.edu)
- Dr. Fernando Garcia, NC State University (f_garcia@ncsu.edu)
- Dr. Cassandra Johnson, USFS Southern Research Station (cjohnson09@fs.fed.us)

JFSP Grant #16-1-08-1
Funded 10/16 – 9/18

Attended by:
David Godwin
Kevin Robertson

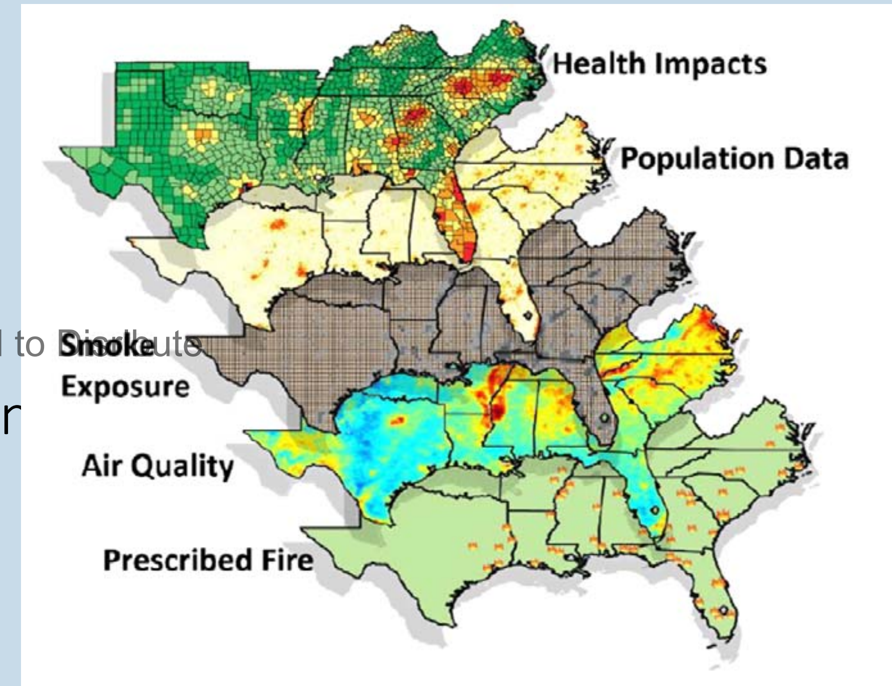
SIPFIS Summary

“The system will compile prescribed burn and air quality data and results from model simulation will address questions regarding the impacts of prescribed burning on air quality, smoke exposure and associated health effects.”

Applied throughout southeastern 13 states

Subprojects

- Unified Rx fire database
- Rx fire and air quality integrated info system
- Analysis of observational air quality record and smoke emissions dispersion tools performance
- Simulation of air quality impacts for exposure assessments
- Impact on human exposure



Progress

- They found current satellite detection of fires (GFED, BBEP) not to be sufficient for their needs. However, GOES16 may be helpful.
- Have validation data from burn authorizations and other sources from FL, GA, MS, NC, TN, Tall Timbers. Looking for more data. Have an online system for reporting recent burns: https://public.tableau.com
- Found that authorization data closely tracks area burned in cases they validated
- Created online system for predicting prescribed fire activity where authorization data provide a history of burning: https://forecast.ce.gatech.edu

Needs identified by participants

- Better information on emission factors, especially VOCs
- Emissions split for flaming vs. smoldering combustion for predicting plume dynamics
- Better information on fuel consumption
- More temporal information – what time of day fires occur
- More accurate fire locations from authorizations
- Confirmation that authorized burns occurred
- Time since last burn essential for emissions and behavior predictions
- Incentives for landowners to report information
- Consider LANDSAT and VIIRS product for finer scale burn monitoring
- Use existing data management frameworks – IFTDSS, IRWIN

Remaining Issues

- Burn authorization incomplete for South-wide monitoring and predictions
- Long-term ownership of project beyond JFSP funding unclear
- EPA would prefer to have the burn data itself rather than a finished product predicting emissions and their impacts, for purposes of national standardization

US Air Force Fire Data Management System

22 September 2017

Kevin Hiers and Steve Laine

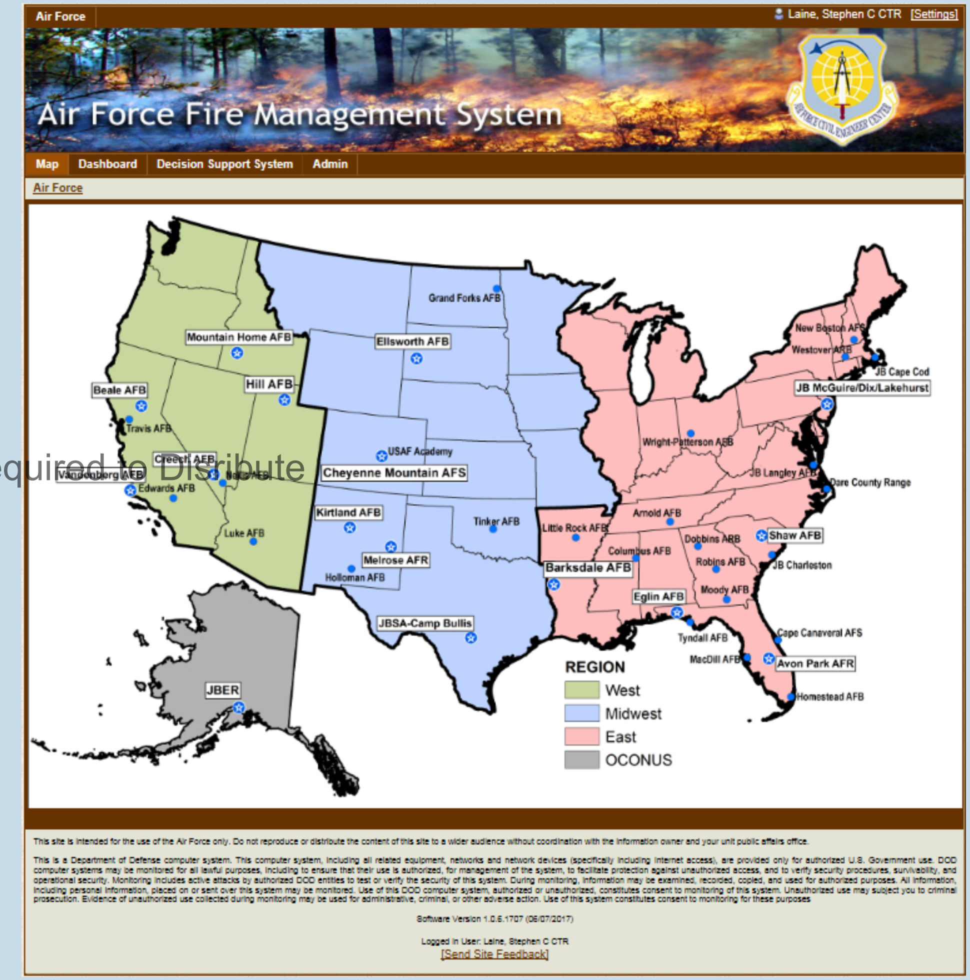
TALL TIMBERS

PENINSULAR FLORIDA LANDSCAPE CONSERVATION COOPERATIVE

Eglin AFB Fire Spatial Data Management

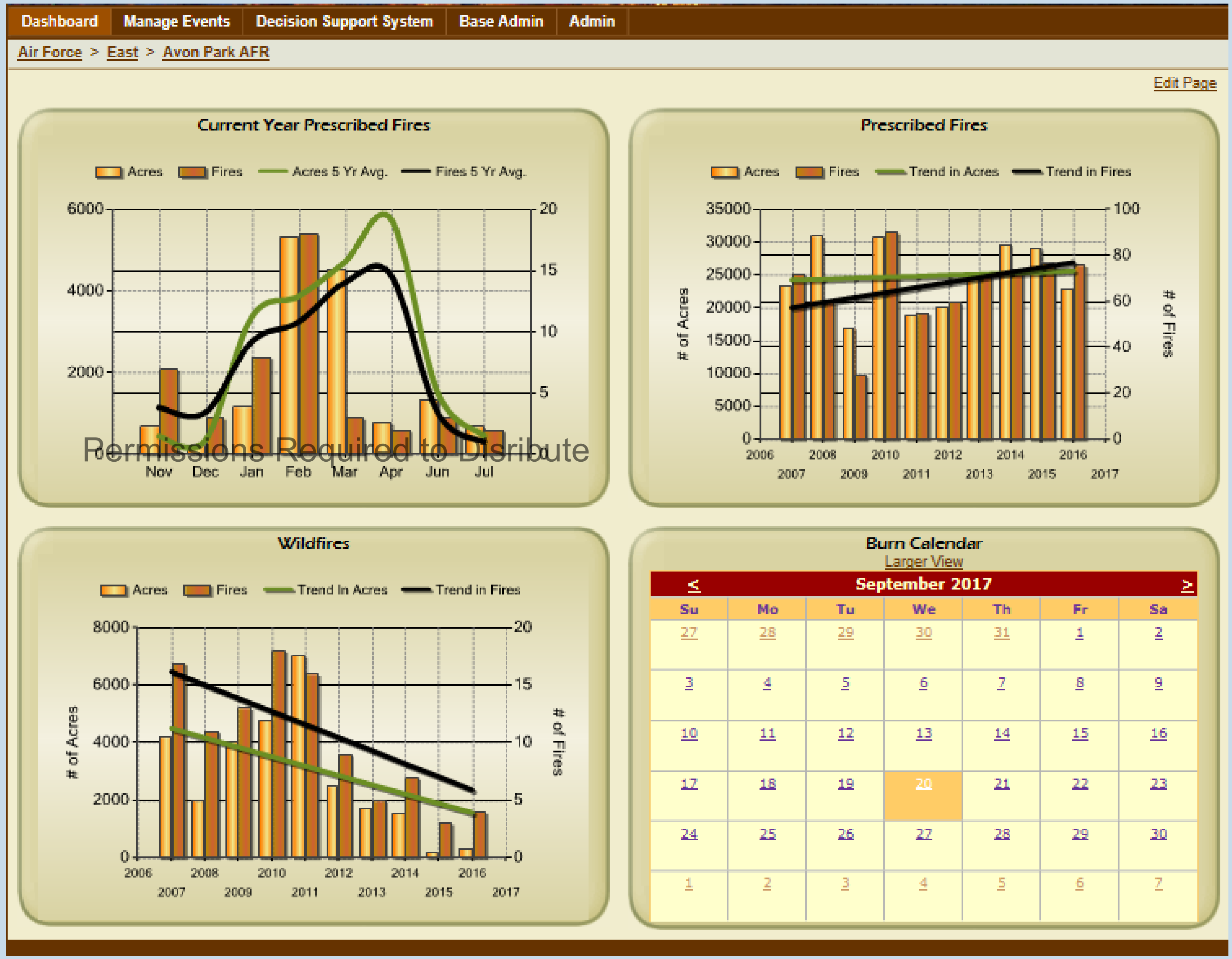
- Developed in 2001 as the Eglin Fire Decision Support System
- Oracle Spatial Database with spatial queries, flexible user interface, and web-based reports in real time
- In 2012-2013, system extended to include all AF Wildland Fire Center data management, personnel experience, and nationwide reporting; renamed the Fire Management System
- Over 7 million acres needed fire history to populate database
- The Air Force used remote sensing products presented here to construct that history

provides data capture and analysis for all wildland fire data tracking. The System is used by Air Force Wildland Fire Center (AFWFC) managers in annual fire planning iterations and to report fire program activity and progress to Air Force Leadership.

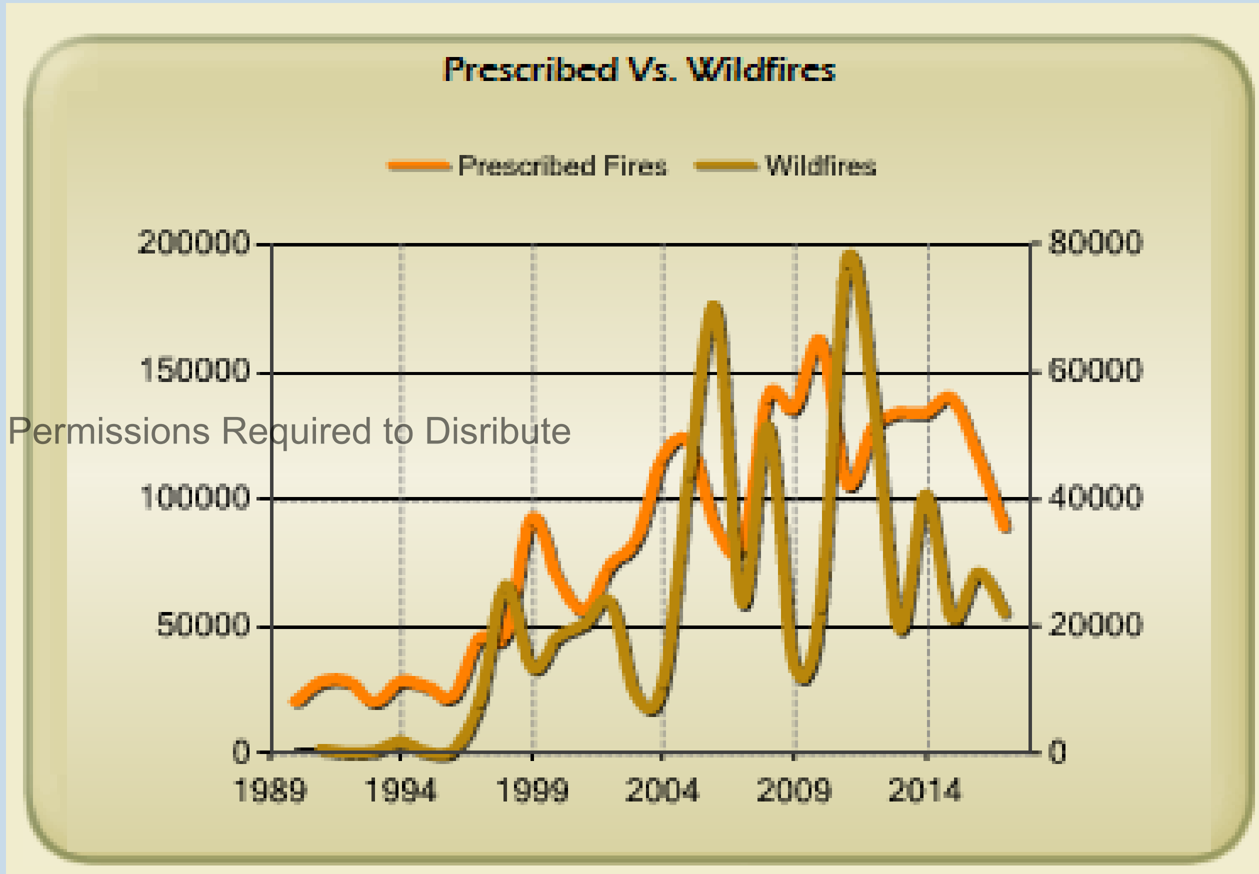


Nationwide Summary Reporting:

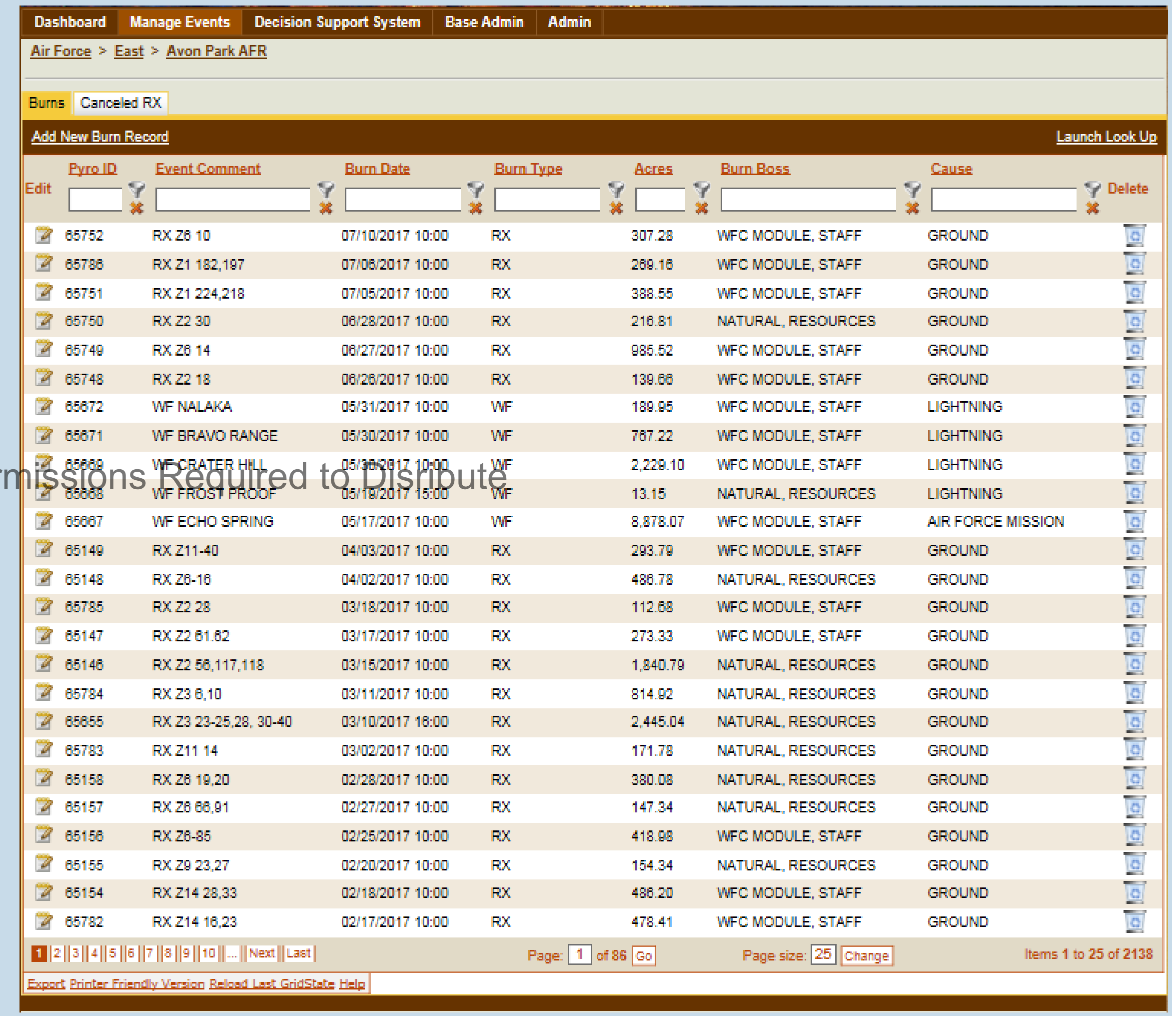
Site Specific Reporting:



Customizable Reporting Dashboard:



Burn Events Custom Queries:



Dashboard | Manage Events | Decision Support System | Base Admin | Admin

Air Force > East > Avon Park AFR

Burns | Canceled RX

Add New Burn Record | Launch Look Up

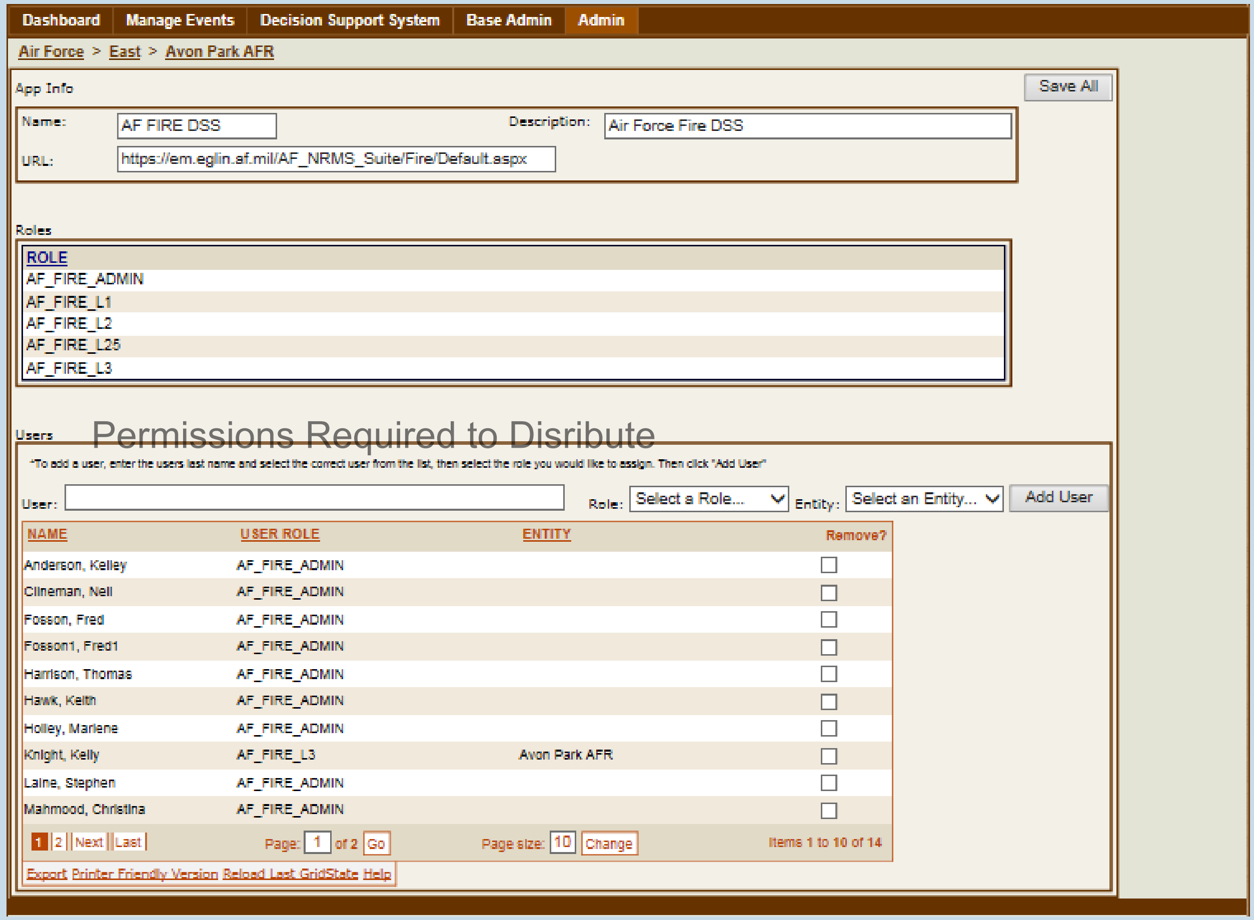
Edit	Pyro ID	Event Comment	Burn Date	Burn Type	Acres	Burn Boss	Cause	Delete
	65752	RX Z6 10	07/10/2017 10:00	RX	307.28	WFC MODULE, STAFF	GROUND	
	65786	RX Z1 182,197	07/06/2017 10:00	RX	269.16	WFC MODULE, STAFF	GROUND	
	65751	RX Z1 224,218	07/05/2017 10:00	RX	388.55	WFC MODULE, STAFF	GROUND	
	65750	RX Z2 30	06/28/2017 10:00	RX	216.81	NATURAL, RESOURCES	GROUND	
	65749	RX Z6 14	06/27/2017 10:00	RX	985.52	WFC MODULE, STAFF	GROUND	
	65748	RX Z2 18	06/26/2017 10:00	RX	139.66	WFC MODULE, STAFF	GROUND	
	65672	WF NALAKA	05/31/2017 10:00	WF	189.95	WFC MODULE, STAFF	LIGHTNING	
	65671	WF BRAVO RANGE	05/30/2017 10:00	WF	767.22	WFC MODULE, STAFF	LIGHTNING	
	65669	WF CRATER HILL	05/30/2017 10:00	WF	2,229.10	WFC MODULE, STAFF	LIGHTNING	
	65668	WF FROST PROOF	05/19/2017 15:00	WF	13.15	NATURAL, RESOURCES	LIGHTNING	
	65667	WF ECHO SPRING	05/17/2017 10:00	WF	8,878.07	WFC MODULE, STAFF	AIR FORCE MISSION	
	65149	RX Z11-40	04/03/2017 10:00	RX	293.79	WFC MODULE, STAFF	GROUND	
	65148	RX Z6-16	04/02/2017 10:00	RX	486.78	NATURAL, RESOURCES	GROUND	
	65785	RX Z2 28	03/18/2017 10:00	RX	112.68	WFC MODULE, STAFF	GROUND	
	65147	RX Z2 61,62	03/17/2017 10:00	RX	273.33	WFC MODULE, STAFF	GROUND	
	65146	RX Z2 56,117,118	03/15/2017 10:00	RX	1,840.79	NATURAL, RESOURCES	GROUND	
	65784	RX Z3 6,10	03/11/2017 10:00	RX	814.92	NATURAL, RESOURCES	GROUND	
	65655	RX Z3 23-25,28, 30-40	03/10/2017 16:00	RX	2,445.04	NATURAL, RESOURCES	GROUND	
	65783	RX Z11 14	03/02/2017 10:00	RX	171.78	NATURAL, RESOURCES	GROUND	
	65158	RX Z6 19,20	02/28/2017 10:00	RX	380.08	NATURAL, RESOURCES	GROUND	
	65157	RX Z6 66,91	02/27/2017 10:00	RX	147.34	NATURAL, RESOURCES	GROUND	
	65156	RX Z6-65	02/25/2017 10:00	RX	418.98	WFC MODULE, STAFF	GROUND	
	65155	RX Z9 23,27	02/20/2017 10:00	RX	154.34	NATURAL, RESOURCES	GROUND	
	65154	RX Z14 28,33	02/18/2017 10:00	RX	486.20	WFC MODULE, STAFF	GROUND	
	65782	RX Z14 16,23	02/17/2017 10:00	RX	478.41	WFC MODULE, STAFF	GROUND	

1 2 3 4 5 6 7 8 9 10 ... Next Last | Page: 1 of 86 Go | Page size: 25 Change | Items 1 to 25 of 2138

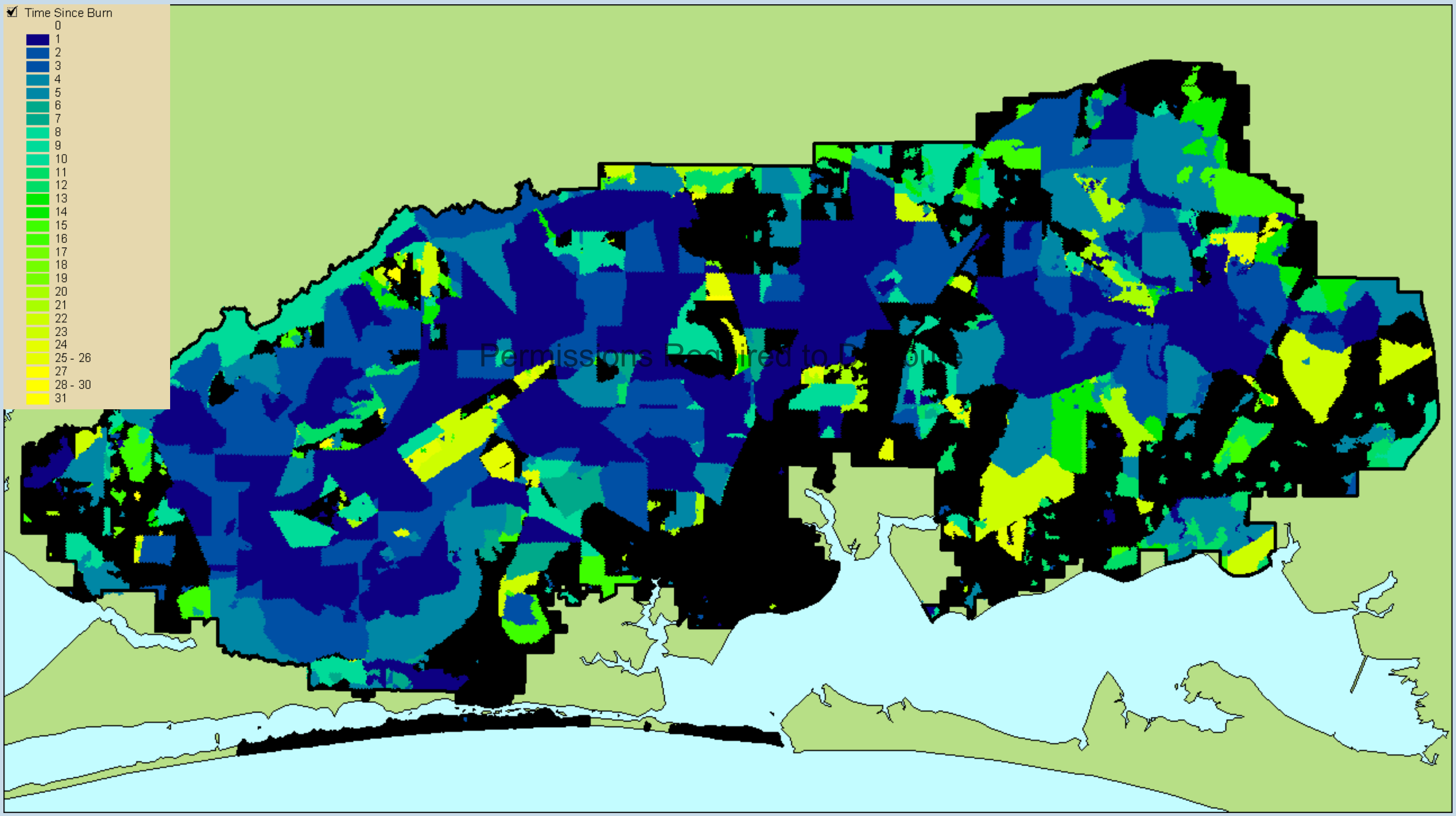
Export Printer Friendly Version Reload Last GridState Help

Access and Administration

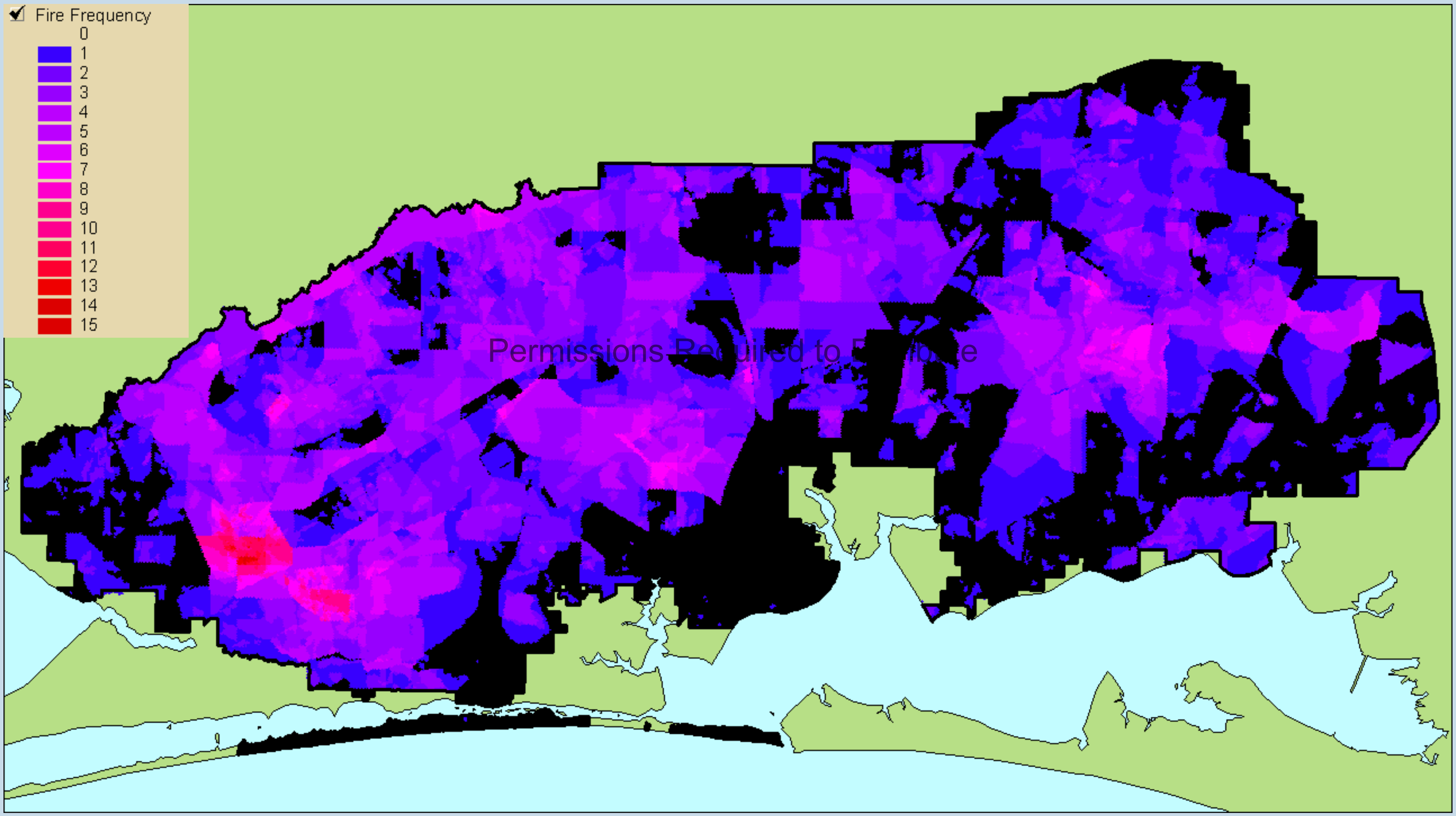
- Roles
- Editing



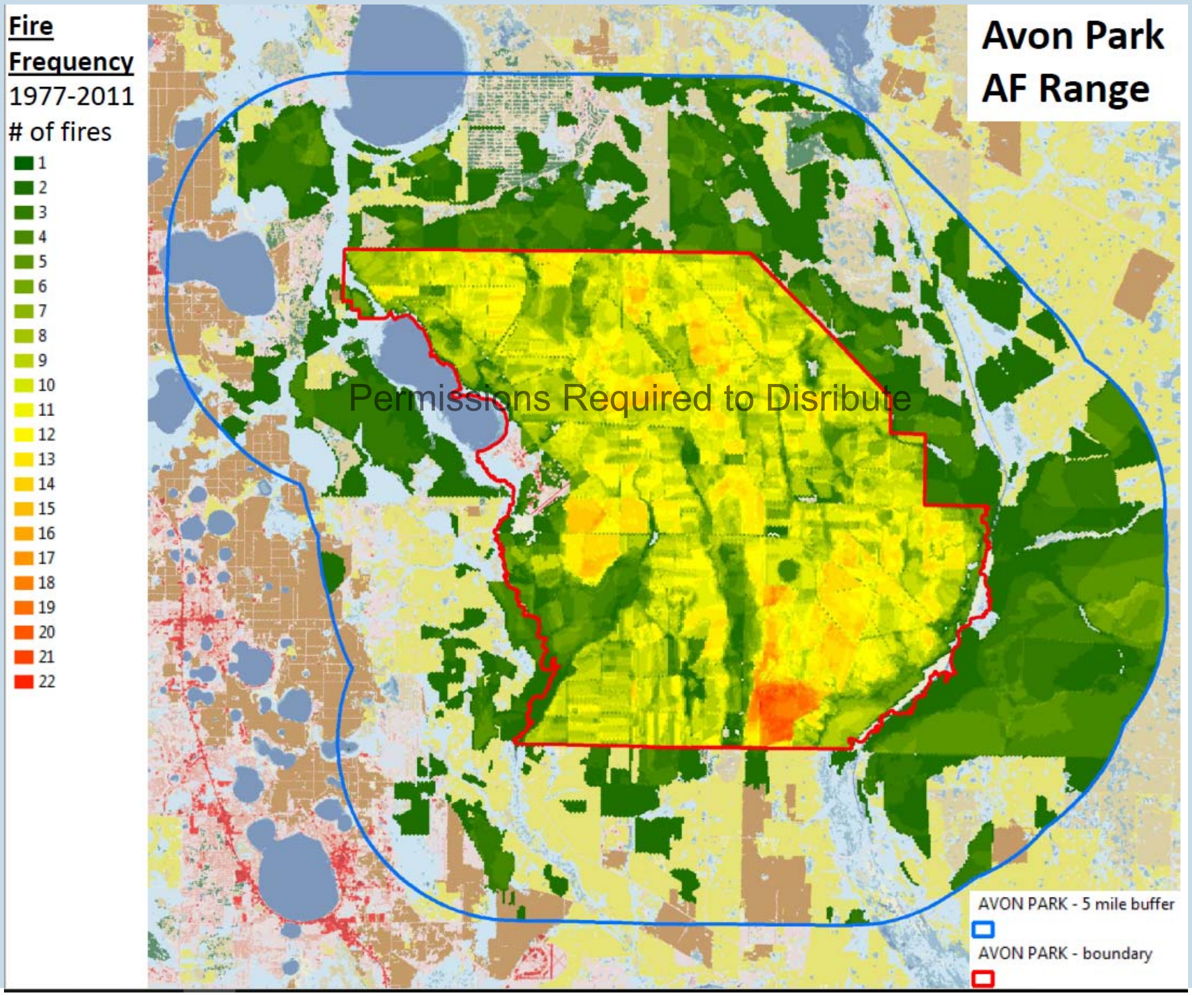
Outputs: Time since last fire



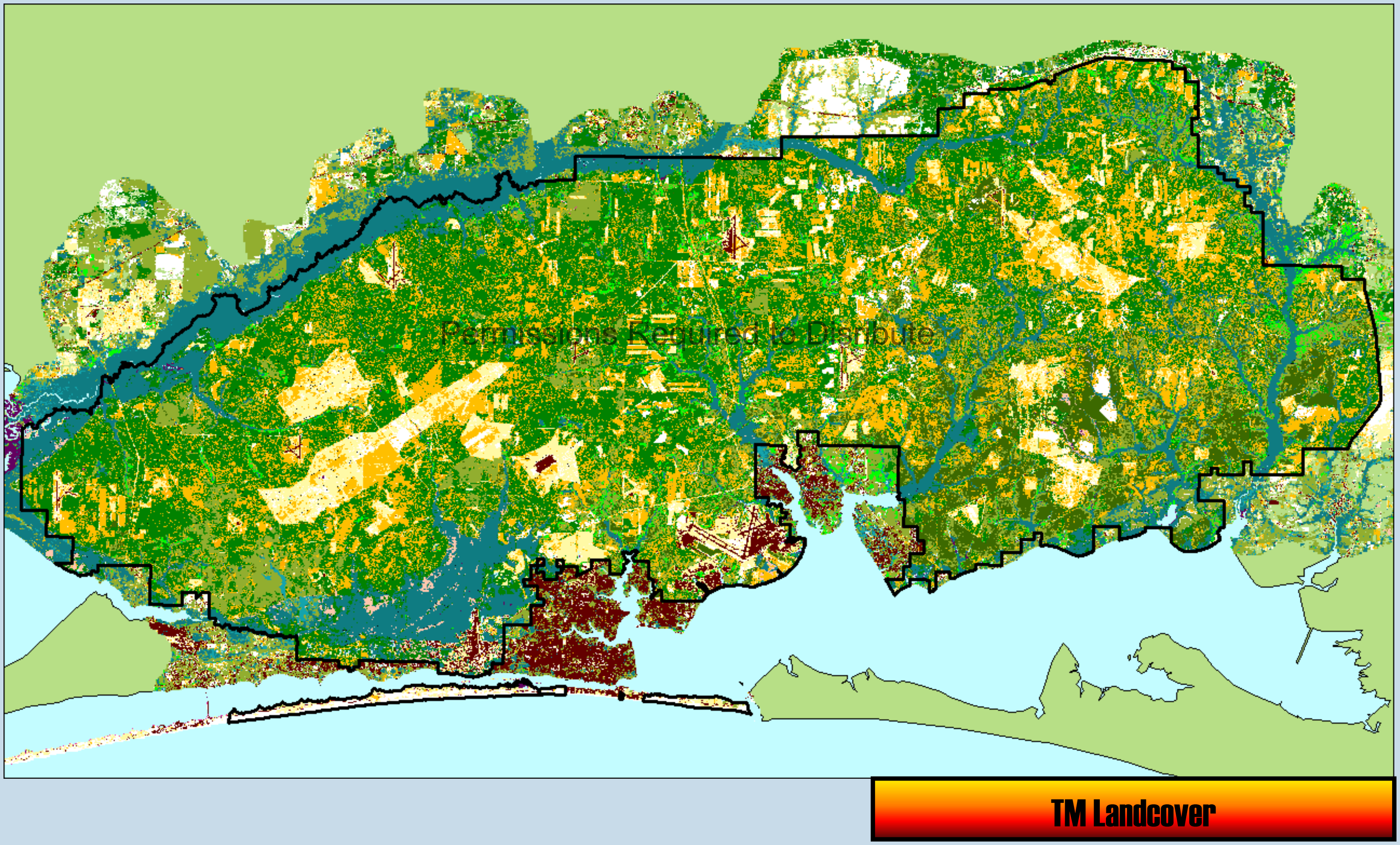
Outputs: Fire Return Intervals



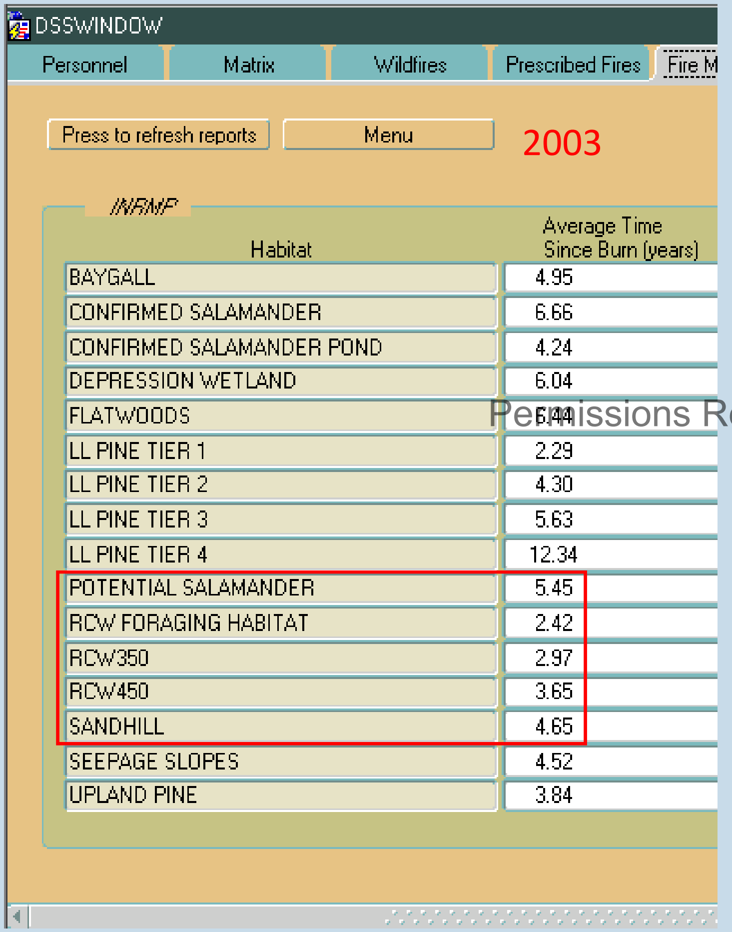
Outputs: Fire Return Intervals

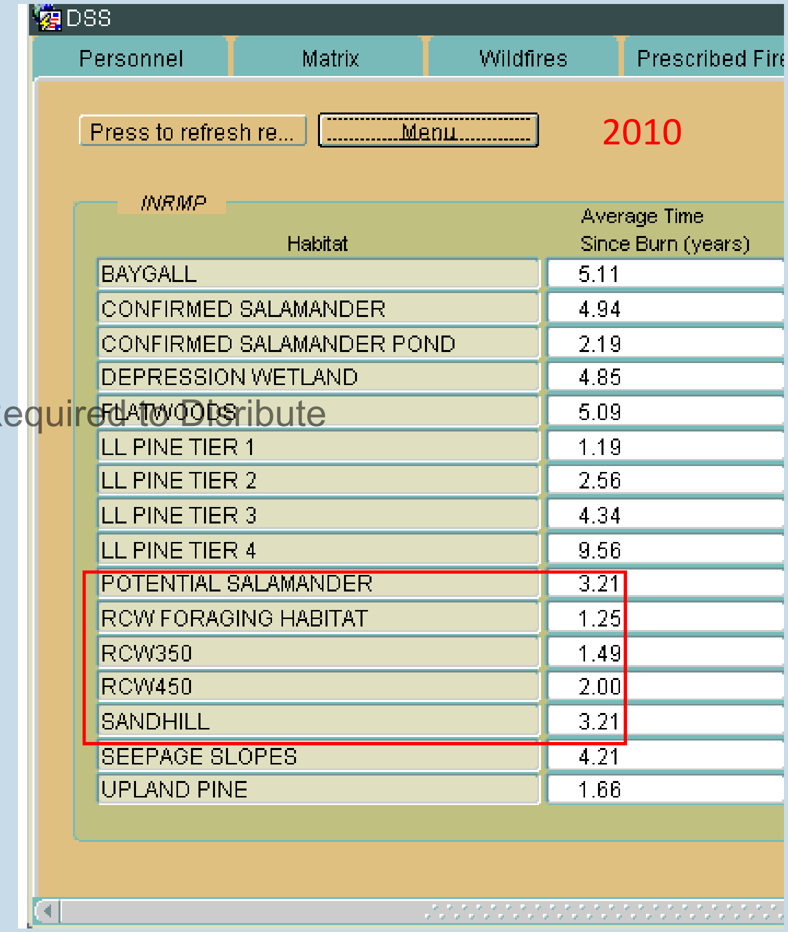


Integration with Ecological Data

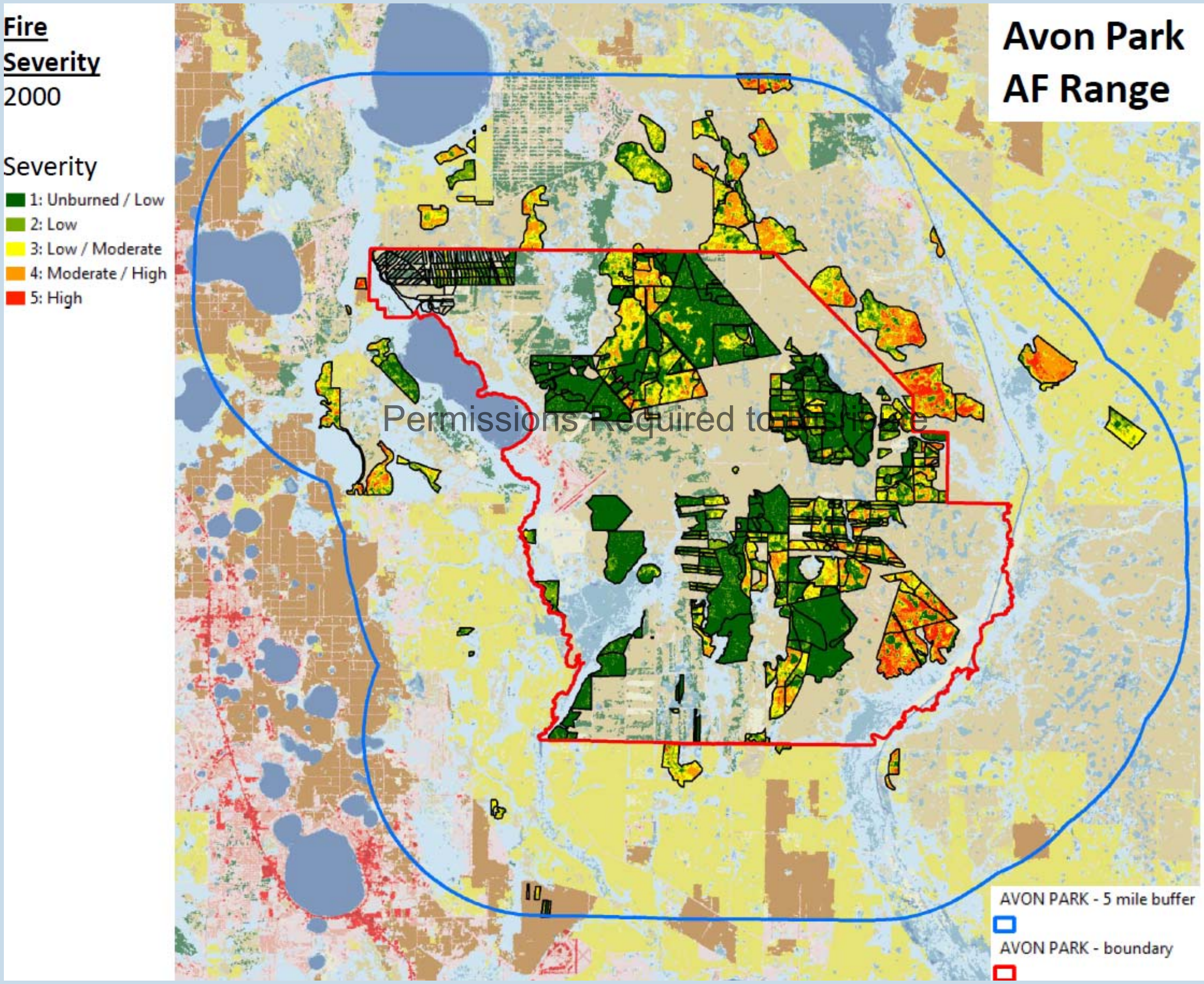


Fire Monitoring: Measuring success





Fire Analysis: Burn Severity




Questions?
Permissions Required to Disribute


EXIT


EXIT
Eglin AFB Fire Spatial Data Management


EXIT


EXIT

Chapter 3: Deliverables #2 & #3.1

FFS Prescribed Fire Database Summary Report

and

SQL Database Structure

Deliverables Update
#2: FFS Prescribed Fire Database Summary Report
3.1: SQL Database Structure

Mapping Fires Across Florida:

Advancement of a Fire Spatial Database

December 2017

Tallahassee, FL

TALL TIMBERS

Principal Investigator/Project Manager

Joe Noble

Co-Principal Investigators

Casey Teske
Kevin Hiers
Vince Sclafani
Kevin Robertson

Project ID

FWC-16/17-135 Spatial Database
A Proposal for Mapping Statewide Fire Occurrence, Fire History, and Ecological Outcomes
Submitted by Tall Timbers Research, Inc., June 20, 2017

All project deliverable reports, including the earlier workshop proceedings, video of expert presentations, summary report, and power point presentations are available free of charge from Tall Timbers Research, Inc. Please contact Joe Noble: jnoble@talltimbers.org

Tall Timbers Research, Inc.
13093 Henry Beadel Drive
Tallahassee, FL 32312

TALL TIMBERS

Table of Contents

Executive Summary

Tall Timbers Research, Inc., is pleased to present the first update on the data analysis (Deliverable #2) and SQL database creation (Deliverable 3.1) since the September 2017 User's Workshop. Development of a comprehensive spatially explicit map of fire occurrence remains one of the most critical needs for conservation in the Southeastern US. Not only are the vast majority of Florida's endangered species and ecosystems reliant on frequent fire, but fire risk analysis, prescribed fire planning, and fire behavior modeling are sensitive to fire history. Fire occurrence in Florida is currently tracked by approximate location through the Florida Forest Service (FFS) burn authorization system, Fire Management Information System (FMIS). While this system represents one of the most advanced prescribed fire planning datasets in the country, the system does not record perimeter data or include assessments regarding which burns are actually completed. Relying solely on this system results in documented data gaps when estimating the size, location and effectiveness of managed fires on a statewide scale. These "actual burned" areas are critical factors in analyses and models evaluating conservation success.

Tall Timbers Research, Inc., is addressing this need by developing a robust spatial database for more precise mapping and tracking of all prescribed fire in Florida. Advanced remote sensing techniques will be applied to known locations of prescribed fires, as identified in the FFS system, to record actual spatial fire boundaries into a modified version of the U.S. Air Force Wildland Fire Database. In addition, custom query tools will be developed to report fire history (e.g., frequency, time-since-burn) in specific fire dependent ecological systems or fire dependent species habitats.

Tall Timbers' staff acquired burn authorization data for 2006-2016 from the Florida Forest Service and analyzed the data using a geographic information system (GIS) to understand the characteristics of prescribed fire authorizations across the state. We developed filtering methods to create summary tables, graphs, charts, and maps to enhance understanding of fire across space and through time in the state. The Florida Forest Service has nearly 1 million pile and broadcast burn authorization records for the time period 2006-2016. Broadcast burns account for 25% of all authorizations. Findings suggest fewer authorizations for broadcast burning are being requested now than occurred in 2006; and the majority of acres have burned in the Mesic Flatwoods land cover type. The highest number of authorizations requested and the highest amount of acreage authorized to burn both occurred in 2010. Most authorizations are requested in the Improved Pasture and Tree Plantations land cover categories, but more acreage is requested in the Mesic Flatwoods. Most authorizations and most of the acreage authorized occurs in the winter months (Jan-Mar). Most authorizations are for silvicultural purposes, and the most requested firing pattern is for using backing fire. The overall fire rotation is approximately 7 years, which was calculated using all burnable land cover categories. We identified data limitations and data quality issues for the FFS burn authorization dataset and provide recommendations for moving forward.

The existing database structure from the Department of Defense Air Force (DoD AF) wildland fire database tracking system was converted to SQL Server for this project. The next steps for the SQL Server database include consultation with FWCC partners, and additional data inputs. This database will house the prescribed fire data and ancillary datasets required for analysis purposes of this project.

Glossary of Terms and Concepts

Broadcast Burn An open burn that is done for agricultural, silvicultural, or land clearing purposes and is not a pile

Burned Area Essential Climate Variable (BAECV) refers to an algorithm that capitalizes on the long temporal availability of Landsat imagery to identify burned areas across the conterminous United States.

Continuation An authorization to continue a previously approved open burn authorization that was not completed for various reasons including late starts, poor weather conditions or lack of resources.

CONUS The Continental United States; this reference excludes Alaska and Hawaii.

Cooperative Land Cover (CLC) The Cooperative Land Cover Map is a project to develop an improved statewide land cover map from existing sources and expert review of aerial photography. The project is directly tied to a goal of Florida's State Wildlife Action Plan (SWAP) to represent Florida's diverse habitats in a spatially-explicit manner.

Environmental Protection Agency (EPA) The agency of the federal government which was created for the purpose of protecting health and environment.

Florida Forest Service (FFS) Agency whose mission is to protect and manage forest resources in Florida.

Florida Natural Areas Inventory (FNAI) Florida's state heritage program responsible for tracking occurrences of species and natural communities statewide.

Fire Mapping Information System (FMIS) integrated set of applications that handle data input, processing and reporting needs for the Florida Division of Forestry (DOF).

Global Fire Emissions Database (GFED) Database combining satellite information on fire activity and vegetation productivity to estimate gridded monthly burned area and fire emissions.

GOES-16 previously known as GOES-R, is part of the Geostationary Operational Environmental Satellite (GOES) system operated by the U.S. National Oceanic and Atmospheric Administration and is the first spacecraft in NOAA's next-generation of geostationary satellites. The GOES-R series satellites will provide advanced imaging with increased spatial resolution and faster coverage, improving the detection of environmental phenomena.

Hazard Mapping Systems (HMS) NOAA product suite that provides both fire and smoke analysis products. It is an interactive processing system that allows analysts to manually integrate data from automated fire detection algorithms using GOES and polar (Advanced Very High Resolution Radiometer (AVHRR) and MODerate resolution Imaging Spectroradiometer (MODIS)) images. The result is a quality controlled display of the locations of fires and significant smoke plumes detected by meteorological satellites.

Interagency Fuel Treatment Decision Support System (IFTDSS) is a web-based software and data integration framework that organizes fire and fuels software applications to make fuels treatment planning and analysis more efficient. The effort was initiated by Joint Fire Science Program and the NWCG Fuels Management Committee in 2007.

Integrated Reporting of Wildland-Fire Information (IRWIN) This service is a Wildland Fire Information and Technology (WFIT) affiliated investment intended to provide an "end-to-end" fire reporting capability. IRWIN is tasked with providing data exchange capabilities between existing applications used to manage data related to wildland fire incidents.

LANDSAT The Landsat Program is a series of Earth-observing satellite missions jointly managed by NASA and the U.S. Geological Survey. Imagery is available since 1972 from six satellites in the Landsat series. These satellites have been a major component of NASA's Earth observation program.

Landscape Conservation Cooperative (LCC) self-directed partnerships between federal agencies, states, tribes, non-governmental organizations, universities, and other entities to collaboratively define science needs and jointly address broad-scale conservation issues.

Monitoring Trends in Burn Severity (MTBS) refers to an interagency program whose goal is to consistently map the burn severity and extent of large fires across all lands of the United States from 1984 to present.

Moderate Resolution Imaging Spectroradiometer (MODIS) is a key instrument aboard the Terra and Aqua satellites. Satellites view the entire Earth's surface every 1 to 2 days acquiring data in 36 spectral bands. These data improve our understanding of global dynamics and processes occurring on the land, oceans and lower atmosphere.

Pile Burn An open burn that is in the form of a pile that is larger than 8' diameter

PostGIS is a spatial database extender for PostgreSQL object-relational database. It adds support for geographic objects allowing queries to be run in SQL.

PostgreSQL is an open source object-relational database system.

Open Burn Authorization (OBA) refers to Florida Forest Service Open Burn Authorization Requests and is available to Certified Prescribed Burners.

QGIS is a free and open source professional Geographical Information System (GIS) that is built on top of Free and Open Source Software (FOSS)

QGIS Event Mapping Tool (EMT) a QGIS plugin for fire assessment developed by U.S. Geological Survey National Center for Earth Resources Observation and Science (EROS)

Southern Integrated Prescribed Fire Information System (SIPFIS) a Joint Fire Science Program initiative to design an integrated information system for fire and air quality data in the SE United States.

Volatile Organic Compounds (VOC) refers to a large group of organic chemicals that include any compound of carbon (excluding carbon monoxide, carbon dioxide, carbonic acid, metallic carbides or carbonates, and ammonium carbonate).

Deliverable #2: Background

This section is the documentation of the data analysis and progress thus far for Deliverable #2 of the FWCC Grant. The following pages contain background information on the project, data descriptions, summaries of techniques developed to filter the FFS burn authorization database, and summary reports on types and number of prescribed fires meeting filter settings.

For over a decade, resource managers in the state have recognized the importance of tracking and monitoring the use of prescribed fire. Many species in Florida are dependent on fire for maintenance of appropriate habitat conditions. Measurements, such as seasonality and years since last burn are important components in assessing the condition of these fire maintained systems. For many species that are dependent on these systems, managing an appropriate fire return interval is critical. Differentiating those areas that have an appropriate fire return interval from those areas without an appropriate fire return interval would allow managers to focus resources on areas most in need of management actions, as well as serve as a means to measure and quantify the success of conservation and restoration efforts.

Cost effective and efficient management of conservation lands requires up to date detailed resource maps. The Peninsular Florida Landscape Conservation Cooperative (PFLCC) is working on a statewide Landscape Conservation Design. As part of this process, the PFLCC is identifying conservation targets (indicators) for each priority resource. It became evident that fire return interval could be a critical indicator for these systems.

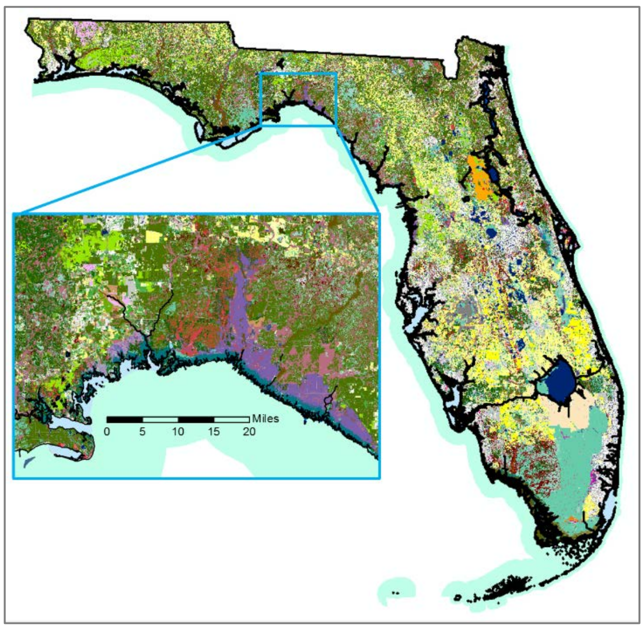
Florida currently has a detailed (10m) land cover map, used by multiple entities (Florida Fish and Wildlife Conservation Commission, FWC's State Wildlife Action Plan, Florida Natural Areas Inventory, and the PFLCC). However, there is a critical missing component from the existing land cover map - qualitative attributes regarding fire. One key qualitative attribute that has long been identified as a critical data gap pertains to prescribed fire. Addition of qualitative attributes based on fire regime characteristics, such as fire return interval, would increase the effectiveness of informing acquisition of conservation lands, supporting land and fire management, and tracking success and failure of conservation efforts. Assessment of the success of management actions will provide a valuable feedback loop to inform future management actions on conservation lands, both public and private.

Currently, a spatial database that tracks prescribed fire statewide does not exist, which means that there is not a comprehensive knowledgebase about fire regimes across the state. This data gap was recognized more than a decade ago. In 2006, it was noted that "…methods for monitoring the use of fire on public lands may be one of the greatest unmet needs in comprehensive wildlife management…" (*Monitoring Prescribed Burning on Public Lands in Florida, 2006).* This project aims to enhance our understanding of prescribed fire characteristics across the state of Florida for integration into further analyses specific to landscape conservation and monitoring. Specific outcomes are noted below:

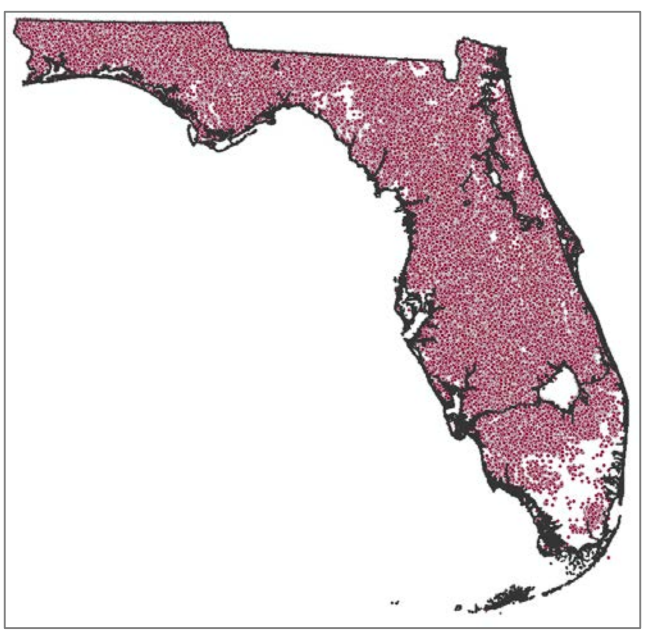
1. We aim to address the data gap by creating a spatial database that can be used to track and analyze burn authorization data between 2006-2016 using FFS Online Burn Authorization data and a modified extension of the US Air Force Wildfire Database.
2. We will develop methods to validate burn authorization records by comparing authorized permits to known fire locations and using remote sensing techniques to record spatial fire boundaries.
3. We will develop custom query tools to evaluate fire regime characteristics and trends in specific fire dependent ecological systems or fire-dependent species habitats.
4. We will develop procedures for annual updates moving forward.

Deliverable #2: Data Description

We analyzed two datasets to understand the amount, type, and location of burning in the state of Florida between 2006 and 2016. The Cooperative Land Cover Classification (CLC) dataset was used as the base dataset and analyzed in conjunction with prescribed fire authorization data to provide context for a first attempt at understanding prescribed fire characteristics across the state (Figure 1a). The CLC dataset is available online (FWCC 2016); it was developed for the purposes of representing Florida's diverse habitats in a spatially-explicit manner to inform conservation and management activities in the state. We used the version 3.2 data published in October 2016. This is a 10m raster dataset that contains 78 different land cover classes (See Appendix A for Land Cover Class descriptions), including non-burnable classifications (e.g., Bare Soil, High Intensity Urban, Estuarine, etc.).



a



b

Figure 1: Detail provided by the cooperative land cover map for Florida (*a*) and prescribed fire authorizations for the state between 2006 and 2016 (*b*).

A geodataset containing information about prescribed fire authorization requests submitted to the Florida Forest Service (FFS) between 2006 and 2016 was provided to Tall Timbers by the FFS. These point data are based on the FFS Open Burn Authorization (OBA) system, which tracks all requests for any type of intentional burning in the state of Florida that is not emitted through a smoke stack (e.g., pile burns, broadcast burns). The OBA geodatabase contains information including date of burn, location, type of burn (i.e., pile, broadcast), size of burn (or number of piles if a pile burn), firing technique, and category of burn type (i.e., agricultural, silvicultural, land clearing, etc.). This is considered a census dataset in terms of prescribed fire for the state of Florida. A map of all points is shown in Figure 1b. While there are numerous other attributes stored in the actual FFS database, many of these attributes were not relevant to our analysis; additionally, only a subset of these FFS OBA data were analyzed for the purposes of this grant project. For example, pile burning is not of interest for the scope of this project, although pile burn data are included in the geodataset that we received. Table 1 identifies the attributes included in the original geodataset for each year.

Table 1: Attributes included in the open burn authorization data from Florida Forest Service.

Attribute	Description
PK	Primary Key; a unique identifier associated with each open burn authorization. Format: YYYY######, where YYYY is the 4-digit year when the authorization was originally requested and ###### is a number that begins at 1000 on January first. So, if the first request for a year was initiated on January 2, 2007, the authorization would have a PK that would appear as 2007001000.
REQUESTED_BY	This is the name of the person requesting the authorization
LANDOWNER	This is the name of the land owner of the land where the piles/unit are to be burned
LANDOWNER_FIRM	This is the name of the company that owns the land where the piles/unit are to be burned
REQUEST_DATE	This is the date the authorization is requested.
START_DATE	This is the date the burn is to start
END_DATE	This is the date the burn is to end
BURN_TYPE	This is the type of burn that will occur, and falls into 4 broad categories: Agricultural Burning, Silvicultural Burning, Land Clearing Burning, and Pile Burning
ACRES	How many acres are being requested to burn
PILES	How many piles (>8’ in diameter) are being requested to burn
PILE_WIDTH	The width of the pile
PILE_HEIGHT	The height of the pile
SIZE_OF_BURN	The size (area) of the burn in acres
STATUS	Shows whether the request was authorized (Approved) or not (Pending, Denied, Revoked, etc.)
APPROVED_BY	The FFS official that approved/denied the authorization
CERTIFIED_BURN_FLAG	Indicates whether the person requesting the burn checked the box asking for the burn to be counted toward their certified burn count
DISTRICT	Refers to the FFS district where the burn is located
COUNTY	Refers to the county where the burn is located
RESTRICTIONS	The restrictions in place for the day of the burn, for the county & district.
CONTINUATION_OF_OBA_FK	Refers to a burn authorization (PK) that is being extended
CONTINUED_BY_OBA_FK	Refers to the person authorizing the continuation

Data Limitations

Understanding fire regime characteristics across the state of Florida is important from a conservation perspective if the aim is to maximize conservation efforts and target conservation opportunities appropriately. However, limited information about fire occurrence in the state exists, particularly in terms of individual fire perimeters for prescribed fires and for any fires occurring on private lands.

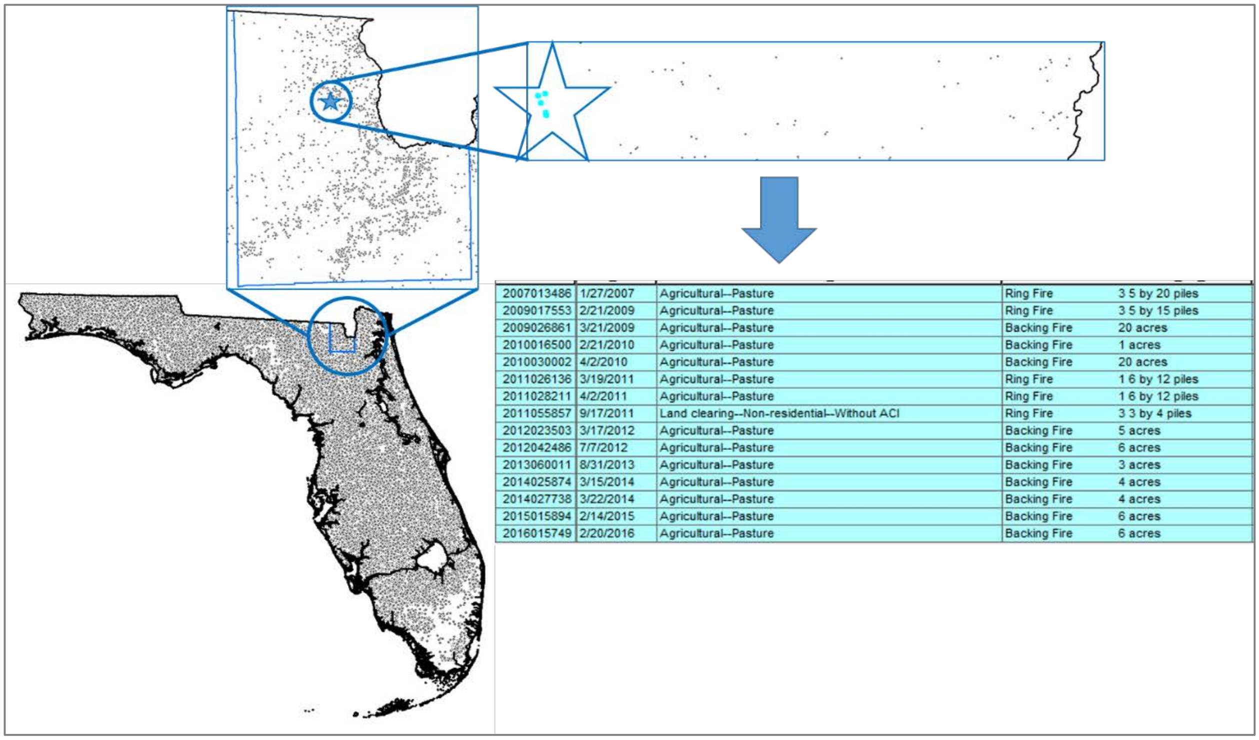
Currently, without a statewide spatial database of fire occurrence in Florida, the FFS OBA database is used as a surrogate. This is an Oracle database where information required for an open burn authorization is recorded, and includes all open burns (e.g., broadcast burns and pile burns larger than 8 feet in diameter) authorized within the state. The data records are exported in point format, which lacks precise spatial extent information. Furthermore, the accuracy and variability of these data points varies significantly through space and time: There is not a standard method of locational reporting required by dispatchers, and reporting system requirements have changed since authorizations started being tracked.

For example, prior to 2008, a request for an open burn authorization required the person doing the request to provide a point location of where the burn would be taking place (this was reported to the nearest quarter section or 160-acre blocks). The location of this point was not standardized by dispatcher. While often located somewhere within the quarter section, it could just as easily be the middle of the owner's property as the middle of the burn unit, or a corner of where the test fire was taking place, or a road intersection. Since August of 2008, the latitude and longitude coordinates have been added to the system; every request still requires a township-range-section location entered on the OBA request form or taken from a point on a web-based map, but the latitude/longitude are determined in the system background and added as attributes to the OBA database. The latitude/longitude were not retroactively determined for requests prior to August 2008, so OBA attributes are not consistent temporally. We accept that without an ability to field verify past OBA location data beyond 160-acre blocks, we do not know the spatial accuracy of the point locations. Therefore, we had to take the reported location at face value for this analysis, which we feel still has merit but the limitations must be recognized.

Additional documented or known issues and limitations include:

- Duplicate authorization numbers exist (these are unique values, known as the PK value in the OBA database, that are associated with each open burn authorization and there should not be duplicate values within the database);
- Lack of consistency for data point spatial accuracy
- Duplicated location values (multiple authorizations using the exact same point location; Figure 2);
- Burning techniques that don't make sense for the type of burn being authorized (for example, aerial ignition for pile burns; Figure 3);
- Cumulative acreage total discrepancies (e.g., if a burn was authorized for 100 acres but only 60 acres were completed and a continuation was authorized, the continuation may be for 100 acres or may be for 40 acres [since there is not a standard in place for this type of request]; this could result in over-reporting of acres [200 acres vs 140 acres, in this example], as opposed to the 100 acres that were actually the target);
- No sense of completion (e.g., if 100 acres were authorized, and only 78 acres burned, there is currently no standard or way to capture that in the FFS OBA database).

In spite of the issues and limitations listed above, we feel this is a rich dataset which can be used to create a spatial database for analyses that will further our understanding of prescribed fire occurrence and characteristics in the state of Florida.



2007013486	1/27/2007	Agricultural--Pasture	Ring Fire	3 5 by 20 piles
2009017553	2/21/2009	Agricultural--Pasture	Ring Fire	3 5 by 15 piles
2009026861	3/21/2009	Agricultural--Pasture	Backing Fire	20 acres
2010016500	2/21/2010	Agricultural--Pasture	Backing Fire	1 acres
2010030002	4/2/2010	Agricultural--Pasture	Backing Fire	20 acres
2011026136	3/19/2011	Agricultural--Pasture	Ring Fire	1 6 by 12 piles
2011028211	4/2/2011	Agricultural--Pasture	Ring Fire	1 6 by 12 piles
2011055857	9/17/2011	Land clearing--Non-residential--Without ACI	Ring Fire	3 3 by 4 piles
2012023503	3/17/2012	Agricultural--Pasture	Backing Fire	5 acres
2012042486	7/7/2012	Agricultural--Pasture	Backing Fire	6 acres
2013060011	8/31/2013	Agricultural--Pasture	Backing Fire	3 acres
2014025874	3/15/2014	Agricultural--Pasture	Backing Fire	4 acres
2014027738	3/22/2014	Agricultural--Pasture	Backing Fire	4 acres
2015015894	2/14/2015	Agricultural--Pasture	Backing Fire	6 acres
2016015749	2/20/2016	Agricultural--Pasture	Backing Fire	6 acres

Figure 2: Example of duplicated locations of authorizations. There are five points selected on the map which returns 15 unique OBA records without any change in the location information.

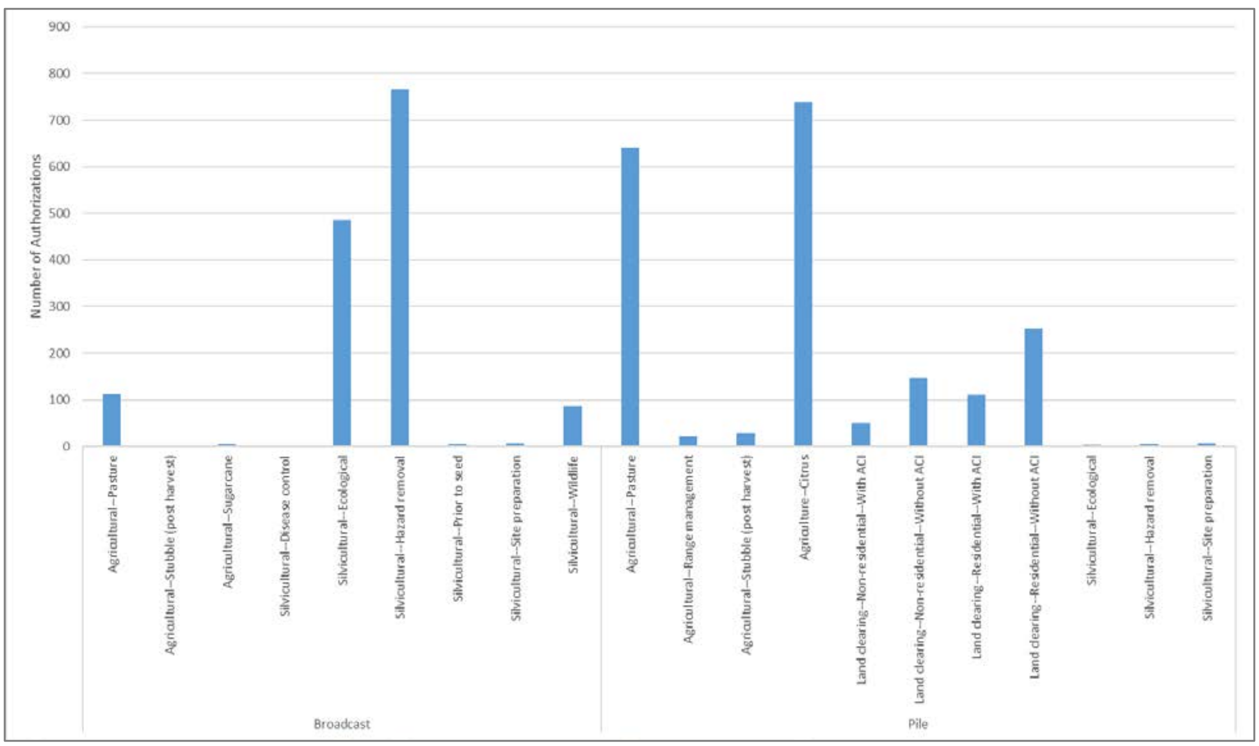


Figure 3: The number of broadcast and pile burn authorizations using aerial ignition as a firing technique by burn type category (e.g., Agricultural – Pasture) are shown to illustrate an example of illogical burn type/firing technique combinations.

Deliverable #2: Data Analysis Methods

Initially, the OBA point data were provided as annual files, which we merged into a single file containing all years. Then, we reprojected the file to match the projection of the CLC data and overlaid it on the CLC raster dataset. We are using the CLC dataset as the reference or 'base data' for our analyses since it currently used by multiple entities (e.g., Florida Fish and Wildlife Conservation Commission, Florida Natural Areas Inventory, and the PFLCC) as a critical input for conservation and planning efforts. The value of each pixel in the raster corresponds to a land cover classification type, and we assume the classifications to be correct. These values were extracted to each OBA point, resulting in a land cover classification associated with each OBA point. Of the 78 different land cover classes occurring in Florida, 75 were attributed to OBA points, including non-burnable classes. If the land cover class will not support fire under any circumstances, it is classified as non-burnable. After initial exploratory data analysis, any authorizations that fell within any of these non-burnable classes were ultimately filtered from further analysis. The non-burnable classes from the raster were also used to create a binary 'non-burnable mask' raster dataset for supplementary analyses. We created and used the non-burnable attribute as a filter to remove low-confidence and/or potentially illogical data points from analysis. For example, a 20-acre broadcast burn in a location classified as 'Barren and Outcrop Communities' may not be logical and would be removed from analysis in this case.

Additional attributes to be used as filters were created for the OBA point dataset (for all authorization points, irrespective of whether a point was a pile burn or not) using extensive logical procedures as part of the data quality assurance/quality control (QA/QC) process. These filter attributes (i.e., fields) were added to the OBA point data so that subsets of data could be quickly selected for further analyses. These field attributes are listed in Table 2. Once all OBA points were attributed with the new fields, the data were exported to Excel to easily create graphs and summaries.

Table 2: Descriptions of the attributes added to the burn authorization data for filtering purposes.

Attribute	**Description**
PileYN	Type of burn (broadcast 0, pile 1, unknown 2)
ContYN	Answers "was this request a continuation of a previous authorization?" (no 0, yes 1, unknown 2)
AcresTot	Total Acres for each broadcast burn authorization (corrects for an error in exporting original data)
StMONTH	Month of Start Date
StDAY	Day of Start Date
StYEAR	Year of Start Date
EndMONTH	Month of End Date
EndDAY	Day of End Date
EndYEAR	Year of End Date
DOYStart	Julian Day of Start Date (1-365, or 366 in leap years)
DOYEnd	Julian Day of End Date (1-365, or 366 in leap years)
StartJD	Modified Julian Date of Start Date for comparing to satellite datasets (YYYYJJJ; where YYYY is year and JJJ is Julian Day. 2006001 is Jan 1 2006; 2006365 is Dec 31 2006).
EndJD	Modified Julian Date of End Date for comparing to satellite datasets (YYYYJJJ; where YYYY is year and JJJ is Julian Day. 2006001 is Jan 1 2006; 2006365 is Dec 31 2006).
AuthYN	Answers whether authorization granted (no 0, yes 1)
BurnableYN	Answers whether authorization landed on a burnable land cover category or not (see list of burnable/non-burnable categories in Appendix A; no 0, yes 1)

Deliverable #2: Data Analysis Results and Discussion

All Authorizations

Between 2006 and 2016, a total of 996,797 requests were made to the FFS; this number includes both Pile Burns and Broadcast Burns. Of these requests, there were 1340 duplicate records, and 11% were continuations of a previous authorization (i.e., burn authorization requests that were required in order to finish a burn due to not completing it for various reasons such as late starts, poor weather conditions or lack of resources). Overall, there were more OBA requests (and continuations) in 2006 than any other year, although a roughly steady decline is indicated in both categories until 2012 (Table 3). Most requests were authorized, with only 1% being listed as revoked, cancelled, or pending.

Table3: All OBA Requests by year for pile and broadcast burns in Florida

		2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	*Grand Total*
Broadcast	**Non-Continuation**	22067	19201	21449	20127	23019	19402	20778	22623	22283	22826	24112	***237887***
	Continuation	1511	1301	1598	1702	1711	1824	1438	1648	1635	1453	1133	***16954***
Pile	**Non-Continuation**	96838	81816	67675	54929	46180	45065	47266	52419	54908	54156	51962	***653214***
	Continuation	12950	9360	7074	6423	6019	6854	5921	7362	8601	8667	9463	***88694***
Unknown	**Non-Continuation**	8						7	15	6	10		***46***
	Continuation	1	1										***2***
	Grand Total	***133375***	***111679***	***97796***	***83181***	***76929***	***73145***	***75410***	***84067***	***87433***	***87112***	***86670***	***996797***

Broadcast Burn Authorizations

Broadcast burn authorizations account for 25% of all approved authorizations (n=250,978) and 23 million acres requested to burn during the time period. This is an annual average of ~100 acres per authorization, and a monthly average of ~145 acres per authorization. Of this number, 7% (n=16,855) of the broadcast burns requested were for a continuation of a previous authorization, and account for 2,146,254 of the requested acres.

The locations reported for some authorizations fell on areas that are classified as non-burnable (n=9177, or 4% of the all non-continuation broadcast authorization requests); 47% of the total non-continuation broadcast burn authorizations requested were for burning in sugarcane fields (representing 4,476,441 acres), and are not included in further analysis. Classification errors (e.g., when an OBA point is assigned to the wrong land cover class due to inaccurate location data) resulting in errors of omission/commission are likely in this analysis because the accuracy of the spatial location of the points is not known. It is just as likely that an authorization point could fall into a location considered 'burnable' as one considered 'unburnable'. As we have no way to know the degree to which spatial errors occur in the FFS OBA data set back through time, we accept the location at 'face-value' and removed non-burnable points from analysis, acknowledging that this has implications in terms of analyses where land cover class is important.

We filtered sugarcane burn authorizations from additional analyses as these burns occur in developed agricultural areas that are not ecological systems of interest in terms of conservation. In this 'Broadcast Burn Authorizations' section, only approved non-continuation broadcast burn authorizations will be discussed further. After removing Sugarcane, the non-continuation authorizations occur predominantly in the following land cover classifications: Cropland/Pasture (7%), Freshwater Forested Wetland (6%), Improved Pasture (13%), Mesic Flatwoods (7%), Mixed Hardwood-Coniferous (5%), Rural (8%), and Tree Plantations (16%; Figures 3 and 4a). This equates to 62% of the authorizations for 46% of the total acres authorized, and includes authorizations falling into non-burnable land cover classes.

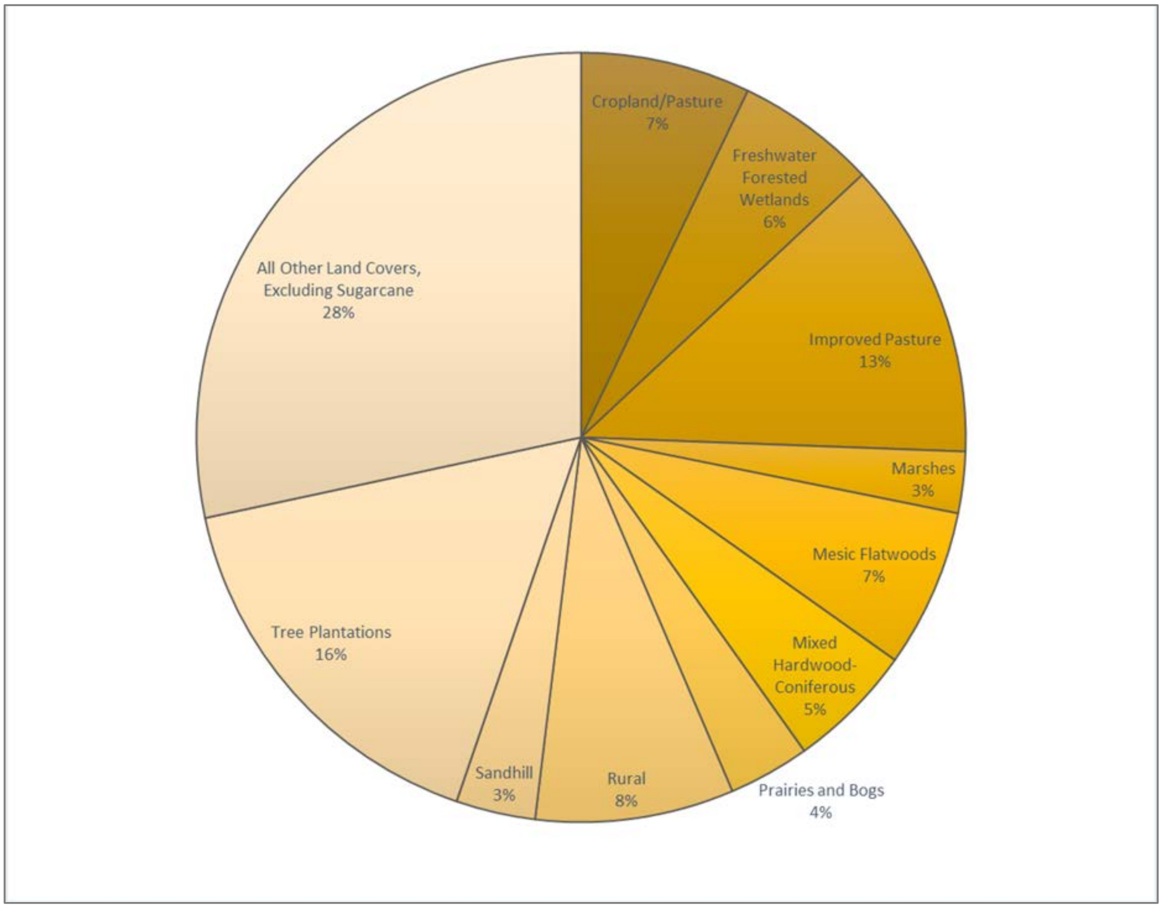
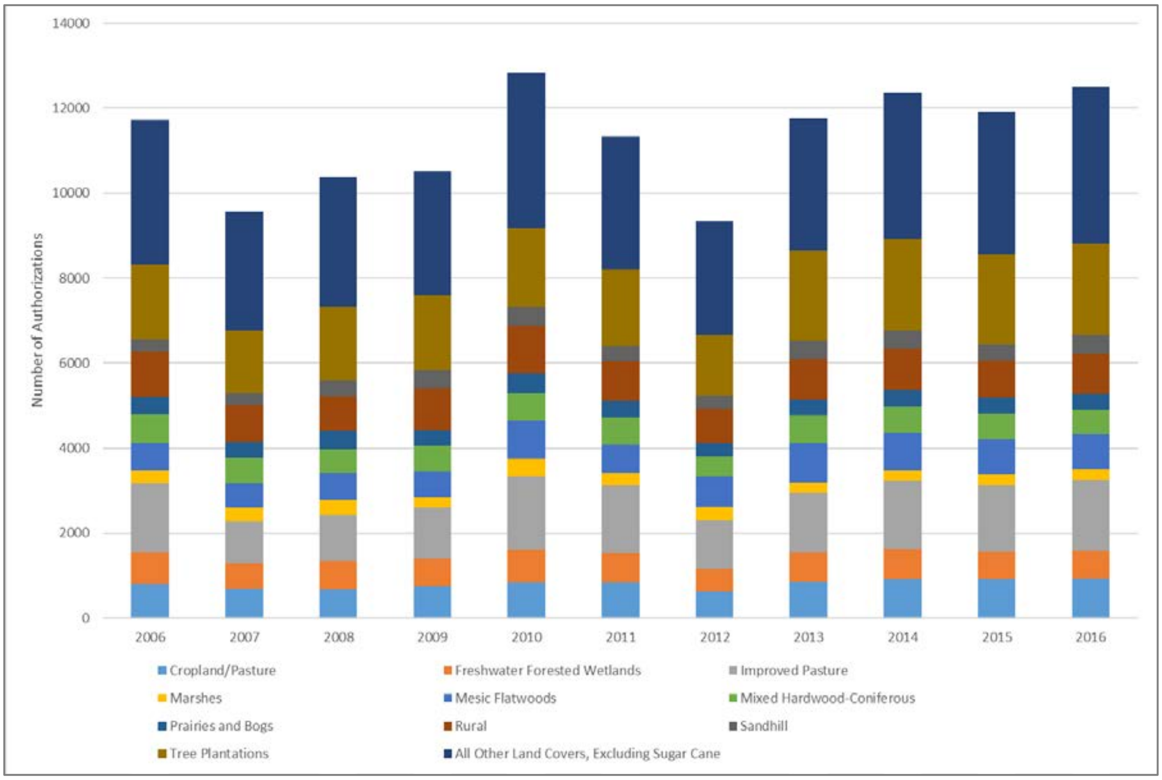


Figure 3: Proportional breakout of all authorizations – excluding Sugarcane – by land cover class.

When analyzing this data by acres authorized, the majority of the acres burned did not necessarily correspond to the most authorizations. For example, most authorizations were requested for burning in the Improved Pasture (13%) and Tree Plantations (16%) land cover categories, but the acreage authorized in these classes was only 8% and 11% (respectively) of the total acreage authorized (Figure 4b). Table 4 contains the number of non-continuation broadcast burn authorizations and acreage authorized for each land cover classification by year, and includes non-burnable land cover classes.



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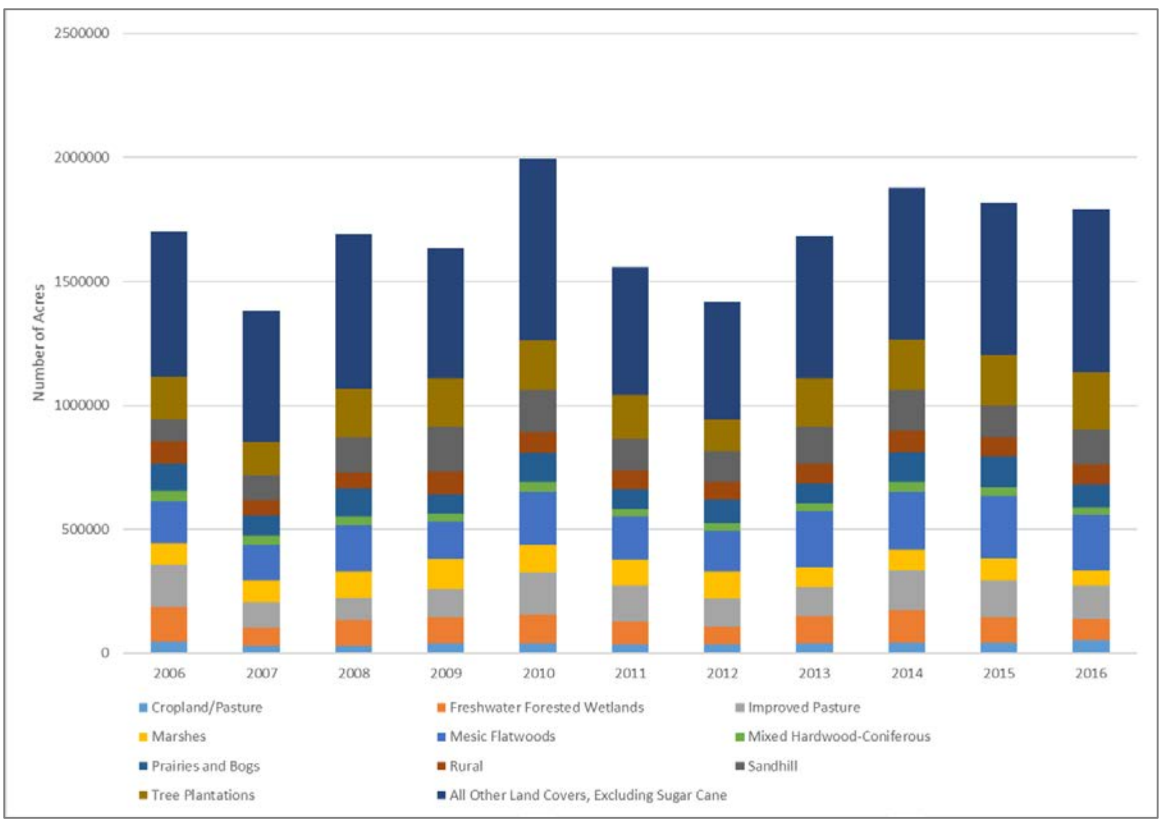

b

Figure 4: Annual non-continuation broadcast burn authorizations (*a*) and acres authorized (*b*) by land cover classification (except sugarcane), including non-burnable land cover classes.

Table 4: Totals and proportions of non-continuation broadcast burn authorizations (and acres authorized) by land cover classification, including non-burnable land cover classes.

Land Cover Classification	Authorizations (% of Total Authorizations)	Acres Authorized (% of Total Acres)
Cropland/Pasture	8 868 (7%)	425 347 (2%)
Freshwater Forested Wetlands	7342 (6%)	1 133 558 (6%)
Improved Pasture	15 590 (13%)	1 471 022 (8%)
Marshes	3 206 (3%)	1 042 577 (6%)
Mesic Flatwoods	8 267 (7%)	2 132 299 (11%)
Mixed Hardwood-Coniferous	6 628 (5%)	382 188 (2%)
Prairies and Bogs	4 247 (3%)	1 101 239 (6%)
Rural	10 368 (8%)	862 611 (5%)
Sandhill	4 147 (3%)	1 511 349 (8%)
Tree Plantations	20 365 (16%)	2 036 489 (11%)
All Other Burnable Land Covers, Excluding Sugarcane	*35 246 (28%)*	*6 444 787 (35%)*
Grand Total	***124 274***	***18 543 466***

Firing Techniques and Burn Type Settings

Table 5 shows the numbers of broadcast burn authorizations and acres authorized by firing technique and burn type settings between 2006 and 2016; it includes only approved authorizations falling on burnable locations and excludes sugarcane OBA points. Most of the authorizations called for backing fire techniques (*n*=95,136) totaling 11,400,408 acres authorized during the time period. The most backing fire authorizations occurred in silvicultural settings (*n*=47,260) accounting for 7,591,715 acres. Ring firing techniques were most prominent in agricultural settings (*n*=6,007) for a total of 342,190 acres authorized. Silvicultural activities accounted for the majority of the authorizations requested overall (*n*=59,139) and the highest total acres authorized (13,180,431 acres). The average acreage requested per permit was highest for aerial ignition firing techniques, which was nearly 13 times the average for backing fire techniques and 23 times the average for ring firing techniques. The table also illustrates some of the potential misappropriations of land cover classes to OBA points. OBA points that fell directly onto the CLC raster locations classified as Sugarcane were filtered from the analysis, which should mean that there are no values associated with the Burn Type Setting labeled 'Agricultural – Sugarcane'; this is clearly not the case (*n*=6,564 authorizations fell into the Agricultural—Sugarcane setting).

Upon completing the initial analyses and descriptions of the FFS authorization data, we determined that for the purposes of this report, only approved non-continuation broadcast burn authorizations occurring on burnable lands will be discussed further in the different sections.

Table 5: Approved non-continuation broadcast burn authorizations (and acres authorized) by firing technique and burn type setting.

	Aerial Ignition		Backing Fire		Flanking Fire		Head Fire		Ring Fire		Grand Total	
	# Authorizations	Acres Authorized	# Authorizations	Acres Authorized	# Authorizations	Acres Authorized	# Authorizations	Acres Authorized	# Authorizations	Acres Authorized	Total # Authorizations	Total Acres Authorized
Agricultural -- Pasture	111	105993	37239	2656912	741	161710	828	180318	397	104953	***39316***	***3209886***
Agricultural -- Range management			5834	999396	154	34289	174	51267	96	45809	***6258***	***1130761***
Agricultural -- Stubble (post harvest)	2	41	1497	53763	14	878	17	595	37	289	***1567***	***55566***
Agricultural -- Sugarcane			1084	33903	3	69	1	10	5476	191119	***6564***	***225101***
Agriculture -- Citrus			60	4838					1	20	***61***	***4858***
ALL AGRICULTURAL	***113***	***106034***	***45714***	***3748812***	***912***	***196946***	***1020***	***232190***	***6007***	***342190***	***53766***	***4626172***
Land clearing -- Non-residential -- With ACI			49	2076					1	5	***50***	***2081***
Land clearing -- Non-residential -- Without ACI			1014	37319	1	100	13	120	4	162	***1032***	***37701***
Land clearing -- Residential -- With ACI			24	616							***24***	***616***
Land clearing -- Residential -- Without ACI			1075	19870	1	1	9	43	1	30	***1086***	***19944***
ALL LAND CLEARING	***0***	***0***	***2162***	***59881***	***2***	***101***	***22***	***163***	***6***	***197***	***2192***	***60342***
Silvicultural -- Disease control	1	40	137	10962	10	1235	4	869	2	110	***154***	***13216***
Silvicultural -- Ecological	486	698711	9459	1959750	2801	865260	1524	540843	200	43953	***14470***	***4108517***
Silvicultural -- Hazard removal	765	1252202	30237	4531333	3240	1172723	963	253599	100	13419	***35305***	***7223276***
Silvicultural -- Prior to seed	5	1122	530	22994	26	7404	18	4024	13	2769	***592***	***38313***
Silvicultural -- Site preparation	7	3969	3941	269492	177	19383	252	24214	115	8895	***4492***	***325953***
Silvicultural -- Wildlife	86	190597	2956	797184	689	322625	354	139589	41	21161	***4126***	***1471156***
ALL SILVICULTURAL	***1350***	***2146641***	***47260***	***7591715***	***6943***	***2388630***	***3115***	***963138***	***471***	***90307***	***59139***	***13180431***
Grand Total	***1463***	***2252675***	***95136***	***11400408***	***7857***	***2585677***	***4157***	***1195491***	***6484***	***432694***	***115097***	***17866945***

Seasonality

Understanding seasonal patterns in burning is important if conservation efforts are to succeed in the state of Florida. When analyzing the seasonality of burning with the FFS authorization data, a pattern of burning is evident that is opposite to the wildfire season in the southeast (Figures 5 through 8). Most of the authorizations are requested in the fall and winter months (October through March), and start tapering in April and May as wildfire season nears. Most authorizations occur in February, followed respectively by March and January. The number of approved authorizations are shown on a yearly basis (grouped by month; Figure 6a) for 2006-2016; Figure 6b breaks the months out individually for closer inspection and comparison between years. Interesting variations between years and months are evident in these graphs. For example, February 2011 ranks second overall for number of broadcast burn authorizations, but there were very few permits authorized in June 2011 compared to all other years.

The corresponding acreage that was authorized is similarly shown in Figures 7a and 7b. The fewest number of acres are burned in September, while February consistently has the highest acreage burned. June 2011 ranks last for having the lowest number of acres authorized across all years and all months. Across all years, the number of authorizations is highest between January and March, which generally corresponds to the three months with the most acres burned; October through December account for the second highest numbers of authorizations and total acreage burned. April and May have shown a trend in increasing numbers of requested authorizations as well as acreage burned for the time period. Between 2006 and 2016, July through October have the lowest number of requests (i.e., less than 500 approved requests monthly), while relatively consistent acreage totals occur in September through November (i.e., less than 100,000 acres authorized monthly).

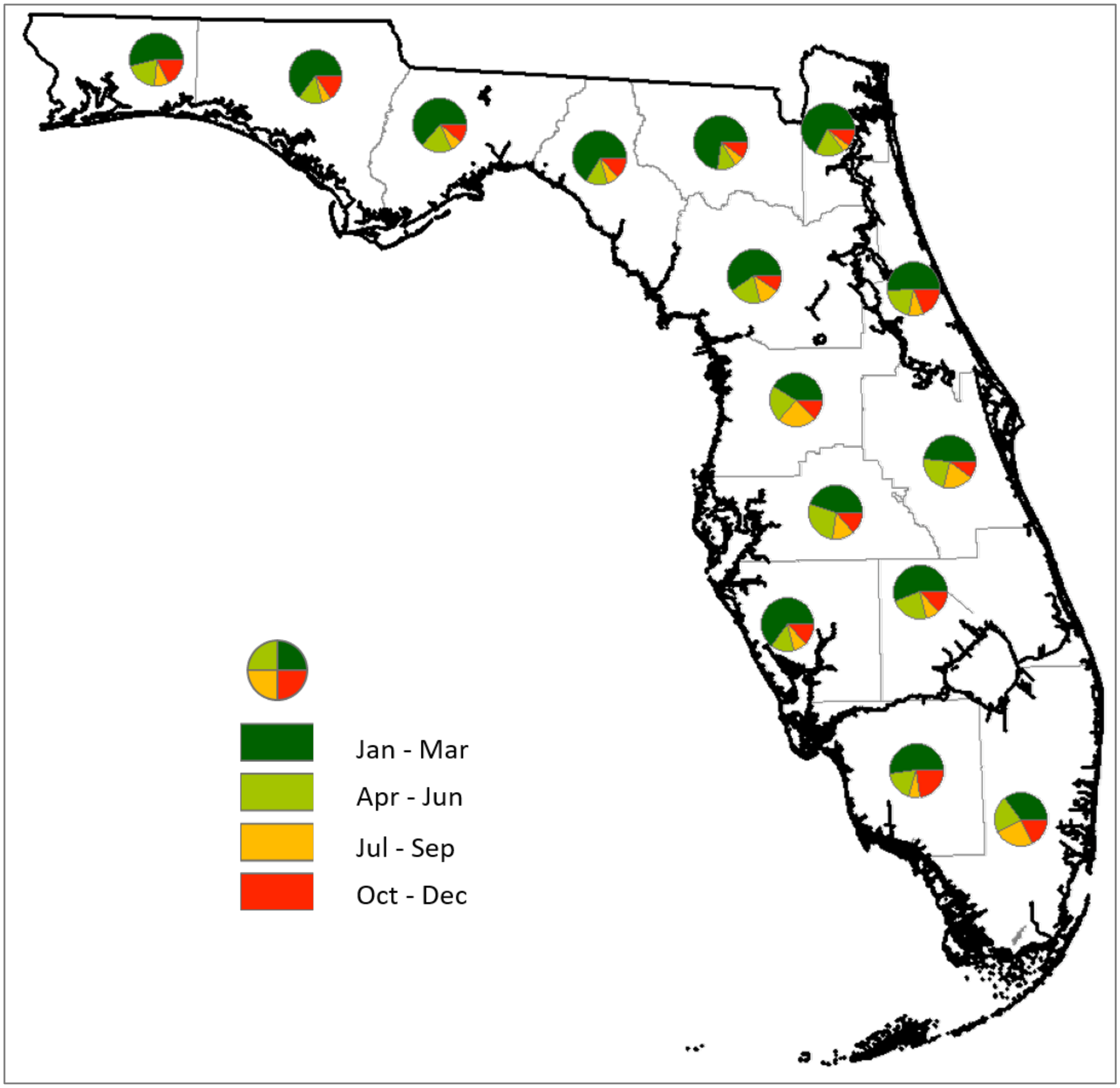

Figure 5: The seasonal proportions of total acres approved in broadcast burn authorizations by FFS District. Seasonal variations are apparent on a latitudinal gradient indicating region-specific burn objectives.

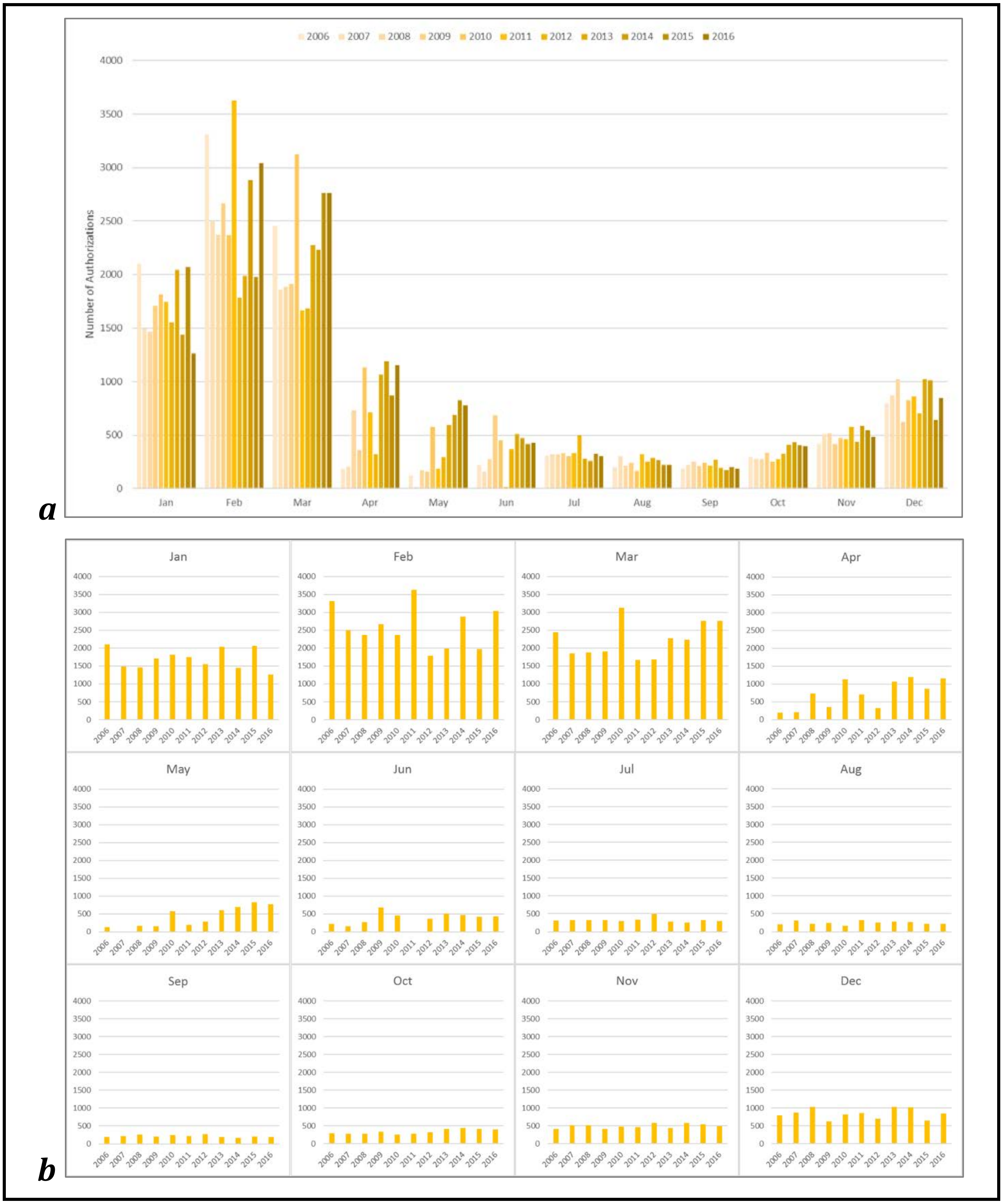

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Figure 6: The number of approved broadcast burn authorizations excluding sugarcane are shown on a yearly basis (grouped by month; *a*) and broken out by individual months (*b*).

Figure 7: The total number of acres approved in broadcast burn authorizations excluding sugarcane are shown on a yearly basis (grouped by month; *a*) and the total acreage authorized broken out by individual months (*b*).

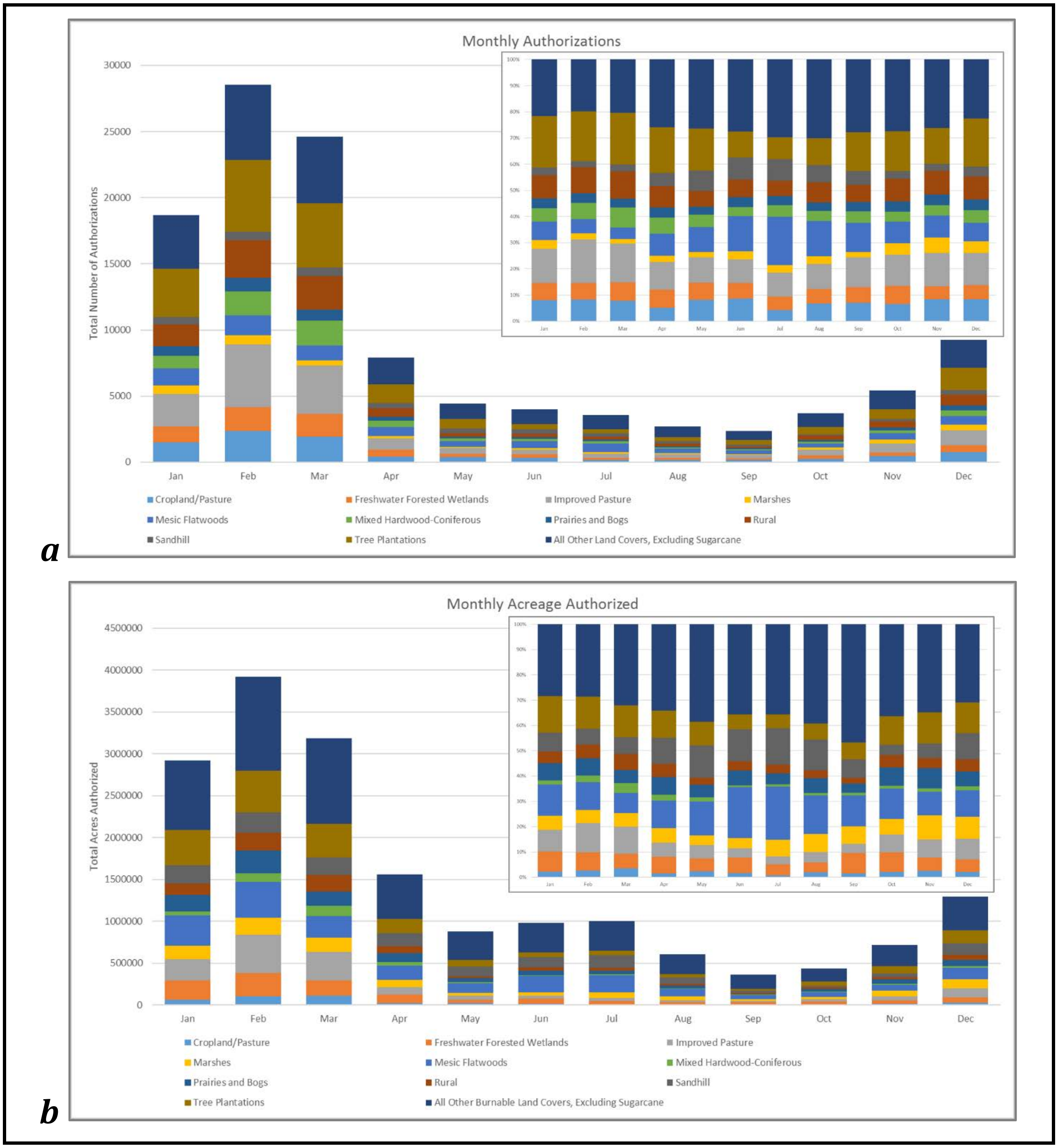

Figure 8: Seasonal variations in burning are apparent when looking at the total number of authorizations approved in broadcast burn authorizations grouped by land cover classification (*a*) and the total acreage authorized (*b*). The insets show proportion of total authorizations (*a*) and acres authorized (*b*).

Figure 8 illustrates how the authorizations and acreage vary monthly by land cover classification, with proportions of totals for each shown in the insets. While the number of authorizations are lower in June and July than many other months, one can see that there are a higher proportion of the authorizations for Mesic Flatwoods than other land cover classes; likewise, May through July show the highest proportions of authorizations for Sandhills. The acreage authorized for both of those land cover classes follows a similar pattern.

Fire Rotations

The FFS OBA dataset is a record of fire occurrence in the state of Florida. If we assume that the requested acres actually did all burn, the data can be used to understand fire rotations, an area-based estimate of fire frequency expressed in years. Specifically, fire rotation is a measure of the expected frequency of fire, calculated for large areas using past fire records, and is considered to be the relative expected interval between fires at regional scales. Fire rotation is interpreted as the best case number of years it would take to burn an area equal to the size of the landscape under consideration. The equation for fire rotation can be expressed as

$$FR = T / [A]$$

where FR is fire rotation expressed in years; T is the time period of interest; and [A] is the proportion of total area burned within each land cover class. In this project, the area of each land cover class is considered to be the landscape of interest, and the time period is 11 years (1/1/2006 through 12/31/2016). For example, the calculation of the fire rotation for the 'Marshes' land cover class would be:

$$FR_{marshes} = \frac{11 \text{ yrs}}{(1042577 \text{ ac burned}_{marshes} / 2435732 \text{ ac total}_{marshes})} = 25.7 \text{ yrs}$$

The fire rotations for each land cover class are shown in Table 6. We calculated the fire rotation values using the acres requested in the FFS OBA data. We assume that the land cover class associated with the actual point location is constant for all acres requested. As such, these fire rotation values have some major limitations. For example, we know that the land cover represented at the specific location of an OBA point for a 100-acre burn would likely not be constant within a 100-acre unit. We also know that there is currently not a method to capture actual acreage burned (versus acreage requested).

Because actual perimeters of the completed burns are not recorded or stored in a standardized way, the only information regarding area burned is the acreage that is associated with the point in the location that is originally requested for the authorization. Therefore, we calculated and show how FR changes if only 75%, 50%, or 25% of the requested acres burned (i.e., Fire Rotation$_{.75}$ corresponds to the fire rotation if only 75% of the total acreage requested burned.). These proportional fire rotations illustrate how the FR can vary depending on the acreage burned and highlights the need for accurate spatial data when reporting prescribed fire accomplishments.

The fire rotations determined using the FFS OBA data can be evaluated against the numbers found in the 2014 land cover classification system report (FWCC 2014) to determine how different they are. Some of these fire rotations make sense (e.g., a FR of 3 years was calculated based on OBA data for Upland Pine, and the FR is reported as 1-3 years in the FWCC [2014] report). Some numbers, however, appear to be too high (e.g., the FR determined for the Pine Rocklands was 14 yrs using OBA data, but is listed as 3-7 yrs in the FWCC [2014] report). A table with fire frequency information is listed in Appendix B for reference; it is included in a document used in the Florida Certified Prescribed Burn Manager training (Saddler *et al.* 2014) and was vetted through the Florida Natural Areas Inventory (FNAI).

Table 6: Fire rotations in years for each land cover class considered to be burnable; corresponding 'proportional' fire rotations are computed for comparison.

	Fire Rotation (Yrs)	Fire Rotation$_{.75}$ (Yrs)	Fire Rotation$_{.5}$ (Yrs)	Fire Rotation$_{.25}$ (Yrs)
Basin Swamp	9	12	19	37
Baygall	16	21	32	63
Coastal Scrub	27	36	54	107
Coastal Strand	28	37	56	111
Coastal Uplands	32	43	64	128
Cropland/Pasture	27	36	54	107
Cultural - Palustrine	12	16	24	47
Cypress	23	31	46	92
Cypress/Tupelo(incl Cy/Tu mixed)	19	26	39	78
Dome Swamp	8	11	16	32
Dry Flatwoods	57	76	114	229
Dry Prairie	4	5	7	14
Exotic Plants	95	127	191	382
Floodplain Marsh	15	20	29	59
Floodplain Swamp	34	45	68	135
Freshwater Forested Wetlands	26	35	52	104
Freshwater Non-Forested Wetlands	26	35	52	104
High Pine and Scrub	8	11	17	34
Hydric Hammock	18	24	36	72
Improved Pasture	23	30	46	91
Isolated Freshwater Marsh	6	8	11	23
Isolated Freshwater Swamp	18	23	35	70
Mangrove Swamp	161	215	323	646
Maritime Hammock	11	15	23	46
Marshes	26	34	51	103
Mesic Flatwoods	7	9	14	27
Mesic Hammock	11	15	22	45
Mixed Hardwood-Coniferous	38	51	77	153
Orchards/Groves	48	64	95	191
Other Agriculture	138	184	277	553
Other Coniferous Wetlands	19	25	37	75
Other Hardwood Wetlands	17	23	34	68
Palmetto Prairie	10	13	20	40
Pine Flatwoods and Dry Prairie	11	15	23	46
Pine Rockland	14	19	29	57
Prairies and Bogs	17	23	35	69
Rockland Hammock	77	103	154	309
Rural	20	27	40	81
Salt Marsh	26	35	53	105
Sand Pine Scrub	31	42	63	125
Sandhill	6	8	11	23
Scrub	9	12	19	37
Scrubby Flatwoods	11	15	22	45
Shrub and Brushland	20	27	40	80
Slope Forest	18	24	37	73
Strand Swamp	10	13	19	38
Sugarcane	2	2	3	6
Tidal Flat	73	97	146	292
Tree Plantations	24	32	48	97
Upland Hardwood Forest	33	44	66	133
Upland Pine	3	4	6	13
Vineyard and Nurseries	68	91	137	274
Wet Flatwoods	10	14	21	41
Xeric Hammock	17	22	34	67
Grand Total (All Land Covers)	***7***	***9***	***14***	***28***

Deliverable #2: Recommendations

These analyses focused on trying to address the prescribed fire data gap and understand the available known datasets for investigating fire regime characteristics in the State of Florida for use with further analyses. This is the first step of the four major steps outlined in the Background section. This groundwork is crucial for creating a 'project map' which will guide other analyses and dataset development moving forward. Some recommendations to consider with respect to the OBA data as the project progresses are summarized by major topics in the bullets below.

Data Consistency

We recommend a thorough testing of the export techniques/scripts/methods currently in place to improve data consistency. We received four different data pulls from the FFS OBA database, none of which were identical.

1. The original dataset received was in excel format and lacked spatial information with which to import into a GIS (i.e., spatial information was lacking for nearly 31,000 of the 131,000+ records).
2. A second request led to a dataset already in a geodatabase format with permit records organized into feature classes by year. The attributes in this dataset were not consistent for the feature classes. We requested a meeting with FFS data managers so they could help us to understand what we had and what we needed. Following the meeting, when FFS attempted to export the data in the format we agreed upon, it was determined that the issues were between the ArcGIS Software and the SQL Server (e.g., beyond the scope of our involvement of this project), and that FFS needed to consult tech support to fix the bugs and issues.
3. In the meantime, a third dataset in the form of an access database with all permit records in one table and all wildfire records in another was received. A quick analysis of this data set revealed that the number of OBA records differed from the geodatabase (the second request).
4. At this point, it was determined to use the data from the second request for further analysis, and to update the feature classes as bugs and issues were fixed. The bugs and issues were fixed and the feature classes were updated to reflect the appropriate changes, and match the rest of the data in the geodatabase from the second request. This version still has some issues that need to be resolved (for example, allowable characters like commas being used in data entry causing export issues). These are minor fixes and we were able to utilize this data for this analysis. However, moving forward, a thorough testing of the database export functions should be analyzed and scripts/protocols updated appropriately.

Data Set Improvements

We assumed that the FFS OBA data would be suitable for us to use as the basis for our analyses regarding fire regime characteristics across the state. We believe that a few changes to how data is captured and QA/QC'd would provide benefits beyond this project. The following suggestions capture some of the things we believe would be helpful in this endeavor:

1. A method to capture spatial data (i.e., perimeters) for completed broadcast burns that are larger than 1 acre (with the possibility of not requiring perimeter for Sugarcane burns). Currently, authorizations are represented only by a point (which may be ok for pile burns, but not for broadcast burns).
2. A method to ensure that duplicated locations are not used for burn authorization requests. Currently, it is possible to 'reuse' a location for another burn authorization. This may occur, for example, if someone knows that they were granted authorization previously with a given point, or if they chose to 'copy information from a previous burn' (an option when entering data via the web interface). The result is that point locations 'stack up' on top of each other through time, which likely is not an accurate reflection of the actual individual burn locations.
3. A method to capture the accuracy of the point data/spatial data. Currently, there is not a standard in place for how the location of a burn is entered; this results in questions about the efficacy of the data locations. No standards exist for how that point is selected, which is especially important for a broadcast burn. For example, requiring all burners requesting authorizations to provide a centroid of a burn block or the location of the test fire would greatly enhance the spatial data in standardized manner.
4. A method to capture information relating to the actual completed acres. Currently, only proposed acres exist in the dataset (i.e., there is no way to capture how many acres were actually burned, or what that burn footprint looks like in a spatial context).
5. A method to better track continuations, and the data associated with these types of authorizations. Currently, there are no standards in place for how to report on this type of authorization, which may result in over-reporting of acres on an annual basis. If a continuation is requested, information on acres previously requested and how many of those acres were completed would help with tracking/accounting for acres burned. Additionally, reasons for requesting a continuation should be captured (e.g., poor weather conditions, lack of resources, etc.).
6. Data entry control methods should be enabled to ensure that only logical combinations of data attributes can be entered which has downline processing implications. For example, if the burn type is a Pile Burn, then 'Aerial Ignition' cannot be used as a Firing Technique. Additionally, a 'check' against the CLC layer (or some other agreed-upon layer) in the background could ensure that if the authorization was being requested for Agricultural--Sugarcane burning, then it should fall on a location identified in the CLC as Sugarcane. Similarly, 'Non-burnable' masks could be used to force re-location of points if they fell on land cover categories that should not support fire.
7. A method to standardize the point location to a specific reference or base dataset. By ensuring that the spatial envelopes of datasets are consistent, OBA data entries could be snapped to an agreed upon location (e.g., the lower right corner or the centroids of a base grid or township-range-section polygon) at a specific resolution that would allow for known minimum mapping unit accuracy. For example, for the purposes of this study, the CLC raster would be considered the base data, with all OBA points entered and snapped to centroids of the CLC grid.

Next Steps

The next steps for the project include developing methods to assess the feasibility of using satellite burn detections to identify fire extents; we will use the FFS OBA data as a guide for identifying areas where satellite detections should exist. Additionally, we will be developing custom query tools to evaluate fire regime characteristics and trends, as well as identifying procedures for annual updates moving forward. To address the challenge of understanding spatial characteristics of the burn authorizations and reconstructing burn histories, we plan to utilize the Burned Area Essential Climate Variable (BAECV) dataset developed by Hawbaker *et al.* (2017) and MTBS dataset (Eidenshink *et al.* 2007) and compare against the FFS OBA data. Some of the methods developed by Nowell *et al.* (*in prep*) will be expanded upon and utilized for this step. The result will be spatial information in the form of fire perimeters for the time period 2006 – 2016. We also plan to use information collected from satellite detection sensors (specifically, VIIRS and MODIS) to add ancillary data about the presence/absence of fires. Data from sensors like these can be used in a consistent and replicable way for comparing to OBA locations. Known limitations and assumptions of BAECV, MTBS, MODIS, and VIIRS are well documented in scientific literature.

Additionally, it should be noted that although we do not specifically address pile burn data in our analyses, these data will likely be important for validation in future protocols, especially when differentiating between large piles and small broadcast burns detected by satellites like MODIS and VIIRS. Therefore, this data will remain in the database, but is filterable depending on the analysis being performed.

Deliverable #3.1: Update

This section documents the conversion of the Air Force wildfire Oracle database to a SQL Server database. The initial database conversion of the Air Force management database from Oracle to SQL Server is complete. A SQL Server database was created on a Tall Timbers server. The necessary tables, views, and procedures were converted to SQL Server format. In additional, all existing data were imported into the new server database. The following major conversion steps are completed:

- Received Oracle Data Pump Export from Eglin AFB.
- Created Oracle test environment.
- Imported Oracle Eglin data and compile and catalog all objects.
- Created SQL Server scripts to migrate necessary objects.
- Created SQL Server test environment.
- Built tables, constraints, and triggers for tables.
- Imported existing data into new data model (reprojection)
- Registered with ESRI software.
- Migrated the SQL Server test database to Tall Timbers production database

To perform this conversion, we obtained an Oracle Data Loader dump file from the Air Force, and Created a temporary Oracle database server to load the Oracle dump file. This allowed the conversion team to obtain the database structure, and to verify the converted results were correct. We worked with the Air Force Fire Management team to determine which database features were necessary for the conversion.

Next, we created a SQL Server instance in a test environment to perform the conversion. The new SQL Server database is named *ttfire*. The following steps were run for all necessary database objects:

- Export the Oracle SQL data definition language (DDL) of the necessary database objects.
- Convert the Oracle SQL DDL to SQL Server DDL. Most of the time this consisted of Oracle to SQL Server syntax issues. Some of the time it involved a complete rewrite of the database object DDL syntax. Table 7 outlines the data type conversions for Oracle and SQL Server.
- Export the Oracle SQL code for the fire management views and procedures. Rewrite the code to SQL Server format.

We then imported the Oracle fire management non-spatial data into SQL Server. This involved exporting the Oracle fire management data to standard SQL insert statements; converting the Oracle insert statements to SQL Server insert SQL for the data tables without geometries; creating SQL Server insert scripts, and loading existing Air Force fire management data into SQL Server. The Oracle fire management spatial data was imported into SQL Server. We used ESRI ArcCatalog to create connections to Oracle and SQL Server, and to copy spatial data from Oracle to SQL Server into temporary tables. We validated and corrected invalid geometries using SQL Server spatial functions. We then created production level fire management spatial tables and registered the tables with ESRI. To verify that the spatial tables are registered with valid geometries, we created test maps (Figure 9).

After the tables were created and the data were loaded, we created SQL Server SQL to support the relational database model. This includes the following items: Primary keys, Foreign keys, Constraints, Triggers, and Functions. The results are shown in the entity relational diagram (Figure 10).

Finally, we converted views and procedures to support the fire management data model. The necessary views and procedures from Oracle were exported into standard SQL, and the Oracle SQL was converted to SQL Server SQL. We compiled and tested the objects in the *ttfire* SQL database.

Table 7: Data type conversions for Oracle and SQL Server.

Microsoft SQL Server	Oracle
BIGINT	NUMBER(19)
BINARY	RAW
BIT	NUMBER(3)
CHAR	CHAR
DATETIME	DATE
DECIMAL	NUMBER(p[,s])
FLOAT	FLOAT(49)
IMAGE	LONG RAW
INTEGER	NUMBER(10)
MONEY	NUMBER(19,4)
NCHAR	NCHAR
NTEXT	LONG
NVARCHAR	NCHAR
NUMERIC	NUMBER(p[,s])
REAL	FLOAT(23)
SMALL DATETIME	DATE
SMALL MONEY	NUMBER(10,4)
SMALLINT	NUMBER(5)
TEXT	LONG
TIMESTAMP	RAW
TINYINT	NUMBER(3)
UNIQUEIDENTIFIER	CHAR(36)
VARBINARY	RAW
VARCHAR	VARCHAR2

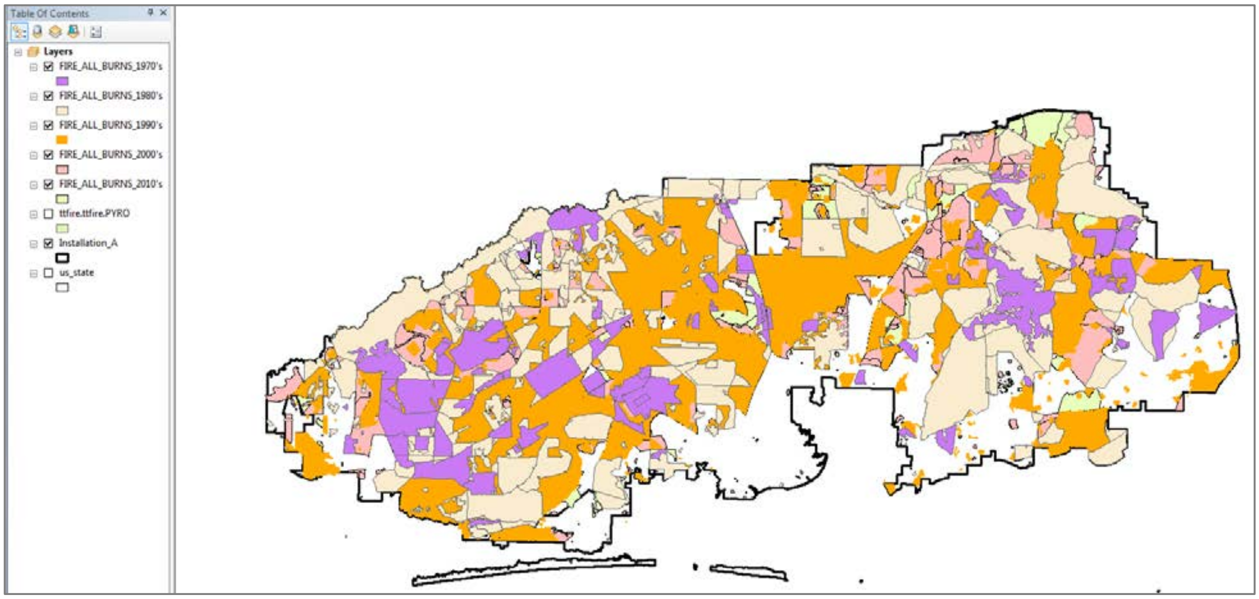

Figure 9: Test map of Eglin Air Force Base fire data created to verify spatial tables have valid geometry; this map would not appear correctly if the geometries were invalid.

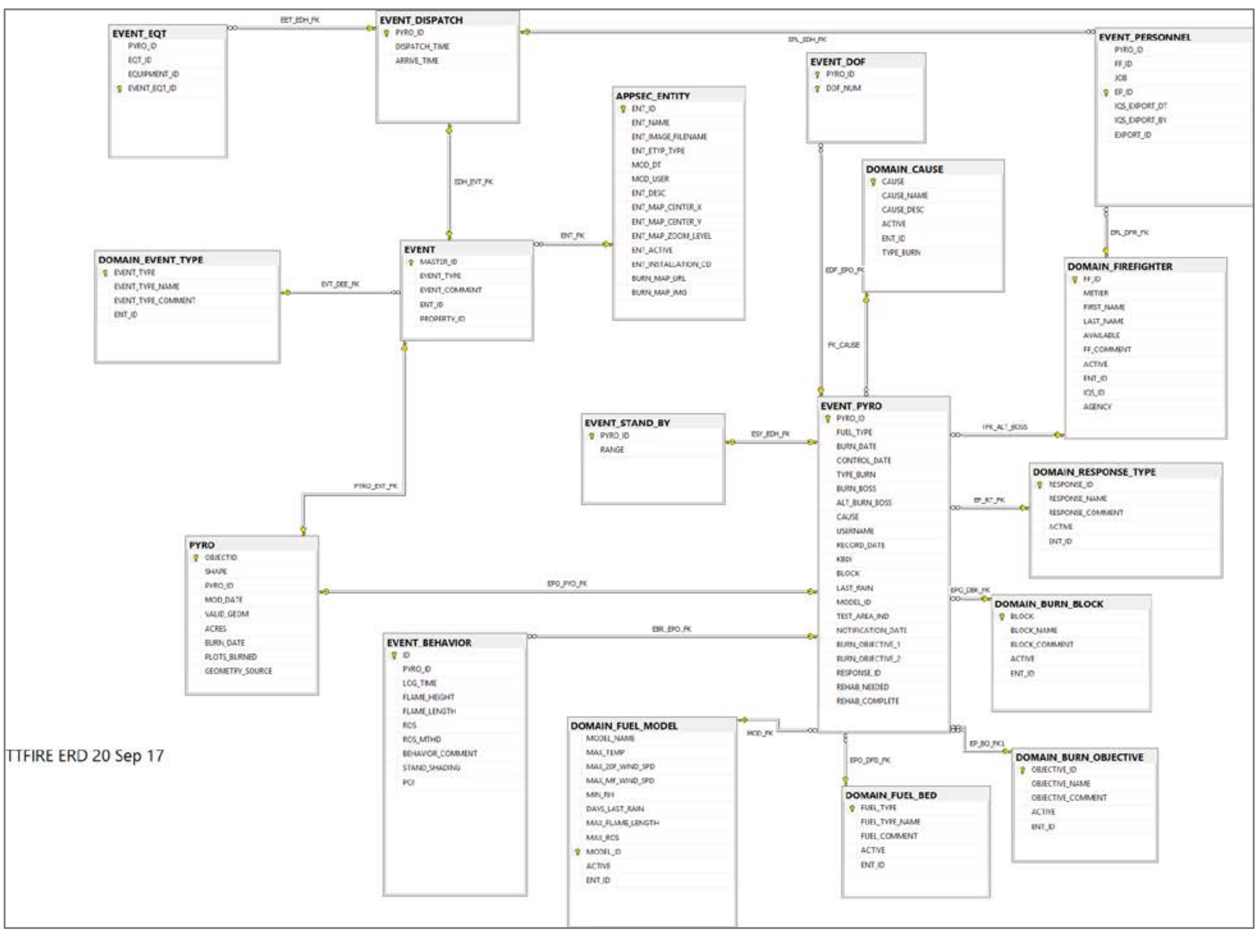

Figure 10: Entity relational diagram of the *ttfire* SQL Server database.

Summary

The overall aim of this project is to develop a spatial database of prescribed fire in Florida. The exploratory data analysis performed for this deliverable provided useful insights into the FFS OBA dataset, and its potential usefulness for assessing fire regime characteristics in the state of Florida. This dataset is considered a census dataset in terms of prescribed fire for the state of Florida. Using the FFS OBA data, we were able to describe prescribed fire characteristics by: number and type of authorizations granted, burn category types, firing techniques, acreage authorized, seasonality, land cover classification, and fire rotations. Because the FFS OBA data is a point source dataset, this information is only part of the picture of prescribed fire in the state. Recommendations for improving the data captured by this dataset are identified. However, the FFS OBA data will be useful moving forward with analyses concerning prescribed fire numbers, especially when compared to spatially explicit data derived from satellite sources.

The conversion of the Air Force Wildfire database from Oracle to SQL Server has been completed. The next steps for using this database include consultation with FWC to determine the required data fields of interest, as well as incorporation of ancillary data for analyses.

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Appendices

Appendix A: *Cooperative Land Cover Classification Descriptions*
Appendix B: *Fire Dependency of Florida's Natural Communities*

Appendix A: Cooperative Land Cover Classification Descriptions

The Florida Cooperative Land Cover Map (CLC) is a partnership between the Florida Fish and Wildlife Conservation Commission (FWC) and Florida Natural Areas Inventory (FNAI) to develop ecologically-based statewide land cover from existing sources and expert review of aerial photography. The CLC is primarily funded by the Florida's State Wildlife Grants program in support of The Florida State Wildlife Action Plan which identified improved habitat mapping as a priority data gap. The resultant classification scheme is hierarchical and extensible, and can be cross-walked among the currently used and maintained classifications. The ability to cross-walk this classification with other currently used schemas will allow the incorporation of other classification efforts and facilitate collaboration between entities producing land cover datasets. This will ultimately result in more accurate and reliable land cover classification that will benefit and add value to all currently maintained land cover classification projects.

The class definitions are listed in this appendix. Existing class definitions were adopted from currently used classifications systems when possible. Capsule descriptions from FNAI's Guide to Natural Communities of Florida (FNAI 1990, 2010) were used and readers are encouraged to read the full class descriptions available on their website (www.fnai.org). Class descriptions from FWC (Gilbert and Stys 2003), SJWMD (SJWMD 2004), SFWMD (SFWMD 2004), FLUCCS (FDOT 1999) and Edinger et al. (2002) were used in their entirety, in part, or modified to meet the needs of this classification.

A full description of the classification process and references can be found at:
http://myfwc.com/media/4311749/landcoverclassification-2014.pdf

Class Definitions

Land Cover Class Code	Land Cover Class	Description	Acres
1880	**Bare Soil/Clear Cut**	Areas of bare soil representing recent timber cutting operations, areas devoid of vegetation as a consequence of recent fires, natural areas of exposed bare soil (e.g., sandy areas within xeric communities), or bare soil exposed due to vegetation removal for unknown reasons	31494
1700	**Barren and Outcrop Communities**	Small extent communities in karst features or on exposed limestone	507
22132	**Basin Swamp**	Typically large basin wetland with peat substrate; seasonally inundated; still water or with water output; Panhandle to central peninsula; occasional or rare fire; forest of cypress/tupelo/mixed hardwoods; pond cypress, swamp tupelo	192634
2231	**Baygall**	Slope or depression wetland with peat substrate; usually saturated and occasionally inundated; statewide excluding Keys; rare or no fire; closed canopy of evergreen trees; loblolly bay, sweetbay, swamp bay, titi, fetterbush	111861
1214	**Coastal Scrub**	This scrub category represents a wide variety of species found in the coastal zone. A few of the more common components are saw palmetto, sand live oak, myrtle oak, yaupon, railroad vine, bay bean, sea oats, sea purslane, sea grape, Spanish bayonet and prickly pear. This cover type is generally found in dune and white sand areas.	19554
1640	**Coastal Strand**	Stabilized coastal dune with sand substrate; xeric; peninsula; rare fire; marine influence; primarily dense shrubs; saw palmetto in temperate coastal strand or seagrape and/or saw palmetto in tropical coastal strand.	6703
1600	**Coastal Uplands**	Mesic or xeric communities restricted to barrier islands and near shore; woody or herbaceous vegetation; other communities may also occur in coastal environments	16570
1850	**Communication**	Airwave communications, radar and television antennas with associated structures are typical major types of communication facilities that will be identified in this category. When stations are associated with a commercial or governmental facility, they will be included in either of those specific categories when located within their bounds and will not be listed as separate elements.	4084
18331	**Cropland/Pasture**	Agricultural land which is managed for the production of row or field crops and improved, unimproved and woodland pastures.	1038495
5300	**Cultural - Estuarine**	Communities that are either created and maintained by human activities, or are modified by human influence to such a degree that the physical conformation of the substrate, or the biological composition of the resident community is substantially different from the character of the substrate or community as it existed prior to human influence.	5366

Land Cover Class Code	Land Cover Class	Description	Acres
3200	**Cultural - Lacustrine**	Communities that are either created, and maintained by human activities, or are modified by human influence to such a degree that the trophic state, morphometry, water chemistry, or biological composition of the resident community are substantially different from the character of the lake community as it existed prior to human influence	414335
2400	**Cultural - Palustrine**	Communities that are both created and maintained by human activities, or are modified by human influence to such a degree that the physical conformation of the substrate, the hydrology, or the biological composition of the resident community is substantially different from the character of the substrate, hydrology, or community as it existed prior to human influence.	367976
4200	**Cultural - Riverine**	Communities that are either created and maintained by human activities, or are modified by human influence to such a degree that stream flow, morphometry, water chemistry, or the biological composition of the resident community are substantially different from the character of the stream community as it existed prior to human influence	79951
1800	**Cultural - Terrestrial**	Includes communities that are both created and maintained by human activities, or are modified by human influence to such a degree that the physical conformation of the substrate, or the biological composition of the resident community is substantially different from the character of the substrate or community as it existed prior to human influence.	19794
2211	**Cypress**	Dominated entirely by cypress, or these species important in the canopy; long hydroperiod.	637310
2210	**Cypress/Tupelo (incl Cy/Tu mixed)**	Dominated entirely by cypress or tupelo, or these species important in the canopy; long hydroperiod	92145
22131	**Dome Swamp**	Small or large and shallow isolated depression in sand/marl/limestone substrate with peat accumulating toward center; occurring within a fire-maintained community; seasonally inundated; still water; statewide excluding Keys; occasional or rare fire; forested, canopy often tallest in center; pond cypress, swamp tupelo.	48862
1310	**Dry Flatwoods**	Non-hydric flatwoods.	2459
1330	**Dry Prairie**	Flatland with sand soils over an organic or clay hardpan; mesic-xeric; central peninsula; annual or frequent fire (1-2 years); treeless with a low cover of shrubs and herbs; wiregrass, dwarf live oak, stunted saw palmetto, bottlebrush threeawn, broomsedge bluestem.	155891

Land Cover Class Code	Land Cover Class	Description	Acres
5000	**Estuarine**	Deepwater tidal habitats and adjacent tidal wetlands that are usually semi-enclosed by land but have open, partly obstructed, or sporadic access to the ocean, with ocean-derived water at least occasionally diluted by freshwater runoff from the land. The upstream and landward limit is where ocean-de rived salts measure less than .5 ppt during the period of average annual low flow. The seaward limit is (1) an imaginary line closing the mouth of a river, bay, or sound; and (2) the seaward limit of wetland emergents, shrubs, or trees when not included in (1)	1619174
7000	**Exotic Plants**	Upland and wetland areas dominated by non-native trees that were planted or have escaped and invaded native plant communities. These exotics include melaleuca, Australian pine, Brazilian pepper, and eucalyptus. This class includes sites known to be vegetated by non-native but for which the actual species composition could not be determined.	66089
1870	**Extractive**	Encompass both surface and subsurface mining operations. Included are sand, gravel and clay pits, phosphate mines, limestone quarries plus oil and gas wells. Industrial complexes where the extracted material is refined, packaged or further processed are also included in this category	256978
2123	**Floodplain Marsh**	Floodplain with organic/sand/alluvial substrate; seasonally inundated; Panhandle to central peninsula; frequent or occasional fire (ca. 3 years, much less frequent in freshwater tidal marshes); treeless herbaceous community with few shrubs; sawgrass, maidencane, sand cordgrass, and/or mixed emergents	49974
2215	**Floodplain Swamp**	Along or near rivers and streams with organic/alluvial substrate; usually inundated; Panhandle to central peninsula; rare or no fire; closed canopy dominated by cypress, tupelo, and/or black gum.	421270
2200	**Freshwater Forested Wetlands**	Floodplain or depression wetlands dominated by hydrophytic trees	2676694
2100	**Freshwater Non-Forested Wetlands**	Herbaceous or shrubby palustrine communities in floodplains or depressions; canopy trees, if present, very sparse and often stunted	138786
1822	**High Intensity Urban**	Residential density > 2 dwelling/acre, commercial, industrial, and institutional	2252895
1200	**High Pine and Scrub**	Hills with mesic or xeric woodlands or shrublands; canopy, if present, open and consisting of pine or a mixture of pine and deciduous hardwoods.	290829
2232	**Hydric Hammock**	Lowland with sand/clay/organic soil over limestone or with high shell content; mesic- hydric; primarily eastern Panhandle and central peninsula; occasional to rare fire; diamond-leaved oak, live oak, cabbage palm, red cedar, and mixed hardwoods.	240562

Land Cover Class Code	Land Cover Class	Description	Acres
183313	**Improved Pasture**	This category in most cases is composed of land which has been cleared, tilled, reseeded with specific grass types and periodically improved with brush control and fertilizer application. Water ponds, troughs, feed bunkers and, in some cases, cow trails are evident.	3056264
2121	**Isolated Freshwater Marsh**	--	276763
2213	**Isolated Freshwater Swamp**	--	74557
52111	**Keys Tidal Rock Barren**	Flatland with exposed limestone in supratidal zone; restricted to Keys; no fire; open, mainly herbaceous vegetation of upper tidal marsh species and stunted shrubs and trees; buttonwood, christmasberry, perennial glasswort, saltwort, seashore dropseed, shoregrass.	8519
3000	**Lacustrine**	Wetlands and deepwater habitats (1) situated in a topographic depression or dammed river channel; (2) lacking trees, shrubs, persistent emergents, emergent mosses, or lichens with greater than 30% areal coverage; and (3) whose total area exceeds 8 hectares (20 acres); or area less than 8 hectares if the boundary is active wave-formed or bedrock or if water depth in the deepest part of the basin exceeds 2 m (6.6 ft) at low water. Ocean- derived salinities are always less than .5 ppt.	388970
1821	**Low Intensity Urban**	Less than two dwelling units per acre. Areas of low intensity residential land use (generally less than one dwelling unit per five acres), such as farmsteads, will be incorporated into the rural structures category.	1302061
5250	**Mangrove Swamp**	Estuarine wetland on muck/sand/or limestone substrate; inundated with saltwater by daily tides; central peninsula and Keys; no fire; dominated by mangrove and mangrove associate species; red mangrove, black mangrove, white mangrove, buttonwood.	571710
6000	**Marine**	Open ocean overlying the continental shelf and coastline exposed to waves and currents of the open ocean shoreward to (1) extreme high water of spring tides; (2) seaward limit of wetland emergents, trees, or shrubs; or (3) the seaward limit of the Estuarine System, other than vegetation. Salinities exceed 30 parts per thousand (ppt).	7841740
1650	**Maritime Hammock**	Stabilized coastal dune with sand substrate; xeric-mesic; statewide but rare in panhandle and Keys; rare or no fire; marine influence; evergreen closed canopy; live oak, cabbage palm, red bay, red cedar in temperate maritime hammock; gumbo limbo, seagrape, and white or Spanish stopper in tropical maritime hammock.	29654
2120	**Marshes**	Long hydroperiod; dominated by grasses, sedges, broadleaf emergents, floating aquatics, or shrubs.	2435732

Land Cover Class Code	Land Cover Class	Description	Acres
1311	**Mesic Flatwoods**	Flatland with sand substrate; mesic; statewide except extreme southern peninsula and Keys; frequent fire (2-4 years); open pine canopy with a layer of low shrubs and herbs; longleaf pine and/or slash pine, saw palmetto, gallberry, dwarf live oak, wiregrass.	1325011
1120	**Mesic Hammock**	Flatland with sand/organic soil; mesic; primarily central peninsula; occasional or rare fire; live oak, cabbage palm, southern magnolia, pignut hickory, saw palmetto.	126285
1400	**Mixed Hardwood-Coniferous**	Mix of hardwood and coniferous trees where neither is dominant	1329657
3100	**Natural Lakes and Ponds**	Includes inland lakes and ponds in which the trophic state, morphometry, and water chemistry have not been substantially modified by human activities, or the native biota are dominant	550976
4100	**Natural Rivers and Streams**	Streams in which the stream flow, morphometry, and water chemistry have not been substantially modified by human activities, or the native biota are dominant.	80295
2300	**Non-vegetated Wetland**	Hydric surfaces on which vegetation is found lacking due to the erosional effects of wind and water transporting the surface material so rapidly that the establishment of plant communities is hindered or the fluctuation of the water surface level is such that vegetation cannot become established. Additionally, submerged or saturated materials often develop toxic conditions of extreme acidity. Intermittent ponds are the main components of this category	13828
18332	**Orchards/Groves**	This class is for active tree cropping operations that produce fruit, nuts, or other resources not including wood products	907991
18335	**Other Agriculture**	--	138533
2220	**Other Coniferous Wetlands**	Coniferous forested wetlands that are not dominated by cypress, tupelo, or a mix of cypress/tupelo	26800
2230	**Other Hardwood Wetlands**	Dominated by a mix of hydrophytic hardwood trees; cypress or tupelo may be occasional or infrequent in the canopy; short hydroperiod	23022
1340	**Palmetto Prairie**	These are areas in which saw palmetto is the most dominant vegetation. Common associates of saw palmetto in this cover type are fetterbush, tar flower, gallberry, wire grass and brown grasses. This cover type is usually found on seldom flooded dry sand areas. These treeless areas are often similar to the pine flatwoods but without the presence of pine trees.	21131
1300	**Pine Flatwoods and Dry Prairie**	Mesic pine woodland or mesic shrubland on flat sandy or limestone substrates, often with a hard pan that impedes drainage	105838
1320	**Pine Rockland**	Flatland with exposed limestone substrate; mesic-xeric; southern peninsula and Keys; frequent to occasional fire (3-7 years); open pine canopy with mixed shrubs and herbs in understory; south Florida slash pine, palms, mixed tropical and temperate shrubs, grasses, and herbs	16866

Land Cover Class Code	Land Cover Class	Description	Acres
2110	**Prairies and Bogs**	Short hydroperiod; dominated by grasses, sedges, and/or titi	1736441
4000	**Riverine**	All wetlands and deepwater habitats contained within a channel except those wetlands (1) dominated by trees, shrubs, persistent emergents, emergent mosses, or lichens, and (2) which have habitats with ocean-derived salinities in excess of .5 ppt.	164993
1130	**Rockland Hammock**	Flatland with limestone substrate; mesic; southern peninsula and Keys; rare or no fire; closed canopy of evergreen mixed tropical hardwoods; gumbo limbo, pigeon plum, stoppers.	19320
1830	**Rural**	--	1581448
5240	**Salt Marsh**	Estuarine wetland on muck/sand/or limestone substrate; inundated with saltwater by daily tides; statewide; occasional or rare fire; treeless, dense herb layer with few shrubs; saltmarsh cordgrass, needle rush, saltgrass, saltwort, perennial glasswort, seaside oxeye	378678
1670	**Sand Beach (Dry)**	Beaches are constantly affected by wave and tidal action. The fine clays and silts are washed away leaving sand. However, in protected bay and marsh areas, fine soil particles from surface drainage may settle out. The beach areas also are subject to water and wind erosion	24386
1213	**Sand Pine Scrub**	Found on ridges throughout the state; rare fire (20-80 years); canopy of sand pine and an understory of the three shrubby oaks, myrtle oak, Chapman's oak, sand live oak, or less commonly, Florida rosemary.	220967
1240	**Sandhill**	Upland with deep sand substrate; xeric; panhandle to central peninsula; frequent fire (1-3 years); open canopy of longleaf pine and/or turkey oak with wiregrass understory.	775755
1210	**Scrub**	Upland with deep sand substrate; xeric; statewide except extreme southern peninsula and Keys, mainly coastal in Panhandle; occasional or rare fire; open or dense shrubs with or without pine canopy; sand pine and/or scrub oaks and/or Florida rosemary.	159788
5252	**Scrub Mangrove**	Areas sparsely vegetated with small, stunted mangroves. Found in extreme south Florida only	42388
1312	**Scrubby Flatwoods**	Flatland with sand substrate; xeric-mesic; statewide except extreme southern peninsula and Keys; occasional fire (5-15 years); widely scattered pine canopy over saw palmetto and scrub oaks; longleaf pine, sand live oak, myrtle oak, Chapman's oak, saw palmetto, wiregrass.	93619

Land Cover Class Code	Land Cover Class	Description	Acres
1500	**Shrub and Brushland**	This association includes a variety of situations where natural upland community types have been recently disturbed through clear-cutting commercial pinelands, land clearing, or fire, and are recovering through natural successional processes. This type could be characterized as an early condition of old-field succession, and various shrubs, tree saplings, and lesser amounts of grasses and herbs dominate the community. Common species include wax myrtle, saltbush, sumac, elderberry, saw palmetto, blackberry, gallberry, fetterbush, staggerbush, broomsedge, dog fennel, together with oak, pine and other tree seedlings or saplings.	342184
1140	**Slope Forest**	Steep slope on bluff or in sheltered ravine within the Apalachicola drainage; sand/clay substrate; mesic-hydric; central panhandle; rare or no fire; closed canopy of mainly deciduous species; American beech, Florida maple, white oak, Ashe's magnolia, southern magnolia, spruce pine, Shumard's oak.	5875
2214	**Strand Swamp**	Broad, shallow channel with peat over mineral substrate; situated in limestone troughs; seasonally inundated; slow flowing water; vicinity of Lake Okeechobee southward in the central and southern peninsula; occasional or rare fire; closed canopy of cypress and mixed hardwoods; cypress, pond apple, strangler fig, willow, abundant epiphytes	44236
1833121	**Sugarcane**	--	618200
5220	**Tidal Flat**	A community of quiet waters, with substrates composed of silt or sand that is rich in organic matter and poorly drained at low tide. The substrate may be covered with algae	43950
1840	**Transportation**	Transportation facilities are used for the movement of people and goods. Highways include areas used for interchanges, limited access rights-of-way and service facilities. The Transportation category encompasses rail-oriented facilities including stations, round-houses, repair and switching yards and related areas. Airport facilities include runways, intervening land, terminals, service buildings, navigational aids, fuel storage, parking lots and a limited buffer zone and fall within the Transportation category. Transportation areas also embrace ports, docks, shipyards, dry docks, locks and water course control structures designed for transportation purposes. The docks and ports include buildings, piers, parking lots and adjacent water utilized by ships in the loading and unloading of cargo or passengers. Locks, in addition to the actual structures, include the control buildings, power supply buildings, docks and surrounding supporting land use (i.e., parking lots and green areas)	1610733
18333	**Tree Plantations**	--	4485132
9100	**Unconsolidated Substrate**	--	3050

Land Cover Class Code	Land Cover Class	Description	Acres
1720	**Upland Glade**	Upland with thin clay soils over limestone outcrops; hydric-xeric; central panhandle only; sparse mixed grasses and herbs with occasional stunted trees and shrubs that are concentrated around the edge; black bogrush, poverty dropseed, diamondflowers, hairawn muhly, Boykin's polygala, red cedar.	34
1110	**Upland Hardwood Forest**	Upland with sand/clay and/or calcareous substrate; mesic; Panhandle to central peninsula; rare or no fire; closed deciduous or mixed deciduous/evergreen canopy; American beech, southern magnolia, hackberry, swamp chestnut oak, white oak, horse sugar, flowering dogwood, and mixed hardwoods.	224388
1231	**Upland Pine**	Upland with sand/clay substrate; mesic-xeric; longleaf pine and/or loblolly pine and/or shortleaf pine.	164839
1860	**Utilities**	Include power generating facilities and water treatment plants including their related facilities such as transmission lines for electric generation plants and aeration fields for sewage treatment sites. Small facilities or those associated with an industrial, commercial or extractive land use are included within these larger respective categories.	113620
18334	**Vineyard and Nurseries**	Includes tree nurseries, sod farms, and three classes of ornamentals. Miscellaneous uses that would belong include vineyards and nurseries other than for trees.	135882
2221	**Wet Flatwoods**	Flatland with sand substrate; seasonally inundated; statewide except extreme southern peninsula and Keys; frequent fire (2-4 years for grassy wet flatwoods, 5-10 years for shrubby wet flatwoods); closed to open pine canopy with grassy or shrubby understory; slash pine, pond pine, large gallberry, fetterbush, sweetbay, cabbage palm, wiregrass, toothache grass.	761947
1150	**Xeric Hammock**	Upland with deep sand substrate; xeric; primarily eastern Panhandle to central peninsula; rare or no fire; closed canopy of evergreen hardwoods; sand live oak, saw palmetto.	24211

Appendix B: Fire Dependency of Florida's Natural Communities

The fire dependencies of Florida's natural communities, taken from Chapter 9 of the Florida Certified Prescribed Burn Manager Training Manual (Saddler *et al.* 2014).

Natural Communi	Fire Depende	Fire Influence	FNAI Fire Frequency/Inter
Hardwood Forested Uplands:			
Mesic Hammock	No	Maybe	Frequent (for prairie variant) to rare depending on surrounding community
Up. Hardwood Forest	No	Maybe	Fire may be important on edges
Xeric Hammock	No	Maybe	Impacts to edges, 30+ yrs
High Pine and Scrub:			
Sandhill	Yes	-	Frequent, 1-3 yrs
Scrub	Yes	-	Variable, 5-30
Up. Mixed Woodland	Yes	-	Fire burns into it, 10-20 yrs
Upland Pine	Yes	Yes	Frequent, 1-3 yrs
Pine Flatwoods and Dry Prairie:			
Dry Prairie	Yes	-	Frequent, 1-2 yrs
Mesic Flatwoods	Yes	-	Frequent, 1- 4 yrs
Pine Rockland	Yes	-	Frequent, 3-7 yrs
Scrubby Flatwoods	Yes	-	Occasional, 5-15 yrs
Wet Flatwoods	Yes	-	Frequent, 3-10 yrs
Coastal Uplands:			
Beach Dune	No	Yes	Occasional – rare
Coastal Grassland	No	Yes	Occasional
Sinkhole and Outcrop Communities:			
Upland Glade	Yes	-	Irregular intervals
Freshwater Non-Forested Wetlands:			
Basin Marsh	Yes	-	Frequency depends on surroundings
Depression Marsh	Yes	-	Burns with surrounding community
Floodplain Marsh	Yes	-	Depends on water levels
Glades Marsh	Yes	-	Tied to surrounding matrix, estimate 2-5 yrs
Marl Prairie	Yes	-	Frequent, 1-6 yrs
Seepage Slope	Yes	-	Frequent to occasional, 2-3 yrs
Shrub Bog	No	Yes	Shrubs, 3-8 yrs; woody, 50-150 yrs
Slough	Yes	-	Tied to surroundings, est. 2-5 yrs
Wet Prairie	Yes	-	Frequent, 2-4 yrs
Freshwater Forested Wetlands:			
Baygall	No	Yes	Fire impacts edge
Basin Swamp	No	Yes	5-150 yrs
Dome Swamp	No	Yes	Light surface fire from nearby community
Hydric Hammock	No	Maybe	Frequent (for prairie variant) to rare depending on surrounding community

Chapter 4: Deliverable #3.2

SQL Database Structure, Field Definitions, & FFS Data Upload

Deliverables Update
3.2: SQL Database Structure Field Definitions, and FFS Data Upload

Mapping Fires Across Florida:

Advancement of a Fire Spatial Database

March 2018

Tallahassee, FL

TALL TIMBERS

Principal Investigator/Project Manager

Joe Noble

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Casey Teske
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Vince Sclafani
Kevin Robertson

Project ID

FWC-16/17-135 Spatial Database
A Proposal for Mapping Statewide Fire Occurrence, Fire History, and Ecological Outcomes
Submitted by Tall Timbers Research, Inc., June 20, 2017

All project deliverable reports, including the earlier workshop proceedings, video of expert presentations, summary report, and power point presentations are available free of charge from Tall Timbers Research, Inc. Please contact Joe Noble: *jnoble@talltimbers.org*

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TALL TIMBERS

Table of Contents

Executive Summary

Tall Timbers Research, Inc., is pleased to present the final update on Deliverable 3.2, the SQL database creation (discussed in Deliverable 3.1) and structure. Development of a comprehensive spatially explicit map of fire occurrence remains one of the most critical needs for conservation in the Southeastern US. Not only are the vast majority of Florida's endangered species and ecosystems reliant on frequent fire, but fire risk analysis, prescribed fire planning, and fire behavior modeling are sensitive to fire history. Fire occurrence in Florida is currently tracked by approximate location through the Florida Forest Service (FFS) burn authorization system, Fire Management Information System (FMIS). While this system represents one of the most advanced prescribed fire planning datasets in the country, the system does not record perimeter data or include assessments regarding which burns are actually completed. Relying solely on this system results in documented data gaps when estimating the size, location and effectiveness of managed fires on a statewide scale. These "actual burned" areas are critical factors in analyses and models evaluating conservation success.

Tall Timbers Research, Inc., is addressing this need by developing a robust spatial database for more precise mapping and tracking of all prescribed fire in Florida. Advanced remote sensing techniques will be applied to known locations of prescribed fires, as identified in the FFS system, to record actual spatial fire boundaries into a modified version of the U.S. Air Force Wildland Fire Database. In addition, custom query tools will be developed to report fire history (e.g., frequency, time-since-burn) in specific fire dependent ecological systems or fire dependent species habitats.

Tall Timbers' staff acquired burn authorization data for 2006-2016 from the Florida Forest Service and analyzed the data using a geographic information system (GIS) to understand the characteristics of prescribed fire authorizations across the state. We developed filtering methods to create summary tables, graphs, charts, and maps to enhance understanding of fire across space and through time in the state. The Florida Forest Service has nearly 1 million pile and broadcast burn authorization records for the time period 2006-2016. Broadcast burns account for 25% of all authorizations. Findings suggest fewer authorizations for broadcast burning are being requested now than occurred in 2006; and the majority of acres have burned in the Mesic Flatwoods land cover type. The highest number of authorizations requested and the highest amount of acreage authorized to burn both occurred in 2010. Most authorizations are requested in the Improved Pasture and Tree Plantations land cover categories, but more acreage is requested in the Mesic Flatwoods. Most authorizations and most of the acreage authorized occurs in the winter months (Jan-Mar). Most authorizations are for silvicultural purposes, and the most requested firing pattern is for using backing fire. The overall fire rotation is approximately 7 years, which was calculated using all burnable land cover categories. We identified data limitations and data quality issues for the FFS burn authorization dataset and provide recommendations for moving forward.

The existing database structure from the Department of Defense Air Force (DoD AF) wildland fire database tracking system was converted to SQL Server in the previous phase of this project. Consultation about the SQL Server database structure and field definitions with FWCC partners and collaborators, as well as additional data inputs, are discussed here. The database will house the prescribed fire data and ancillary datasets required for analysis purposes of this project.

Glossary of Terms and Concepts

Broadcast Burn An open burn that is done for agricultural, silvicultural, or land clearing purposes and is not a pile

Burned Area Essential Climate Variable (BAECV) refers to an algorithm that capitalizes on the long temporal availability of Landsat imagery to identify burned areas across the conterminous United States.

Continuation An authorization to continue a previously approved open burn authorization that was not completed for various reasons including late starts, poor weather conditions or lack of resources.

CONUS The Continental United States; this reference excludes Alaska and Hawaii.

Cooperative Land Cover (CLC) The Cooperative Land Cover Map is a project to develop an improved statewide land cover map from existing sources and expert review of aerial photography. The project is directly tied to a goal of Florida's State Wildlife Action Plan (SWAP) to represent Florida's diverse habitats in a spatially-explicit manner.

Environmental Protection Agency (EPA) The agency of the federal government which was created for the purpose of protecting health and environment.

Florida Forest Service (FFS) Agency whose mission is to protect and manage forest resources in Florida.

Florida Natural Areas Inventory (FNAI) Florida's state heritage program responsible for tracking occurrences of species and natural communities statewide.

Fire Mapping Information System (FMIS) integrated set of applications that handle data input, processing and reporting needs for the Florida Division of Forestry (DOF).

Global Fire Emissions Database (GFED) Database combining satellite information on fire activity and vegetation productivity to estimate gridded monthly burned area and fire emissions.

GOES-16 previously known as GOES-R, is part of the Geostationary Operational Environmental Satellite (GOES) system operated by the U.S. National Oceanic and Atmospheric Administration and is the first spacecraft in NOAA's next-generation of geostationary satellites. The GOES-R series satellites will provide advanced imaging with increased spatial resolution and faster coverage, improving the detection of environmental phenomena.

Hazard Mapping Systems (HMS) NOAA product suite that provides both fire and smoke analysis products. It is an interactive processing system that allows analysts to manually integrate data from automated fire detection algorithms using GOES and polar (Advanced Very High Resolution Radiometer (AVHRR) and MODerate resolution Imaging Spectroradiometer (MODIS)) images. The result is a quality controlled display of the locations of fires and significant smoke plumes detected by meteorological satellites.

Interagency Fuel Treatment Decision Support System (IFTDSS) is a web-based software and data integration framework that organizes fire and fuels software applications to make fuels treatment planning and analysis more efficient. The effort was initiated by Joint Fire Science Program and the NWCG Fuels Management Committee in 2007.

Integrated Reporting of Wildland-Fire Information (IRWIN) This service is a Wildland Fire Information and Technology (WFIT) affiliated investment intended to provide an "end-to-end" fire reporting capability. IRWIN is tasked with providing data exchange capabilities between existing applications used to manage data related to wildland fire incidents.

LANDSAT The Landsat Program is a series of Earth-observing satellite missions jointly managed by NASA and the U.S. Geological Survey. Imagery is available since 1972 from six satellites in the Landsat series. These satellites have been a major component of NASA's Earth observation program.

Landscape Conservation Cooperative (LCC) self-directed partnerships between federal agencies, states, tribes, non-governmental organizations, universities, and other entities to collaboratively define science needs and jointly address broad-scale conservation issues.

Monitoring Trends in Burn Severity (MTBS) refers to an interagency program whose goal is to consistently map the burn severity and extent of large fires across all lands of the United States from 1984 to present.

Moderate Resolution Imaging Spectroradiometer (MODIS) is a key instrument aboard the Terra and Aqua satellites. Satellites view the entire Earth's surface every 1 to 2 days acquiring data in 36 spectral bands. These data improve our understanding of global dynamics and processes occurring on the land, oceans and lower atmosphere.

Pile Burn An open burn that is in the form of a pile that is larger than 8' diameter

PostGIS is a spatial database extender for PostgreSQL object-relational database. It adds support for geographic objects allowing queries to be run in SQL.

PostgreSQL is an open source object-relational database system.

Open Burn Authorization (OBA) refers to Florida Forest Service Open Burn Authorization Requests and is available to Certified Prescribed Burners.

QGIS is a free and open source professional Geographical Information System (GIS) that is built on top of Free and Open Source Software (FOSS)

QGIS Event Mapping Tool (EMT) a QGIS plugin for fire assessment developed by U.S. Geological Survey National Center for Earth Resources Observation and Science (EROS)

Southern Integrated Prescribed Fire Information System (SIPFIS) a Joint Fire Science Program initiative to design an integrated information system for fire and air quality data in the SE United States.

Volatile Organic Compounds (VOC) refers to a large group of organic chemicals that include any compound of carbon (excluding carbon monoxide, carbon dioxide, carbonic acid, metallic carbides or carbonates, and ammonium carbonate).

Deliverable #3.2: Background

This section is the documentation of the progress thus far for Deliverable #3.2 of the FWCC Grant. The following pages contain documentation information on database structure and the Events, Domains, and Queries needed for the final product.

For over a decade, resource managers in the state have recognized the importance of tracking and monitoring the use of prescribed fire. Many species in Florida are dependent on fire for maintenance of appropriate habitat conditions. Measurements, such as seasonality and years since last burn are important components in assessing the condition of these fire maintained systems. For many species that are dependent on these systems, managing an appropriate fire return interval is critical. Differentiating those areas that have an appropriate fire return interval from those areas without an appropriate fire return interval would allow managers to focus resources on areas most in need of management actions, as well as serve as a means to measure and quantify the success of conservation and restoration efforts.

Cost effective and efficient management of conservation lands requires up to date detailed resource maps. The Peninsular Florida Landscape Conservation Cooperative (PFLCC) is working on a statewide Landscape Conservation Design. As part of this process, the PFLCC is identifying conservation targets (indicators) for each priority resource. It became evident that fire return interval could be a critical indicator for these systems.

Florida currently has a detailed (10m) land cover map, used by multiple entities (Florida Fish and Wildlife Conservation Commission, FWC's State Wildlife Action Plan, Florida Natural Areas Inventory, and the PFLCC). However, there is a critical missing component from the existing land cover map - qualitative attributes regarding fire. One key qualitative attribute that has long been identified as a critical data gap pertains to prescribed fire. Addition of qualitative attributes based on fire regime characteristics, such as fire return interval, would increase the effectiveness of informing acquisition of conservation lands, supporting land and fire management, and tracking success and failure of conservation efforts. Assessment of the success of management actions will provide a valuable feedback loop to inform future management actions on conservation lands, both public and private.

Currently, a spatial database that tracks prescribed fire statewide does not exist, which means that there is not a comprehensive knowledgebase about fire regimes across the state. This data gap was recognized more than a decade ago. In 2006, it was noted that "…methods for monitoring the use of fire on public lands may be one of the greatest unmet needs in comprehensive wildlife management…" (*Monitoring Prescribed Burning on Public Lands in Florida, 2006).* This project aims to enhance our understanding of prescribed fire characteristics across the state of Florida for integration into further analyses specific to landscape conservation and monitoring. Specific outcomes are noted below:

1. We aim to address the data gap by creating a spatial database that can be used to track and analyze burn authorization data between 2006-2016 using FFS Online Burn Authorization data and a modified extension of the US Air Force Wildfire Database.
2. We will develop methods to validate burn authorization records by comparing authorized permits to known fire locations and using remote sensing techniques to record spatial fire boundaries.
3. We will develop custom query tools to evaluate fire regime characteristics and trends in specific fire dependent ecological systems or fire-dependent species habitats.
4. We will develop procedures for annual updates moving forward.

Deliverable #3.2: Completion Report

This serves as documentation of completion of Deliverable 3.2. The Mapping Fires Across Florida *database structure has been developed, complete with field definitions. It has been populated with filtered FFS database records that have been converted to the appropriate database structure, including location information* (italics indicate specific deliverable requirements). The following section documents the completion of the spatial database structure, as well as field definitions, domains and queries in the SQL Server database. The initial database conversion of the Air Force management database from Oracle to SQL Server is complete (see previously submitted Deliverable 3.1 write-up) and being hosted on a Tall Timbers server. The necessary tables, views, and procedures were converted to SQL Server format and vetted with FWC partners in an update meeting, and Database Events, Domains, and Queries were discussed in a deliverables meeting with FWC partners and collaborators.

Existing Events, Domains, Queries (from the converted DOD database) and additional datasets were evaluated with FWC partners. The existing database structure (Figure 1) identifies the schema that were assessed, with red boxes highlighting those Domains and Events that should be dropped or changed in some way. The green box and dashed arrows identify Events that can potentially be consolidated into one. A complete list of the changes agreed upon by FWC partners follows in Table 1.

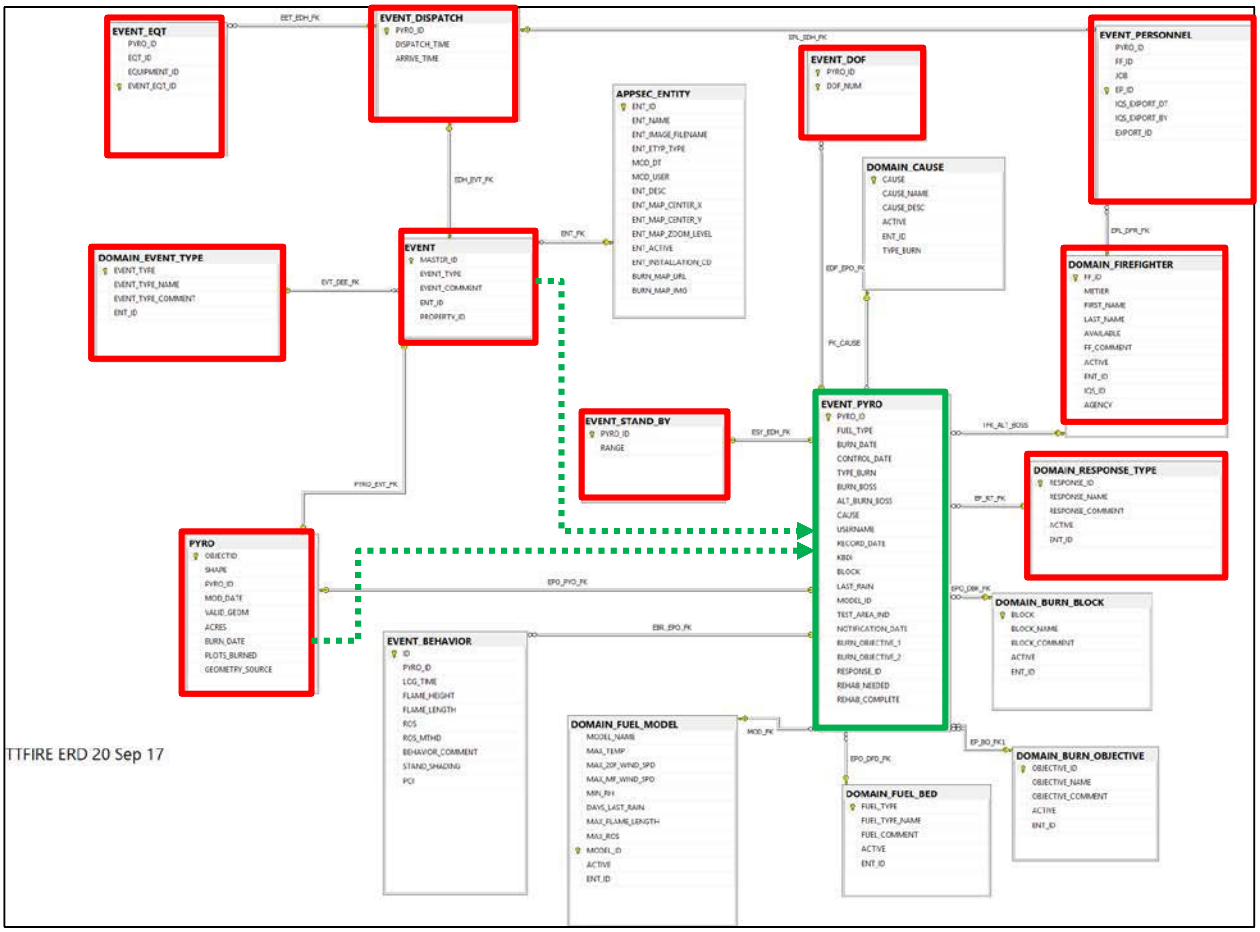

Figure 1: Events, domains, and domain items to retain or drop from existing database.

Table 1: Domains, events, and event 'items' to add, drop, or change from the existing schema.

<table>
<tr><th></th><th>Drop</th><th>Add</th></tr>
<tr><td>Event Table</td><td>Event_DOF
Event_personnel
Event_Standby
Event_dispatch
Event_Eqt</td><td></td></tr>
<tr><td>Domain Table</td><td>Domain_Firefighter
Domain_Response_Type
Domain_Event_Type</td><td>Possibly link Pyro & Event Tables, converge into existing Event_Pyro if possible.

Change Event_Pyro as follows:
Drop Alt_Burn_Boss, Burn_Boss, KBDI, Test_area_ind, Notification_Date, Response_ID, Rehab_Needed, Rehab_Complete

Add Responsible Agency, Landcover Domain

Change
Add Landcover Domain to Event_Pyro (see landcovers in CLC layer, state level)

Clean up Domain_Type_Burn (Rx, Escaped Rx, Wildfire)

Add additional agencies to Domain_Agency (DOD, TNC, FFS, NPS, DEP, WMD, WRI, Private, County, Other)

Create solution to query species affected by fire (species lists provided by FWC species management data)</td></tr>
</table>

Additional updates discussed included Queries. While these are not a part of the deliverable specifically, the ability to query the database is needed for the FWC partners, so it is imperative to ensure that Queries on the data are possible. The following is a list of example queries that are desirable (either individually or some combination thereof); additional 'ad-hoc' queries should also be possible:

- How many and what size are fires by season? (What months compose each of the seasons? Rules will vary by location—TTRS+FWC will determine based on statewide distributions of burning)
- How many and what size are fires by year?
- How many and what size are fires by mgmt. area (agency ownership, as well as agency doing burning)
- How many and what size are fires by land cover and/or species habitat
- How many and what size are fires by objective type
- How many and what size are fires by size

Chapter 5: Deliverable #4

Summary Report

of

Tool and Data Exploration

and

Recommendations

<u>Deliverables Update</u>
#4: Summary Report of Tool and Data Exploration and Recommendations

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Advancement of a Fire Spatial Database

June 2018

Tallahassee, FL

TALL TIMBERS

Principal Investigator/Project Manager

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TALL TIMBERS

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Executive Summary

Tall Timbers Research, Inc. is pleased to present the *Mapping Fires Across Florida: Deliverable #4* update. The overall purpose of the project is to develop a spatial database of prescribed fire extents in Florida with querying and reporting capabilities. Development of a comprehensive spatially explicit map of fire occurrence remains one of the most critical needs for conservation in the Southeastern US. Not only are the vast majority of Florida's endangered species and ecosystems reliant on frequent fire, but fire risk analysis, prescribed fire planning, and fire behavior modeling are sensitive to fire history. Fire occurrence in Florida is currently tracked by approximate location through the Florida Forest Service (FFS) burn authorization system, Fire Management Information System (FMIS). While this system represents one of the most advanced prescribed fire planning datasets in the country, the system does not record perimeter data or include assessments regarding which burns are actually completed. Relying solely on this system results in documented data gaps when estimating the size, location and effectiveness of managed fires on a statewide scale. These "actual burned" areas are critical factors in analyses and models evaluating conservation success.

Tall Timbers Research, Inc. is addressing this need by developing a robust spatial database for more precise mapping and tracking of all prescribed fire in Florida. Advanced remote sensing techniques are being applied to known locations of prescribed fires, as identified by the FFS data and select landowner-provided datasets, to record actual spatial fire boundaries into a modified version of the U.S. Air Force Wildland Fire Database. In addition, custom query tools will be developed to report fire history (e.g., frequency, time-since-burn) in specific fire dependent ecological systems or fire dependent species habitats.

The work documented here builds on the spatial database project work previously completed by Tall Timbers' staff. We have already completed exploratory data analysis on the FFS FMIS open burn authorization (OBA) data, which provided insights into the potential usefulness of the dataset for assessing fire regime characteristics in the state of Florida. We have also converted the existing DoD database from Oracle to SQL Server and imported the FFS OBA data into it after consultation with FWCC partners.

The current work is provided in the form of a summary report on prescribed and wildfire information sources for locations in Florida. We have included wildfires as they often meet management objectives and impact species habitats, and as such are an important part of the fire regime evidence used to inform conservation-monitoring decisions. This report contains detailed background information on the types of imagery and fire data sets that we evaluated, as well as processes tested and processes proposed for use in the database. We also provide some recommendations for moving forward. We examined fire datasets from twenty-six sources for the period 2006-2016. The datasets include satellite-based thermal detections and fire extent maps, as well as landowner-provided fire atlases and fire occurrence databases.

Datasets ranged from national in scope to landowner specific; data formats included raster and vector (*i.e.,* points or polygons). All datasets are currently in a format that is ready for upload into the SQL database. As part of the evaluation process, we participated in a Florida-specific fire extent mapping validation project in collaboration with the USGS, in order to help improve automated extent mapping outcomes in the state. Analyses, validation, and results of that project are pending as of this report. We also assessed a couple tools and scripts that may be useful as the project moves toward completion. These would allow users to derive fire extent information on known fires quickly and easily in a fashion consistent with national standardized products. Outputs from these tools could be included in the spatial database.

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Environmental Protection Agency (EPA) The agency of the federal government which was created for the purpose of protecting health and environment.

Florida Forest Service (FFS) Agency whose mission is to protect and manage forest resources in Florida.

Florida Natural Areas Inventory (FNAI) Florida's state heritage program responsible for tracking occurrences of species and natural communities statewide.

Fire Mapping Information System (FMIS) integrated set of applications that handle data input, processing and reporting needs for the Florida Division of Forestry (DOF).

Global Fire Emissions Database (GFED) Database combining satellite information on fire activity and vegetation productivity to estimate gridded monthly burned area and fire emissions.

GOES-16 previously known as GOES-R, is part of the Geostationary Operational Environmental Satellite (GOES) system operated by the U.S. National Oceanic and Atmospheric Administration and is the first spacecraft in NOAA's next-generation of geostationary satellites. The GOES-R series satellites will provide advanced imaging with increased spatial resolution and faster coverage, improving the detection of environmental phenomena.

Hazard Mapping Systems (HMS) NOAA product suite that provides both fire and smoke analysis products. It is an interactive processing system that allows analysts to manually integrate data from automated fire detection algorithms using GOES and polar (Advanced Very High Resolution Radiometer (AVHRR) and MODerate resolution Imaging Spectroradiometer (MODIS)) images. The result is a quality controlled display of the locations of fires and significant smoke plumes detected by meteorological satellites.

Interagency Fuel Treatment Decision Support System (IFTDSS) is a web-based software and data integration framework that organizes fire and fuels software applications to make fuels treatment planning and analysis more efficient. The effort was initiated by Joint Fire Science Program and the NWCG Fuels Management Committee in 2007.

Integrated Reporting of Wildland-Fire Information (IRWIN) This service is a Wildland Fire Information and Technology (WFIT) affiliated investment intended to provide an "end-to-end" fire reporting capability. IRWIN is tasked with providing data exchange capabilities between existing applications used to manage data related to wildland fire incidents.

LANDSAT The LANDSAT Program is a series of Earth-observing satellite missions jointly managed by NASA and the U.S. Geological Survey. Imagery is available since 1972 from six satellites in the LANDSAT series. These satellites have been a major component of NASA's Earth observation program.

Landscape Conservation Cooperative (LCC) self-directed partnerships between federal agencies, states, tribes, non-governmental organizations, universities, and other entities to collaboratively define science needs and jointly address broad-scale conservation issues.

Monitoring Trends in Burn Severity (MTBS) refers to an interagency program whose goal is to consistently map the burn severity and extent of large fires across all lands of the United States from 1984 to present.

Moderate Resolution Imaging Spectroradiometer (MODIS) is a key instrument aboard the Terra and Aqua satellites. Satellites view the entire Earth's surface every 1 to 2 days acquiring data in 36 spectral bands. These data improve our understanding of global dynamics and processes occurring on the land, oceans and lower atmosphere.

Pile Burn An open burn that is in the form of a pile that is larger than 8' diameter

PostGIS is a spatial database extender for PostgreSQL object-relational database. It adds support for geographic objects allowing queries to be run in SQL.

PostgreSQL is an open source object-relational database system.

Open Burn Authorization (OBA) refers to Florida Forest Service Open Burn Authorization Requests and is available to Certified Prescribed Burners.

QGIS is a free and open source professional Geographical Information System (GIS) that is built on top of Free and Open Source Software (FOSS)

QGIS Event Mapping Tool (EMT) (now known as the Fire Mapping Tool, FMT), a QGIS plugin for fire assessment developed by U.S. Geological Survey National Center for Earth Resources Observation and Science (EROS)

Southern Integrated Prescribed Fire Information System (SIPFIS) a Joint Fire Science Program initiative to design an integrated information system for fire and air quality data in the SE United States.

Volatile Organic Compounds (**VOC)** refers to a large group of organic chemicals that include any compound of carbon (excluding carbon monoxide, carbon dioxide, carbonic acid, metallic carbides or carbonates, and ammonium carbonate).

Deliverable #4: Background

This document serves as the summary report of data exploration activities and should be considered as the final "Deliverable #4" of the FWCC Grant. It contains background information and recommendations on the types of imagery, data sets, processes tested, and processes proposed for use in populating the spatial database developed and submitted previously (see Deliverables 3.1 and 3.2).

For over a decade, resource managers in the state have recognized the importance of tracking and monitoring the use of prescribed fire. Many species in Florida are dependent on fire for maintenance of appropriate habitat conditions. Measurements, such as seasonality and years since last burn are important components in assessing the condition of these fire-maintained systems. For many species that are dependent on these systems, managing an appropriate fire return interval is critical. Differentiating those areas that have an appropriate fire return interval from those areas without an appropriate fire return interval would allow managers to focus resources on areas most in need of management actions, as well as serve as a means to measure and quantify the success of conservation and restoration efforts.

Cost effective and efficient management of conservation lands requires up to date detailed resource maps. The Peninsular Florida Landscape Conservation Cooperative (PFLCC) is working on a statewide Landscape Conservation Design. As part of this process, the PFLCC is identifying conservation targets (*i.e.,* indicators) for each priority resource. It became evident that fire return interval could be a critical indicator for these systems.

Florida currently has a detailed (10m) land cover map, used by multiple entities (*e.g.,* Florida Fish and Wildlife Conservation Commission, FWC's State Wildlife Action Plan, Florida Natural Areas Inventory, and the PFLCC). However, there is a critical missing component from the existing land cover map - qualitative attributes regarding fire. One key qualitative attribute that has long been identified as a critical data gap pertains to prescribed fire. Addition of qualitative attributes based on fire regime characteristics, such as fire return interval, would increase the effectiveness of informing acquisition of conservation lands, supporting land and fire management, and tracking success and failure of conservation efforts. Assessment of the success of management actions will provide a valuable feedback loop to inform future management actions on conservation lands, both public and private.

Currently, a spatial database that tracks prescribed fire *extents* statewide does not exist, which means that there is not a comprehensive knowledgebase about fire regimes across the state. Managers recognized this data gap more than a decade ago. In 2006, they noted "…methods for monitoring the use of fire on public lands may be one of the greatest unmet needs in comprehensive wildlife management…" (*Monitoring Prescribed Burning on Public Lands in Florida, 2006).* This project aims to enhance our understanding of prescribed fire characteristics across the state of Florida for integration into further analyses specific to landscape conservation and monitoring. We list specific outcomes below:

1. We address the data gap through a spatial database designed to track and analyze burn authorization data between 2006-2016 using FFS Online Burn Authorization data and a modified extension of the US Air Force Wildfire Database.
2. We are working on methods to validate burn authorization records by comparing authorized permits to known fire locations and using remote sensing techniques to record spatial fire boundaries.
3. We will develop custom query tools to evaluate fire regime characteristics and trends in specific fire dependent ecological systems or fire-dependent species habitats.
4. We will develop procedures for annual updates moving forward.

Deliverable #4: Dataset Exploration

Understanding fire regime characteristics across the state of Florida is important from a conservation perspective if the aim is to maximize conservation efforts and target conservation opportunities appropriately. However, limited information about fire occurrence in the state exists, particularly in terms of a statewide spatial database that includes individual fire perimeters for prescribed fires and for many fires occurring on private lands. We explored multiple datasets to determine the spatial representation of fire extents. This section provides descriptions and evaluations of these datasets.

We evaluated multiple sources of data for the study period of interest (2006-2016) to determine if they met the needs of the FWC project in terms of spatial resolution, geographic extent, and time stamping. In general, the datasets evaluated include prescribed fire information, wildfire information, or both. Data types include point, polygon, and raster data. The temporal characteristics of the data vary depending on the source: Some fire atlases may include data from the early 1900s, while some of the newer satellites started data collection in the 2010's and thus do not include data for the early part of the study period. Most datasets are current up to present. For this project, we evaluated only the data that represent fires occurring sometime in the 2006-2016 timeframe for possible inclusion in the SQL geodatabase. The ability exists to upload any additional data as needed (*e.g.*, as available, pre-2006 or post-2016, if available from the original sources). Table 1 lists the datasets that we evaluated for their utility to illuminate our knowledge of the occurrence and spatial extent of fires in Florida. Specifically, we are interested the extents for fires larger than 5-10 acres.

Florida Forest Service Open Burn Authorizations (FFS OBA)

Currently, without a statewide spatial database of fire occurrence in Florida, we can use the FFS OBA dataset as a surrogate. The data are in an Oracle database (maintained by the FFS) where information required for an open burn authorization is recorded, and includes all open burns (*e.g.,* broadcast burns and pile burns larger than 8 feet in diameter) authorized within the state. These records exist from at least 2004 to present, although we are currently only focusing on the period of interest (2006-2016). The data records are in a point format, which lacks precise spatial extent information. Furthermore, the accuracy and variability of these data points varies significantly through space and time: There is not a standard method of locational reporting required by FFS dispatchers, and reporting system requirements have changed since authorization tracking started. Additionally, there is currently not a mechanism in place to 'close' a permit and track how many acres actually burned once the burning is complete. However, we feel the FFS OBA data still has merit for data exploration and analysis purposes, but we must acknowledge and recognize the limitations.

For example, prior to 2008, a request for an open burn authorization required the person requesting a permit to provide a point location of where the burn would be taking place (they reported to the nearest quarter section or 160-acre block). There was no standard for reporting the location. While often located somewhere within the quarter section, it could just as easily be the middle of the owner's property as the middle of the burn unit, a corner of where the test fire was taking place, or a road intersection. Since August of 2008, automatic calculation of the latitude and longitude coordinates occurs; every request still requires a township-range-section location entered on the OBA request form or taken from a point on a web-based map, but the latitude/longitude are determined in the system background and added as attributes to the OBA database. The latitude/longitude were not retroactively determined for requests prior to August 2008, so OBA attributes are not consistent temporally. We accept that without an ability to field verify past OBA location data beyond 160-acre blocks, there is no verifiable spatial accuracy of the point locations.

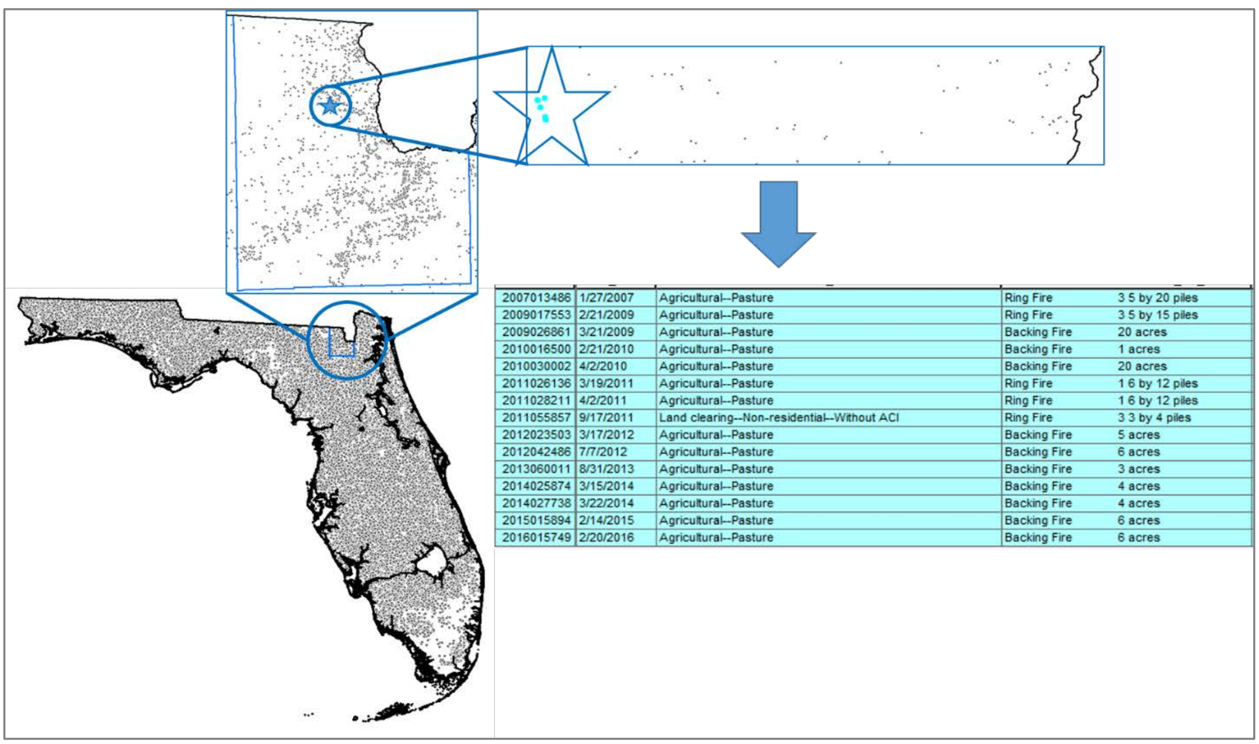
Table 1: Datasets evaluated for mapping fires in Florida, including spatial and temporal characteristics (including update availability, period of record, and data coverage timeframe) pertinent to this project. Unless otherwise noted, the data we used spans 2006-2016.

Data Source	Data Type	Spatial Characteristics	Dataset Period of Record	Wildfire (W), Prescribed Fire (P), or Both (WP)	Description
FFS OBA	Point	¼ ¼ section (PLSS) (through 2008) Lat/Long (2008-present)	1981-present	P	• Prescribed Fire Authorization Database • Updated Daily • We used data between 2006-2016
MTBS	Polygon*	30m	Dataset current 1984-2015	WP	• 500ac+ fires only (in SE) • * Burned area is derived from LANDSAT-based raster products & smoothed • Annual Updates Nationally 1-2 yr post-fire • Can be derived for known fires using standardized methods and tools available. • We used data between 2006-2016
LANDFIRE Disturbance	Raster	30m	Dataset current through 2014	WP	• Updated Annually with a 2-yr time lag following disturbance • We used data between 2006-2014
MODIS Active Fire (AF)	Point	Footprint: 1km	Dataset current through present (2018)	WP	• Updated Twice Daily • We used data between 2006-2016
VIIRS-AF	Point	Footprint: 750m	Twice Daily, 2012-present (2018)	WP	• Updated Twice Daily • We used data between 2014-2016
VIIRS I-Band	Point	Footprint: 375m	Twice Daily, 2012-present (2018)	WP	• Updated Twice Daily • We used data between 2014-2016
BAECV	Raster, Polygon*	30m	Dataset current through 2015*	WP	• Can be derived for known fires using standardized methods and tools available. • Can be updated every ~2 weeks • *We used privately available (USGS-provided) polygon data covering the period 2006-2016
Fire Data by Landowner*	Point, Polygon	Varies	Varies	W, P, or WP	• Characteristics vary by landowner and their policies and procedures • We used data between 2006-2016 as available by landowner • *See Table 3

Known issues and limitations of the FFS OBA that are pertinent to this report include (See Deliverable #2 for full documentation):

- Lack of consistency for data point spatial accuracy through time;
- Duplicated location values (multiple authorizations using the exact same point location through time, even after latitude/longitude reporting implemented; Figure 1);
- Single points representing multiple burn units (including non-contiguous units that can be up to ~10km away [Nowell *et al.,* 2018 *in press*]; Figure 2);
- Cumulative acreage total discrepancies (*e.g.,* an OBA for 100 acres but only 60 acres were completed and a continuation was authorized – the continuation may be for 100 acres or may be for 40 acres [since there is not a standard in place for this type of request]. This could result in over-reporting of acres [200 acres vs 140 acres, in this example], as opposed to the 100 acres that were actually the target);
- No record of accomplishment/completion (e.g., if 100 acres were authorized, and only 78 acres burned, there is currently no standard or way to capture that in the FFS OBA database).

In spite of the limitations listed above, the FFS OBA is a rich dataset which can be used in a spatial database as ancillary data for analyses that will further our understanding of prescribed fire occurrence and characteristics in the state of Florida. To that end, we have separated the pile burns from the broadcast burns and loaded both of these as individual point-based datasets into the current version of the SQL database (see Deliverable #2 for details related to OBA processing and analyses and Deliverables #3.1 and 3.2 for SQL database development).



2007013486	1/27/2007	Agricultural--Pasture	Ring Fire	3 5 by 20 piles
2009017553	2/21/2009	Agricultural--Pasture	Ring Fire	3 5 by 15 piles
2009026861	3/21/2009	Agricultural--Pasture	Backing Fire	20 acres
2010016500	2/21/2010	Agricultural--Pasture	Backing Fire	1 acres
2010030002	4/2/2010	Agricultural--Pasture	Backing Fire	20 acres
2011026136	3/19/2011	Agricultural--Pasture	Ring Fire	1 6 by 12 piles
2011028211	4/2/2011	Agricultural--Pasture	Ring Fire	1 6 by 12 piles
2011055857	9/17/2011	Land clearing--Non-residential--Without ACI	Ring Fire	3 3 by 4 piles
2012023503	3/17/2012	Agricultural--Pasture	Backing Fire	5 acres
2012042486	7/7/2012	Agricultural--Pasture	Backing Fire	6 acres
2013060011	8/31/2013	Agricultural--Pasture	Backing Fire	3 acres
2014025874	3/15/2014	Agricultural--Pasture	Backing Fire	4 acres
2014027738	3/22/2014	Agricultural--Pasture	Backing Fire	4 acres
2015015894	2/14/2015	Agricultural--Pasture	Backing Fire	6 acres
2016015749	2/20/2016	Agricultural--Pasture	Backing Fire	6 acres

Figure 1: Example of duplicated locations of authorizations. There are five points selected on the map, which returns 15 unique OBA records without any change in the location information.

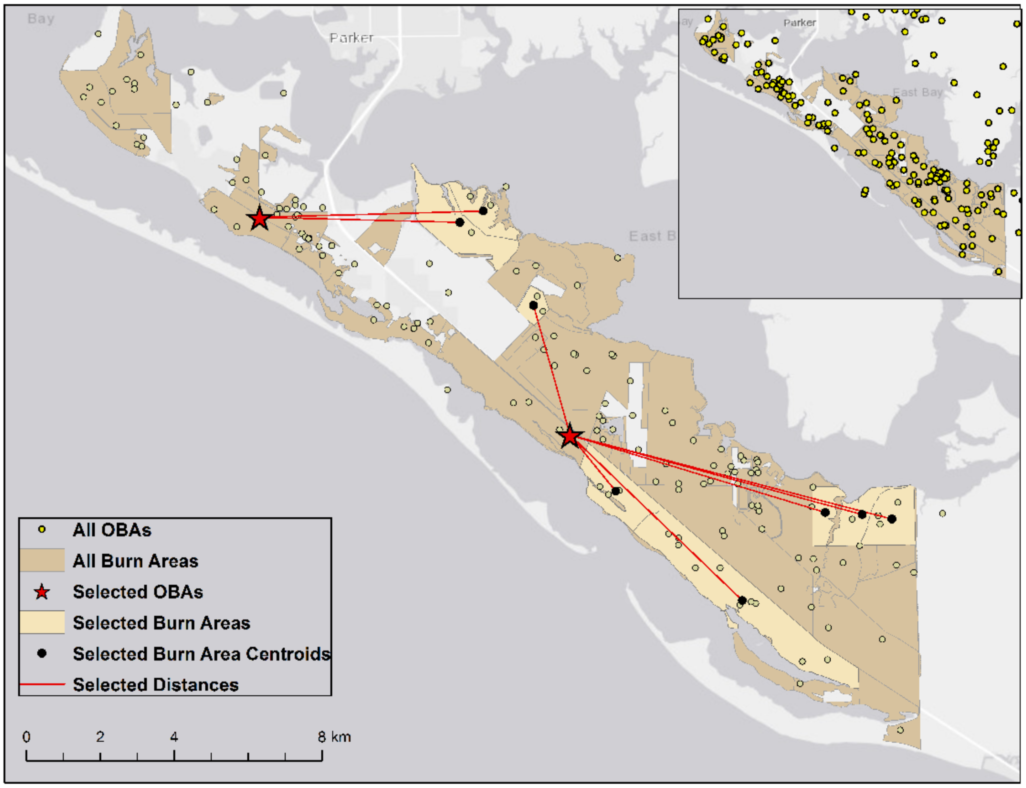


Figure 2: Example of single OBA representing multiple burn units from Nowell *et al.* (2018). Here, two authorizations (red stars) for February 9, 2006 and the multiple units (yellow polygons) which Tyndall AFB burned that day at are shown. Black dots indicate the centroids of burn units, and red lines to the closest authorization issued on that date link these. Yellow dots represent authorizations issued on other days.

Monitoring Trends in Burn Severity (MTBS)

The Monitoring Trends in Burn Severity (MTBS) program is national in scope, and uses standardized consistent methods to derive burned areas using imagery from sensors on the LANDSAT-series satellites (Eidenshink *et al.* 2007). Burned area data from the interagency program include all known wildfires in the southeastern US larger than 500 acres in size. In some instances, MTBS maps smaller burned areas if the fires are part of a complex, or of specific concern to a landowner. In addition to burned area information, data pertinent to fire severity are included. The sizes of fires mapped by MTBS are larger than the minimum size of fires of interest to this project, but the spatial resolution of the MTBS data is 30m, and datasets date back to 1984. Burned area delineations are 'smoothed' by analysts, so that the blocky appearance common with raster-derived data does not exist.

The burned areas are mapped using change detection methods (Key and Benson 2006), and post-fire images used for this purpose range from within 2 weeks post-fire to 1 year post-fire depending on ecosystem. The long data record, fine spatial resolution, smooth burned area polygons, and consistent mapping methodologies make this dataset desirable to use for the *Mapping Fires Across Florida* project; however, the minimum nationally mapped fire size (500ac) and delayed production of automated fire assessments (up to 2 years post-fire, due to 1-yr post-fire imaging requirements in many locations) are prohibitive. Additionally, prescribed fires or any fires on privately owned lands may not be included as the MTBS program uses wildfire-reporting data to derive burned areas on images around a known point. However, if fire locations are known (either by an actual point within the fire, or by an actual fire perimeter), the methods are easily replicable and smaller fires (as well as private ownership fires) could be added to this data set. In fact, the USGS has developed and made publicly available a tool (the Fire Mapping Tool [FMT]) to help individuals to perform these burn severity-mapping steps independently at any time, which could counter some of the lag time of the national program for updating burned areas locally or regionally. The MTBS dataset is a good ancillary dataset for investigation of spatial extents of larger fires in Florida, and can be imported into the spatial database easily.

LANDFIRE Disturbance

LANDFIRE (LF) Disturbance data depict locations on the landscape where a change occurred (Figure 3). The data are available as 30m rasters at a national scale (composited annually) for disturbances such as insects/disease, wind throw, fuel treatments, and fire, among others. At present, the data are current and available for the years 1999-2014. The LANDFIRE program derives LF Disturbance products from a combination of fire management program data, satellite image processing methods, and other ancillary data.

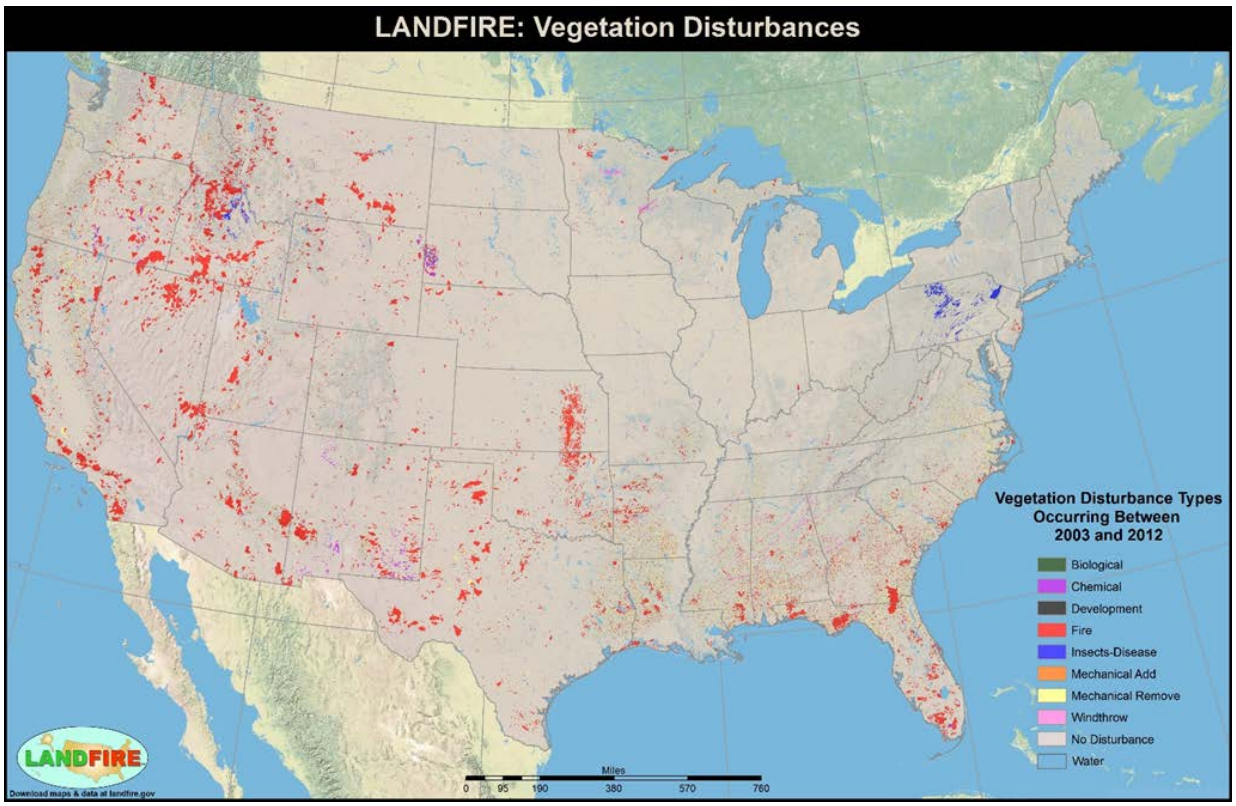


Figure 3: Example of the LF Disturbance dataset, indicating the prevalence of fire across the US including Florida. The LANDFIRE program provides data as 30m rasters for the US, but is only current through 2014.

These LF Disturbance data may be useful at a regional level as a supplement for locating places where fires have occurred. However, the products are not current for our project period (2006-2016), products will always have a 1-2 year post-fire availability lag as a result of processing times and algorithm requirements, and dataset generation is dependent on some of the datasets we have chosen not to use as primary fire location sources (e.g., MTBS). Thus, we can upload the LF Disturbance dataset into the database as needed to provide ancillary information, but it will not be a primary source for identifying fires' spatial extents.

MODIS Active Fire Product

We explored the MODIS Active Fire (MODIS-AF) Product to determine feasibility for use in identifying burned locations. The MODIS-AF Product characterizes daily fire detection data based on thermal anomalies (Giglio *et al.* 2003) for the period 2000 to present in point format. The data represent the centroid of a 1km fire detection pixel (*e.g*., the footprint) that signifies an active fire detection location at the time of the satellite overpass given clear skies. The geolocation of the centroid is within one-half of one pixel (*i.e.,* 500m) of the identified location. The datasets are generated in near-real time from MODIS sensors onboard the Terra and Aqua satellites. These satellites are in sun-synchronous orbits and can therefore image areas in the state of Florida twice (each) per day, with roughly 12-hrs between an individual satellite's daytime and nighttime pass as well as approximately 3-hrs between the two satellites for each daytime pass and each nighttime pass.

While these data do signify detections in the vicinities of fires due to derivation using thermal anomaly detection algorithms, the point-based data are difficult to use for mapping the extent of fires in Florida *ex post facto* for a number of reasons. As noted by Hawbaker *et al.* (2008), fires in locations with small, rapidly burning, low-intensity fires or frequent cloud cover are likely under-represented; this statement characterizes much of Florida quite well. Secondly, the data are point based, which means that an extent is not inherently associated with the point and we would need to derive the extents somehow. Additionally, the entire footprint represented by the area around a MODIS 'fire' centroid may not all be fire: a hot fire in a small area or a cool fire over a large area can both trigger a detection, and there is no way to discriminate between the two. Finally, the spatial resolution of a MODIS pixel (*i.e.,* 1 pixel = 1km^2, or ~247ac) is much too coarse for the minimum fire sizes of interest in this project. This is because a 3x3 window of pixels is the minimum mapping unit (MMU) that we require to detect and identify fire extents while accounting for error (*i.e.,* and in this instance, 3x3 pixels = 9km^2, or ~2225ac minimum fire size). This project requires a range of fire sizes from small to large (*i.e.,* tens to thousands of acres) to be detectable and represented, which is equivalent to the smallest pixel being 1/5 the size of current MODIS pixels. The MODIS data are available to upload into the spatial database as supplementary data that represent the possible presence/absence of fires; however, we have chosen not to utilize MODIS-AF data to identify the extents of fires in this project.

Although a MODIS Burned Area product is also available, we did not explore this product based solely on its base characteristics. In spite of it being derived from change detection algorithms and having areal extent properties, we felt that its coarse spatial resolution (1 pixel = 500m [per side], or ~60ac) did not meet the minimum fire size requirements of this project (*e.g.,* since the 3x3 pixel MMU results in a minimum fire size of ~550ac). These data are available from national sources and we can import them into the database if the need arises; however, for the purposes of this project, we did not assess them and they are not included.

VIIRS-AF and VIIRS-I Band

We also investigated the VIIRS-AF (750m; 2012-present) and VIIRS-I Band (375m; 2012-present) data products as options for helping to identify fire locations. The VIIRS detections of thermal anomalies are similar to the MODIS-AF products (but with modified processing algorithms). The satellite that VIIRS sensors reside on revisits places every 12 hours, making it possible to capture diurnal fire characteristics. The spatial resolution of both the VIIRS-AF and VIIRS-I bands are finer than MODIS, which allows the potential to detect smaller fires, but the data should still be considered moderate resolution products. These data only represent heat detected at the time of satellite overpass and thus may not represent the entirety of the area burned (*i.e.,* they may be used for understanding the presence/absence of fires at a given moment in time, but not total area for those fires). We chose not to use this product alone as a determination of fire extent for the same reasons mentioned previously. These data are nationally available and we can import them into the database if needed; however, they are not included for the purposes of this project.

Figure 4 highlights some examples of the different satellite-based data types mentioned as compared to a GPS'd perimeter. Note that even if lines were drawn connecting the outermost centroids of the MODIS-AF (or VIIRS-AF) data to create polygons, the extents would be quite coarse, and may not represent the actual final fire areas well in the cases of irregularly shaped fires. Additionally, locations identified as heat by either the MODIS thermal detections or the VIIIRS thermal detections are valid for the time of the satellite overpass. In many cases, this could lead to incomplete mapping of a fire event, or the complete 'omission' of a fire event. An example of when an omission might occur is if a prescribed fire starts between satellite overpasses and is completely out or cold by the time of the next pass. An example of an incomplete fire mapping would be if a fire spans multiple burn periods (*e.g.,* a wildfire) but the places that burn between satellite overpasses are cold and therefore not detectable at the time of the next pass (See Appendices for further examples).

Burned Area Essential Climate Variable (BAECV)

The Burned Area Essential Climate Variable (BAECV) products are a recent product suite developed and validated by the USGS (Hawbaker *et al.* 2017) that show promise for identifying geospatial extents of fires (Vanderhoof *et al.* 2017). This national product is independent of any type of fire reporting system. Hawbaker *et al.* (2017) document the methods use for automatic derivation of BAECV products using regression models and a combination of change detection algorithms, spectral indices, and reference conditions with LANDSAT imagery. The resultant probability surface and region growing tools can then be used to identify and delineate burned areas at a 30m pixel resolution for every LANDSAT image on record (*i.e.,* 1984-present), which is the longest consistent record of burned area information available. Vanderhoof *et al.* (2017) evaluated the BAECV products against known datasets (*e.g.,* MTBS) and against finer-resolution sensors (*e.g.,* QuickBird) with satisfactory results that suggest that the products would be suitable for use in this project.

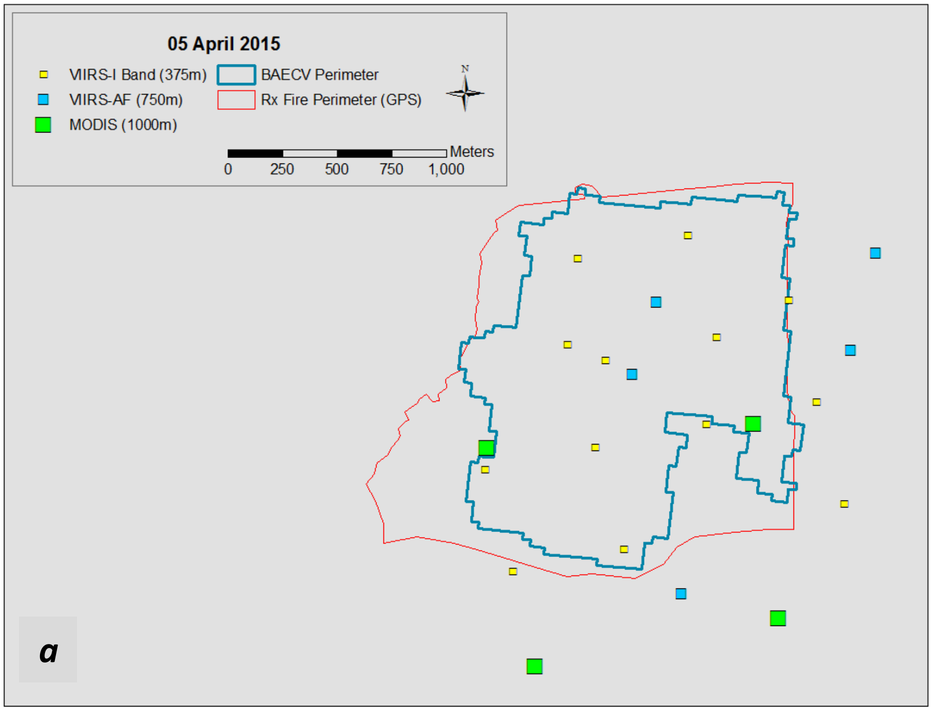
It is possible that BAECV products can provide additional/unknown burn locations and extents within Florida, including smaller fires (*e.g.,* fires smaller than a national standard, such as the 500ac used by MTBS in the southeastern US) or those not recorded in other national datasets (*i.e.,* areas where reporting is not required, such as on private property; see Figure 4a). Given that more than a million acres of prescribed fire alone burn across the state annually, but many of these fires are difficult to detect post-fire using traditional burn scar mapping protocols, it seems that the BAECV methods could be used to locate burned areas in an automated and systematic way. Currently, BAECV products include fires as small as 10 acres.

However, there are limitations to the BAECV products. Impediments to burned area detection/mapping include rapid green-up following a burn; cloud cover and shadows obscuring burn signatures; difficulty detecting or differentiating a low intensity burn signature beneath tree canopies; and the satellite product resolution often being too coarse to capture fine-scale differences or small burns (Hawbaker *et al.* 2008, 2017). Since these are known and predominant issues in Florida, we are working with the USGS on a Florida-specific validation project to refine the BAECV training data in the state following the protocols in Hawbaker *et al.* (2017) with some slight modifications. The aim is to help improve BAECV fire detection and burn probability mapping outcomes in Florida, as we feel this option is the best available for mapping fire extents in the state at many scales automatically.

For the validation, we acquired known fire locations from a variety of land management agencies for the period 2006-2016. The point fire locations and fire perimeter polygons included prescribed fires and wildfires. Descriptions of these data are in the next section (Table 2). Additionally, we selected five WRS-2 path and row (P/R) ‘footprints’ across Florida (Figure 5) that represent the variety of ecosystems that burn in the state. We downloaded all LANDSAT scenes within each footprint between 2006-2016 with less than 30% cloud clover and less than 30% cloud shadow, which after final scene selection ultimately resulted in a number of LANDSAT 5, 7, and 8 images (*n*=373) to be used for evaluation.

For each of three of the P/R footprints (*i.e.,* P/R 19/39, 16/40 and 16/41), a unique set of 50 random points was generated. We visually evaluated the LANDSAT scenes in these three footprints against the random point locations to determine whether the areas where points fell were mostly cloud-free. If too many points (~>20%) appeared to land on clouds/shadows, the scene was dropped and not evaluated. We preferentially selected the remaining scenes to represent seasonality and sensor. This method of scene selection resulted in a manageable list of scenes to evaluate.

To ensure that each analyst evaluated the same pixels, we copied and shared the random point file with three analysts. The analysts individually evaluated and coded each point in the footprint for every image selected in the footprint between 2006-2016 to determine whether the point fell on an unburned pixel (0), a burned pixel (1), a water source (2), or a cloud or cloud shadow (9). Point file naming conventions indicated the scene and the analyst (*e.g.,* LE07_L1TP_019039_20060305_20160923_01_T1_Analyst2.shp).



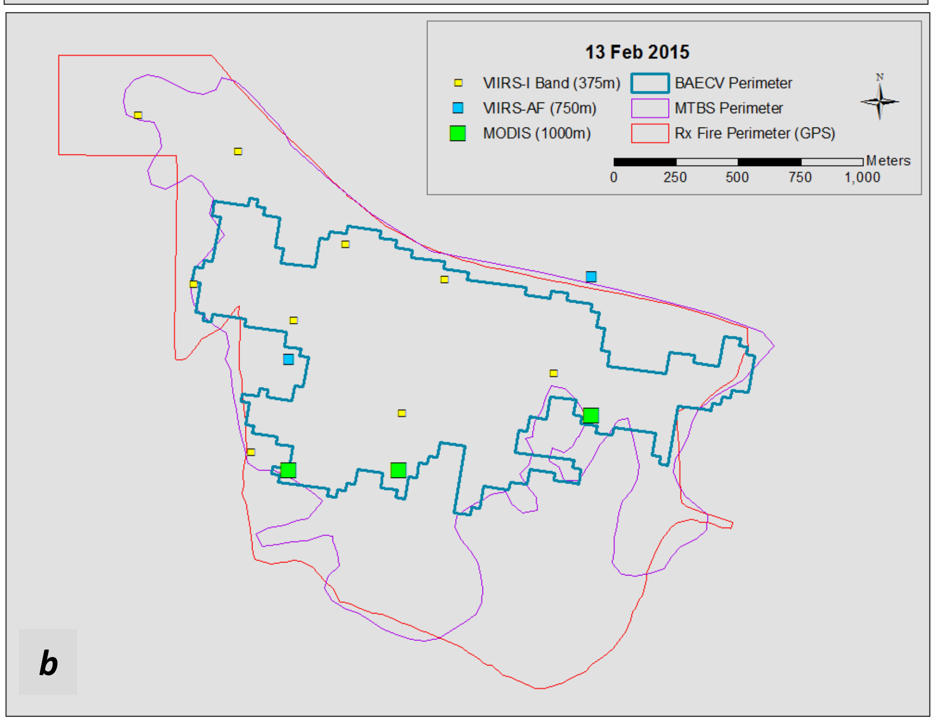


Figure 4: *(a)* 5 April 2015 fire detection center points for MODIS-AF, VIIRS-AF, VIIRS-I band overlaid on the BAECV burned area (blue) and the actual GPS'd prescribed fire perimeter (red) of a prescribed fire on Eglin AFB. MTBS did not pick up a burn here, possibly due to this being a prescribed fire not reported in a national fire occurrence database. *(b)* 13 Feb 2015 fire detection center points for MODIS-AF, VIIRS-AF, VIIRS-I band overlaid on the BAECV burned area (blue), the MTBS perimeter (purple) and the actual GPS'd prescribed fire perimeter (red) of a prescribed fire on Ocala NF. Note the scale bar represents 1000m, which is the size of a MODIS pixel, and roughly the width of each of these fires. Also, note the difference in smooth vs. blocky appearance of the MTBS vs. BAECV burned area polygons.

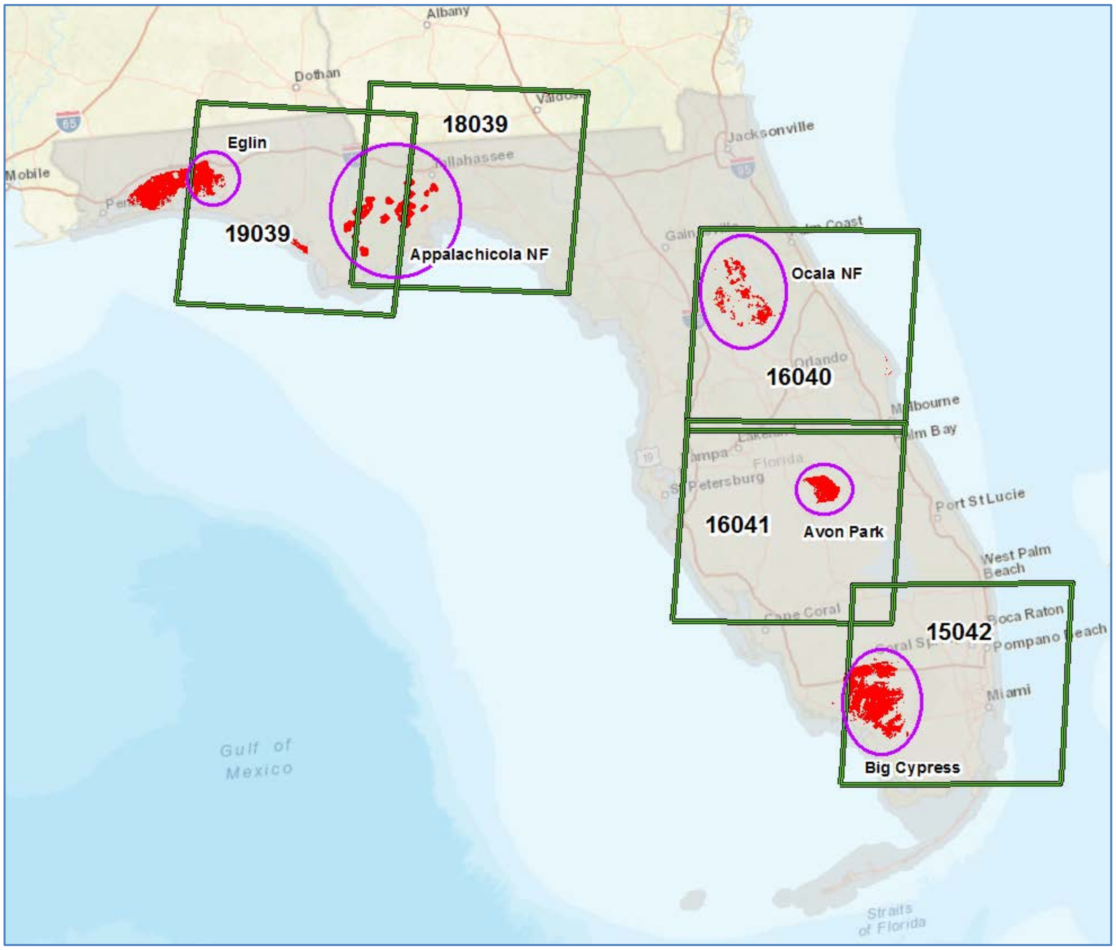


Figure 5: WRS-2 Path/Row locations across Florida. Green outlines indicate the Path/Row footprints, and a selection of known fire locations are shown in red and circled in purple.

A supervised evaluation was done on the other two P/R footprints (P/R 18/39 and 15/42) for three fire years (2007, 2011, and 2015). We created point or polygon feature classes of known fires from each source agency dataset for each of the three years and stored them in a geodatabase. We visually evaluated the three years of LANDSAT scenes in these two footprints against the known fire locations to determine whether these areas were mostly cloud-free. If too many clouds/shadows obscured the fire, we did not evaluate the scene. We preferentially selected the remaining scenes to represent seasonality and sensor. Analysts then evaluated the LANDSAT images to locate fire pixels, and create points at these locations. As a result, the location and number of points classified as burned vary between analysts, but should give high probability that a pixel burned. The Florida-specific validation effort resulted in three analysts viewing and attributing nearly 43,000 validation points in five path/row footprints around the state. The files were uploaded to a geodatabase and exported to the USGS for evaluation against the BAECV.

Table 2: Total number of images evaluated using the 50-point randomized method.

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Grand Total
LANDSAT 5	**2006**	1	1	2	2	2	1	2	1		2	2	1	***17***
	2007		6	1	1	2	1	4	3	1				***19***
	2008	2	2	3	3	2	3	1	1	1	1	3	1	***23***
	2009	3	2	3	1	3	1	2	1	2		2		***20***
	2010	3	3	2	3	2	2	4		2	4	3	4	***32***
	2011	2	2	3	2	4	1	3	2	3	1	1		***24***
	L5 Total	*11*	*16*	*14*	*12*	*15*	*9*	*16*	*8*	*9*	*8*	*11*	*6*	***135***
LANDSAT 7	**2006**		1	2	2	2	1	1	1	2	2	1	1	***16***
	2007			2	3	1	1				2	3	1	***13***
	2008	1	2	3	3	2		2	1	1	1	2	3	***21***
	2009	2	3	2	2		2	1	1	1	3	2		***19***
	2010	2		1	1	1	1	1	1	3	1	1	5	***18***
	2011		1	3		3	1	1	2	1	2	2	1	***17***
	2012	3	3	2	2	2	1	1	2		2	1	1	***20***
	2013	3		3	1	2	1	1	1	1	3	2	1	***19***
	2014	2	2		1				1		1			***7***
	2015	1		1	1	2	1			1		2		***9***
	2016				2	2			1	2	2	1		***10***
	L7 Total	*14*	*12*	*19*	*18*	*17*	*9*	*8*	*11*	*12*	*19*	*17*	*13*	***169***
LANDSAT 8	**2013**			1		1								***2***
	2014	1	3	4		3		1	3	1	2	1	2	***21***
	2015	2	4	2	2	1		2	1	1	1	3	1	***20***
	2016	2	4	1	2	4	1	4	2	2	2	1	1	***26***
	L8 Total	*5*	*11*	*8*	*4*	*9*	*1*	*7*	*6*	*4*	*5*	*5*	*4*	***69***
	Grand Total	***30***	***39***	***41***	***34***	***41***	***19***	***31***	***25***	***25***	***32***	***33***	***23***	***373***

An additional project with the USGS that we are working on to improve fire extent mapping involves evaluating whether Sentinel-2 datasets can be used to supplement the LANDSAT imagery. Currently, derivation of BAECV and MTBS products uses LANDSAT-based datasets, but given the limitations mentioned earlier with regard to things like green-up and cloud cover, it is worth investigating whether assimilating similar datasets can be of value. The Sentinel-2 data have a 20m resolution, and the ability to image a location from different angles every 5 days is available. By adding additional data coverage possibilities, Sentinel-2 data could provide increased opportunities to fill LANDSAT data gaps; thus, the potential exists to improve the chances of detecting changes in surface reflectance, which is required for developing the MTBS and BAECV products. As of this writing, we are still awaiting results of both the Sentinel-2 and point validation projects.

We have acquired an initial version of BAECV-derived perimeters for the period 2006-2016 for Florida. As mentioned previously, these data do not encompass all fires, but hold promise in terms of identifying fire extents in locations where mapped fires do not currently exist. Data acquisition is easy and the importing the datasets into the database is possible. However, the BAECV data are not included at this time since we are awaiting updated results from our validation effort and will update as they become available.

Fire Datasets by Landowner

Multiple landowner sources across the state provided fire information in the form of fire occurrence databases and fire perimeters for both prescribed and wild fires. Landowners included public (*i.e.,* USFS, FWC, Florida Park Service, etc.), and private landowners (*i.e.,* Tall Timbers, Archbold, etc.), as well as some nationally available datasets that span ownerships (*i.e.,* the National Fire Occurrence Database [Short 2017]). Table 3 describes datasets by landowner. There is no cross-dataset standardization in any manner: Projections, tracking, and reporting methods vary among ownerships; fields and attributes differ; various time periods area covered; and data types differ. For example, some landowners may record an entire burn unit for a prescribed fire as having burned even if the burn is patchy or incomplete; other landowners may subset the burnable area within the unit or GPS the actual burn perimeter (and the variability of effects within the burn) following the fire and record that (see Figures 6-8). The data we currently possess can be uploaded into the database for use on an 'as-is' basis, or with some serious quality control, to supplement further analyses.

It is possible to use these datasets as ancillary information with an understanding that the data can serve as a guide but may have divergent accuracies depending on source and protocols. We used the fire datasets provided by the landowners 'as-is' to help us locate general areas where prescribed or wild fires had been recorded by the different landowners in order to find fires for our BAECV validation effort. If there were a fire perimeter recorded, we would search within the perimeter on post-fire LANDSAT imagery for evidence of a burn, and identify pixels as burned or unburned accordingly. If there were a fire occurrence point recorded, we would search post-fire imagery within the general area of the point for evidence of a burn. The data were quite useful in helping us focus in on known fire areas for the validation effort, but we encourage use with caution and a complete understanding of what the data represent.

Furthermore, data acquisition is not simple; to acquire these landowner-based data sets in the future in a consistent fashion, we recommend that a standardized statewide data call with specific reporting requirements be developed and utilized. This may also necessitate some automation on this end to process data from each individual ownership in a standardized way for incorporation into the database.

Fire Mapping Tools

The USGS has a publicly available free tool called the Fire Mapping Tool (FMT; USGS 2017) to assist individuals interested in determining the location and severity effects of fires, including the small ones that are below the 500ac threshold of MTBS. The tool incorporates the MTBS protocols for generating fire perimeters and severity information, and provides a way for end users to do this in a standard and consistent fashion. In its current version, the tool can be downloaded and installed to use in conjunction with QGIS software (a free/open source GIS package), and a user can delineate fires in an area of interest for specific timeframe with the FMT. While easy to use once installed, installation of the tool and the dependent packages for it are confusing if not a computer savvy/power user type of person. We will be investigating the option to include this tool's functionality in the SQL database. We will also look at testing the FMT to derive fire extents of small fires in the three pilot areas we will be validating during the next phase of the *Mapping Fires Across Florida* project.

In addition, the USGS has provided us with customizable python scripts that generate 'perimeters' through the use of clustering algorithms that are based on the probability of a pixel being burned (as identified in the BAECV raster data available online to download). These scripts can be modified to create fire 'perimeters' for small to large fires, such as those that would be of interest for analyses in our project. These tools just became available to us at the beginning of June, and we have not had the chance to evaluate them fully as of the time of this deliverable. However, the ability to automatically identify probable burn locations and generate perimeters is of interest for our efforts moving forward with the BAECV data products.

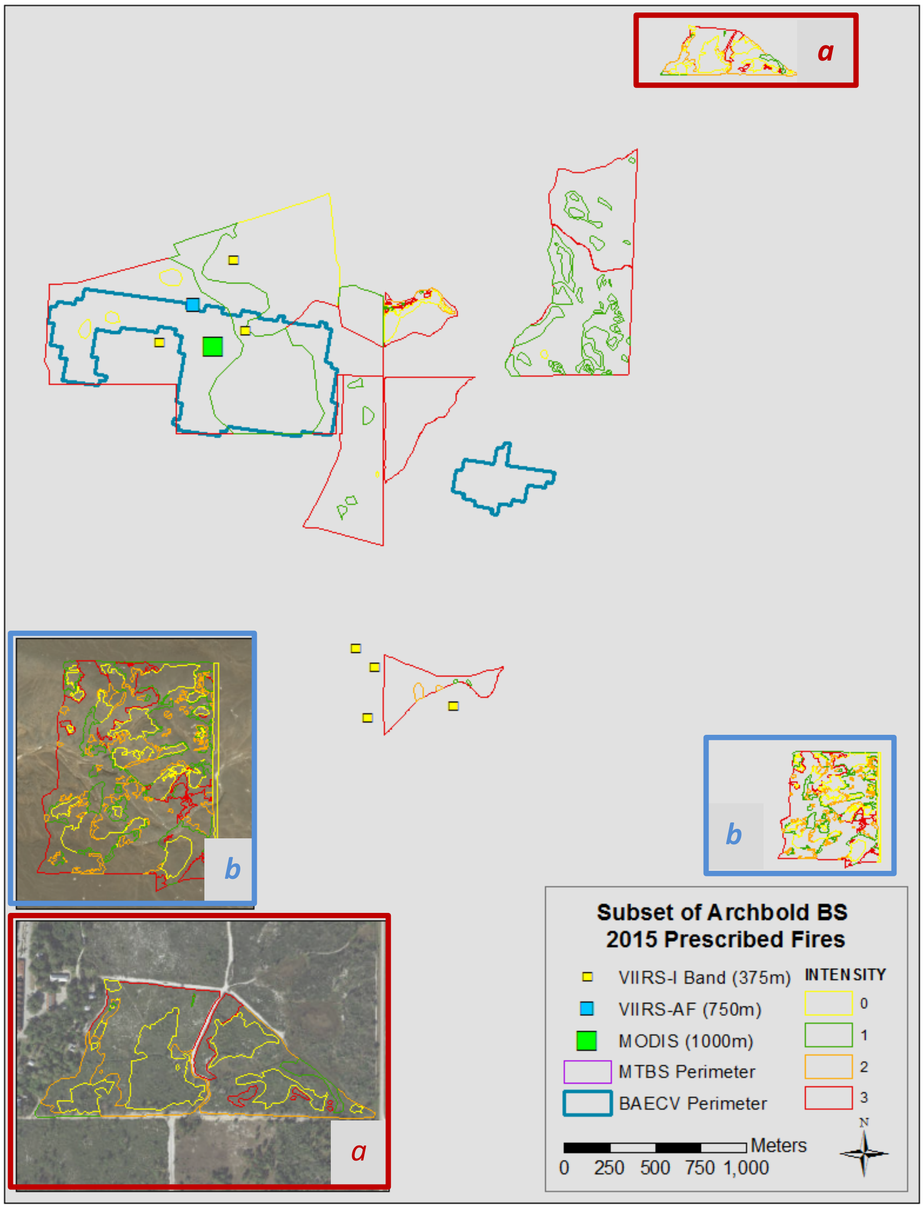


Figure 6: This image illustrates one of the different ways that landowners record fire data. It shows a subset of 2015 prescribed fire perimeters (as mapped by Archbold Biological Station [BS]). Notice that Archbold details the interior variation related to the fire effects resulting from the fire intensity (*a,b*) within their perimeters. All of the 2015 VIIRS-I band, VIIRS-AF, and MODIS-AF fire detections, and the 2015 perimeters derived from BAECV in the area are also mapped. BAECV protocols did not capture all fires (although an additional fire not mapped by Archbold BS is mapped by BAECV), and BAECV perimeters do not necessarily appear to line up with the fire intensity mapped by Archbold (at least visually). MTBS did not map any fires in the area.

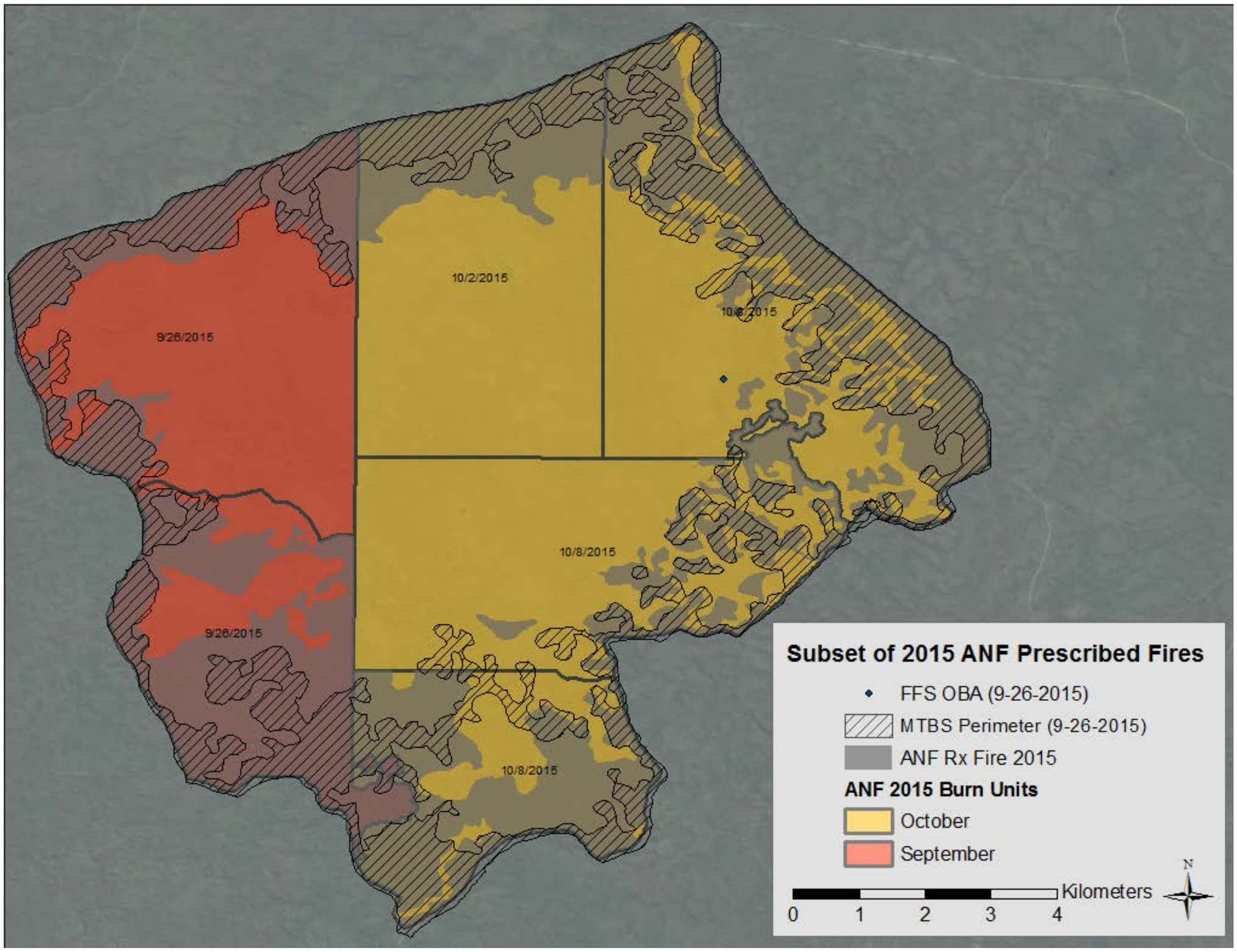


Figure 7: Prescribed fire perimeters as mapped by the Apalachicola National Forest (ANF) for a group of six burn units, encompassing ~24,500 acres. The color of the burn units corresponds to the month burned; labels identify the specific date that ANF applied fire to the unit. The total area identified by the ANF as burned in the 6 units is 10,120 acres (grey area in map). To get this data, ANF subsets only the burnable vegetation within the burn unit to generate the total acres burned by prescribed fire in that unit. In the example above, a FFS OBA permit exists for 11,500 acres on September 26, 2015, and is nearly 4.5 miles away from the center of the northwestern-most unit. ANF identified the two western burn units as having fire applied to them on that date. The total area of the two units combined is ~7,900 acres (of which ~3,800 acres burned in those two units according ANF records). The MTBS perimeter (hatched area) wraps around all six of the units, lists a burn date of September 26, 2015, and encompasses 7,052 acres (2,200 of which are in the two western units).

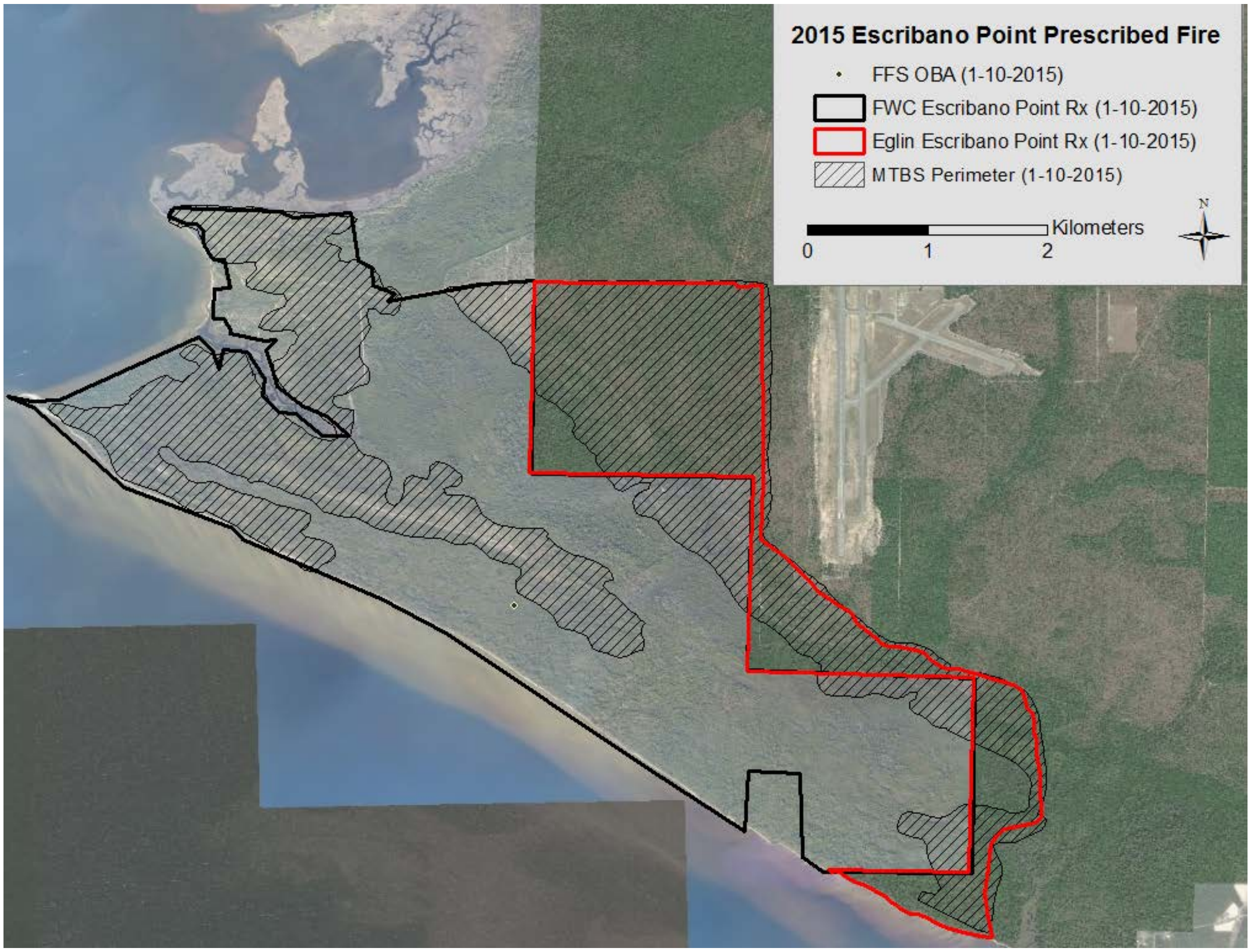


Figure 8: Prescribed fire perimeters for the Escribano Point burn that occurred on January 10, 2015. The burn encompasses two ownerships: FWC and Eglin AFB. Each owner recorded the area where they applied fire in their respective units. FWC recorded nearly 3,350 acres and Eglin recorded nearly 1,100 acres, which correspond to the size of the burn units themselves. The FFS OBA point for the burn was for ~4,500 acres, and corresponds to the two units being combined and burned as one. The area identified as burned by MTBS (hatched area) for the unit encompasses ~2300 acres.

Table 3: Landowner-provided datasets evaluated for mapping fires in Florida, and their spatial and temporal characteristics (this includes update availability, period of record, and data coverage timeframe) pertinent to this project. Unless otherwise noted, the data we used is bounded by the years 2006-2016.

Data Source (Fire Data by Landowner)	Data Type	Spatial Characteristics	Dataset Period of Record	Wildfire (W), Prescribed Fire (P), or Both (WP)	Source, notes, description
Archbold Research Station	Polygon	Varies depending on source	2006-2017		• Source: Archbold R.S. GIS Dept. • Rx Fires • Variability within fire mapped
Florida State Forests RX Fires	Polygon		2009-2017	P	• Source: FFS GIS Dept. • Details about seasonality, weather, fire behavior, ignition pattern, etc. included
FFS Wildfire	Point, Polygon		2006-2016	W	• Source: FFS GIS Dept. • Perimeters include ROS, cause, date/time • Points (FOD) include name, date/time, fire behavior metrics, etc. • FOD points link to existing perimeters
Florida Park Service	Polygon		2006-2016	WP	• Source: FPS GIS Dept. • Burn Unit perimeters; must be linked to .csv provided to derive fire history by year
FWC	Polygon		1998-2018	WP	• Source: FWC GIS Dept. • Includes date/time of burns, rx burn purpose, and notes on burn
US FWS	Point, Polygon		2002-2018 (points) 1963-2016 (SMNWR)	WP	• Source: WIMS Fire Occurrence Database (includes points outside of FL) • Source: Prescribed Fire Burn Units (St Marks NWR) • Polygon data includes ignition method, seasonality, date/time
National Fire Occurrence Database	Point		1992-2015	WP	• Source: Fire Occurrence Database (Short 2017) • Includes fires outside of Florida
Tall Timbers Research Station	Polygon		1990-2016	P	• Source: Tall Timbers R.S. GIS Dept. • Details include burn date, landcover

Data Source (Fire Data by Landowner)	Data Type	Spatial Characteristics	Dataset Period of Record	Wildfire (W), Prescribed Fire (P), or Both (WP)	Source, notes, description
NPS	Point, Polygon	Varies depending on source	1940-2017	WP	• Source: J.Shedd (NPS Fire Dataset) • Points (FOD) & Perimeters • Includes Wildfire and Prescribed Fire • Includes fires in SE Park Units (outside of FL)
NPS – BICY	Polygon		2006-2018	WP	• Source: BICY GIS Dept. • Includes wildfire & prescribed fire • Details about fire type, cause, ignition source, fire wx, fire effects, etc. included
TNC- Saddle Blanket Scrub	Polygon		2008-2016 (Intermittent)	P	• Source: TNC GIS Dept. • Rx Fires • Includes Burn Date
TNC – Tiger Creek Preserve	Polygon		2008-2018	P	• Source: TNC GIS Dept. • Rx Fires • Includes Burn Date
TNC – Disney Wilderness Preserve	Polygon		2008-2018	P	• Source: TNC GIS Dept. • Rx Fires • Includes Burn Date
USFS – Apalachicola NF Rx Fires	Point, Polygon		1970-2017 (Wildfire FOD) 1993-2017 (Rx FOD)	WP	• Source: USFS Forests in Florida GIS Dept. • Wildfires and Rx Fires • Rx Fires require relates/joins to derive history on annual basis • Separate FOD for wildfires and Rx Fires
USFS – Osceola NF Rx Fires	Polygon		2007-2018	P	• Source: USFS Forests in Florida GIS Dept. & Fire Planner • Rx Fires • Includes Burn Date
USFS – Ocala NF Rx Fires	Polygon		1962-2017 (intermittent ’62-’81)	P	
DoD – Eglin AFB	Polygon		1972-2016	WP	• Source: DoD WFMIS • Includes wildfires and Rx Fires • Details include Date, cause, comments
DoD – Avon Park	Polygon		1972-2016	WP	• Source: DoD WFMIS • Includes wildfires and Rx Fires • Details include Date, cause, comments
DoD – Tyndall AFR	Polygon		1972-2016	WP	• Source: DoD WFMIS • Includes wildfires and Rx Fires • Details include Date, cause, comments

Deliverable #4: Recommendations

Deliverable #4 of the *Mapping Fires Across Florida* project focused on trying to address the prescribed fire data gap and understand the available known datasets and satellite-based datasets for analyses of fire regime characteristics in the State of Florida. We evaluated owner-provided fire location datasets, and concluded that they are most useful as ancillary datasets due to their inconsistent mapping and reporting requirements and methodologies. We also assessed a variety of satellite datasets to determine how to use the data or derive data for use in mapping the spatial extent of fires. Two satellite-based datasets – MTBS and BAECV – showed promise due to having peer reviewed standardized methods already in place for deriving fire perimeters. The methods used for these nationally scoped datasets are replicable and it is possible to adapt them regionally to map a range of fire sizes in Florida.

As noted in the section on individual landowner-based fire data, we recommend that a standardized statewide data call with specific reporting requirements be developed and utilized. This may also necessitate some standardized automation to process data from each individual ownership in order for incorporation into the database.

Next Steps

The next steps for the project include identifying three pilot areas to validate current methods for evaluating fire regime characteristics and trends, and developing procedures for annual updates moving forward. To address the challenge of understanding spatial characteristics of burns and reconstructing burn histories, we intend to use the BAECV dataset developed by Hawbaker *et al.* (2017) and MTBS dataset (Eidenshink *et al.* 2007), data derived in-house using the fire mapping tools for smaller fires, and known fire perimeters for the three pilot areas. We will select the pilot areas based on having known fire location data and having fire-maintained systems where species of greatest conservation need occur (to coincide with another project [funded through a FWC State Wildlife Grant]). This will entail validating perimeters using satellite-based products against known fire perimeters, and using the FMT and automatic queries in the SQL geodatabase to derive fire regime characteristics. The result will be spatial information in the form of fire perimeters for the period 2006 – 2016, including queries, reports, and metadata. If desired, we can make information that we have collected from satellite detection sensors (specifically, VIIRS and MODIS) available for upload to the database in order to add ancillary data about the presence/absence of fires.

Additionally, as noted in previous deliverables, it should be stated that although we will not specifically address pile burn data in our analyses or use broadcast burn authorizations, these data will likely be important for validation in future protocols, especially when differentiating between large piles and small broadcast burns detected by satellites like MODIS and VIIRS. Therefore, this data will remain in the database, but is filterable depending on the analysis performed.

Deliverable #4: Summary

The overall aim of the *Mapping Fires Across Florida* project is to develop a spatial database of prescribed fire extents in Florida with querying and reporting capabilities. The fires in this spatial database will range from less than ten acres to greater than 100 acres. To recap accomplishments so far on this project:

- The exploratory data analysis performed for Deliverable #2 provided useful insights into the FFS OBA dataset, and its potential usefulness for assessing fire regime characteristics in the state of Florida.
- For Deliverable #3 we focused on converting the existing DoD database from Oracle to SQL Server and importing the FFS OBA data.

For this deliverable (Deliverable #4), we explored multiple sources and types of fire extent information, including landowner-provided fire atlas datasets and satellite based detections and extent maps, and we reviewed literature about the sensors and datasets. All of the datasets are currently in a format that is ready for upload into the SQL database. Additionally, we evaluated (or are in the process of evaluating) the possibility of using tools developed by USGS to include in our processing procedures for mapping smaller fires which are not automatically included in national fire datasets.

In summary, we have evaluated various satellite-based fire products for use in determining the location and extent of fires across the state of Florida. Satellite-based datasets (and their derivatives) are promising since it is possible to extract fire extent information across large regional areas in a standardized replicable way. Because of the longevity of many of the current satellite sensors and products that we evaluated, there is an abundance of scientific literature describing the known limitations, assumptions, and utility of different datasets for fire detections and burn scar mapping. However, many things detract from the ability to rely solely on satellite-based data for the specifics of this project.

Florida has many small, rapidly burning, low-intensity fires (often under a tree canopy), frequent cloud cover, and rapid green-up following fires. The detections of any satellite sensor used for imaging or detecting fires requires a cloud-free sky at the time of satellite overpass. In the case of using imagery to derive information about fire extents, post-fire images occurring on cloudy days may not suitable for deriving burned area, and low-intensity fires beneath a tree canopy may not be detectable. In the case of active fire detection, it may not be possible to detect fires burning on cloudy days. Additionally, the inability to derive fine-scale burned area data from thermal detection centroids (e.g., MODIS-AF and VIIRS-AF) prohibit the use of these data for anything other than identifying likely presence/absence of fires in a general area. Care must be taken using these as absolute truths since enough active fire must be present at the time of the satellite overpass to trigger the detection (*i.e.,* the absence of a detection point does not mean a fire did not occur). VIIRS-I band data are promising for ongoing large fires in that if polygons connecting the outermost detection point centroids are drawn, they likely represent where the fire has burned or progressed to in a very generalized way. It is possible to process data from sensors in a consistent manner for comparing to known fire locations.

Nationally scoped datasets such as LANDFIRE Disturbance products, MTBS, and BAECV may be useful as ancillary data in instances of large fires reported in a standardized way. One can replicate the methods used to derive the MTBS datasets for individual fires and at smaller scales, which is useful for being able to generate perimeters systematically. In addition, much smaller fires are mapped (~10ac) as part of the regular protocol for deriving the BAECV products, which is of benefit in Florida where many small fires prevail and where habitat-based analyses for those species with the greatest conservation needs are involved.

We believe that the automated portion of developing perimeters using BAECV and MTBS methodology can be useful for updating these datasets in a consistent fashion moving forward, and we are exploring the FMT and python scripts provided by the USGS to enhance this ability. The FFS OBA, BAECV, MTBS, and landowner data combined can help locate areas that have burned in prescribed fires and clarify fire characteristics across the state, perhaps better than any particular dataset alone – especially if there were simple standardized tracking and reporting options required that did not burden landowners with extra work. The next steps for this database include deciding on three pilot areas to use as validation locations for the spatial database. In addition, we will consult with FWC on exactly what data to upload into the SQL Server as ancillary data for analyses.

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Appendices

Appendix A: *Visual Examples of Fire Detections by Various Satellites and Derivative Products*

Appendix A:
Visual Examples of Fire Detections by Various Satellites and Derivative Products

The following pages contain examples of fire detections and extent derivatives from different satellites. We have included them to highlight similarities and differences of the different datasets. These images are for illustrative purposes only. Further examples are available upon request.

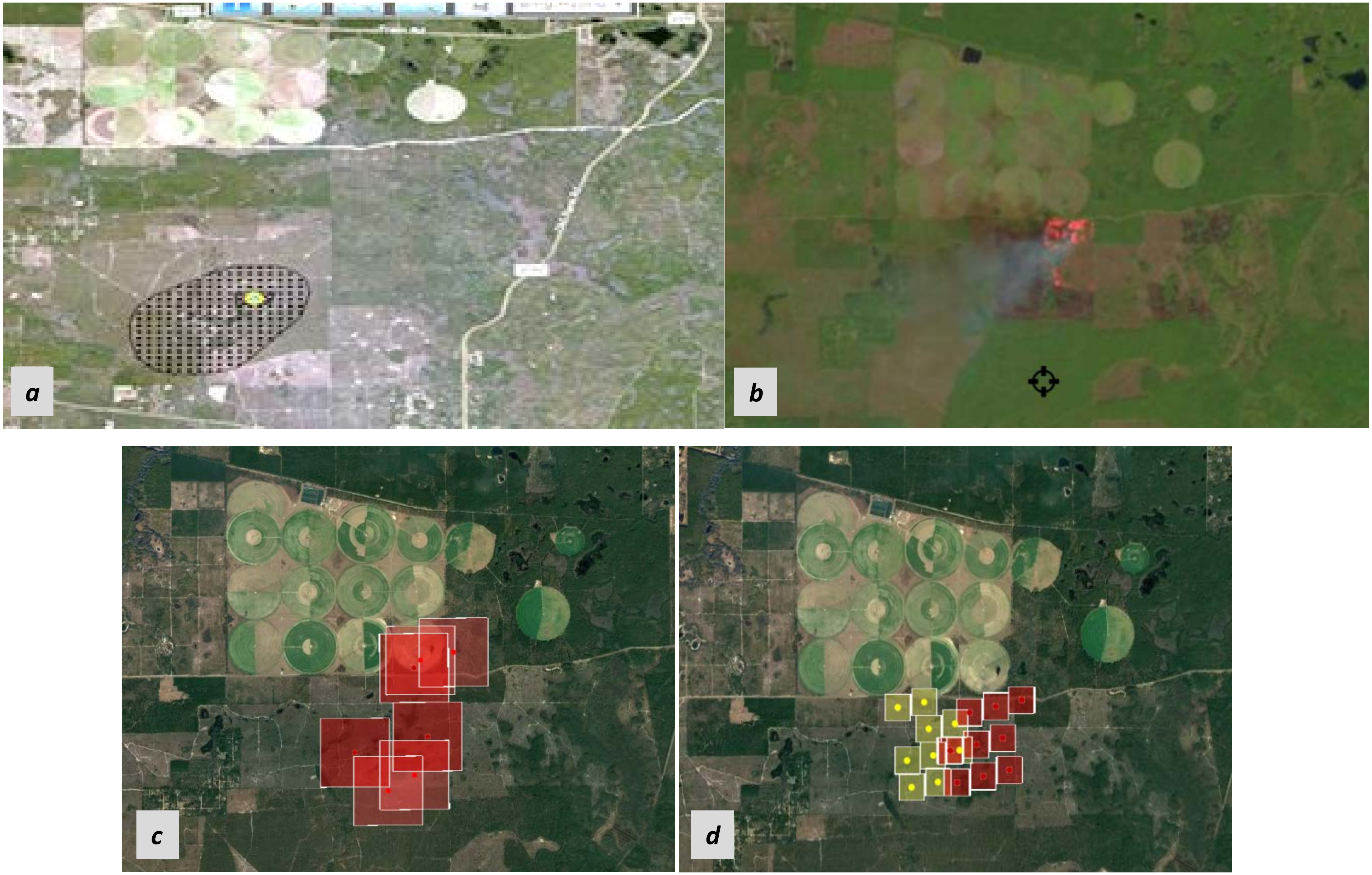

Figure A1: 200ac Burn Authorization (FFS OBA) for 15 Nov 2017(*a*). The yellow point is the location of the request; crosshatched polygon is the smoke prediction used. The LANDSAT 8 (*b*) image on that date for that location, and the MODIS-AF (*c*) and VIIRS-I band (*d*) detects, show that the FFS OBA is nearly 1km south of the actual fire location (identified on the LANDSAT image by the black crosshairs). The VIIRS-I band closely corroborates the LANDSAT 8 image, in terms of where the fire is actually burning (yellow dots are fire detections from the previous day). The MODIS-AF corroborates the smoke prediction; it could be misleading in terms of specific fire location. If using any of the point data in an isolated fashion, information about what burned and where may be incorrect (*e.g.,* north of road there is no fire [MODIS-AF], and the OBA shows the burn being in a field 1km south of the actual fire). However, the sensor data is likely within the range of error (*i.e.*, +/- 500m for a MODIS-AF detect).

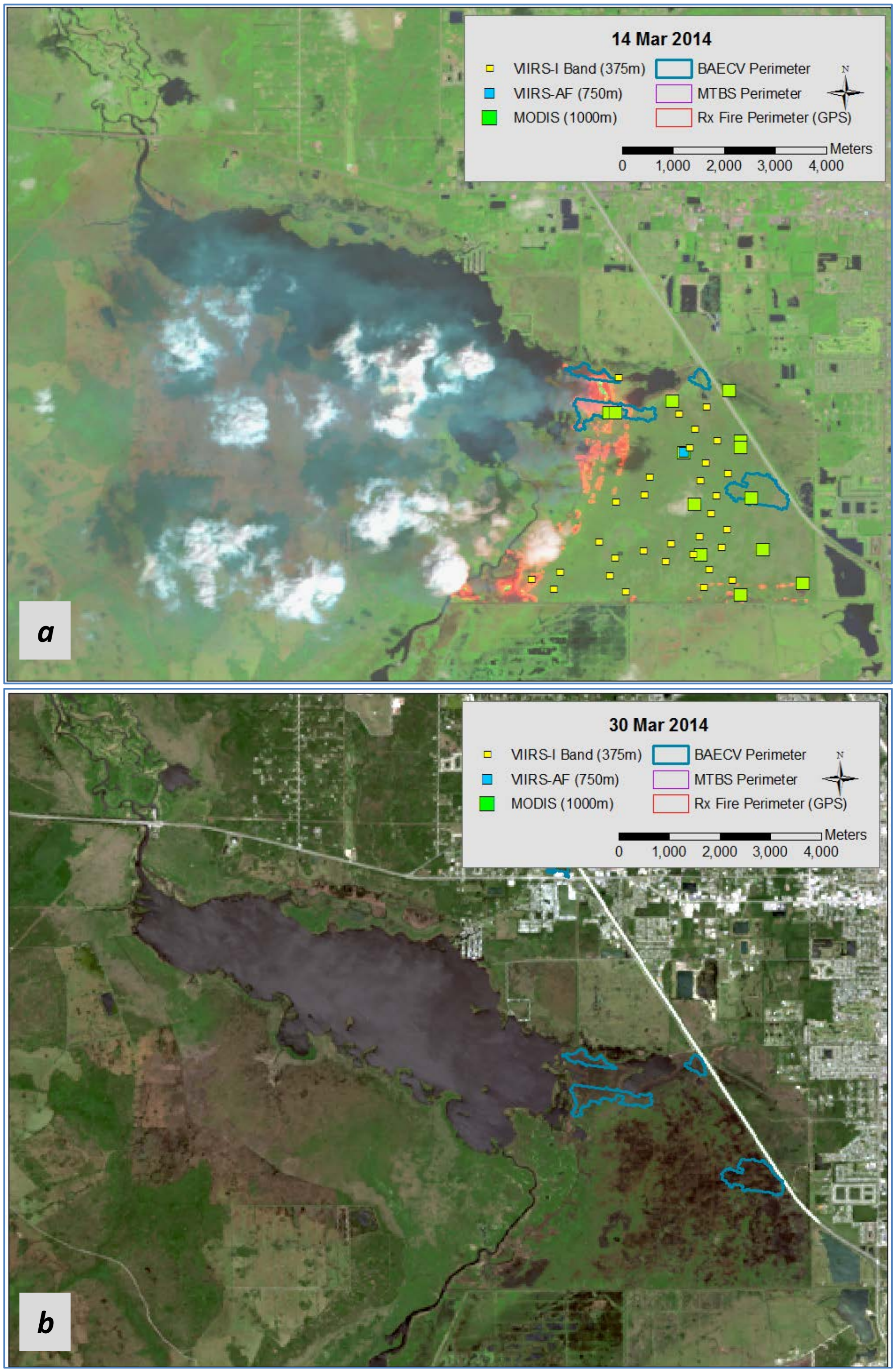

Figure A2: Fire Detections from satellites during a fire (*a*) and post-fire (*b*), demonstrating how sensor detections vary in terms of a fire's geospatial extent information. In the top image (*a*), captured at 11:55 a.m. local time by LANDSAT 8, the actual ignitions of a prescribed fire are visible. BAECV perimeters are the blue lines on the image. MODIS_AF detects are from 2:33-2:35 p.m. local time; VIIRS-AF detect is from 1:38 p.m. local time; and VIIRS-I band detects are from 1:43 p.m. local time. Deducing from the ignition pattern visible in the top image (*a*), it is likely that the area near the road on the eastern edge of the unit was burning (*i.e.,* where the MODIS detects are located) or had just burned at the time of the satellite overpasses. Thus, these detections are useful in identifying the presence/absence of a heat source. As you can see by the bottom image (*b*), much more of the area is black within the burn unit than is identified by the BAECV perimeter. The BAECV perimeter is from an initial version of the BAECV product that we tested, and under-representation of fires in areas like this led us to perform the validation effort with the USGS. An MTBS perimeter does not exist at all for this fire.

Figure A3: The VIIRS-I band detects between June 5-7, 2018 on the G-205 fire burning in S. Florida. The different colors represent detections over the past 0-6 hrs (dark red; none visible in this image), 6-12 hrs (red), 12-24 hrs (orange) and 6d to last 24 hrs (yellow). This is not two distinct fires, but one fire, which either had spotted to the north or in which portions between the southern and northern portions were cold (*i.e.,* undetectable) when the satellites passed over.

Chapter 6: Deliverable #5.1

Summary Report – 10 Years of Data for 3 Pilot Areas

Deliverables Update
#5.1: Summary Report – 10 Years of Data for 3 Pilot Areas

Mapping Fires Across Florida:
Advancement of a Fire Spatial Database

September 2018

Tallahassee, FL

TALL TIMBERS

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Project ID

FWC-16/17-135 Spatial Database
A Proposal for Mapping Statewide Fire Occurrence, Fire History, and Ecological Outcomes
Submitted by Tall Timbers Research, Inc., June 20, 2017

Previous project deliverable reports, including the earlier workshop proceedings, video of expert presentations, summary report, and power point presentations are available free of charge from Tall Timbers Research, Inc. Please contact Joe Noble: jnoble@talltimbers.org

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TALL TIMBERS

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Executive Summary

Tall Timbers Research, Inc. is pleased to present the *Mapping Fires Across Florida: Deliverable #5.1* update. The overall purpose of the project is to develop a spatial database of prescribed fire extents in Florida with querying and reporting capabilities. Development of a comprehensive spatially explicit map of fire occurrence remains one of the most critical needs for conservation in the Southeastern US. Not only are the vast majority of Florida's endangered species and ecosystems reliant on frequent fire, but fire risk analysis, prescribed fire planning, and fire behavior modeling are sensitive to fire history. Fire occurrence in Florida is currently tracked by approximate location through the Florida Forest Service (FFS) burn authorization system, Fire Management Information System (FMIS). While this system represents one of the most advanced prescribed fire planning datasets in the country, the system does not record perimeter data or include assessments regarding which burns are actually completed. Relying solely on this system results in documented data gaps when estimating the size, location and effectiveness of managed fires on a statewide scale. These "actual burned" areas are critical factors in analyses and models evaluating conservation success.

Tall Timbers Research, Inc. is addressing this need by developing a robust spatial database for more precise mapping and tracking of all prescribed fire in Florida. Advanced remote sensing techniques are being applied to known locations of prescribed fires, as identified by the FFS data and select landowner-provided datasets, to record actual spatial fire boundaries into a modified version of the U.S. Air Force Wildland Fire Database. In addition, custom query tools are being developed to report fire history (e.g., frequency, time-since-burn, year last burned, etc.) in specific fire dependent ecological systems or fire dependent species habitats.

The work documented here builds on the spatial database project work previously completed by Tall Timbers' staff. We have already completed exploratory data analysis on the FFS FMIS open burn authorization (OBA) data, which provided insights into the potential usefulness of the dataset for assessing fire regime characteristics in the state of Florida. We have also converted the existing DoD database from Oracle to SQL Server and imported the FFS OBA data into it after consultation with FWCC partners. We have evaluated fire datasets from twenty-six sources for the period 2006-2016. The datasets include satellite-based thermal detections and fire extent maps, as well as landowner-provided fire atlases and fire occurrence databases.

The current work is provided in the form of a summary report on prescribed and wildfire information sources for three pilot areas in Florida. We have included wildfires as they often meet management objectives and impact species habitats, and as such are an important part of the fire regime evidence used to inform conservation-monitoring decisions. Additionally, it is not possible to discriminate fully between wildfire and prescribed fire with these products. This report contains information on the processes used to derive spatial footprints of fires, and resulting information from the evaluation of results with the three pilot areas. We also provide some recommendations for moving forward.

Glossary of Terms and Concepts

Broadcast Burn An open burn that is done for agricultural, silvicultural, or land clearing purposes and is not a pile

Burned Area Essential Climate Variable (BAECV) refers to an algorithm that capitalizes on the long temporal availability of LANDSAT imagery to identify burned areas across the conterminous United States.

Continuation An authorization to continue a previously approved open burn authorization that was not completed for various reasons including late starts, poor weather conditions or lack of resources.

CONUS The Continental United States; this reference excludes Alaska and Hawaii.

Cooperative Land Cover (CLC) The Cooperative Land Cover Map is a project to develop an improved statewide land cover map from existing sources and expert review of aerial photography. The project is directly tied to a goal of Florida's State Wildlife Action Plan (SWAP) to represent Florida's diverse habitats in a spatially-explicit manner.

Environmental Protection Agency (EPA) The agency of the federal government which was created for the purpose of protecting health and environment.

Florida Forest Service (FFS) Agency whose mission is to protect and manage forest resources in Florida.

Florida Natural Areas Inventory (FNAI) Florida's state heritage program responsible for tracking occurrences of species and natural communities statewide.

Fire Mapping Information System (FMIS) integrated set of applications that handle data input, processing and reporting needs for the Florida Division of Forestry (DOF).

Global Fire Emissions Database (GFED) Database combining satellite information on fire activity and vegetation productivity to estimate gridded monthly burned area and fire emissions.

GOES-16 previously known as GOES-R, is part of the Geostationary Operational Environmental Satellite (GOES) system operated by the U.S. National Oceanic and Atmospheric Administration and is the first spacecraft in NOAA's next-generation of geostationary satellites. The GOES-R series satellites will provide advanced imaging with increased spatial resolution and faster coverage, improving the detection of environmental phenomena.

Hazard Mapping Systems (HMS) NOAA product suite that provides both fire and smoke analysis products. It is an interactive processing system that allows analysts to manually integrate data from automated fire detection algorithms using GOES and polar (Advanced Very High Resolution Radiometer (AVHRR) and MODerate resolution Imaging Spectroradiometer (MODIS)) images. The result is a quality controlled display of the locations of fires and significant smoke plumes detected by meteorological satellites.

Interagency Fuel Treatment Decision Support System (IFTDSS) is a web-based software and data integration framework that organizes fire and fuels software applications to make fuels treatment planning and analysis more efficient. The effort was initiated by Joint Fire Science Program and the NWCG Fuels Management Committee in 2007.

Integrated Reporting of Wildland-Fire Information (IRWIN) This service is a Wildland Fire Information and Technology (WFIT) affiliated investment intended to provide an "end-to-end" fire reporting capability. IRWIN is tasked with providing data exchange capabilities between existing applications used to manage data related to wildland fire incidents.

LANDSAT The LANDSAT Program is a series of Earth-observing satellite missions jointly managed by NASA and the U.S. Geological Survey. Imagery is available since 1972 from six satellites in the LANDSAT series. These satellites have been a major component of NASA's Earth observation program.

Landscape Conservation Cooperative (LCC) self-directed partnerships between federal agencies, states, tribes, non-governmental organizations, universities, and other entities to collaboratively define science needs and jointly address broad-scale conservation issues.

Monitoring Trends in Burn Severity (MTBS) refers to an interagency program whose goal is to consistently map the burn severity and extent of large fires across all lands of the United States from 1984 to present.

Moderate Resolution Imaging Spectroradiometer (MODIS) is a key instrument aboard the Terra and Aqua satellites. Satellites view the entire Earth's surface every 1 to 2 days acquiring data in 36 spectral bands. These data improve our understanding of global dynamics and processes occurring on the land, oceans and lower atmosphere.

Pile Burn An open burn that is in the form of a pile that is larger than 8' diameter

PostGIS is a spatial database extender for PostgreSQL object-relational database. It adds support for geographic objects allowing queries to be run in SQL.

PostgreSQL is an open source object-relational database system.

Open Burn Authorization (OBA) refers to Florida Forest Service Open Burn Authorization Requests and is available to Certified Prescribed Burners.

QGIS is a free and open source professional Geographical Information System (GIS) that is built on top of Free and Open Source Software (FOSS)

QGIS Event Mapping Tool (EMT) (now known as the Fire Mapping Tool, FMT), a QGIS plugin for fire assessment developed by U.S. Geological Survey National Center for Earth Resources Observation and Science (EROS)

Southern Integrated Prescribed Fire Information System (SIPFIS) a Joint Fire Science Program initiative to design an integrated information system for fire and air quality data in the SE United States.

Volatile Organic Compounds (**VOC)** refers to a large group of organic chemicals that include any compound of carbon (excluding carbon monoxide, carbon dioxide, carbonic acid, metallic carbides or carbonates, and ammonium carbonate).

Deliverable #5.1: Background

This document serves as the summary report of data exploration activities and should be considered as the final “Deliverable #5.1” of the FWCC Grant. It details the processes used to derive the spatial footprints of fires, as well as information gathered from evaluation meetings with managers from each of the three pilot areas we chose. We also provide some recommendations on the data sets and processes proposed for moving forward in populating the spatial database developed and submitted previously (see Deliverables 3.1, 3.2, and 4).

For over a decade, resource managers in the state have recognized the importance of tracking and monitoring the use of prescribed fire. Many species in Florida are dependent on fire for maintenance of appropriate habitat conditions. Measurements, such as seasonality and years since last burn are important components in assessing the condition of these fire-maintained systems. For many species that are dependent on these systems, managing an appropriate fire return interval is critical. Differentiating those areas that have an appropriate fire return interval from those areas without an appropriate fire return interval would allow managers to focus resources on areas most in need of management actions, as well as serve as a means to measure and quantify the success of conservation and restoration efforts.

Cost effective and efficient management of conservation lands requires up to date detailed resource maps. The Peninsular Florida Landscape Conservation Cooperative (PFLCC) is working on a statewide Landscape Conservation Design. As part of this process, the PFLCC is identifying conservation targets (*i.e.,* indicators) for each priority resource. It became evident that fire return interval could be a critical indicator for these systems.

Florida currently has a detailed (10m) land cover map, used by multiple entities (*e.g.,* Florida Fish and Wildlife Conservation Commission, FWC’s State Wildlife Action Plan, Florida Natural Areas Inventory, and the PFLCC). However, there is a critical missing component from the existing land cover map - qualitative attributes regarding fire. One key qualitative attribute that has long been identified as a critical data gap pertains to prescribed fire. Addition of qualitative attributes based on fire regime characteristics, such as fire return interval, would increase the effectiveness of informing acquisition of conservation lands, supporting land and fire management, and tracking success and failure of conservation efforts. Assessment of the success of management actions will provide a valuable feedback loop to inform future management actions on conservation lands, both public and private.

Currently, a spatial database that tracks prescribed fire *extents* statewide does not exist, which means that there is not a comprehensive knowledgebase about fire regimes across the state. Managers recognized this data gap more than a decade ago. In 2006, they noted “…methods for monitoring the use of fire on public lands may be one of the greatest unmet needs in comprehensive wildlife management…” (*Monitoring Prescribed Burning on Public Lands in Florida, 2006).* This project aims to enhance our understanding of prescribed fire characteristics across the state of Florida for integration into further analyses specific to landscape conservation and monitoring. We list specific outcomes and accomplishments to date below:

1. We will address the data gap through a spatial database designed to track and analyze burn authorization data between 2006-2016 using FFS Online Burn Authorization data and a modified extension of the US Air Force Wildfire Database.
2. We are working on methods to validate burn authorization records by comparing authorized permits to known fire locations and using remote sensing techniques to record spatial fire boundaries.
3. We will develop custom query tools to evaluate fire regime characteristics and trends in specific fire dependent ecological systems or fire-dependent species habitats.
4. We will develop procedures for annual updates moving forward.

Deliverable #5.1: Dataset Exploration

Understanding fire regime characteristics across the state of Florida is important from a conservation perspective if the aim is to maximize conservation efforts and target conservation opportunities appropriately. However, limited information about fire occurrence in the state exists, particularly in terms of a statewide spatial database that includes individual fire perimeters for prescribed fires and for many fires occurring on private lands. We explored satellite-based detection products to determine the spatial representation of fire extents, and compared these products against known fire locations for three pilot areas: Eglin AFB, the Apalachicola National Forest, and Big Cypress National Preserve (Figure 1). This section provides descriptions of the pilot areas and datasets, as well as evaluations of these datasets for the pilot areas.

For the previous deliverable (Deliverable 4), we evaluated multiple sources of fire information and data to determine if they met the needs of the FWC project in terms of spatial resolution, geographic extent, and time stamping for the study period of interest (2006-2016). In general, the datasets evaluated included prescribed fire information, wildfire information, or both. Data types included point, polygon, and raster data. The temporal characteristics of the data varied depending on the source. For this project, we are only interested in fires occurring in the 2006-2016 timeframe for possible inclusion in the SQL geodatabase. The ability exists to upload any additional data as needed (*e.g.*, as available, pre-2006 or post-2016, if available from the original sources).

For Deliverable 5.1, we expand upon that assessment by comparing spatial footprints of fires derived from the satellite-based BAECV product (Hawbaker *et al.* 2017) against known locations of fires at Eglin Air Force Base (EAFB), the Apalachicola National Forest (ANF), and Big Cypress National Preserve (BICY). We worked with fire managers at the three locations to get feedback on the products and gauge interest and usefulness of the products. We chose the pilot areas for multiple reasons. They all have active prescribed fire programs, have supported wildfires in the past, and have well documented burn records that detail fire sizes, types and dates. Together, the three areas span a large portion of the state, and encompass many fire-dependent systems and species habitats of interest to PFLCC and FWCC.

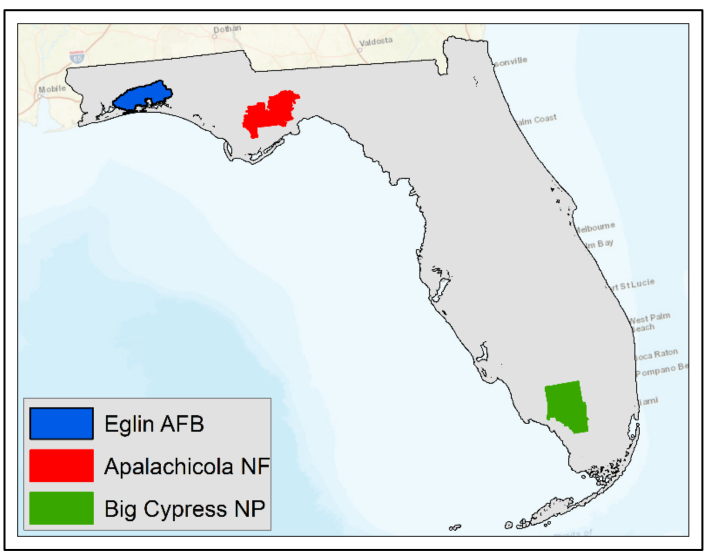

Figure 1: Three pilot area locations: Big Cypress National Preserve, Apalachicola National Forest, and Eglin Air Force Base.

Big Cypress National Preserve (BICY)

The nation's first national preserve, Big Cypress National Preserve, was established in October 1974, a result of the efforts of many to protect the wildlands of Big Cypress Swamp. The 729,000-acre preserve is centrally located between Miami and Naples in southern Florida. BICY protects the freshwaters of the Big Cypress Swamp, contains a diversity of wildlife and a mixture of tropical and temperate plant communities. Vegetation types at BICY are diverse and fire adapted species occur in pine forests, mixed grass prairies, cypress forests, and marshes. BICY has many fire-dependent animal and plant species – including threatened, endangered, and rare species – which require fire to restore and maintain their native communities. The BICY Fire Management Plan (FMP; 2010 amended 2013) requires BICY to "Provide for fire-dependent ecological communities and wildfire populations, and restore the dynamic role of fire in the Preserve" and supports the need for the application of fire as a means to re-establish natural systems while protecting resources. As a result, BICY has one of the largest fire management programs in the National Park System, burning ~60,000-acres each year.

Fire can burn in all seasons at BICY; fire behavior and spread is moderated or inhibited during the wet season (July-October), while the dry season (March-May) and shoulder seasons (November-February, and June) are conducive to fire spread if water and fire breaks do not stop it. Human-caused fires generally occur March-June during the dry season and coincide with of increased recreational activity. Lightning fires generally occur between April and August. Historically, the overall BICY fire rotation is less than 35 years and the area burns with a moderate to low burn severity.

Eglin Air Force Base (EAFB)

Eglin Air Force base is located within Santa Rosa, Okaloosa, and Walton counties in northwest Florida. It occupies ~465,000 acres on the western end of the Florida panhandle, is home to globally significant fire-dependent ecosystems and faces a significant threat from wildfires. It is one of the leading biodiversity hotspots in the US, and lies within the third largest biodiversity hotspot in the world (EAFB INRMP). Coastal sand dunes, cypress swamps, hardwood forests, flatwoods, sandhills, seepage slopes and steephead ravines cover the area. Frequent fire is necessary to maintain and preserve species composition and structure for most of the habitat types found on EAFB. For example, many of the pine sandhill communities are adapted to fire and require fire every three to five years to retain their assorted structure and composition components.

The fire management program is highly complex due to mission requirements, smoke management constraints, its adjacency with urban areas, and a legal requirement for an aggressive prescribed fire program. From 1940 until the mid-1970s, EAFB focused on fire suppression, although they did have a small-scale prescribed fire program in the 1960s that burned 5000-15,000 acres annually for range maintenance, fuels reduction, and habitat improvement purposes (EAFB INRMP). Presently, Eglin responds to ~75 wildfires annually – most of which are caused by military mission activity. Since 1989, prescribed fire has been reintroduced at a significant scale; the current prescribed fire goal is 90,000 acres per year on a five-year average – one of the highest amounts of prescribed fire in the nation. Annual prescribed fire planning takes into consideration the complexities of balancing mission requirements and natural resource management needs to determine areas of fire exclusion and areas of prescribed fire. Fire managers use a GIS-based burn prioritization model to identify priority areas in order to accomplish prescribed fire objectives.

Apalachicola National Forest (ANF)

The 575,000-acre Apalachicola National Forest is located in the Florida panhandle. The ANF is located within Leon, Liberty, Franklin, and Wakulla Counties; it shares borders with Tallahassee to the northeast, the Apalachicola River to the west, and is dissected into an east and west half by the Ochlockonee River. The gently rolling to flat terrain is peppered with sandhills, sinkholes, bays and swamps, and very well drained to very poorly drained soil types.

The ANF is considered a biodiversity hotspot with many rare endemic species in the seepage bogs, savannahs and swamps, and longleaf, slash, and loblolly pine with an understory of wiregrass, palmetto, and gallberry covering the sandhills (ANF LRMP 1999; Trager et al. 2018). These ecosystems provide habitat for many plant and wildlife species that depend on fire, including threatened/endangered species and species of great concern. As a result, the ANF has one of the largest prescribed burning programs in the country in order to maintain the fire-dependent species and habitats, burning an average of 80,000 acres annually (based on 10-yr average).

Prescribed fires are used to maintain ecological processes when lightning ignitions do not occur with the frequency or intensity needed. Although the full range of management options are available to ANF managers, only those fires caused by lightning occurring in wilderness or wilderness study areas may be allowed to burn for the benefit of the resource. Most lightning fires happen in the summer in Florida, and the Forest Service often conducts prescribed burns during this time to mimic the effects of natural fires as close as possible (*i.e.,* extent, duration, seasonality and intensity), especially in those areas where the management objectives require maintaining forest and other natural vegetative communities. However, prescribed fires can occur year-round as environmental conditions allow.

Burned Area Essential Climate Variable (BAECV)

The Burned Area Essential Climate Variable (BAECV) products are a recent product suite developed and validated by the USGS (Hawbaker *et al.* 2017) that show promise for identifying geospatial extents of fires (Vanderhoof *et al.* 2017). This national product is independent of any type of fire reporting system. Hawbaker *et al.* (2017) document the methods used for automatic derivation of BAECV products using regression models and a combination of change detection algorithms, spectral indices, and reference conditions with LANDSAT imagery. The resultant probability surface and region growing tools can then be used to identify and delineate burned areas at a 30m pixel resolution for every LANDSAT image on record (*i.e.,* 1984-present), which is the longest consistent record of burned area information available. Vanderhoof *et al.* (2017) evaluated the BAECV products against known datasets (*e.g.,* MTBS) and against finer-resolution sensors (*e.g.,* QuickBird) with satisfactory results that suggest that the products would be suitable for use in this project.

We have acquired an updated version of BAECV-derived products from our USGS partners for the period 2006-2016 for Florida. As mentioned previously, these data may not encompass all fires, but hold promise in terms of identifying fire extents in locations where mapped fires do not currently exist. We have imported data derived from the BAECV datasets into the database, and describe the methods for deriving database-ready products in the following section.

It is possible that BAECV products can provide additional/unknown burn locations and extents within Florida, including smaller fires (*e.g.,* fires smaller than a national standard, such as the 500ac used by MTBS in the southeastern US) or those not recorded in other national datasets (*i.e.,* areas where reporting is not required, such as on private property; refer to Deliverable 4 for examples). Given that more than a million acres of prescribed fire alone burn across the state annually, but many of these fires are difficult to detect post-fire using traditional burn scar mapping protocols, it seems that the BAECV methods could be used to locate burned areas in an automated and systematic way. Currently, using BAECV products, one can identify locations (at a 30m pixel level) that have burned. The BAECV product suite includes raster datasets that indicate a probability of having burned (burn probability; BP) and the date first detected by satellite sensors (burn date; BD). These products can be used to identify fires as small as 10 acres, and we are currently assessing the ability to detect down to approximately 2 acres.

Fire Datasets Evaluated by Pilot Area

Multiple landowner sources across the state provided fire information in the form of fire occurrence databases and fire perimeters for both prescribed and wild fires. Landowners included public (*i.e.,* USFS, FWC, Florida Park Service, etc.) and private landowners (*i.e.,* Tall Timbers, Archbold, etc.), as well as some nationally available datasets that span ownerships (*i.e.,* the National Fire Occurrence Database [Short 2017]). Refer to Deliverable 4 for complete dataset descriptions.

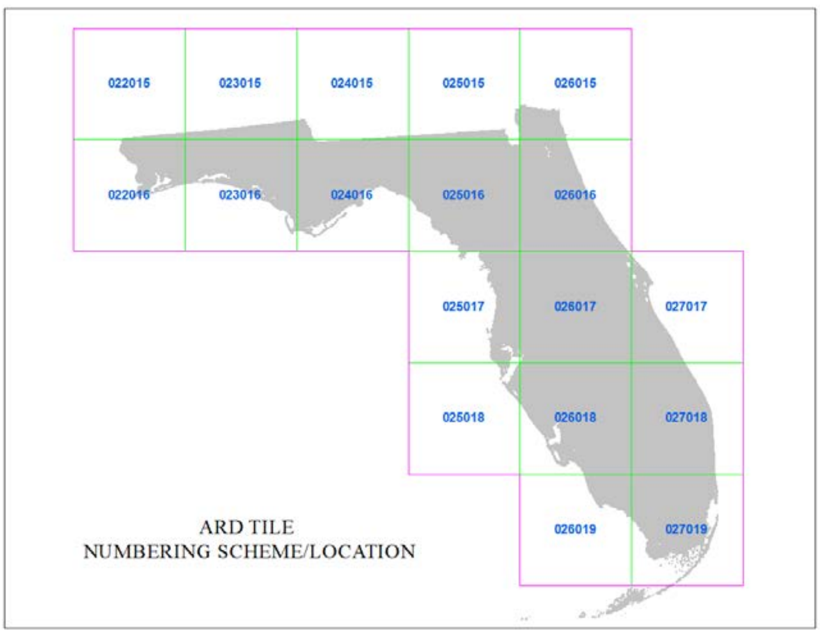

Figure 2: Analysis Ready Data Tile numbering scheme and location; the Florida Keys tiles are in progress, and will be updated as they become available to us.

The fire data we currently possess from these three pilot areas (EAFB, ANF, and BICY) can be uploaded into the database for use on an 'as-is' basis, or with some serious quality control, to supplement further analyses. The data were quite useful in helping us focus in on known fire areas for the evaluation of the annual BAECV products; however, we encourage further use with caution and a complete understanding of what the data represent.

The USGS provided the BAECV data in the Analysis Ready Data (ARD) Tile format, a top-level product meant for analyzing time-series data that are terrain corrected and have known data quality. The state of Florida occupies portions of 20 ARD Tiles, but we were initially provided only the 18 tiles shown below (Figure 2) and thus performed analyses on datasets for those tiles (we will update with the other two tiles as they are provided by USGS). For this project, the various datasets for each BAECV product are represented individually within an ARD tile.

We evaluated the *annual* BAECV Burn Probability (BP) datasets –which are raster datasets – for evidence of burns. The annual datasets span an entire calendar year (*e.g.,* Jan 1 through Dec 31) and indicate the maximum BP within the year; the exact same products exist for each individual scene within a year, but it can be difficult to resolve/refine information for the purposes of this project at this temporal scale. Therefore, we chose to analyze the annual products for this Deliverable, but we developed the methods to be scalable for any BAECV product (*i.e.,* individual scenes or composites covering specific timeframes).

For each year between 2006 and 2016, we combined the annual datasets of interest within individual ARD Tiles into a single annual raster dataset (*i.e.,* we mosaicked the tiles) for further processing (Figure 3). We performed all additional processing steps on the annual mosaicked datasets as this provided statewide consistency. We identified pixels as burned or unburned according to their probability value; initially, we retained all pixels with an annual BP between 85-100% based on Hawbaker *et al.* (2017). Values between 90-100% were then converted to presence/absence rasters and we used image processing methods to remove 'speckling' (*e.g.,* fill in small holes within a burned area and remove groups of pixels less than a specified size/amount). This process resulted in annual rasters and vectors indicating burn presence (with 90-100% probability) for groups of pixels greater than ~2.24 acres (*e.g.,* 10 30m pixels, in any arrangement). The newly created datasets were then evaluated to begin the process of determining fire regime characteristics (Appendix A) such as number of times burned, and year last burned; these metrics are a required portion of a SWG deliverable, and Deliverable 6 of this project.

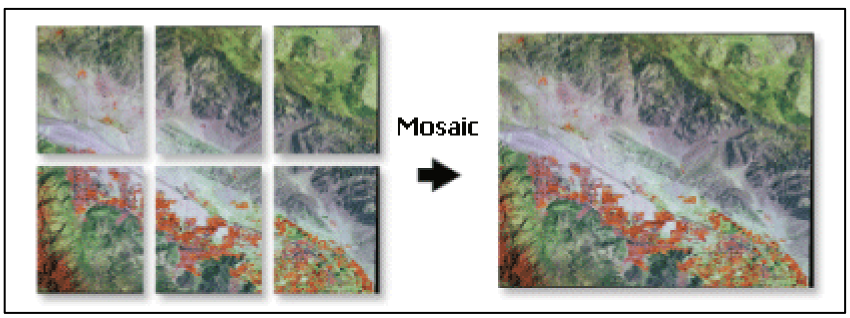

Figure 3: Example illustrating the results of combining multiple adjacent/overlapping raster datasets into a single dataset using the *mosaic* method.

We then evaluated these products against fire records for the three pilot areas. For each area, we held a meeting with fire managers, either in person or via web conferencing methods. We provided a quick background of the project, and explained the process we used to derive the BAECV BP-based fire information. We then invited managers to inspect the data with us to evaluate their thoughts on the products. Through this process, managers provided many explanations for why no burn was detected and where/why fire detection was performing very well, as well as some ideas and suggestions for moving forward (all of which we relayed to USGS). Many of these comments reflect known limitations previously documented (see Deliverable 4; Hawbaker *et al.* 2017).

Appendix B provides summary notes on findings from each of the three meetings. Overall, managers received the products well, and their comments will be useful in guiding further refinements and protocols in the next deliverable. Furthermore, these meetings illustrate that it is imperative to hold 'stakeholder' meetings and workshops with the folks who have provided the data to help us better understand where these products are doing well "as is" and where we might want to apply some different thresholds to set up baseline protocols for locations moving forward. For example, after consultation with BICY fire management staff, we will be exploring the effects of re-thresholding the BP products to 70% to determine if we are able to capture burned areas better.

Once managers at the three pilot areas evaluated the datasets and data derivations against their institutional knowledge and fire records, we finalized datasets and uploaded them into the database. We updated and simplified the original DoD-based SQL database based on needs identified by FWC partners in meetings leading up to and subsequent to Deliverable 4 (Figure 4). We have populated it with 10 years of fire data for three pilot areas (including metadata); it can be queried to identify burn locations (as identified by FFS OBA permit [Deliverable 2, 3.1, and 3.2], agency-provided datasets [Deliverable 4], and by annual burn probability [this deliverable]) by year and/or by Cooperative Land Cover classes. Current datasets in the database include FFS OBA permit data, annual BP-based burned area rasters and polygons, and landcover classification raster/polygons. We will continuously update the datasets in the database throughout the life of the project based on conversations with FWC partners to provide for their needs and requirements.

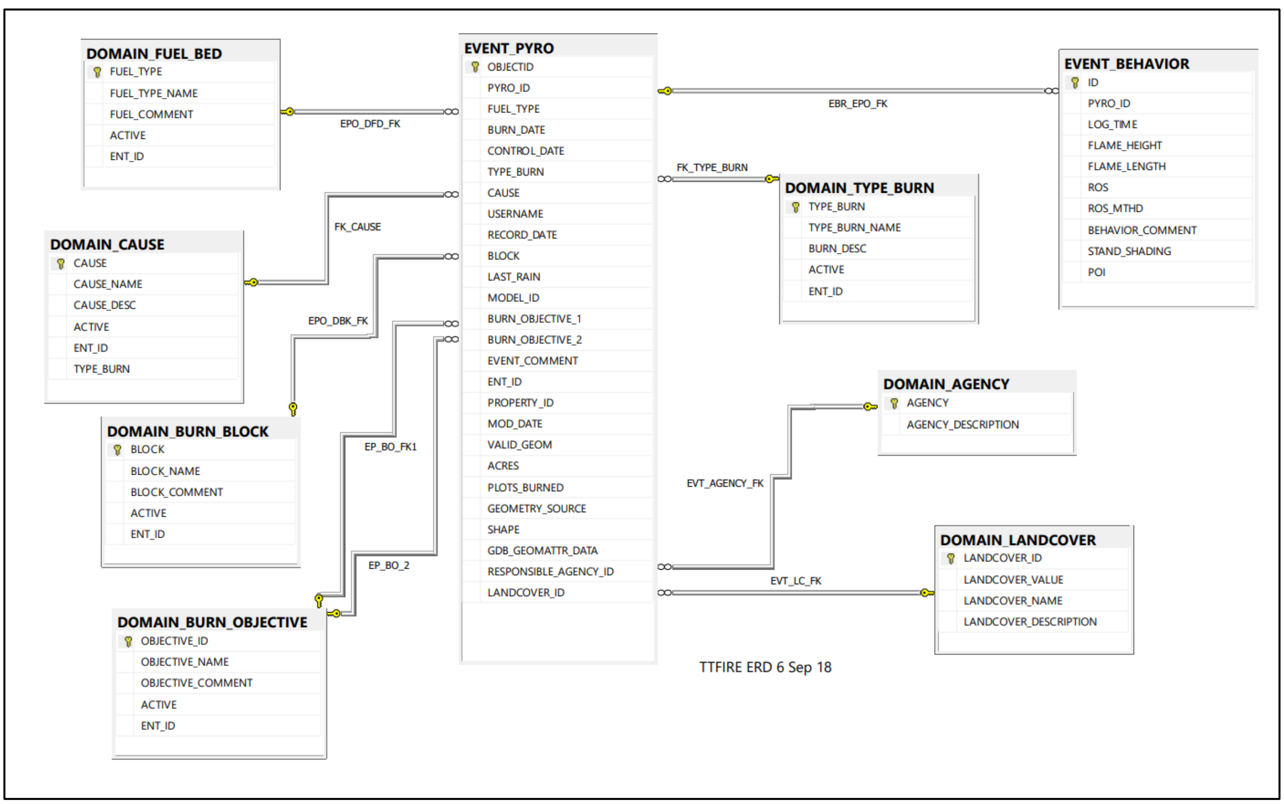

Figure 4: Updated database schema, based on consultation with FWC partners.

Deliverable #5.1: Recommendations

We expand upon previous work by comparing spatial footprints of fires derived from the satellite-based BAECV product (Hawbaker *et al.* 2017) against known locations of fires in three pilot areas: BICY, ANF, and EAFB. We selected the pilot areas based on having known fire location data, having large-scale prescribed fire programs, and having fire-maintained systems where species of greatest conservation need occur (to coincide with another project funded through a FWC State Wildlife Grant). A series of data derivation methods and protocols resulted in annual fire datasets that we evaluated with managers. The following section describes their comments, suggestions, and recommendations.

As noted in the Deliverable #4, we recommend that a standardized statewide data call with specific reporting requirements be developed and utilized to acquire individual landowner-based fire data. In this deliverable, we additionally recommend a follow-up meeting with landowners who provide their fire data once the BAECV-based products exist for their land. This meeting serves multiple purposes; it allows us to understand the data they provided better, and it allows us to provide background information to the landowners on the BAECVdata and product derivation. The managers then provide feedback on where the data products are capturing fire extent in an acceptable fashion and why. The managers can additionally isolate locations/types of fires/seasonal characteristics, which may cause data products to underperform, and it provides opportunities for them to help identify potential solutions. Having landowner buy-in is imperative for the success of these types of projects.

Appendix B shows a complete list of comments and recommendations from the three pilot areas. Common to managers from all three areas was the notion that, overall, these annually-based datasets are capturing actual fire footprints within areas where fire has been applied relatively well. However, the BAECV products' ability to identify these locations differs. Managers noted that in the Panhandle (*e.g.,* EAFB and ANF), the burns that were less likely to be captured in the annual 90-100% BP range had well-documented characteristics. For example:

- They occurred in grass-dominated locations;
- The actual fire did not burn very hot and did not alter canopy characteristics;
- The fire was at the end of prescribed fire season and beginning of wildfire season, where days are typically more often cloudy than clear;
- Fires were set in units that did not have much fuel to begin with, so detection is normally difficult;
- Fires followed thinning or chemical treatments; and
- Fire was at the end of the calendar year so was perhaps captured in the following year's data.

In BICY, while many of the same characteristics were noted, managers also suggested that lowering the BP threshold from 90% to somewhere in the range of 70-80% might produce better results in the ecosystems prevalent in that part of Florida. We have considered those suggestions and are currently working on evaluating protocols to determine when and where thresholding is appropriate. Therefore, the data uploaded for this Deliverable for BICY only capture 90-100% BP, but they will be updated as results become available.

Next Steps

The next steps for the project include updating and refining methods based on the three pilot areas and applying them statewide to identify fire locations, analyze fire regime characteristics and trends, and develop procedures for annual updates moving forward. To address the challenge of understanding spatial characteristics of burns and reconstructing burn histories, we intend to continue using the BAECV dataset developed by Hawbaker *et al.* (2017), data derived in-house using the fire mapping tools for smaller fires, and known fire perimeters for all areas statewide.

Additionally, we will create additional data-based queries in the SQL geodatabase to derive fire regime characteristics. The final project result will be spatial information in the form of fire perimeters for the period 2006 – 2016, including queries, reports, and metadata.

Deliverable #5.1: Summary

The overall aim of the *Mapping Fires Across Florida* project is to develop a spatial database of prescribed fire extents in Florida with querying and reporting capabilities. The fires in this spatial database will range from less than ten acres to greater than 100 acres. To recap accomplishments so far on this project:

- The exploratory data analysis performed for Deliverable #2 provided useful insights into the FFS OBA dataset, and its potential usefulness for assessing fire regime characteristics in the state of Florida.
- For Deliverable #3 we focused on converting the existing DoD database from Oracle to SQL Server and importing the FFS OBA data.
- In Deliverable #4, we explored multiple sources and types of fire extent information, including landowner-provided fire atlas datasets and satellite based detections and extent maps, and we reviewed literature about the sensors and datasets.

Deliverable #5.1 of the *Mapping Fires Across Florida* project focuses on assessing the utility of the satellite-based BAECV product suite for identification of the spatial extents of fires in three pilot areas within Florida: Big Cypress National Preserve, Eglin Air Force Base, and the Apalachicola National Forest. These three sites have large-scale prescribed fire programs, fire-dependent ecosystems, and records of known fire locations. In these areas, as well as across Florida, there exist many small, rapidly burning, low-intensity fires (often under a tree canopy), frequent cloud cover, and rapid green-up following fires. The detections of any satellite sensor used for imaging or detecting fires requires a cloud-free sky at the time of satellite overpass. When using satellite imagery to derive information about fire extents, post-fire images occurring on cloudy days may not be suitable for deriving burned area, and low-intensity fires beneath a tree canopy may not be detectable. It is possible to process data from sensors in a consistent manner for comparing to known fire locations. In our evaluation meetings, the fire managers from the three pilot areas acknowledged that some of these issues could possibly explain "missing" fires (*i.e.,* locations where the annual BP data are not capturing burn extents very well) on their lands. However, satellite-based datasets (and their derivatives) are promising since it is possible to extract fire extent information across large regional areas in a standardized replicable way. Because of the longevity of many of the current satellite sensors and products that we evaluated, there is an abundance of scientific literature describing the known limitations, assumptions, and utility of different datasets for fire detections and burn scar mapping.

We evaluated annual BAECV-based data products and derivatives within the three pilot areas and facilitated meetings with fire managers from these locations to gauge the usefulness of the data products. Hawbaker *et al.* (2017) developed and described the satellite-based BAECV dataset and suite of products, which Vanderhoof *et al.* (2017) subsequently validated. The methods used for these nationally scoped datasets are replicable, and we showed that it is possible to adapt them regionally to map the spatial extent of a range of fire sizes in Florida. In addition, much smaller fires are mapped (~2 ac) as part of the protocol we developed for deriving the BAECV-based fire products, which is of benefit in Florida where many small fires prevail and where habitat-based analyses for those species with the greatest conservation needs are involved. We have determined that the BAECV-based datasets are quite useful for understanding fire regime characteristics across the landscape within Florida, in spite of the known/documented limitations. We provide evaluations and suggestions for moving forward with identifying the spatial extents at a statewide level.

We believe that the automated portion of developing datasets and generating fire extents and perimeters using BAECV and MTBS methodology can be useful for updating these datasets in a consistent fashion moving forward. As mentioned in the previous Deliverable, we are exploring additional options to enhance this ability. The FFS OBA, BAECV, and landowner data combined can help locate areas that have burned in prescribed fires and clarify fire characteristics across the state, perhaps better than any particular dataset alone – especially if there were simple standardized tracking and reporting options required that did not burden landowners with extra work. The next steps for this database include developing the datasets statewide based on results from the three pilot areas for the spatial database. In addition, we will consult with FWC on exactly what data to upload into the SQL Server as ancillary data for queries and analyses.

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Appendices

Appendix A: Fire Regime Derivatives
Appendix B: Manager Meeting Notes

Appendix A: Fire Regime Derivatives

The following pages contain examples of fire extent and fire regime derivatives from the current work for the three pilot areas. We produced these while testing the methods and procedures in preparation for Deliverable 6. Any location identified in these maps can be considered to have burned at least once between 2006-2016. An annual raster dataset indicating presence/absence of burning, and an annual 'area burned' vector dataset, exist and are loaded in the database for each of the three pilot areas. We have included these maps to highlight the utility of the BAECV-based datasets. These images are for illustrative purposes only. Further examples are available upon request.

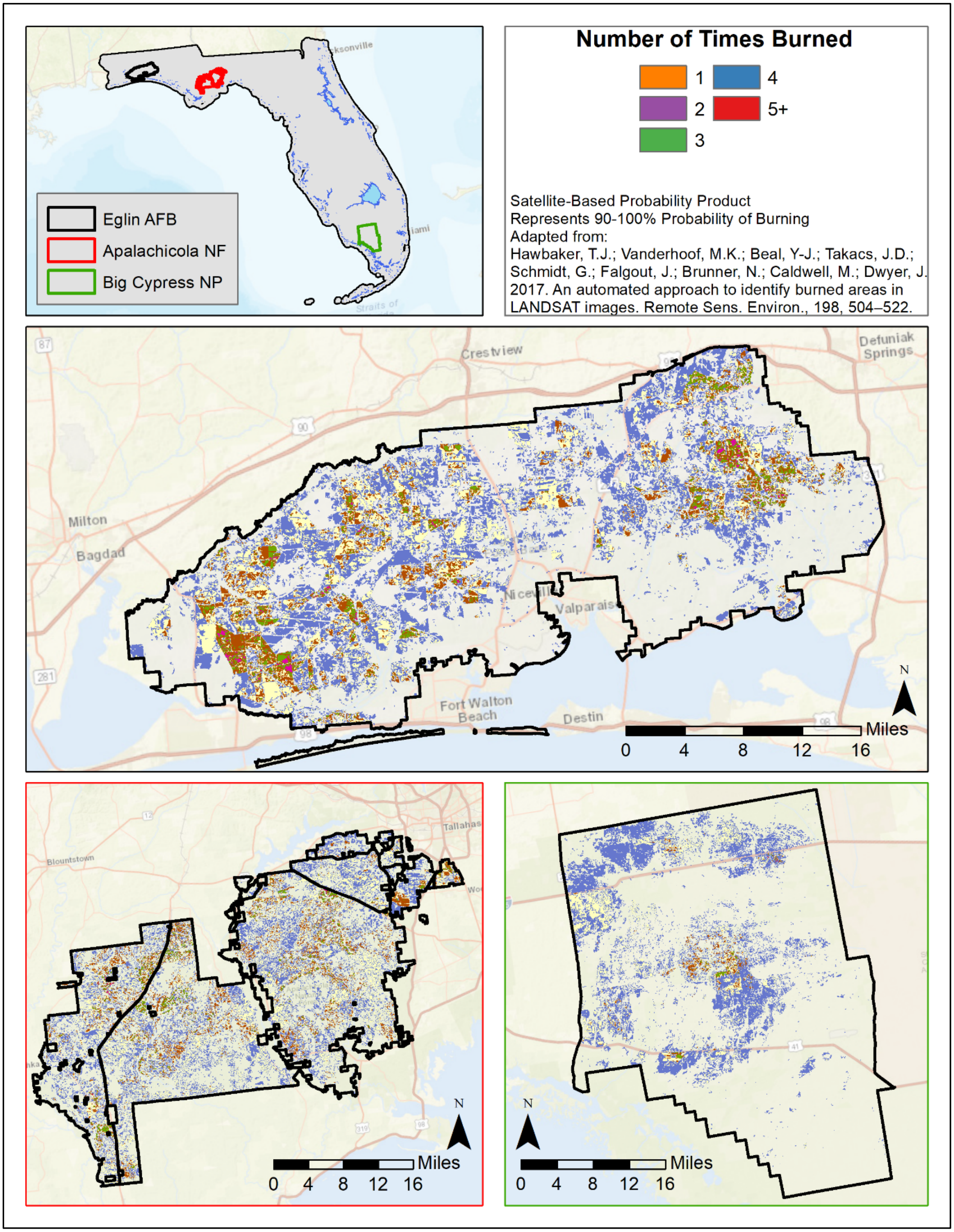

Figure A1: *Number of times burned between 2006 and 2016 based on annual composite 90-100% burn probability.*

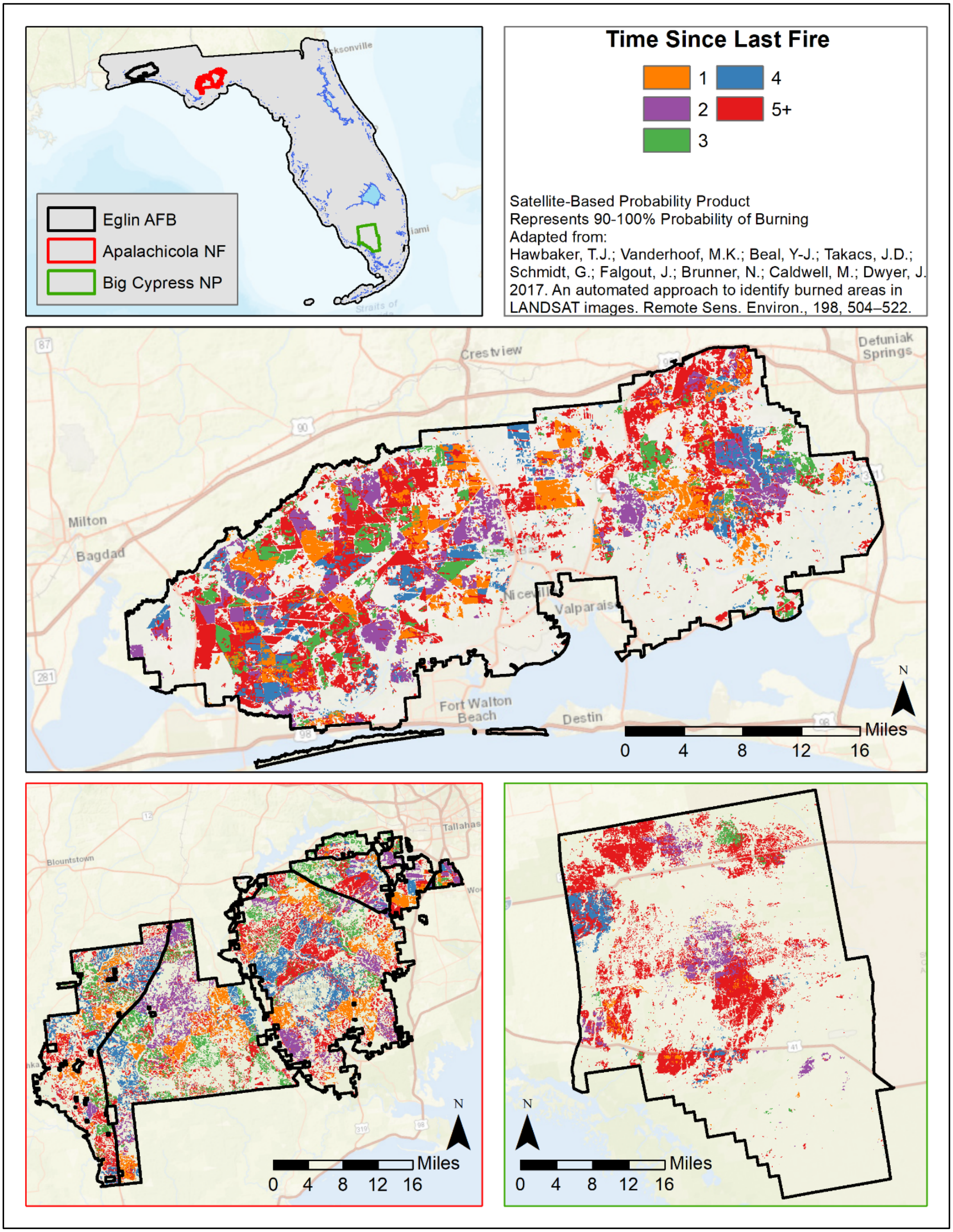

Figure A2: *Number of years since last fire (measured from 2017) for the period 2006 - 2016 based on annual composite 90-100% burn probability.*

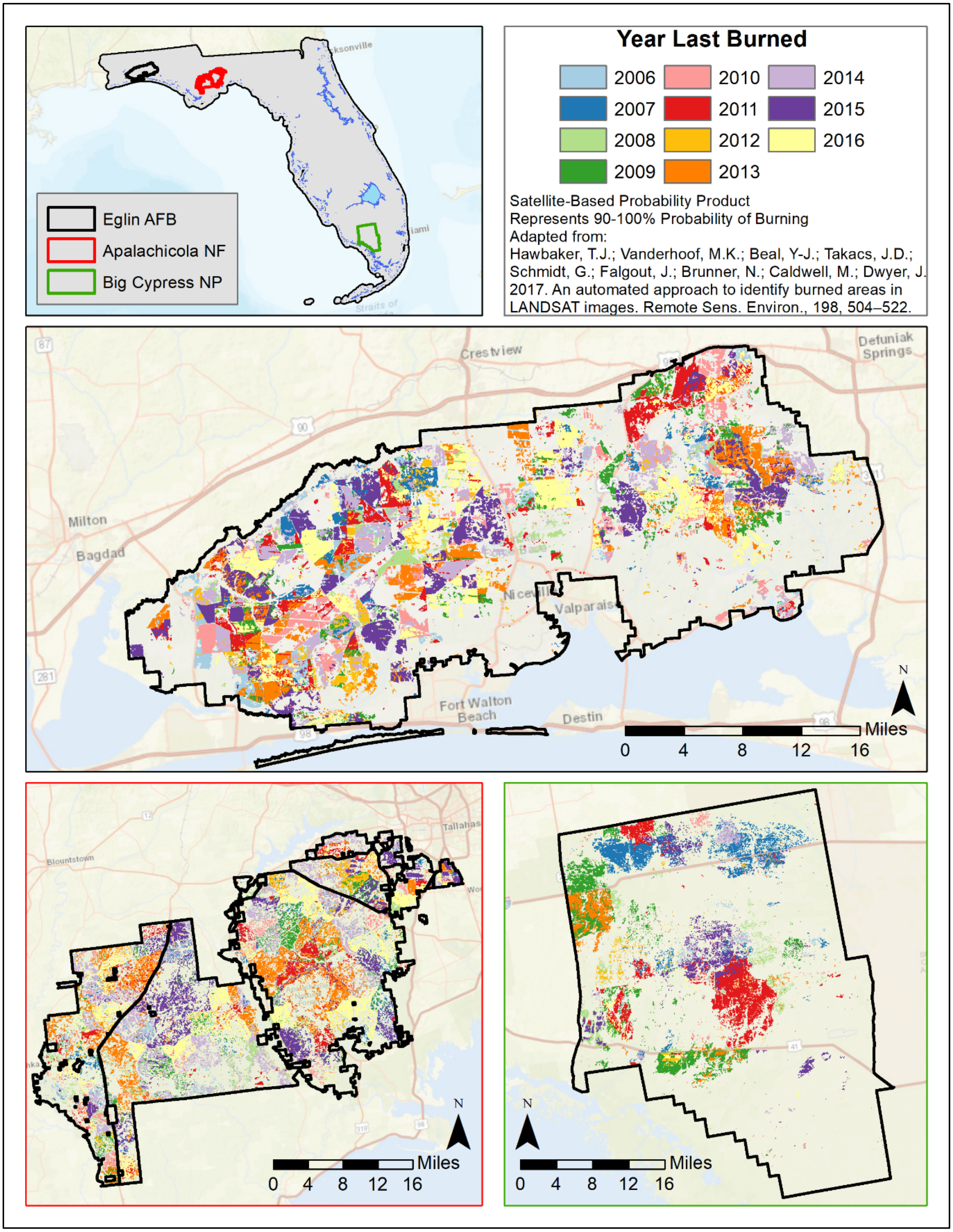

Figure A3: *Year most recently burned between 2006 and 2016 based on annual composite 90-100% burn probability.*

Appendix B: Manager Meeting Notes

The following pages contain notes from meetings with fire managers at each of the three pilot areas. We briefed managers on the products and how we derived them, as well as what they illustrate. Managers provided feedback on the products, and we summarize those notes here. As a direct result of our update meetings with managers, the ANF and the Southern Fire Exchange and others have written USGS letters of support for continuation of BAECV development.

Table B1: Fire Manager meeting notes about the BAECV-based BP products for the three Pilot Areas.

Pilot Area	Notes
Apalachicola NF	• Seems to capture the patchiness of burning well • Low intensity fires may not be captured as easily • "Very impressed with this product and are hopeful that we can incorporate it into many different tools and workflows here on the NFs in FL" • "BAECV fills a critical niche because it is not dependent on data from disparate fire databases or on manual mapping of fire extents"
Big Cypress NP	• Think it is doing a good job given what fuel type we have • June through August burns seem to be difficult to capture due to seasonal cloud cover, rapid green up • November/December burns seem to appear in following calendar year • Seems to capture the patchiness of the fuels • May be easier to capture burns in drier years • Might consider a different threshold (70%) to capture fire better in these systems.
Eglin AFB	• Late season burns seem to show up in following year (e.g., burns in late Nov, Dec) • Burns may not be detected if burned after a treatment • Burns in low productivity sites not captured, but often hard to tell that they burned (i.e., fire is applied to unit, but may not carry well) • Cool burns, night burns, and burns in wet season seemed harder to detect • Burns leading into the summer season may not be detected (due to increased cloud cover during summer months) • First entry burns and burns early in the fire record may have burned more intensely than those later in record due to fire frequency reducing fuels (and thus intensity and detectability) • Just because we don't have a record of it doesn't mean it didn't burn – we burn enough that we don't get reports of fires due to folks thinking we are doing prescribed burn • May provide useful insight at a large scale, but we'd still have to ground truth at an individual fire scale if we were interested • Would be nice to be able to see these on a 'fiscal year' as opposed to a calendar year

Chapter 7: Deliverable #5.2

Summary Report – 10 Years of Data for Florida

Deliverables Update
#5.2: Summary Report – 10 Years of Data for Florida

Mapping Fires Across Florida:

Advancement of a Fire Spatial Database

December 2018

Tallahassee, FL

TALL TIMBERS

Principal Investigator/Project Manager

Joe Noble

Co-Principal Investigators

Casey Teske
Kevin Hiers
Vince Sclafani
Kevin Robertson

Project ID

FWC-16/17-135 Spatial Database
A Proposal for Mapping Statewide Fire Occurrence, Fire History, and Ecological Outcomes
Submitted by Tall Timbers Research, Inc., June 20, 2017

Previous project deliverable reports, including the earlier workshop proceedings, video of expert presentations, summary report, and power point presentations are available free of charge from Tall Timbers Research, Inc. Please contact Joe Noble: jnoble@talltimbers.org

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TALL TIMBERS

Table of Contents

Executive Summary

Tall Timbers Research, Inc. is pleased to present the *Mapping Fires Across Florida: Deliverable #5.2* update. The overall purpose of the project is to develop a spatial database of prescribed fire extents in Florida with querying and reporting capabilities. Development of a comprehensive spatially explicit map of fire occurrence remains one of the most critical needs for conservation in the Southeastern US. Not only are the vast majority of Florida's endangered species and ecosystems reliant on frequent fire, but fire risk analysis, prescribed fire planning, and fire behavior modeling are sensitive to fire history. Fire occurrence in Florida is currently tracked by approximate location through the Florida Forest Service (FFS) burn authorization system, Fire Management Information System (FMIS). While this system represents one of the most advanced prescribed fire planning datasets in the country, the system does not record perimeter data or include assessments regarding which burns are actually completed. Relying solely on this system results in documented data gaps when estimating the size, location and effectiveness of managed fires on a statewide scale. These "actual burned" areas are critical factors in analyses and models evaluating conservation success.

Tall Timbers Research, Inc. is addressing this need by developing a robust spatial database for more precise mapping and tracking of all prescribed fire in Florida. Advanced remote sensing techniques are being applied to known locations of prescribed fires, as identified by the FFS data and select landowner-provided datasets, to record actual spatial fire boundaries into a modified version of the U.S. Air Force Wildland Fire Database. In addition, custom query tools are being developed to report fire history (e.g., frequency, time-since-burn, year last burned, etc.) in specific fire dependent ecological systems or fire dependent species habitats.

The work documented here builds on the spatial database project work previously completed by Tall Timbers' staff. We have already completed exploratory data analysis on the FFS FMIS open burn authorization (OBA) data, which provided insights into the potential usefulness of the dataset for assessing fire regime characteristics in the state of Florida. We have also converted the existing DoD database from Oracle to SQL Server and imported the FFS OBA data into it after consultation with FWCC partners. We have evaluated fire datasets from twenty-six sources for the period 2006-2016. The datasets include satellite-based thermal detections and fire extent maps, as well as landowner-provided fire atlases and fire occurrence databases. We submitted a summary report on prescribed and wildfire information sources for three pilot areas in Florida in the previous Project Deliverable.

The current work is provided in the form of a summary report and database of satellite-based prescribed and wildfire location datasets for the entire state of Florida. We have included wildfires as they often meet management objectives and impact species habitats, and as such are an important part of the fire regime evidence used to inform conservation-monitoring decisions. This report contains information on the processes used to derive spatial footprints of fires, and resulting information from the evaluation of results with the three pilot areas applied at a statewide level. We also provide some recommendations for moving forward.

Glossary of Terms and Concepts

Broadcast Burn An open burn that is done for agricultural, silvicultural, or land clearing purposes and is not a pile

Burned Area Essential Climate Variable (BAECV) refers to an algorithm that capitalizes on the long temporal availability of LANDSAT imagery to identify burned areas across the conterminous United States.

Continuation An authorization to continue a previously approved open burn authorization that was not completed for various reasons including late starts, poor weather conditions or lack of resources.

CONUS The Continental United States; this reference excludes Alaska and Hawaii.

Cooperative Land Cover (CLC) The Cooperative Land Cover Map is a project to develop an improved statewide land cover map from existing sources and expert review of aerial photography. The project is directly tied to a goal of Florida's State Wildlife Action Plan (SWAP) to represent Florida's diverse habitats in a spatially-explicit manner.

Environmental Protection Agency (EPA) The agency of the federal government which was created for the purpose of protecting health and environment.

Florida Forest Service (FFS) Agency whose mission is to protect and manage forest resources in Florida.

Florida Natural Areas Inventory (FNAI) Florida's state heritage program responsible for tracking occurrences of species and natural communities statewide.

Fire Mapping Information System (FMIS) integrated set of applications that handle data input, processing and reporting needs for the Florida Division of Forestry (DOF).

Global Fire Emissions Database (GFED) Database combining satellite information on fire activity and vegetation productivity to estimate gridded monthly burned area and fire emissions.

GOES-16 previously known as GOES-R, is part of the Geostationary Operational Environmental Satellite (GOES) system operated by the U.S. National Oceanic and Atmospheric Administration and is the first spacecraft in NOAA's next-generation of geostationary satellites. The GOES-R series satellites will provide advanced imaging with increased spatial resolution and faster coverage, improving the detection of environmental phenomena.

Hazard Mapping Systems (HMS) NOAA product suite that provides both fire and smoke analysis products. It is an interactive processing system that allows analysts to manually integrate data from automated fire detection algorithms using GOES and polar (Advanced Very High Resolution Radiometer (AVHRR) and MODerate resolution Imaging Spectroradiometer (MODIS)) images. The result is a quality controlled display of the locations of fires and significant smoke plumes detected by meteorological satellites.

Interagency Fuel Treatment Decision Support System (IFTDSS) is a web-based software and data integration framework that organizes fire and fuels software applications to make fuels treatment planning and analysis more efficient. The effort was initiated by Joint Fire Science Program and the NWCG Fuels Management Committee in 2007.

Integrated Reporting of Wildland-Fire Information (IRWIN) This service is a Wildland Fire Information and Technology (WFIT) affiliated investment intended to provide an "end-to-end" fire reporting capability. IRWIN is tasked with providing data exchange capabilities between existing applications used to manage data related to wildland fire incidents.

LANDSAT The LANDSAT Program is a series of Earth-observing satellite missions jointly managed by NASA and the U.S. Geological Survey. Imagery is available since 1972 from six satellites in the LANDSAT series. These satellites have been a major component of NASA's Earth observation program.

Landscape Conservation Cooperative (LCC) self-directed partnerships between federal agencies, states, tribes, non-governmental organizations, universities, and other entities to collaboratively define science needs and jointly address broad-scale conservation issues.

Monitoring Trends in Burn Severity (MTBS) refers to an interagency program whose goal is to consistently map the burn severity and extent of large fires across all lands of the United States from 1984 to present.

Moderate Resolution Imaging Spectroradiometer (MODIS) is a key instrument aboard the Terra and Aqua satellites. Satellites view the entire Earth's surface every 1 to 2 days acquiring data in 36 spectral bands. These data improve our understanding of global dynamics and processes occurring on the land, oceans and lower atmosphere.

Pile Burn An open burn that is in the form of a pile that is larger than 8' diameter

PostGIS is a spatial database extender for PostgreSQL object-relational database. It adds support for geographic objects allowing queries to be run in SQL.

PostgreSQL is an open source object-relational database system.

Open Burn Authorization (OBA) refers to Florida Forest Service Open Burn Authorization Requests and is available to Certified Prescribed Burners.

QGIS is a free and open source professional Geographical Information System (GIS) that is built on top of Free and Open Source Software (FOSS)

QGIS Event Mapping Tool (EMT) (now known as the Fire Mapping Tool, FMT), a QGIS plugin for fire assessment developed by U.S. Geological Survey National Center for Earth Resources Observation and Science (EROS)

Southern Integrated Prescribed Fire Information System (SIPFIS) a Joint Fire Science Program initiative to design an integrated information system for fire and air quality data in the SE United States.

Volatile Organic Compounds (**VOC)** refers to a large group of organic chemicals that include any compound of carbon (excluding carbon monoxide, carbon dioxide, carbonic acid, metallic carbides or carbonates, and ammonium carbonate).

Deliverable #5.2: Background

This document serves as the summary report of data exploration activities and should be considered as the final "Deliverable #5.2" of the FWCC Grant. It details the processes used to derive the spatial footprints of fires and some of the impetus for those decisions based on manager meetings. We also provide some recommendations on the data sets and processes proposed for moving forward in populating the spatial database developed and submitted previously (see Deliverables 3.1, 3.2, and 4).

For over a decade, resource managers in the state have recognized the importance of tracking and monitoring the use of prescribed fire. Many species in Florida are dependent on fire for maintenance of appropriate habitat conditions. Measurements, such as seasonality and years since last burn are important components in assessing the condition of these fire-maintained systems. For many species that are dependent on these systems, managing an appropriate fire return interval is critical. Differentiating those areas that have an appropriate fire return interval from those areas without an appropriate fire return interval would allow managers to focus resources on areas most in need of management actions, as well as serve as a means to measure and quantify the success of conservation and restoration efforts.

Cost effective and efficient management of conservation lands requires up to date detailed resource maps. The Peninsular Florida Landscape Conservation Cooperative (PFLCC) is working on a statewide Landscape Conservation Design. As part of this process, the PFLCC is identifying conservation targets (*i.e.,* indicators) for each priority resource. It became evident that fire return interval could be a critical indicator for these systems.

Florida currently has a detailed (10m) land cover map, used by multiple entities (*e.g.,* Florida Fish and Wildlife Conservation Commission, FWC's State Wildlife Action Plan, Florida Natural Areas Inventory, and the PFLCC). However, there is a critical missing component from the existing land cover map - qualitative attributes regarding fire. One key qualitative attribute that has long been identified as a critical data gap pertains to prescribed fire. Addition of qualitative attributes based on fire regime characteristics, such as fire return interval, would increase the effectiveness of informing acquisition of conservation lands, supporting land and fire management, and tracking success and failure of conservation efforts. Assessment of the success of management actions will provide a valuable feedback loop to inform future management actions on conservation lands, both public and private.

Currently, a spatial database that tracks prescribed fire *extents* statewide does not exist, which means that there is not a comprehensive knowledgebase about fire regimes across the state. Managers recognized this data gap more than a decade ago. In 2006, they noted "…methods for monitoring the use of fire on public lands may be one of the greatest unmet needs in comprehensive wildlife management…" (*Monitoring Prescribed Burning on Public Lands in Florida, 2006).* This project aims to enhance our understanding of prescribed fire characteristics across the state of Florida for integration into further analyses specific to landscape conservation and monitoring. We list specific outcomes and accomplishments to date below:

1. We address the data gap through a spatial database designed to track and analyze burn authorization data between 2006-2016 using FFS Online Burn Authorization data and a modified extension of the US Air Force Wildfire Database.
2. We looked at methods to validate burn authorization records by comparing authorized permits to known fire locations, and developed methods to use remote sensing techniques to record spatial fire boundaries.
3. We developed custom query tools to evaluate fire regime characteristics and trends in specific fire dependent ecological systems and fire-dependent species habitats.
4. We will continue to develop procedures for annual updates moving forward.

Deliverable #5.2: Dataset Exploration

Understanding fire regime characteristics across the state of Florida is important from a conservation perspective if the aim is to maximize conservation efforts and target conservation opportunities appropriately. However, limited information about fire occurrence in the state exists, particularly in terms of a statewide spatial database that includes individual fire perimeters for prescribed fires and for many fires occurring on private lands. We utilize satellite-based detection products to determine the spatial representation of fire extents for the state of Florida and populate the database with these datasets. This section provides descriptions of the Burned Area Essential Climate Variable (BAECV) based dataset, as well as evaluations of these datasets for the state of Florida.

In previous deliverables (specifically Deliverable 4), we evaluated multiple sources of fire information and data to determine if they met the needs of the FWC project in terms of spatial resolution, geographic extent, and time stamping for the study period of interest (2006-2016). In general, the datasets evaluated included prescribed fire information, wildfire information, or both. Data types included point, polygon, and raster data. The temporal characteristics of the data varied depending on the source. For this project, we are only interested in fires occurring in the 2006-2016 timeframe for possible inclusion in the SQL geodatabase. The ability exists to upload any additional data as needed (*e.g.*, as available, pre-2006 or post-2016, if available from the original sources).

In Deliverable 5.1, we expanded upon that assessment by comparing spatial footprints of fires derived from the satellite-based BAECV product (Hawbaker *et al.* 2017) against known locations of fires at Eglin Air Force Base, the Apalachicola National Forest, and Big Cypress National Preserve (Figure 1). We worked with fire managers at the three locations to get feedback on the products and gauge interest and usefulness of the products. We chose the pilot areas for multiple reasons. They all have active prescribed fire programs, have supported wildfires in the past, and have well documented burn records that detail fire sizes, types and dates – all things that would help us evaluate usefulness of BAECV, especially in places without fire records (e.g., private lands). Together, the three pilot areas span a large portion of the state, and encompass many fire-dependent systems and species habitats of interest to PFLCC and FWCC. Based on manager evaluations of these data and recommendations for moving forward, we have extended the satellite-based mapping process to the entire state of Florida.

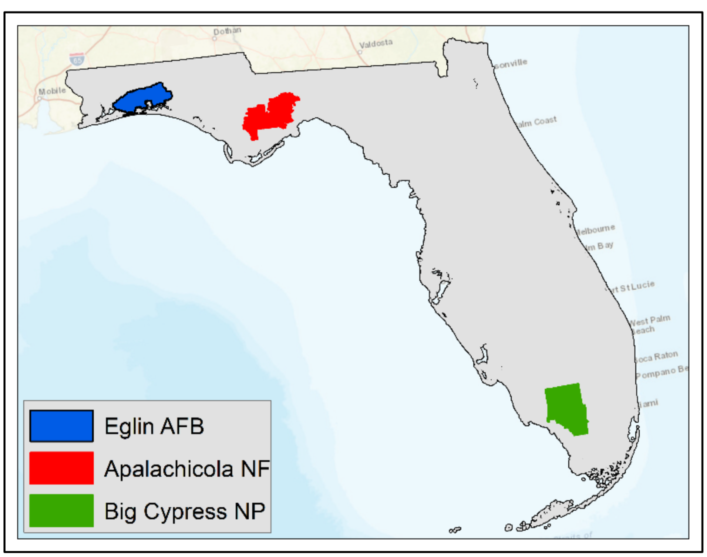

Figure 1: Three pilot area locations: Big Cypress National Preserve, Apalachicola National Forest, and Eglin Air Force Base.

Florida

Florida is a large state, encompassing nearly 66,000 square miles. It is largely a peninsular state bounded by both water (the Gulf of Mexico to the west and the Atlantic Ocean to the east) and land (Georgia to the north, and Alabama to the northwest; Myers and Ewel 1990). The climate can be described as a humid subtropical climate north of Lake Okechobee and a tropical climate south of Lake Okechobee, with an average annual precipitation amount of 59.2 inches (USCD 2018). The dry season is generally cool (*e.g.,* winter) and the warm season is typically rainy and marked by tropical storms and even hurricanes. The highest point in Florida is only 345 feet above sea level, although inland areas have rolling hills with elevations up to 250 feet above sea level. Variations in topography may be slight or occur over short distances, but can have large effects on the vegetation due to impacts on water, soil, and nutrient regimes. The biodiversity in Florida is quite high, with many species of flora and fauna, including fire-adapted species and threatened/endangered/rare species. Upland ecosystems in the state consist of the pine flatwoods and dry prairies, scrub, temperate hardwood forests and South Florida rocklands (Myers and Ewel 1990). Fire is a strong influence in the composition and structure of the Upland ecosystems, and many species that occur in these areas are considered 'pyrogenic', or having fire adaptations. In the wetlands of the state, which includes marshes and swamps, hydrology cycles and fire cycles have interchangeable impacts. Variations in hydroperiods, organic matter accumulation, and fire frequency all have important structural impacts on the wetlands. Fire frequencies and rotations vary across the state, and range from frequent low intensity surface fires to infrequent high intensity crown fires.

Burned Area Essential Climate Variable (BAECV)

The Burned Area Essential Climate Variable (BAECV) products are a recent product suite developed and validated by the USGS (Hawbaker *et al.* 2017) that show promise for identifying geospatial extents of fires (Vanderhoof *et al.* 2017). This national product is independent of any type of fire reporting system. Hawbaker *et al.* (2017) document the methods used for automatic derivation of BAECV products using regression models and a combination of change detection algorithms, spectral indices, and reference conditions with LANDSAT imagery. The resultant probability surface and region growing tools can then be used to identify and delineate burned areas at a 30m pixel resolution for every LANDSAT image on record (*i.e.,* 1984-present), which is the longest consistent record of burned area information available. Vanderhoof *et al.* (2017) evaluated the BAECV products against known datasets (*e.g.,* MTBS) and against finer-resolution sensors (*e.g.,* QuickBird) with satisfactory results that suggest that the products would be suitable for use in this project.

We have acquired an updated version of BAECV-derived products from our USGS partners for the period 2006-2016 for Florida. As mentioned previously, these data may not encompass all fires, but hold promise in terms of identifying fire extents in locations where mapped fires do not currently exist. We have imported data derived from the BAECV datasets into the database, and describe the methods for deriving database-ready products in the following section.

It is possible that BAECV products can provide additional/unknown burn locations and extents within Florida, including smaller fires or those not recorded in other national datasets. For example, fires smaller than a national standard (*e.g.*, the 500ac used by MTBS in the southeastern US), or fires in those areas where reporting is not required (*e.g.,* on private property) may be detected in a standardized fashion. Given that more than a million acres of prescribed fire alone burn across the state annually, but many of these fires are difficult to detect post-fire using traditional burn scar mapping protocols, it seems that the BAECV methods could be used to locate burned areas in an automated and systematic way. Currently, using BAECV products, one can identify locations (at a 30m pixel level) that have burned, and the probability associated with the pixel having burned (burn probability; BP) and the date first detected by satellite sensors (burn date; BD). These products have be used to identify fires as small as 10 acres, and we are assessing the ability to detect down to approximately 2 acres.

Fire Datasets Evaluated

Multiple landowner sources across the state provided fire information in the form of fire occurrence databases and fire perimeters for both prescribed and wild fires. Landowners included public (*i.e.,* USFS, FWC, Florida Park Service, etc.), and private landowners (*i.e.,* Tall Timbers, Archbold, etc.), as well as some nationally available datasets that span ownerships (*i.e.,* the National Fire Occurrence Database [Short 2017]). Refer to Deliverable 4 for complete dataset descriptions. The fire data we currently possess from these sources can be uploaded into the database for use on an 'as-is' basis, or with some serious quality control, to supplement further analyses. The data were quite useful in helping us focus in on known fire areas for the evaluation of the annual BAECV products; however, we encourage further use with caution and a complete understanding of what the data represent.

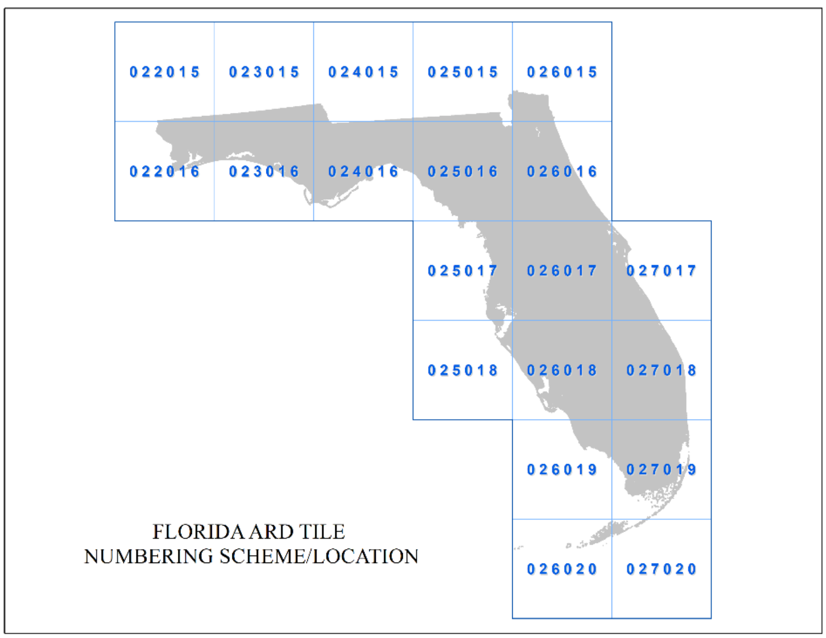

Figure 2: Analysis Ready Data Tile numbering scheme and location; as of this writing, the Florida Keys tiles (*i.e.,* the southernmost tiles, 026020 and 027020) have just become available to us and processing is in progress. The data will be updated as the processing is completed.

The USGS provided the BAECV data in the Analysis Ready Data (ARD) Tile format, a top-level product meant for analyzing time-series data that are terrain corrected and have known data quality. The state of Florida occupies portions of 20 ARD Tiles, but we were initially provided only 18 tiles (all but 026020 and 027022; Figure 2) and thus performed analyses on datasets for those tiles. We are currently updating the other two tiles which we have just received from the USGS, and will upload when completed. For this project, the various datasets for each BAECV product are represented individually within an ARD tile.

We evaluated the *annual* BAECV Burn Probability (BP) datasets –which are raster datasets – for evidence of burns. The annual datasets span an entire calendar year (*e.g.,* Jan 1 through Dec 31) and indicate the maximum BP within the year; the exact same products exist for each individual scene within a year, but it can be difficult to resolve/refine information for the purposes of this project at this temporal scale. Therefore, we chose to analyze the annual products for this Deliverable, but we developed the methods to be scalable for any BAECV product (*i.e.,* individual scenes or composites covering specific timeframes).

For each year between 2006 and 2016, we combined the annual datasets of interest within individual ARD Tiles into a single annual raster dataset (*i.e.,* we mosaicked the tiles) for further processing (Figure 3). We performed all additional processing steps on the annual mosaicked datasets as this provided statewide consistency. We identified pixels as burned or unburned according to their probability value; initially, we retained all pixels with an annual BP between 85-100% based on Hawbaker *et al* (2017). Values between 90-100% were then converted to presence/absence rasters and we used image processing methods to remove 'speckling' (*e.g.,* fill in small holes within a burned area and remove groups of pixels less than a specified size/amount). This process resulted in annual rasters and vectors indicating burn presence (with 90-100% probability) for groups of pixels greater than ~2.24 acres (*e.g.,* 10 contiguous 30m pixels, in any arrangement). The newly created datasets were then evaluated to begin the process of determining fire regime characteristics (Appendix A) such as number of times burned and year last burned; these metrics are a required portion of a SWG deliverable, and Deliverable 6 of this project.

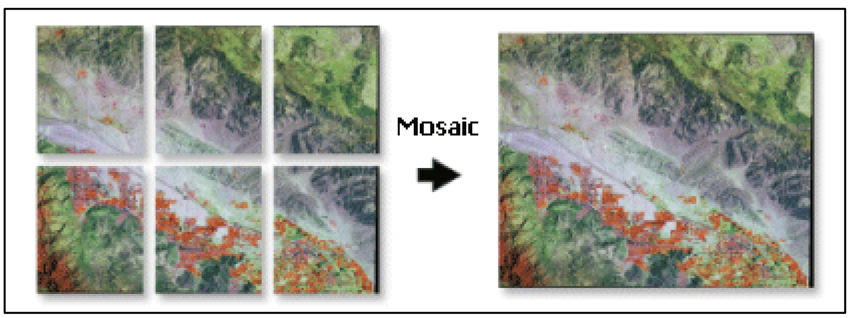

Figure 3: Example illustrating the results of combining multiple raster datasets into a single dataset using the *mosaic* method.

We then evaluated these products against fire records for the three pilot areas (Eglin AFB, Apalachicola NF, and Big Cypress National Preserve; Deliverable 5.1). These three sites have large-scale prescribed fire programs, fire-dependent ecosystems, and records of known fire locations. In these areas, as well as across Florida, there exist many small, rapidly burning, low-intensity fires (often under a tree canopy), frequent cloud cover, and rapid green-up following fires. The detections of any satellite sensor used for imaging or detecting fires requires a cloud-free sky at the time of satellite overpass. When using satellite imagery to derive information about fire extents, post-fire images occurring on cloudy days may not be suitable for deriving burned area, and low-intensity fires beneath a tree canopy may not be detectable.

For each area, we held a meeting with fire managers, either in person or via web conferencing methods. We provided a quick background of the project, and explained the process we used to derive the BAECV BP-based fire information. We then invited managers to inspect the data with us to evaluate their thoughts on the products. In our evaluation meetings, the fire managers from the three pilot areas acknowledged that cloudiness/green-up/low intensity fire issues could possibly explain “missing” fires (*i.e.,* locations where the annual BP data are not capturing burn extents very well) on their lands. Through this process, managers provided many other explanations for why no burn was detected and where/why fire detection was performing very well, as well as some ideas and suggestions for moving forward (all of which we relayed to USGS). Many of these comments reflect known limitations previously documented (see Deliverable 4; Hawbaker *et al.* 2017). However, satellite-based datasets (and their derivatives) are promising since it is possible to extract fire extent information across large regional areas in a standardized replicable way, which makes it possible to process data from sensors in a consistent manner for comparing to known fire locations. Because of the longevity of many of the current satellite sensors and products that we evaluated, there is an abundance of scientific literature describing the known limitations, assumptions, and utility of different datasets for fire detections and burn scar mapping.

Appendix B provides summary notes on findings from each of the three meetings. Overall, managers received the products well, and their comments will be useful in guiding further refinements and protocols in the next deliverable. Furthermore, these meetings illustrate that it is imperative to hold ‘stakeholder’ meetings and workshops with the folks who have provided the data to help us better understand where these products are doing well “as is” and where we might want to apply some different thresholds to set up baseline protocols for locations moving forward. For example, after consultation with BICY fire management staff, we will be exploring the effects of re-thresholding the BP products to 70% in certain land cover classes to determine if we are able to capture burned areas better.

Once managers at the three pilot areas evaluated the datasets and data derivations against their institutional knowledge and fire records, we finalized the datasets and uploaded them into the database. We updated and simplified the original DoD-based SQL database based on needs identified by FWC partners in meetings leading up to and subsequent to Deliverable 4. We have populated it with 10 years of fire data for the state of Florida; it can be queried to identify burn locations (as identified by FFS OBA permit [Deliverable 2, 3.1, and 3.2], agency-provided datasets [Deliverable 4], and by annual burn probability [Deliverable 5.1]), by year and/or by Cooperative Land Cover classes. Current datasets in the database include FFS OBA permit data, annual BP-based burned area rasters and polygons, and landcover classification rasters/polygons. We will continuously update the datasets in the database throughout the life of the project based on conversations with FWC partners to provide for their needs and requirements.

Deliverable #5.2: Recommendations

For the previous Deliverable, we expanded upon previous work by comparing spatial footprints of fires derived from the satellite-based BAECV product (Hawbaker *et al.* 2017) against known locations of fires in three pilot areas. We selected the pilot areas based on having known fire location data, having large-scale prescribed fire programs, and having fire-maintained systems where species of greatest conservation need occur (to coincide with another project funded through a FWC State Wildlife Grant). A series of data derivation methods and protocols resulted in annual fire datasets that we evaluated with managers. Based on their recommendations and suggestions, we have extended this work to encompass the entire state of Florida. The burned area footprints may under-predict fire in some instances; however, we feel that this is a step forward from the FFS permit point data for identifying fire location/extent in a spatial manner, and are continuing efforts to improve datasets and methodologies.

As noted in the Deliverable #4, we continue to recommend that a standardized statewide data call with specific reporting requirements be developed and utilized to acquire individual landowner-based fire data. In this deliverable, we additionally recommend a follow-up meeting with landowners who provide their fire data once the BAECV-based products exist for their land. This meeting serves multiple purposes; it allows us to understand the data they provided better, and it allows us to provide background information to the landowners on the BAECV data and product derivation. The managers then provide feedback on where the data products are capturing fire extent in an acceptable fashion and why. The managers can additionally isolate locations/types of fires/seasonal characteristics, which may cause data products to over/underperform, and it provides opportunities for them to help identify potential solutions. Having landowner buy-in is imperative for the success of these types of projects.

Appendix B shows a complete list of comments and recommendations from the three pilot areas. Common to managers from all three areas was the notion that, overall, these annually-based datasets are doing an acceptable job of capturing actual fire footprints within areas where fire has been applied. However, the BAECV products' ability to identify these locations differs. Managers noted that in the Panhandle (*e.g.,* Eglin AFB and Apalachicola National Forest), the burns that were less likely to be captured in the annual 90-100% BP range had well-documented characteristics. For example:

- They occurred in grass-dominated locations;
- The actual fire did not burn very hot and did not alter canopy characteristics;
- The fire was at the end of prescribed fire season and beginning of wildfire season, where days are typically more often cloudy than clear;
- Fires were set in units that did not have much fuel to begin with, so detection is normally difficult;
- Fires followed thinning or chemical treatments; and
- Fire was at the end of the calendar year so was perhaps captured in the following year's data.

In southern Florida (*e.g.,* Big Cypress and Everglades), while many of the same characteristics were noted, managers also suggested that lowering the BP threshold from 90% to somewhere in the range of 70-80% might produce better results in the ecosystems prevalent in that part of Florida. We have considered those suggestions and are currently working on evaluating protocols to determine when and where thresholding is appropriate. The data uploaded for this Deliverable captures 90-100% BP, and we will update the 70% threshold results (if they are acceptable) as they become available.

Next Steps

The next steps for the project include:

- updating and refining methods based on manager inputs and applying them locally/regionally/statewide to identify fire locations;
- analyzing fire regime characteristics and trends statewide;
- developing procedures for annual updates moving forward;
- compiling recommendations for current (and future/extended) uses of the database.

To address the challenge of understanding spatial characteristics of burns and reconstructing burn histories, we intend to continue using the BAECV dataset developed by Hawbaker *et al.* (2017), data derived in-house using the fire mapping tools for smaller fires, and known fire perimeters for all areas statewide. Further work may include testing outputs of new algorithms for BAECV-derived products in the southeast; adding supplementary datasets derived from other satellite sensors (*e.g.,* Sentinel 2A); extending the products in the database back through the LANDSAT record and updating through the current year (*i.e.,* 1984 through 2018); and hosting the database. Additionally, we will create additional data-based queries in the SQL geodatabase to derive fire regime characteristics for this and other projects we are currently completing. The final project result will be spatial information in the form of fire perimeters for the period 2006 – 2016, including queries, reports, and metadata.

Deliverable #5.2: Summary

The overall aim of the *Mapping Fires Across Florida* project is to develop a spatial database of prescribed fire extents in Florida with querying and reporting capabilities. The fires in this spatial database will range from less than ten acres to greater than 100 acres. To recap accomplishments so far on this project:

- A Partner Workshop was held at Tall Timbers in September 2017 to introduce the project and get ideas from partners about specific interests and needs; Deliverable #1 is a summary document about the workshop.
- The exploratory data analysis performed for Deliverable #2 provided useful insights into the FFS OBA dataset, and its potential usefulness for assessing fire regime characteristics in the state of Florida.
- For Deliverable #3 we focused on converting the existing DoD database from Oracle to SQL Server and importing the FFS OBA data.
- In Deliverable #4, we explored multiple sources and types of fire extent information, including landowner-provided fire atlas datasets and satellite based detections and extent maps, and we reviewed literature about the sensors and datasets.
- Deliverable #5.1 of the *Mapping Fires Across Florida* project focused on assessing the utility of the satellite-based BAECV product suite for identification of the spatial extents of fires in three pilot areas within Florida: Big Cypress National Preserve, Eglin Air Force Base, and the Apalachicola National Forest.

Based on previous evaluations of annual BAECV-based data products and derivatives within the three pilot areas and facilitated meetings with fire managers at those locations, we expanded the BAECV-based products across the state. The methods used to develop these nationally scoped datasets are replicable, and we showed that it is possible to adapt them regionally to map the spatial extent of a range of fire sizes in Florida. In addition, much smaller fires are mapped (~2 ac) as part of the protocol we developed for deriving the BAECV-based fire products, which is of benefit in Florida where many small fires prevail and where habitat-based analyses for those species with the greatest conservation needs are involved. We have determined that the BAECV-based datasets are quite useful as a first step for understanding fire regime characteristics in a spatial manner across the landscape within Florida, in spite of the known/documented limitations. We provide evaluations and suggestions for moving forward with identifying the spatial extents at a statewide level.

We believe that the automated portion of developing datasets and generating fire extents and perimeters using BAECV methodology can be useful for updating these datasets in a consistent fashion moving forward. As mentioned in the previous Deliverable, we are exploring additional options to enhance this ability. The FFS OBA, BAECV, and landowner data combined can help locate areas that have burned in prescribed fires and clarify fire characteristics across the state, perhaps better than any particular dataset alone – especially if there were simple standardized tracking and reporting options required that did not burden landowners with extra work. The next steps for this database include finalizing the processing and uploading of the lower-threshold BP datasets (e.g., 70% in S. Florida), developing queries, fire metrics, and user guides, as well as update procedures moving forward. In addition, we will consult with FWC on exactly what data to upload into the SQL Server as ancillary data for queries and analyses.

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Appendices

Appendix A: Fire Regime Derivatives
Appendix B: Manager Meeting Notes

Appendix A: Fire Regime Derivatives

The following pages contain examples of fire extent and fire regime derivatives from the previous work for the three pilot areas, as well as for each FFS District. Any location identified in these maps can be considered to have burned at least once between 2006-2016 (with 90-100% probability of the detection being a burn). An annual raster dataset indicating presence/absence of burning, and an annual 'area burned' vector dataset, exist and are loaded in the database for the entire state. We have included these maps to highlight the utility of the BAECV-based datasets. These images are for illustrative purposes only. Further examples are available upon request.

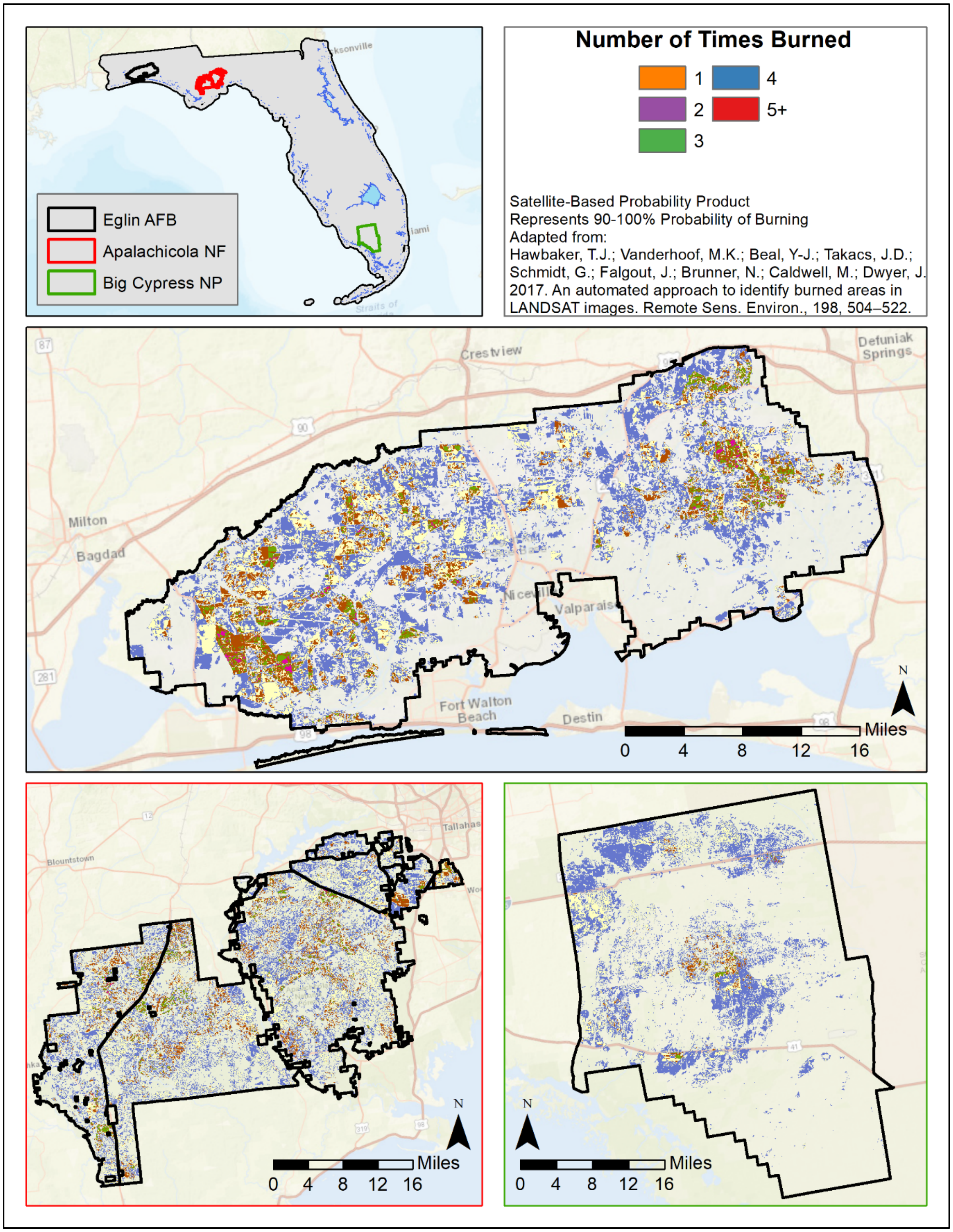

Figure A1: *Number of times burned between 2006 and 2016 in each of the three pilot areas based on annual composite 90-100% burn probability.*

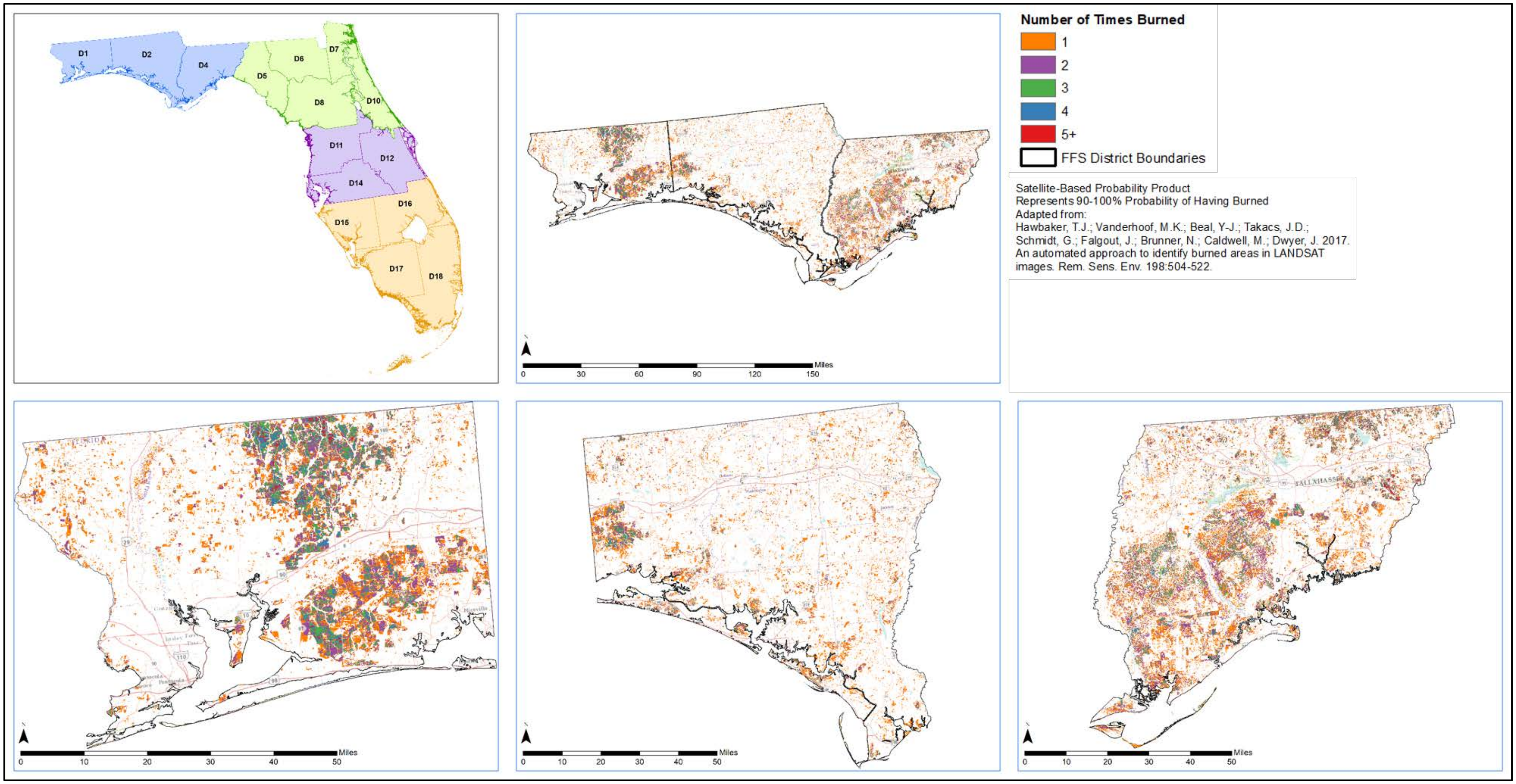

Figure A1.a: *Number of times burned between 2006 and 2016 based on annual composite 90-100% burn probability in FFS Districts 1-4.*

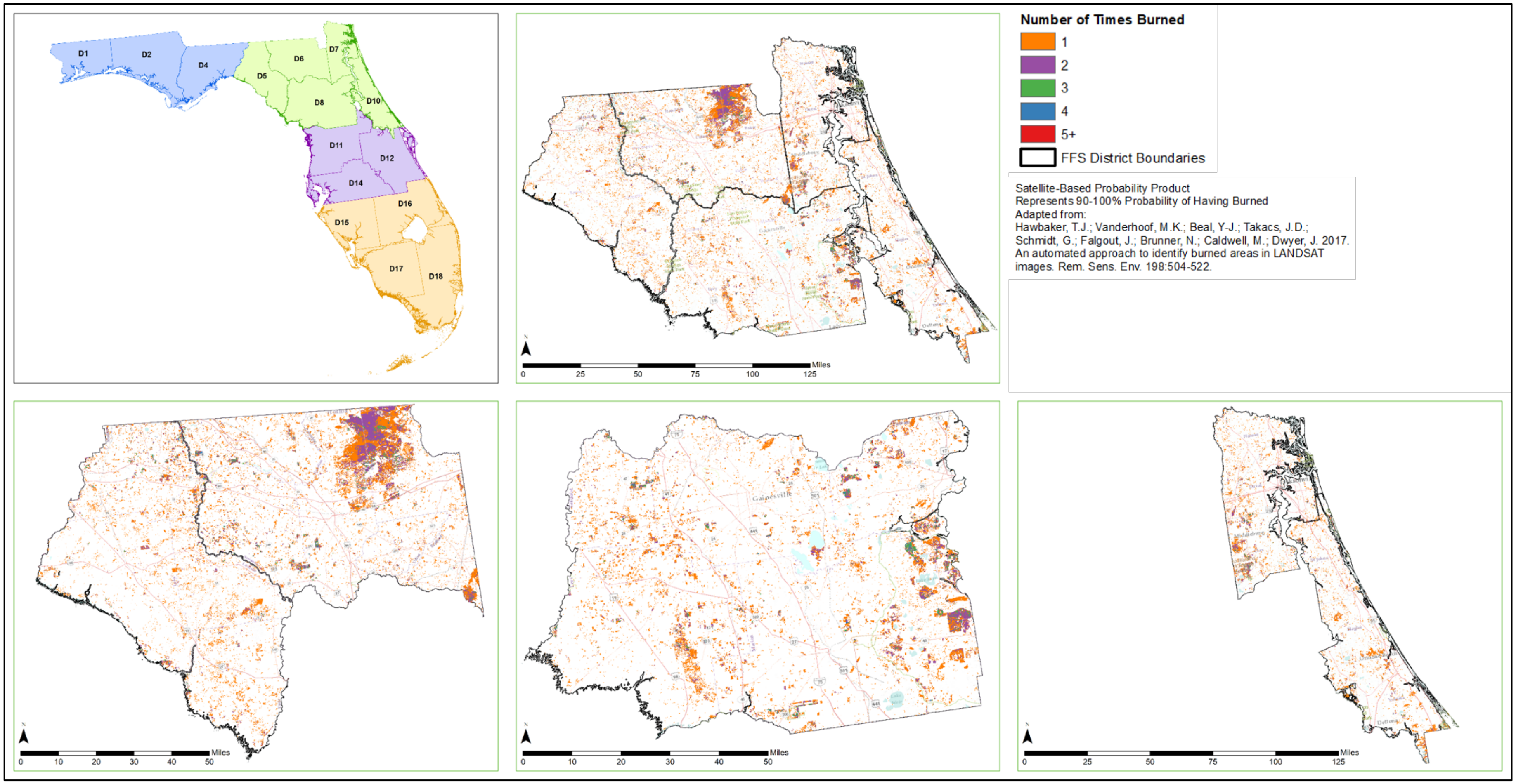

Figure A1.b: *Number of times burned between 2006 and 2016 based on annual composite 90-100% burn probability in FFS Districts 5-10.*

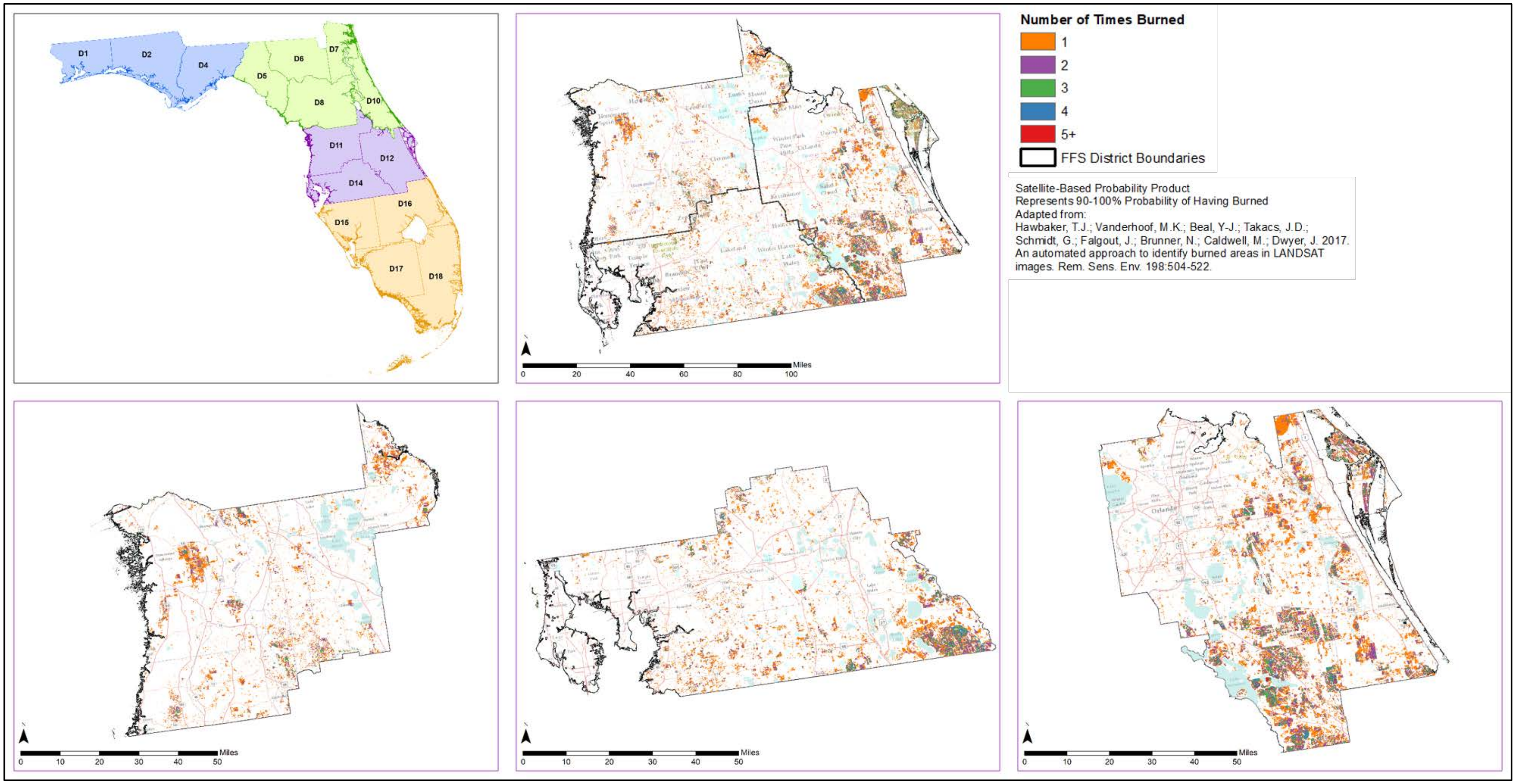

Figure A1.c: *Number of times burned between 2006 and 2016 based on annual composite 90-100% burn probability in FFS Districts 11-14.*

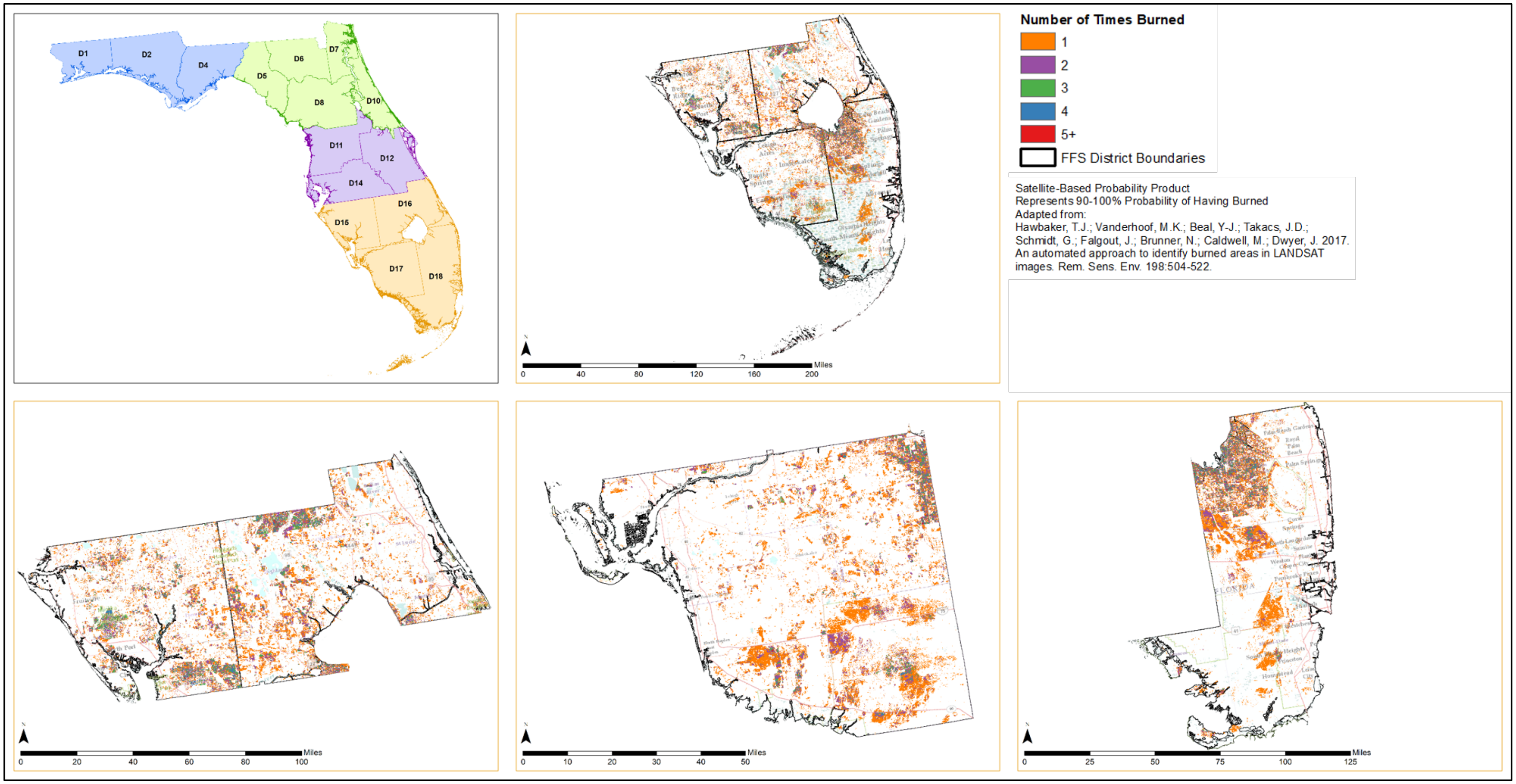

Figure A1.d: *Number of times burned between 2006 and 2016 based on annual composite 90-100% burn probability in FFS Districts 15-18.*

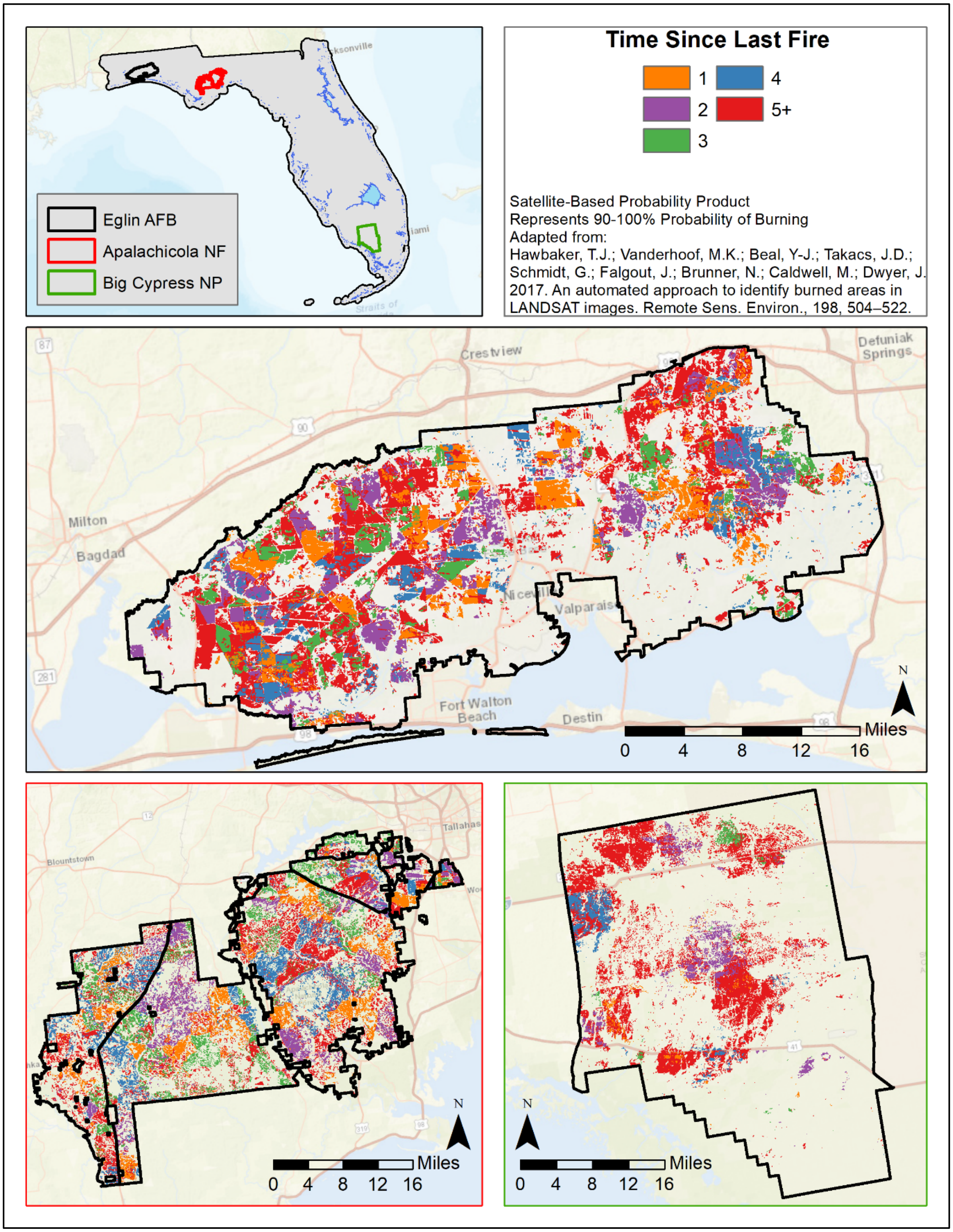

Figure A2: *Number of years since last fire (measured from 2017) in each of the three pilot areas for the time period 2006 - 2016 based on annual composite 90-100% burn probability.*

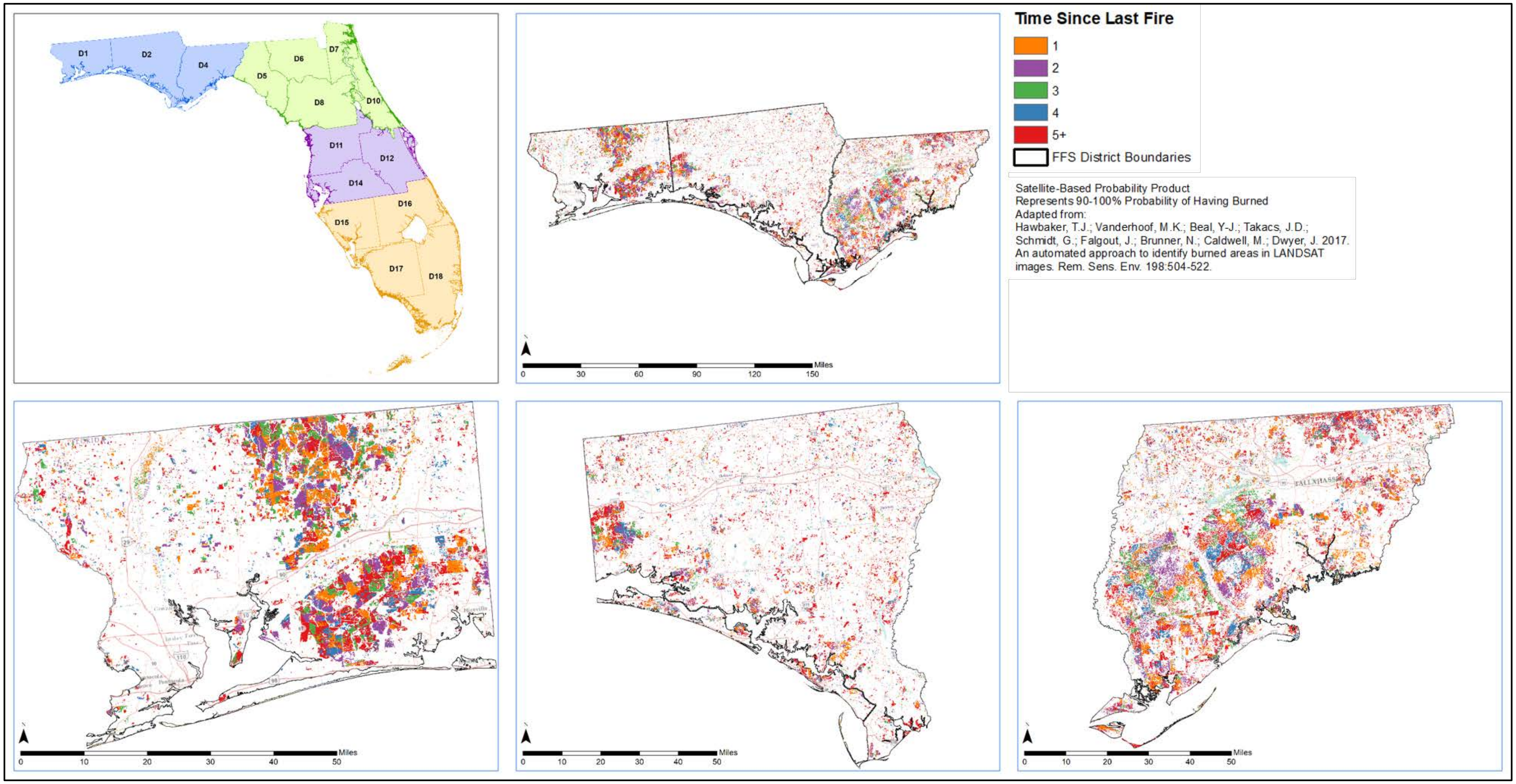

Figure A2.a: *Number of years since last fire (measured from 2017) for the time period 2006 - 2016 based on annual composite 90-100% burn probability, FFS Districts 1-4.*

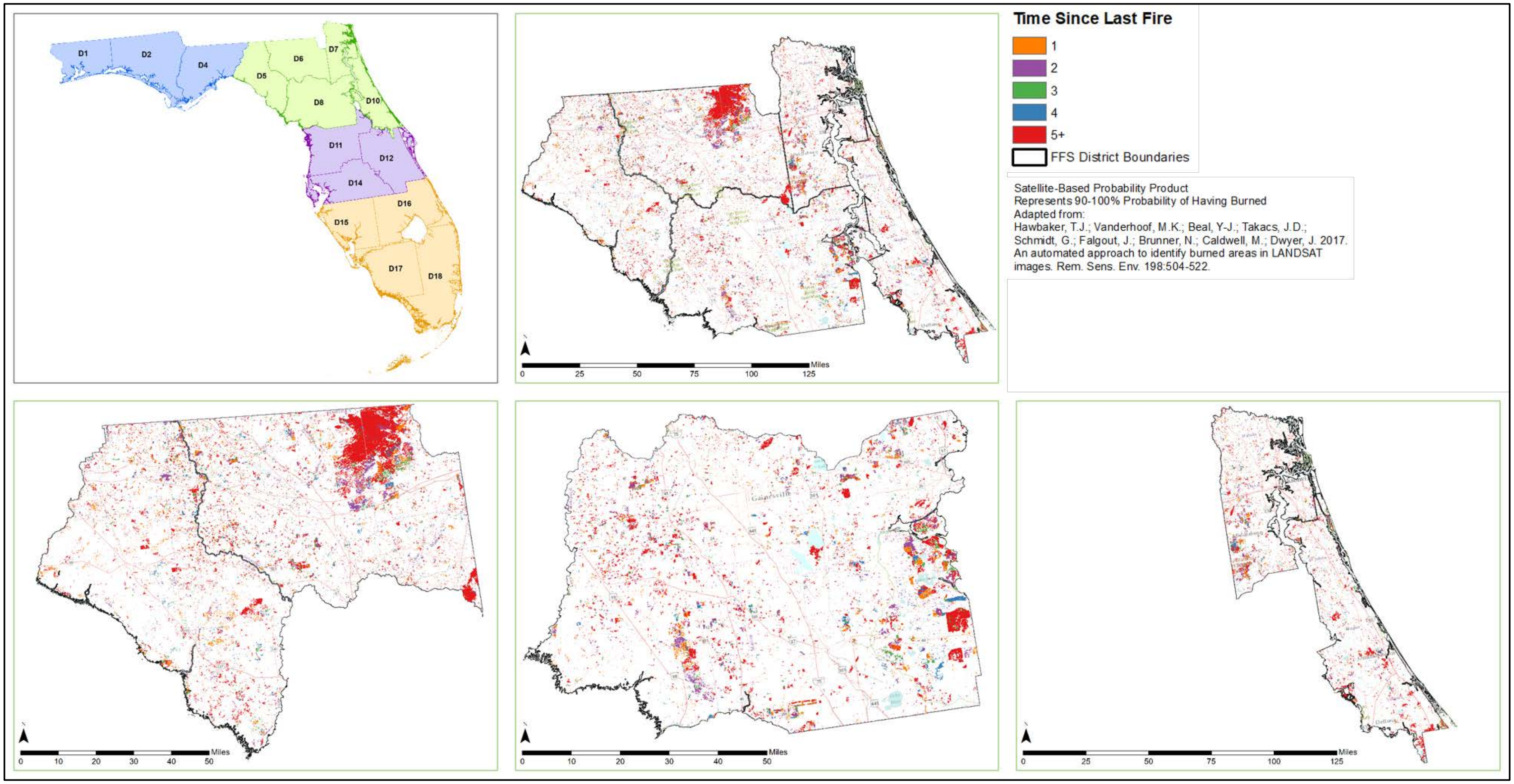

Figure A2.b: *Number of years since last fire (measured from 2017) for the time period 2006 - 2016 based on annual composite 90-100% burn probability, FFS Districts 5-10.*

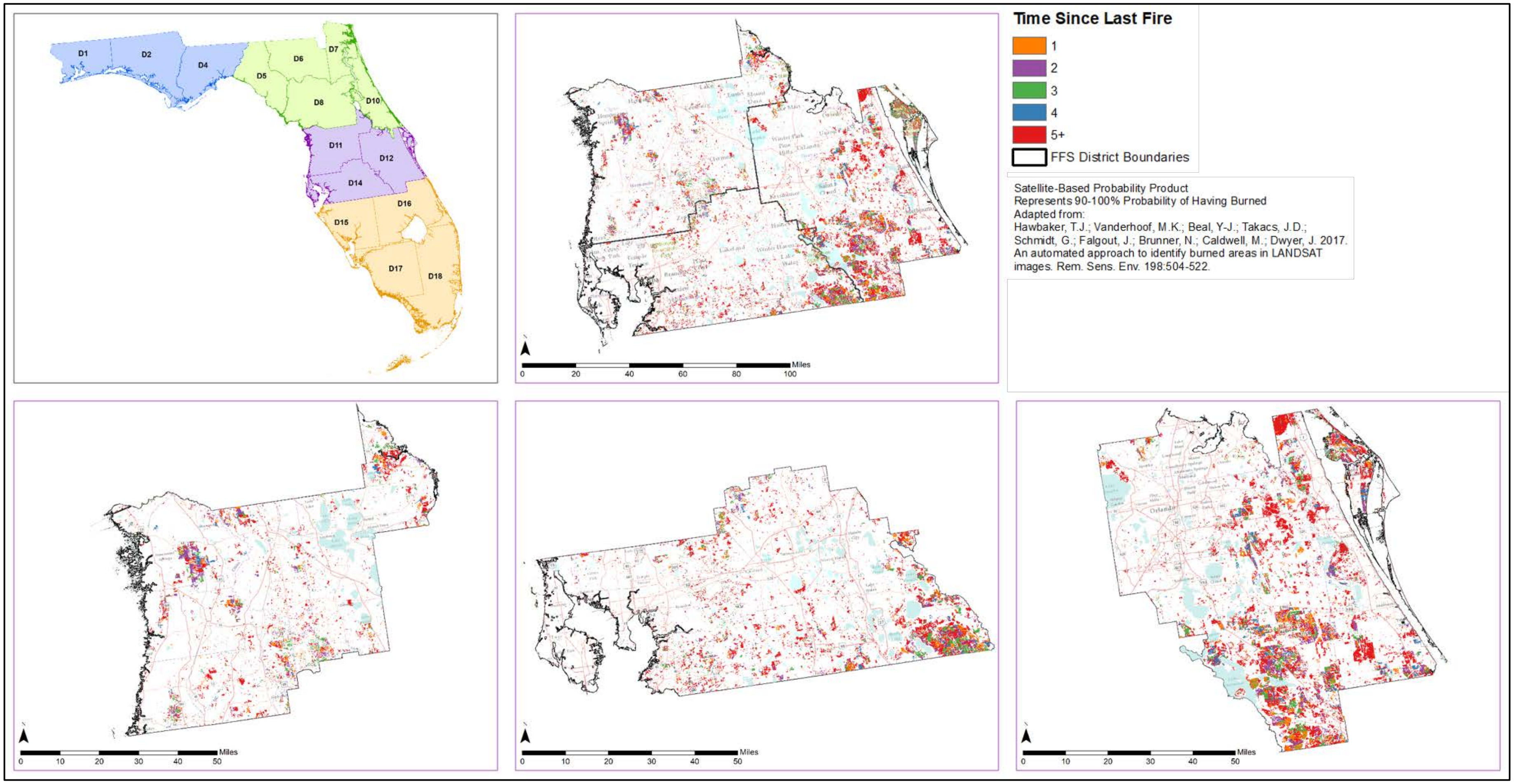

Figure A2.c: *Number of years since last fire (measured from 2017) for the time period 2006 - 2016 based on annual composite 90-100% burn probability, FFS Districts 11-14.*

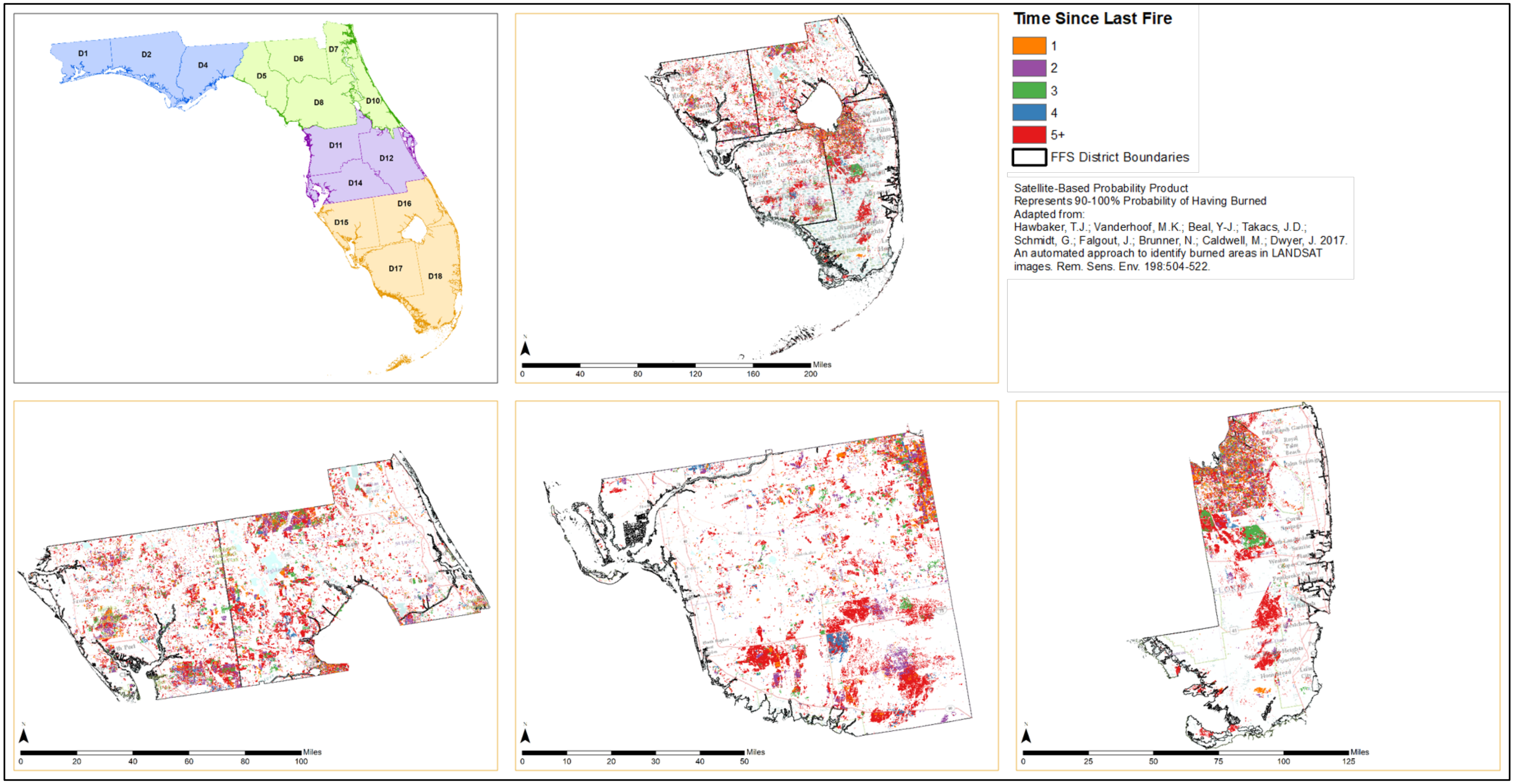

Figure A2.d: *Number of years since last fire (measured from 2017) for the time period 2006 - 2016 based on annual composite 90-100% burn probability, FFS Districts 15-18.*

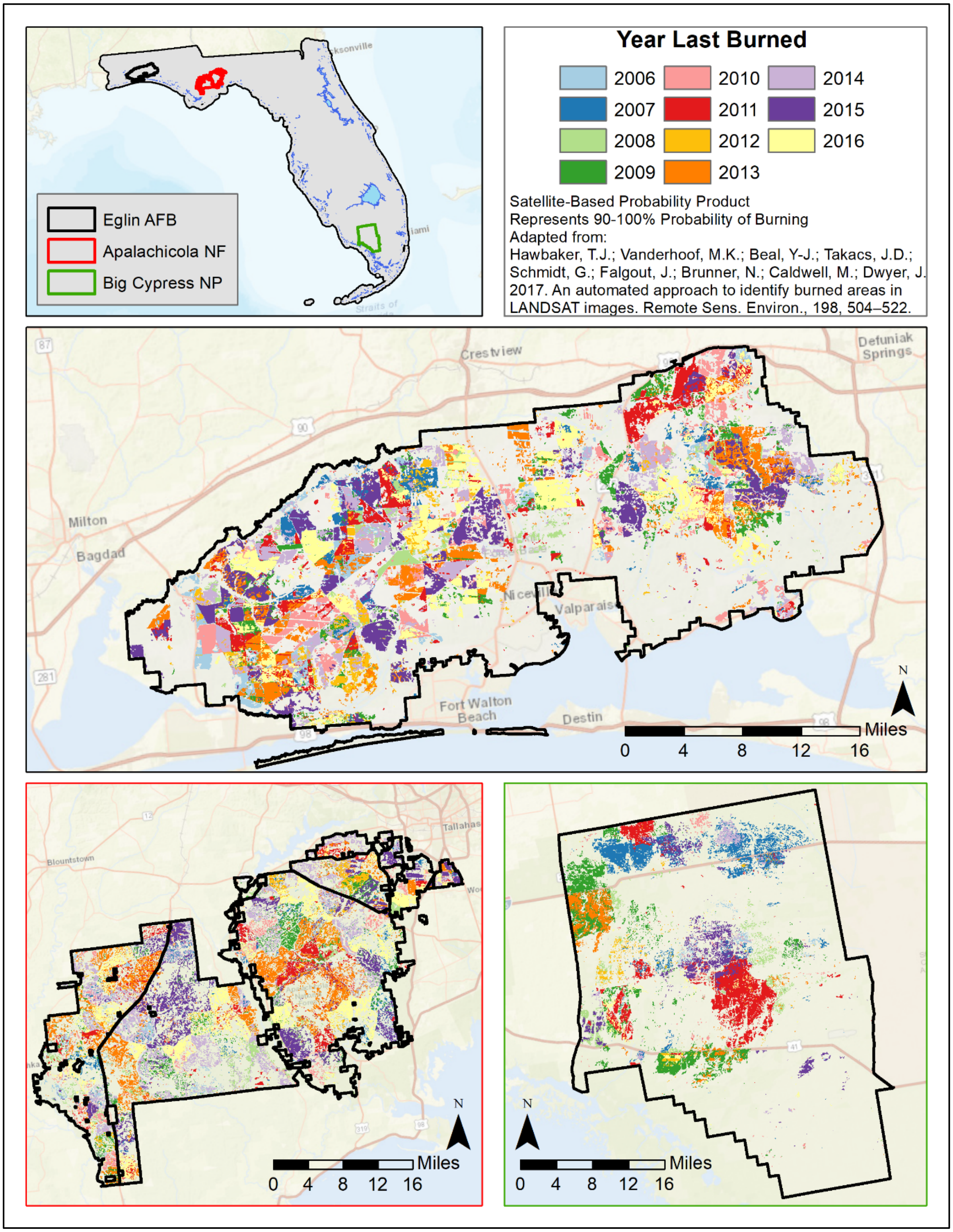

Figure A3: *Year most recently burned between 2006 and 2016 for each of the three pilot areas based on annual composite 90-100% burn probability.*

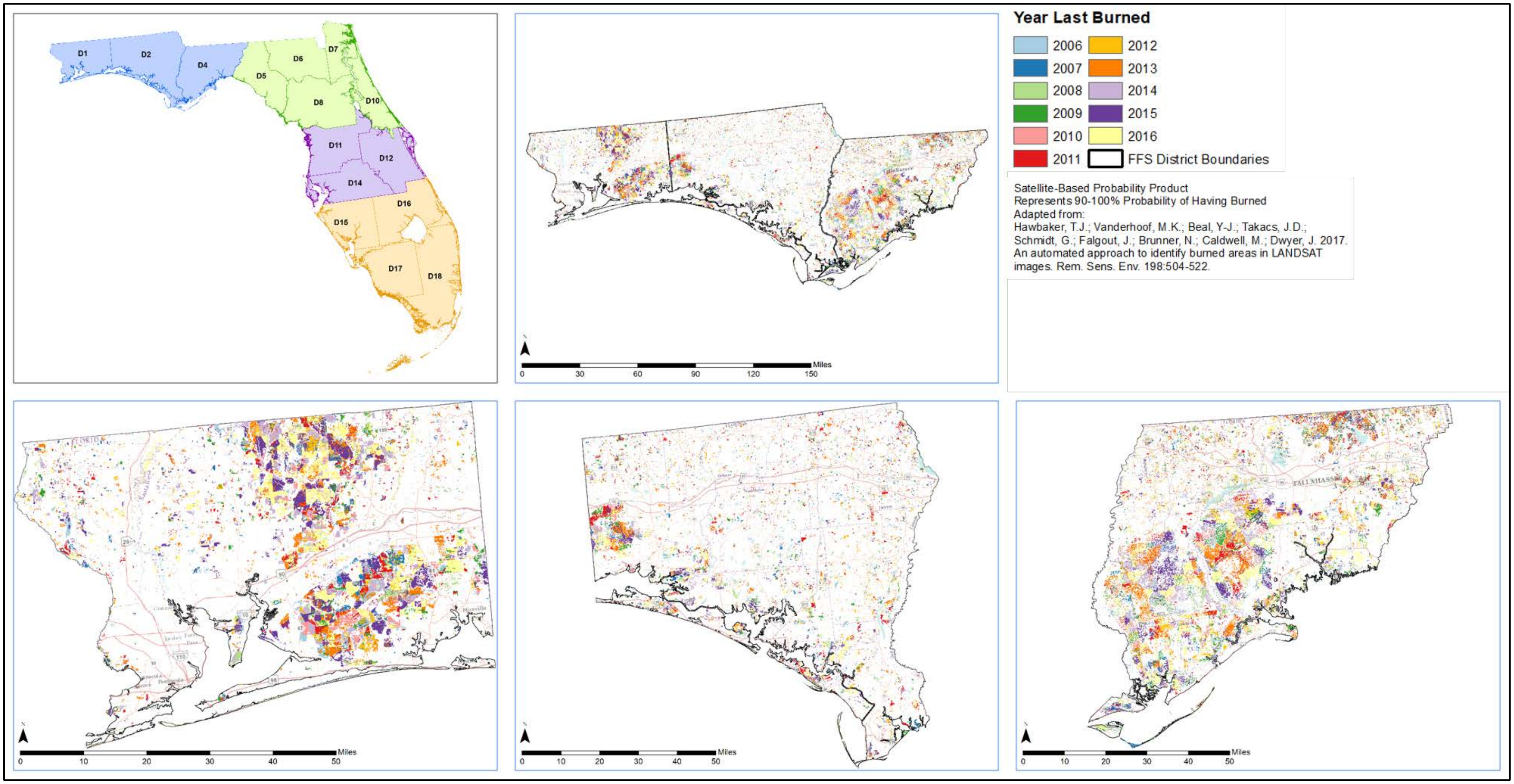

Figure A3.a: *Year most recently burned between 2006 and 2016 based on annual composite 90-100% burn probability for FFS Districts 1-4.*

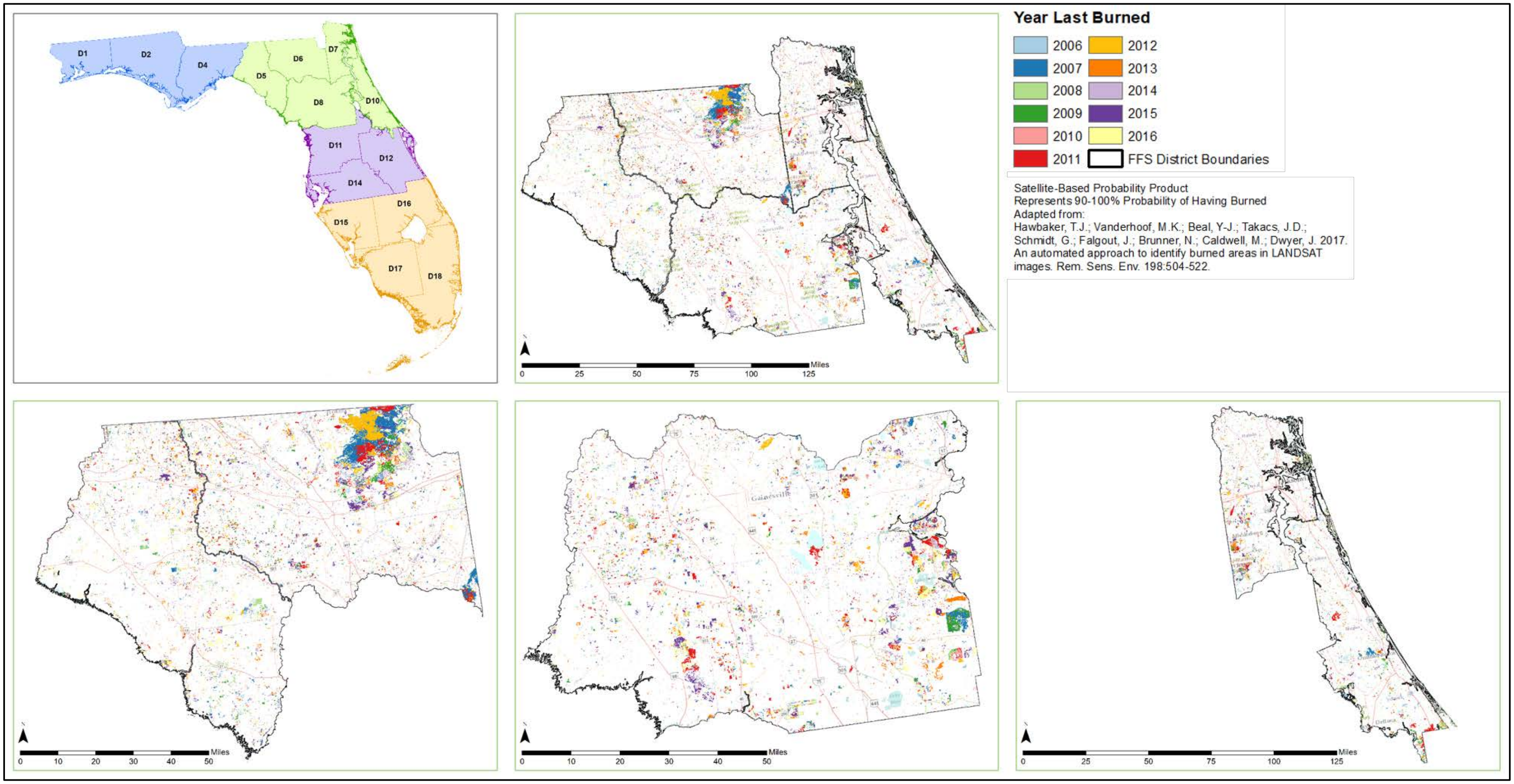

Figure A3.b: *Year most recently burned between 2006 and 2016 based on annual composite 90-100% burn probability for FFS Districts 5-10.*

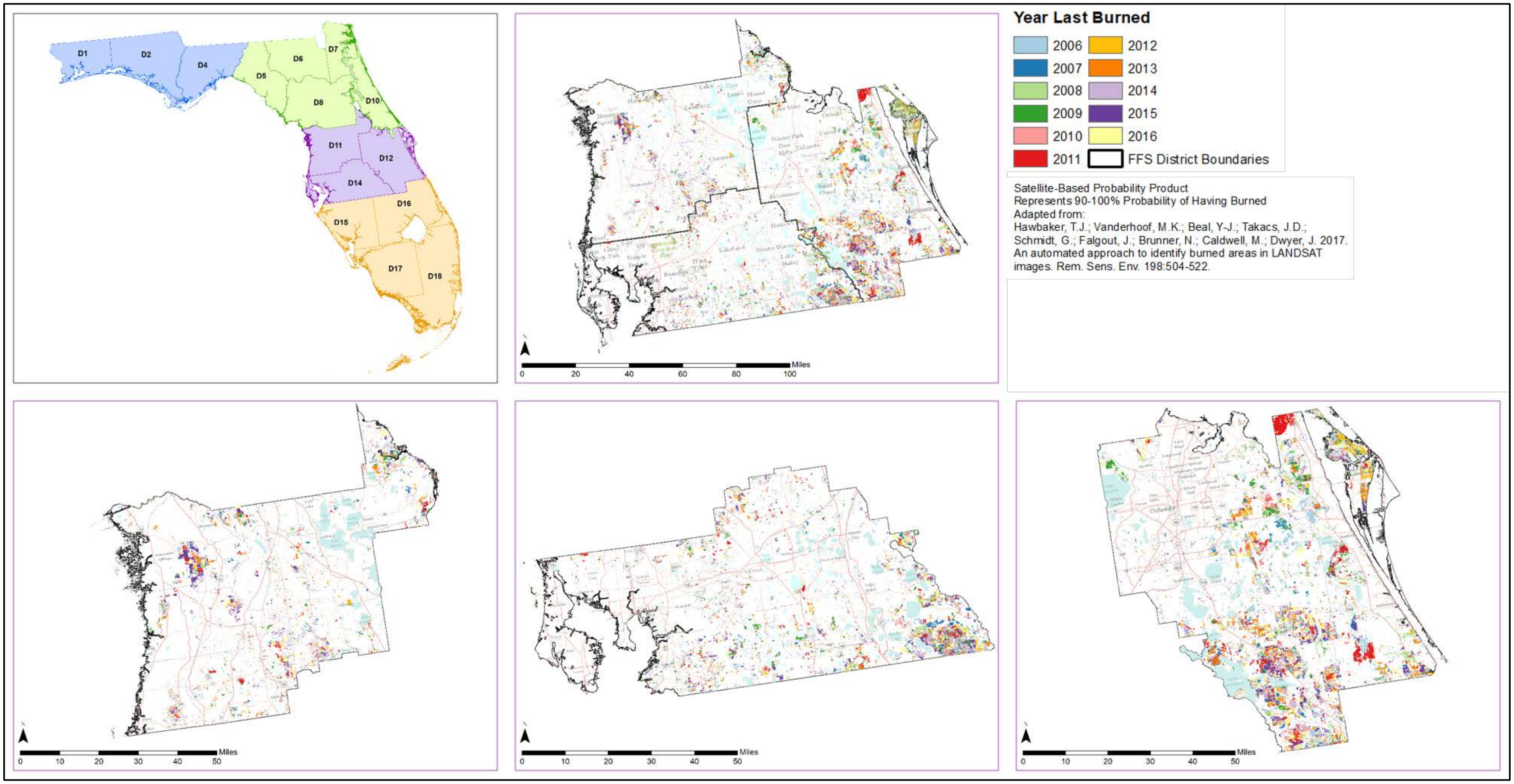

Figure A3.c: *Year most recently burned between 2006 and 2016 based on annual composite 90-100% burn probability for FFS Districts 11-14.*

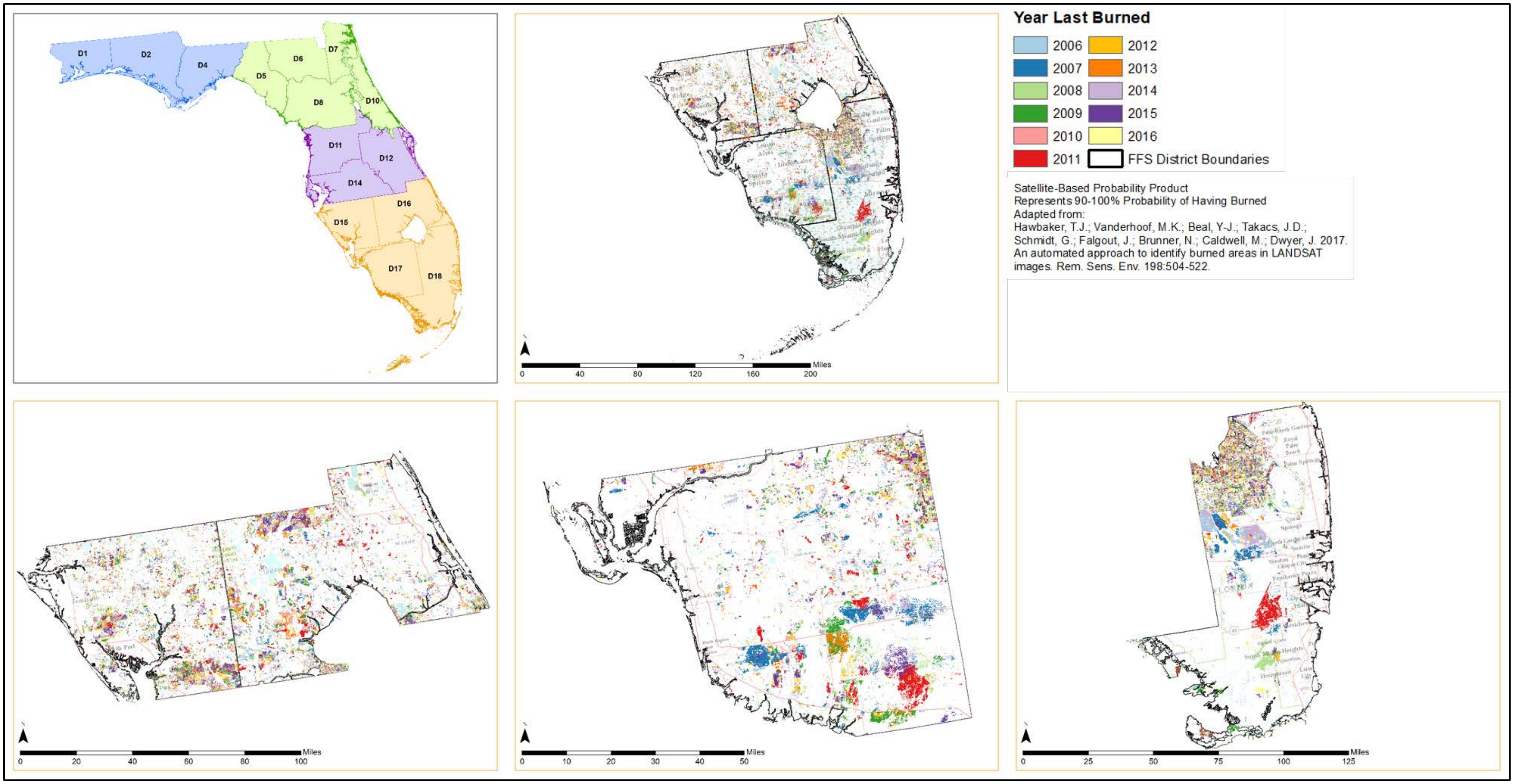

Figure A3.d: *Year most recently burned between 2006 and 2016 based on annual composite 90-100% burn probability for FFS Districts 15-18.*

Appendix B: Manager Meeting Notes

The following pages contain notes from meetings with fire managers at each of the three pilot areas. We briefed managers on the products and how we derived them, as well as what they illustrate. Managers provided feedback on the products, and we summarize those notes here. As a direct result of our update meetings with managers, the ANF and the Southern Fire Exchange and others have written USGS letters of support for continuation of BAECV development.

Table B1: Fire Manager meeting notes about the BAECV-based BP products for the three Pilot Areas.

Pilot Area	Notes
Apalachicola NF	• Seems to capture the patchiness of burning well • Low intensity fires may not be captured as easily • "Very impressed with this product and are hopeful that we can incorporate it into many different tools and workflows here on the NFs in FL" • "BAECV fills a critical niche because it is not dependent on data from disparate fire databases or on manual mapping of fire extents"
Big Cypress NP	• Think it is doing a good job given what fuel type we have • June through August burns seem to be difficult to capture due to seasonal cloud cover, rapid green up • November/December burns seem to appear in following calendar year • Seems to capture the patchiness of the fuels • May be easier to capture burns in drier years • Might consider a different threshold (70%) to better capture fire in these systems.
Eglin AFB	• Late season burns seem to show up in following year (e.g., burns in late Nov, Dec) • Burns may not be detected if burned after a treatment • Burns in low productivity sites not captured, but often hard to tell that they burned (i.e., fire is applied to unit, but may not carry well) • Cool burns, night burns, and burns in wet season seemed harder to detect • Burns leading into the summer season may not be detected (due to increased cloud cover during summer months) • First entry burns and burns early in the fire record may have burned more intensely than those later in record due to fire frequency reducing fuels (and thus intensity and detectability) • Just because we don't have a record of it doesn't mean it didn't burn – we burn enough that we don't get reports of fires due to folks thinking we are doing prescribed burn • May provide useful insight at a large scale, but we'd still have to ground truth at an individual fire scale if we were interested • Would be nice to be able to see these on a 'fiscal year' as opposed to a calendar year

Chapter 8: Deliverables #6 & #7

Summary Report – Tool/Metric Development

And

User Guide & Update Policies

<u>Deliverables Update</u>
#6 & #7: Summary Report – Tool/Metric Development
&
FINAL User Guide & Update Policies

Mapping Fires Across Florida:

Advancement of a Fire Spatial Database

April 2019

Tallahassee, FL

TALL TIMBERS

Principal Investigator/Project Manager

Joe Noble

Co-Principal Investigators

Casey Teske

Kevin Hiers

Vince Sclafani

Kevin Robertson

Project ID

FWC-16/17-135 Spatial Database

A Proposal for Mapping Statewide Fire Occurrence, Fire History, and Ecological Outcomes

Submitted by Tall Timbers Research, Inc., June 20, 2017

Previous project deliverable reports, including the earlier workshop proceedings, video of expert presentations, summary report, and power point presentations are available free of charge from Tall Timbers Research, Inc. Please contact Joe Noble: jnoble@talltimbers.org

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TALL TIMBERS

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Executive Summary

Tall Timbers Research, Inc. is pleased to present the *Mapping Fires Across Florida: Deliverable #6* update. The overall purpose of the project is to develop a spatial database of prescribed fire extents in Florida with querying and reporting capabilities. Development of a comprehensive spatially explicit map of fire occurrence remains one of the most critical needs for conservation in the Southeastern US. Not only are the vast majority of Florida's endangered species and ecosystems reliant on frequent fire, but fire risk analysis, prescribed fire planning, and fire behavior modeling are sensitive to fire history. Fire occurrence in Florida is currently tracked by approximate location through the Florida Forest Service (FFS) burn authorization system, Fire Management Information System (FMIS). While this system represents one of the most advanced prescribed fire planning datasets in the country, the system does not record perimeter data or include assessments regarding which burns are actually completed. Relying solely on this system results in documented data gaps when estimating the size, location and effectiveness of managed fires on a statewide scale. These "actual burned" areas are critical factors in analyses and models evaluating conservation success.

Tall Timbers Research, Inc. is addressing this need by developing a robust spatial database for more precise mapping and tracking of all prescribed fire in Florida. Advanced remote sensing techniques are being applied to known locations of prescribed fires, as identified by the FFS data and select landowner-provided datasets, to record actual spatial fire boundaries into a modified version of the U.S. Air Force Wildland Fire Database. In addition, custom query tools are being developed to report fire history (e.g., frequency, time-since-burn, year last burned, etc.) in specific fire dependent ecological systems or fire dependent species habitats.

The work documented here builds on the spatial database project work previously completed by Tall Timbers' staff. We have already completed exploratory data analysis on the FFS FMIS open burn authorization (OBA) data, which provided insights into the potential usefulness of the dataset for assessing fire regime characteristics in the state of Florida. We have also converted the existing DoD database from Oracle to SQL Server and imported the FFS OBA data into it after consultation with FWCC partners. We have evaluated fire datasets from twenty-six sources for the period 2006-2016. The datasets include satellite-based thermal detections and fire extent maps, as well as landowner-provided fire atlases and fire occurrence databases. We submitted a summary report on prescribed and wildfire information sources for three pilot areas and the entire state in Florida in the previous Project Deliverables. We do not differentiate between prescribed fires and wildfires since both types of fire can meet management objectives and impact species habitats, and as such are both an important part of the fire regime evidence used to inform conservation-monitoring decisions.

The current work is provided in the form of a summary report on tool and metric development, and a user guide. This report contains information on the processes used to derive spatial footprints of fires, and resulting information from the evaluation of results with the three pilot areas applied at a statewide level. We also provide some recommendations for moving forward.

Glossary of Terms and Concepts

Broadcast Burn An open burn that is done for agricultural, silvicultural, or land clearing purposes and is not a pile

Burned Area Essential Climate Variable (BAECV) refers to an algorithm that capitalizes on the long temporal availability of LANDSAT imagery to identify burned areas across the conterminous United States.

Continuation An authorization to continue a previously approved open burn authorization that was not completed for various reasons including late starts, poor weather conditions or lack of resources.

CONUS The Continental United States; this reference excludes Alaska and Hawaii.

Cooperative Land Cover (CLC) The Cooperative Land Cover Map is a project to develop an improved statewide land cover map from existing sources and expert review of aerial photography. The project is directly tied to a goal of Florida's State Wildlife Action Plan (SWAP) to represent Florida's diverse habitats in a spatially-explicit manner.

Environmental Protection Agency (EPA) The agency of the federal government which was created for the purpose of protecting health and environment.

Florida Forest Service (FFS) Agency whose mission is to protect and manage forest resources in Florida.

Florida Natural Areas Inventory (FNAI) Florida's state heritage program responsible for tracking occurrences of species and natural communities statewide.

Fire Mapping Information System (FMIS) integrated set of applications that handle data input, processing and reporting needs for the Florida Division of Forestry (DOF).

Global Fire Emissions Database (GFED) Database combining satellite information on fire activity and vegetation productivity to estimate gridded monthly burned area and fire emissions.

GOES-16 previously known as GOES-R, is part of the Geostationary Operational Environmental Satellite (GOES) system operated by the U.S. National Oceanic and Atmospheric Administration and is the first spacecraft in NOAA's next-generation of geostationary satellites. The GOES-R series satellites will provide advanced imaging with increased spatial resolution and faster coverage, improving the detection of environmental phenomena.

Hazard Mapping Systems (HMS) NOAA product suite that provides both fire and smoke analysis products. It is an interactive processing system that allows analysts to manually integrate data from automated fire detection algorithms using GOES and polar (Advanced Very High Resolution Radiometer (AVHRR) and MODerate resolution Imaging Spectroradiometer (MODIS)) images. The result is a quality controlled display of the locations of fires and significant smoke plumes detected by meteorological satellites.

Interagency Fuel Treatment Decision Support System (IFTDSS) is a web-based software and data integration framework that organizes fire and fuels software applications to make fuels treatment planning and analysis more efficient. The effort was initiated by Joint Fire Science Program and the NWCG Fuels Management Committee in 2007.

Integrated Reporting of Wildland-Fire Information (IRWIN) This service is a Wildland Fire Information and Technology (WFIT) affiliated investment intended to provide an "end-to-end" fire reporting capability. IRWIN is tasked with providing data exchange capabilities between existing applications used to manage data related to wildland fire incidents.

LANDSAT The LANDSAT Program is a series of Earth-observing satellite missions jointly managed by NASA and the U.S. Geological Survey. Imagery is available since 1972 from six satellites in the LANDSAT series. These satellites have been a major component of NASA's Earth observation program.

Landscape Conservation Cooperative (LCC) self-directed partnerships between federal agencies, states, tribes, non-governmental organizations, universities, and other entities to collaboratively define science needs and jointly address broad-scale conservation issues.

Monitoring Trends in Burn Severity (MTBS) refers to an interagency program whose goal is to consistently map the burn severity and extent of large fires across all lands of the United States from 1984 to present.

Moderate Resolution Imaging Spectroradiometer (MODIS) is a key instrument aboard the Terra and Aqua satellites. Satellites view the entire Earth's surface every 1 to 2 days acquiring data in 36 spectral bands. These data improve our understanding of global dynamics and processes occurring on the land, oceans and lower atmosphere.

Pile Burn An open burn that is in the form of a pile that is larger than 8' diameter

PostGIS is a spatial database extender for PostgreSQL object-relational database. It adds support for geographic objects allowing queries to be run in SQL.

PostgreSQL is an open source object-relational database system.

Open Burn Authorization (OBA) refers to Florida Forest Service Open Burn Authorization Requests and is available to Certified Prescribed Burners.

QGIS is a free and open source professional Geographical Information System (GIS) that is built on top of Free and Open Source Software (FOSS)

QGIS Event Mapping Tool (EMT) (now known as the Fire Mapping Tool, FMT), a QGIS plugin for fire assessment developed by U.S. Geological Survey National Center for Earth Resources Observation and Science (EROS)

Southern Integrated Prescribed Fire Information System (SIPFIS) a Joint Fire Science Program initiative to design an integrated information system for fire and air quality data in the SE United States.

Volatile Organic Compounds (**VOC)** refers to a large group of organic chemicals that include any compound of carbon (excluding carbon monoxide, carbon dioxide, carbonic acid, metallic carbides or carbonates, and ammonium carbonate).

Deliverable #7: Project Background

This document serves as the summary report of tool and metric development and a user guide for the *Mapping Fires Across Florida* project; it should be considered as the DRAFT "Deliverable #6 and #7" for review to ensure TTRS is including all information required for Deliverables 6 and 7 (as agreed upon by B. Stys; pers comm.) with the FINAL version due at the end of April. It details the processes used to derive the spatial footprints of fires and some of the impetus for those decisions based on manager meetings.

For over a decade, resource managers in the state have recognized the importance of tracking and monitoring the use of prescribed fire. Many species in Florida are dependent on fire for maintenance of appropriate habitat conditions. Measurements, such as seasonality and years since last burn are important components in assessing the condition of these fire-maintained systems. For many species that are dependent on these systems, managing an appropriate fire return interval is critical. Differentiating those areas that have an appropriate fire return interval from those areas without an appropriate fire return interval would allow managers to focus resources on areas most in need of management actions, as well as serve as a means to measure and quantify the success of conservation and restoration efforts.

Cost effective and efficient management of conservation lands requires up to date detailed resource maps. The Peninsular Florida Landscape Conservation Cooperative (PFLCC) is working on a statewide Landscape Conservation Design. As part of this process, the PFLCC is identifying conservation targets (*i.e.,* indicators) for each priority resource. It became evident that fire return interval could be a critical indicator for these systems.

Florida currently has a detailed (10m) land cover map, used by multiple entities (*e.g.,* Florida Fish and Wildlife Conservation Commission, FWC's State Wildlife Action Plan, Florida Natural Areas Inventory, and the PFLCC). However, there is a critical missing component from the existing land cover map - qualitative attributes regarding fire. One key qualitative attribute that has long been identified as a critical data gap pertains to prescribed fire. Addition of qualitative attributes based on fire regime characteristics, such as fire return interval, would increase the effectiveness of informing acquisition of conservation lands, supporting land and fire management, and tracking success and failure of conservation efforts. Assessment of the success of management actions will provide a valuable feedback loop to inform future management actions on conservation lands, both public and private.

Currently, a spatial database that tracks prescribed fire *extents* statewide does not exist, which means that there is not a comprehensive knowledgebase about fire regimes across the state. Managers recognized this data gap more than a decade ago. In 2006, they noted "…methods for monitoring the use of fire on public lands may be one of the greatest unmet needs in comprehensive wildlife management…" (*Monitoring Prescribed Burning on Public Lands in Florida, 2006).* This project aims to enhance our understanding of prescribed fire characteristics across the state of Florida for integration into further analyses specific to landscape conservation and monitoring. We list specific outcomes and accomplishments to date below:

1. We address the data gap through a spatial database designed to track and analyze burn authorization data between 2006-2016 using FFS Online Burn Authorization data and a modified extension of the US Air Force Wildfire Database.
2. We looked at methods to validate burn authorization records by comparing authorized permits to known fire locations, and developed methods to use remote sensing techniques to record spatial fire boundaries.
3. We developed custom query tools to evaluate fire regime characteristics and trends in specific fire dependent ecological systems and fire-dependent species habitats.
4. We will continue to develop procedures for annual updates moving forward.

Deliverable #7: Tool/Metric Development & User Guide

Introduction

Understanding fire regime characteristics across the state of Florida is important from a conservation perspective if the aim is to maximize conservation efforts and target conservation opportunities appropriately. However, limited information about fire occurrence in the state exists, particularly in terms of a statewide spatial database that includes individual fire perimeters for prescribed fires and for many fires occurring on private lands. We utilize satellite-based detection products to determine the spatial representation of fire extents for the state of Florida and have populated the database with these datasets.

In previous deliverables (specifically Deliverable 4), we evaluated multiple sources of fire information and data to determine if they met the needs of the FWC project in terms of spatial resolution, geographic extent, and time stamping for the study period of interest (2006-2016). In general, the datasets evaluated included prescribed fire information, wildfire information, or both. Data types included point, polygon, and raster data. The temporal characteristics of the data varied depending on the source. For this project, we only assessed fires occurring in the 2006-2016 timeframe for possible inclusion in the SQL geodatabase. The ability exists to upload any additional data as needed (*e.g.*, as available, pre-2006 or post-2016, if available from the original sources).

In Deliverables 5.1 and 5.2, we expanded upon that assessment by comparing spatial footprints of fires derived from the satellite-based BAECV product (Hawbaker *et al.* 2017) against known locations of fires at Eglin Air Force Base, the Apalachicola National Forest, and Big Cypress National Preserve (Figure 1). We chose the pilot areas for multiple reasons. They all have active prescribed fire programs, have supported wildfires in the past, and have well documented burn records that detail fire sizes, types and dates – all things that would help us evaluate usefulness of BAECV, especially in places without fire records (e.g., private lands). Together, the three pilot areas span a large portion of the state, and encompass many fire-dependent systems and species habitats of interest to PFLCC and FWCC. We worked with fire managers at the three locations to get feedback on the products and gauge interest and usefulness of the products. Based on manager evaluations of these data and recommendations for moving forward, we extended the satellite-based mapping process to the entire state of Florida for the same time period. The next sections provide descriptions of the Burned Area Essential Climate Variable (BAECV)-based dataset, as well as derivations of fire metrics using this dataset in Florida.

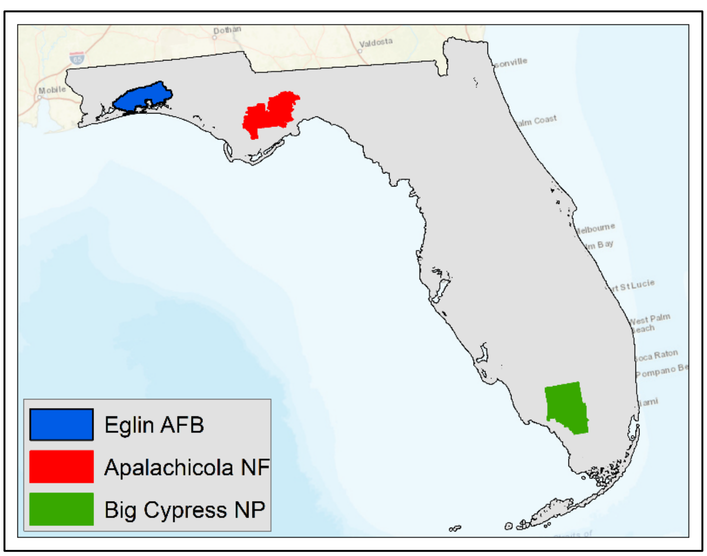

Figure 1: Three pilot area locations: Big Cypress National Preserve, Apalachicola National Forest, and Eglin Air Force Base.

Florida

Florida is a large state, encompassing nearly 66,000 square miles, approximately 70% of which is privately owned. It is largely a peninsular state bounded by both water (the Gulf of Mexico to the west and the Atlantic Ocean to the east) and land (Georgia to the north, and Alabama to the northwest; Myers and Ewel 1990). The climate can be described as a humid subtropical climate north of Lake Okechobee and a tropical climate south of Lake Okechobee, with an average annual precipitation amount of 59.2 inches (USCD 2018). The dry season is generally cool (*e.g.,* winter) and the warm season is typically rainy and marked by tropical storms and even hurricanes. The highest point in Florida is only 345 feet above sea level, although inland areas have rolling hills with elevations up to 250 feet above sea level. Variations in topography may be slight or occur over short distances, but can have large effects on the vegetation due to impacts on water, soil, and nutrient regimes. The biodiversity in Florida is quite high, with many species of flora and fauna, including fire-adapted species and threatened/endangered/rare species. Upland ecosystems in the state consist of the pine flatwoods and dry prairies, scrub, temperate hardwood forests and South Florida rocklands (Myers and Ewel 1990). Fire is a strong influence in the composition and structure of the Upland ecosystems, and many species that occur in these areas are considered 'pyrogenic', or having fire adaptations. In the wetlands of the state, which includes marshes and swamps, hydrology cycles and fire cycles have interchangeable impacts. Variations in hydroperiods, organic matter accumulation, and fire frequency all have important structural impacts on the wetlands. Fire frequencies and rotations vary across the state, and range from frequent low intensity surface fires to infrequent high intensity crown fires; prescribed burning is common and occurs throughout the entire year, much of it on private lands. However, exact spatial locations are largely unknown outside of state and federal (*i.e.,* the 30% public) ownership.

Fire Datasets Evaluated

Multiple landowner sources across the state provided fire information in the form of fire occurrence databases and fire perimeters for both prescribed and wild fires. Landowners included public (*i.e.,* USFS, FWC, Florida Park Service, etc.), and private landowners (*i.e.,* Tall Timbers, Archbold, etc.), as well as some nationally available datasets that span ownerships (*i.e.,* the National Fire Occurrence Database [Short 2017]). Refer to Deliverable 4 for complete dataset descriptions. The fire data we currently possess from these sources can be uploaded into the database for use on an 'as-is' basis, or with some serious quality control, to supplement further analyses. The data were quite useful in helping us focus in on known fire areas for the evaluation of the annual BAECV products; however, we encourage further use with caution and a complete understanding of what the data represent.

Burned Area Essential Climate Variable (BAECV)

The Burned Area Essential Climate Variable (BAECV) products are a recent product suite developed and validated by the USGS (Hawbaker *et al.* 2017) that show promise for identifying geospatial extents of fires (Vanderhoof *et al.* 2017). This national product is independent of any type of fire reporting system. Hawbaker *et al.* (2017) document the methods used for automatic derivation of BAECV products using regression models and a combination of change detection algorithms, spectral indices, and reference conditions with LANDSAT imagery. The resultant probability surface and region growing tools can then be used to identify and delineate burned areas at a 30m pixel resolution for every LANDSAT image on record (*i.e.,* 1984-present), which is the longest consistent record of burned area information available. Vanderhoof *et al.* (2017) evaluated the BAECV products against known datasets (*e.g.,* MTBS) and against finer-resolution sensors (*e.g.,* QuickBird) with satisfactory results that suggest that the products would be suitable for use in this project.

It is possible that BAECV products can provide additional/unknown burn locations and extents within Florida, including smaller fires or those not recorded in other national datasets. For example, fires smaller than a national standard (*e.g*., the 500ac used by MTBS in the southeastern US), or fires in those areas where reporting is not required (*e.g.,* on private property) may be detected in a standardized fashion. Given that more than a million acres of prescribed fire alone burn across the state annually, but many of these fires are difficult to detect post-fire using traditional burn scar mapping protocols, it seems that the BAECV methods could be used to locate burned areas in an automated and systematic way. Currently, using BAECV products, one can identify locations (at a 30m pixel level) that have burned using the probability associated with the pixel having burned (burn probability; BP) and also derive the date the burn was first detected by satellite sensors (burn date; BD). These products have been used to identify fires as small as 10 acres, and we are assessing the ability to detect down to approximately 2.5 acres.

We have acquired an updated version of BAECV-derived products from our USGS partners for the period 2006-2018 for Florida. As mentioned previously, these data may not encompass all fires, but hold promise in terms of identifying fire extents in locations where mapped fires do not currently exist. We have imported data derived from the BAECV datasets into the database, and describe the methods for deriving database-ready products in the following section.

The USGS provided the BAECV data in the Analysis Ready Data (ARD) Tile format, a top-level product meant for analyzing time-series data that are terrain corrected and have known data quality. The state of Florida occupies portions of 20 ARD Tiles (Figure 2). For this project, the various datasets for each BAECV product are represented individually within an ARD tile.

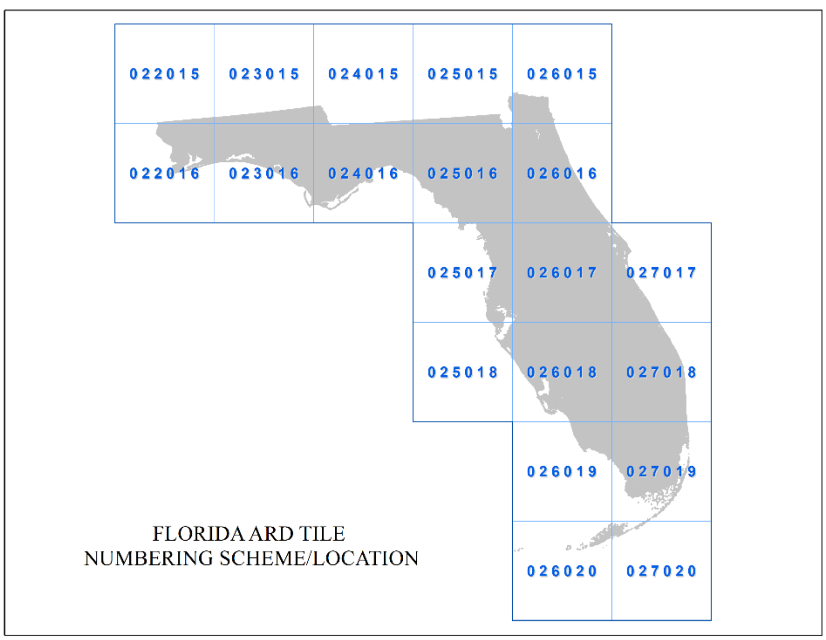

Figure 2: Analysis Ready Data Tile numbering scheme and location; as of this writing, the Florida Keys tiles (*i.e.,* the southernmost tiles, 026020 and 027020) have just become available to us and processing is in progress. The data will be updated as the processing is completed.

We evaluated the *annual* BAECV Burn Probability (BP) datasets –which are raster datasets – for evidence of burns. The annual datasets span an entire calendar year (*e.g.,* Jan 1 through Dec 31) and indicate the maximum BP within the year; the exact same products exist for each individual scene within a year, but it can be difficult to resolve/refine information for the purposes of this project at this temporal scale. Therefore, we chose to analyze the annual products for this Deliverable, but we developed the methods to be scalable for any BAECV product (*i.e.,* individual scenes or composites covering specific timeframes).

For each year between 2006 and 2018, we combined the annual datasets of interest within individual ARD Tiles into a single annual raster dataset (*i.e.,* we mosaicked the tiles) for further processing (Figure 3). We performed all additional processing steps on the annual mosaicked datasets as this provided statewide consistency. We identified pixels as burned or unburned according to their probability value; initially, we retained all pixels with an annual BP between 85-100% based on Hawbaker *et al* (2017). Burn Probability values between 90-100% were then converted to presence/absence rasters and we used image processing methods to remove 'speckling' (*e.g.,* fill in small holes within a burned area and remove groups of pixels less than a specified size/amount). This process resulted in annual rasters and vectors indicating burn presence (with 90-100% probability) for groups of pixels greater than ~2.24 acres (*e.g.,* 10 contiguous 30m pixels, in any arrangement). Appendix A highlights examples of these metrics mapped across the state. The associated burn dates for these same areas were also derived; the date of the first scene where a pixel was identified as having burned within a calendar year was recorded to the pixel and saved to an annual Burn Date (BD) raster for use in seasonality metrics. The newly created datasets were then evaluated to begin the process of determining fire regime characteristics such as number of times burned and year last burned (for the period between 2006 and 2018). These metrics are included in the final spatial database, and meet the needs of another grant (SWG) deliverable as well.

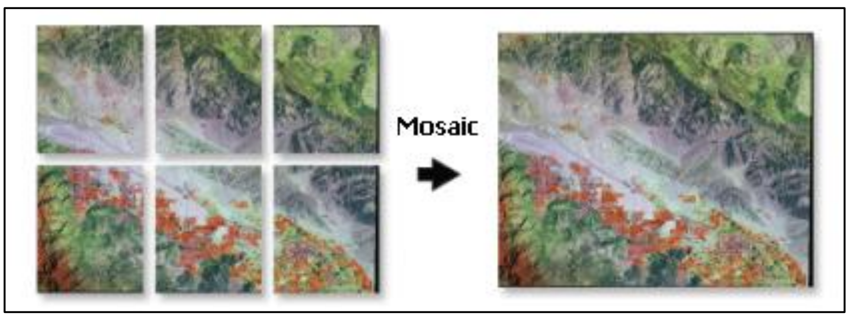

Figure 3: Example illustrating the results of combining multiple raster datasets into a single dataset using the *mosaic* method.

We initially evaluated the satellite-based products against fire records provided by managers at the three pilot areas (Eglin AFB, Apalachicola NF, and Big Cypress National Preserve; see Deliverable 5.1). These three sites have large-scale prescribed fire programs, fire-dependent ecosystems, and records of known fire locations.

For each area, we held a meeting with fire managers, either in person or via web conferencing methods. We provided a quick background of the project, and explained the process we used to derive the BAECV BP-based fire information. We then invited managers to inspect the data with us to evaluate their thoughts on the products. In our evaluation meetings, the fire managers from the three pilot areas acknowledged that cloudiness/green-up/low intensity fire issues could possibly explain "missing" fires (*i.e.,* locations where the annual BP data are not capturing burn extents very well) on their lands. Through this process, managers provided many other explanations for why no burn was detected and where/why fire detection was performing very well, as well as some ideas and suggestions for moving forward (all of which we relayed to USGS).

Many of these comments reflect known limitations previously documented (see Deliverable 4; Hawbaker *et al.* 2017). For Example, in Florida there exist many small, rapidly burning, low-intensity fires (often under a tree canopy), frequent cloud cover, and rapid green-up following fires. The detections of any satellite sensor used for imaging or detecting fires requires a cloud-free sky at the time of satellite overpass. When using satellite imagery to derive information about fire extents, post-fire images occurring on cloudy days may not be suitable for deriving burned area, and low-intensity fires beneath a tree canopy may not be detectable. However, satellite-based datasets (and their derivatives) are promising since it is possible to extract fire extent information across large regional areas in a standardized replicable way, which makes it possible to process data from sensors in a consistent manner for comparing to known fire locations. Because of the longevity of many of the current satellite sensors and products that we evaluated, there is an abundance of scientific literature describing the known limitations, assumptions, and utility of different datasets for fire detections and burn scar mapping.

Appendix B provides summary notes on findings from each of the three meetings. Overall, managers received the products well, and their comments will be useful in guiding further refinements and protocols into the future. Furthermore, these meetings illustrate that it is imperative to regularly hold 'stakeholder' meetings or workshops with the folks who have provided the data to help us better understand where these products are doing well "as is" and where we might want to apply some different thresholds to set up baseline protocols for locations moving forward. For example, after consultation with BICY fire management staff, we explored re-thresholding the BP products down to 70% in certain land cover classes to determine if we were able to capture burned areas better. While this lower threshold seemed to help with a select few recent fires, it did not consistently help overall, so we stuck with the 90%BP products statewide. However, we can test other options and methods with the datasets we have, and we are working with USGS on additional avenues to explore for better mapping in these areas/ecosystems.

Once managers at the three pilot areas evaluated the datasets and data derivations against their institutional knowledge and fire records, we finalized the datasets and uploaded them into the database. We updated and simplified the original DoD-based SQL database based on needs identified by FWC partners in meetings leading up to and subsequent to Deliverable 4. We have populated it with 10+ years of fire data for the state of Florida; it can be queried to identify burn locations (as identified by FFS OBA permit [Deliverable 2, 3.1, and 3.2], agency-provided datasets [Deliverable 4], and by annual burn probability [Deliverable 5.1]), by seasonality, year, ownership, and/or by Cooperative Land Cover classes. Current datasets in the database include FFS OBA permit data, annual BD- and BP-based burned area polygons, landowner, species models, and landcover classification rasters/polygons. We will continuously update the datasets in the database throughout the life of the project based on conversations with FWC partners to provide for their needs and requirements.

Fire Metrics

Once the Annual Mosaic Burn Area Data were processed, fire history and seasonality metrics were determined. The metrics are defined in Appendix C and the derivations are detailed in Appendix D. For this project, we are interested in where and when fires have burned in the state between 2006 and 2018. Ultimately, the particular timing of the fires is important to assess things like effects due to seasonality and sub-annual burn characterizations; however, in the interest of timeliness for this project, we determined that an annual starting point was acceptable, and we are currently able to loosely associate time of year and seasonality based on satellite data timestamps in annual BD-based products. The methodologies described here for deriving the datasets are scalable and can be applied at the individual scene level as well as user-defined annual or seasonal composites. A complete 'User Guide' and 'Update Guide' (both in 'draft' form) are included in Appendices D and E.

Based on discussions with FWCC partners, we derived the following fire and seasonality metrics using the annual BP-based and BD-based burned area raster and polygon products:

- Fire Frequency (Number of Times Burned)
- Year Last Burned
- Time Since Previous Fire
- Longest Fire Free Interval
- Time of Year (Spring, Summer, etc.)
- Seasonality (Growing and Dormant)

These fire regime characteristics are important for managers in Florida, as they can inform planning and conservation efforts. Since they are in a spatial format, we have the ability to focus our efforts and identify where successes and/or issues may be located on the landscape. Because the data have a temporal component, we are also able to identify these locations and evaluate them at different times of the year as well as through the years. The information gathered from this process can further our understanding of the use of fire – or lack thereof – on the landscape through space and time for different purposes. The definitions used in the project for individual fire and seasonality metrics are listed here.

Fire Frequency refers to the number of times a specific location has burned in the period of record (or for a given period of interest if a subset of total fire record). In a raster dataset, fire frequency is calculated at a pixel level; in a vector dataset, it is calculated at the geometric intersection where more than one polygon overlap. Either way, the burned area is categorically differentiated from the unburned area, and the total number of occurrences is 'summed' over a pixel or common area through time. This value cannot be greater than the number of years in the fire history record.

***Year Last Burned* (YLB)** is the year of the last detected fire in a location; it corresponds with the Time Since Previous Fire. For the purposes of this project, the four-digit year was used to designate this information (*i.e.,* YLB=2008). This value cannot be outside the range of years in the fire history record.

Time Since Previous Fire (or Time Since Last Fire; TSPF or TSLF) is the measure of time from a specific date back in time to the last date of a detected or known fire. Units can be months, days, or years. In the database, since we used annual burned areas to populate the database, it is reported as the number of years from "present" to the last identifiable burn (i.e., where "present" would be 2008 for a dataset current through 2007, or 2017 for a dataset current through 2016). This value cannot be greater than the number of years in the fire history record.

Fire Free Interval (FFI) is the period between two consecutive fires in a given location. In places where more than two fires have burned throughout time, the longest (LFFI; or shortest [SFFI]) fire free intervals are calculated as the maximum (or minimum) period between two consecutive fires at a given location within the time period. The term *Fire Return Interval* is often used interchangeably in the southeast with this term. However, the time between fires in a defined area is not specifically the same as the FRI, which is defined as the time period (T) divided by the number of fire occurrences plus 1 (i.e., T / [FRQ+1], Safford et al. [2014]; which more closely represents the average number of years between fires in a given time period).

Time of Year refers to the loose grouping of months into the four seasons; Spring; Summer; Fall; and Winter. The first date of detection of high probability fire pixels was recorded in the BAECV Burn Date (BD) products as a Day of Year value. We used this date to categorize Time of Year into the four seasons. We recognize that there is a lag associated with Landsat-based detection data (on the order of 2 weeks), so a burn could have occurred in the end of May but not been detected until June thereby skewing Time of Year categories. Additionally, we understand the potential limitations of the ability to detect fires in a timely manner given the characteristics described previously (*e.g.,* small, rapidly burning, low-intensity fires, frequent cloud cover, and rapid green-up following fires). However, in the absence of correctly located permit data, this is the finest level of temporal detail for a surrogate that we could determine with these datasets.

Seasonality refers to whether the burn occurred during growing season (March 15 - October 14) or dormant season (October 15 – March 14). Again, these classes are based on the BD product, and thus may be skewed in the October and March time frames due to limitations described above. Additionally, seasonality varies for individual years (*i.e.,* 2019 growing season started ~2 weeks earlier than 'normal'), and this is not reflected currently in the database as seasonality is not a constant across the state or through the years. Moving forward, this can be entered specifically for a given area/statewide, or re-entered with input from subject matter experts/local knowledge for individual years/locations.

Table 1: Rules for deriving and attributing seasonality and time of year from the annual Burn Date (BD) datasets.

Time Of Year	***Months***	***GRIDCODE (Day Of Year)***
Spring	Mar/Apr/May	>=60 & <152
Summer	Jun/Jul/Aug	>=152 & <244
Fall	Sep/Oct/Nov	>=244 & <335
Winter	Dec/Jan/Feb	>=335 or >=1 & <60
Dorm/Grow	***Dates***	***GRIDCODE (Day Of Year)***
Growing	March 15 – October 14	>=74 & <=288
Dormant	October 15 - December 31 and January 1 - March 14	>288 or <74

While the BAECV-based data are quite useful, the way we have portrayed the products in this database are based on a calendar year as mentioned before. Therefore, in terms of number of fires, if a pixel burns more than one time within a calendar year it is only counted one time. Additionally, values for time since previous fire are reported at an annual level, even if they may have actually been less than 12 months apart. Finally, while the project requirements only stipulated data for 2006-2016, we have included 2017 and 2018 in the dataset, so that this can be considered current for the last 13 years.

Deliverable #7: Recommendations

For the previous Deliverables, we explored various fire datasets for populating a spatial database. We expanded upon earlier work by comparing spatial footprints of fires derived from the satellite-based BAECV product (Hawbaker *et al.* 2017) against known locations of fires in three pilot areas. We selected the pilot areas based on having known fire location data, having large-scale prescribed fire programs, and having fire-maintained systems where species of greatest conservation need occur (to coincide with another project funded through a FWC State Wildlife Grant). A series of data derivation methods and protocols resulted in annual fire datasets that we evaluated with managers. Based on their recommendations and suggestions, we have extended this work to encompass the entire state of Florida. The 90-100%BP burned area footprints may under-predict fire in some instances; however, we feel that this is a step forward from the FFS permit point data for identifying fire location/extent in a spatial manner, and are continuing efforts to improve datasets and methodologies.

As noted previously, we continue to recommend that a standardized statewide data call with specific reporting requirements be developed and utilized to acquire individual landowner-based fire data. In this deliverable, we additionally recommend a follow-up meeting with landowners who provide their fire data once the BAECV-based products exist for their land. This meeting serves multiple purposes; it allows us to understand the data they provided better, and it allows us to provide background information to the landowners on the BAECV data and product derivation. The managers then provide feedback on where the data products are capturing fire extent in an acceptable fashion and why. The managers can additionally isolate locations/types of fires/seasonal characteristics, which may cause data products to over/underperform, and it provides opportunities for them to help identify potential solutions. Having landowner buy-in is imperative for the success of these types of projects.

Appendix B shows a complete list of comments and recommendations from the three pilot areas. Common to managers from all three areas was the notion that, overall, these annually-based datasets are doing an acceptable job of capturing actual fire footprints within areas where fire has been applied. However, the BAECV products' ability to identify these locations differs. Managers noted that in the Panhandle (*e.g.,* Eglin AFB and Apalachicola National Forest), the burns that were less likely to be captured in the annual 90-100% BP range had well-documented characteristics. For example:

- They occurred in grass-dominated locations;
- The actual fire did not burn very hot and did not alter canopy characteristics;
- The fire was at the end of prescribed fire season and beginning of wildfire season, where days are typically more often cloudy than clear at the time of sensor overpasses;
- Fires were set in units that did not have much fuel to begin with, so detection is normally difficult;
- Fires followed thinning or chemical treatments; and
- Fire was at the end of the calendar year so was perhaps captured in the following year's data.

In southern Florida (*e.g.,* Big Cypress and Everglades), while many of the same characteristics were noted, managers also suggested that lowering the BP threshold from 90% to somewhere in the range of 70-80% might produce better results in the ecosystems prevalent in that part of Florida. We considered those suggestions and evaluated protocols to determine when and where thresholding is appropriate, although were unable to improve detection. Currently this is a workshop topic to address with a larger audience to help us decide options. The data presently uploaded in the database captures 90-100% BP and the burn dates associated with those detected locations.

The final SQL database contains fire datasets derived using the BAECV-based products, as well as other ancillary datasets (*i.e.,* species occurrence data, FFS OBA data, ownership and landcover data). Spatial and tabular queries are possible with the database. We presented this database, and all phases of its development – including examples of tools, queries, reports, etc. – at a workshop at the end of March. To address the challenge of understanding spatial characteristics of burns and reconstructing burn histories, we discussed continued use of the BAECV dataset developed by Hawbaker *et al.* (2017), data derived in-house using the fire mapping tools for smaller fires, and known fire perimeters for all areas statewide at our workshop. It is our hope with the workshop that we gain some insight and feedback on the final products and their intended uses, which we can address and incorporate into a final, comprehensive user guide and update protocol.

Next Steps

The next steps for the project include compiling information from the workshop, providing recommendations, and determining potential next steps (project extensions, database hosting, etc.), as well as the final versions of the User Guide and Update Methods. We expect that feedback from the workshop will include additional information related to end-user needs, including:

- How to update and refine methods based on manager inputs and how to apply them locally/regionally/statewide to identify fire locations;
- How to analyze fire regime characteristics and trends statewide;
- Developing procedures for annual updates moving forward;
- Compiling recommendations for current (and future/extended) uses of the database.

Further work may include testing outputs of new algorithms for BAECV-derived products in the southeast; adding supplementary datasets derived from other satellite sensors (*e.g.,* Sentinel 2A); extending the products in the database back through the LANDSAT record and updating through the current year (*i.e.,* 1984 through 2018); and hosting the database. Additionally, we may create additional data-based queries in the SQL geodatabase to derive fire regime characteristics for this and other projects we are currently completing. The final project result will be spatial information in the form of fire perimeters for the period 2006 – 2018, including queries, reports, and metadata.

Deliverable #7: Summary

The overall aim of the *Mapping Fires Across Florida* project is to develop a spatial database of prescribed fire extents in Florida with querying and reporting capabilities. The fires in this spatial database will range from less than ten acres to greater than 100 acres. To recap accomplishments so far on this project:

- A Partner Workshop was held at Tall Timbers in September 2017 to introduce the project and get ideas from partners about specific interests and needs; Deliverable #1 is a summary document about the workshop.
- The exploratory data analysis performed for Deliverable #2 provided useful insights into the FFS OBA dataset, and its potential usefulness for assessing fire regime characteristics in the state of Florida.
- For Deliverable #3 we focused on converting the existing DoD database from Oracle to SQL Server and importing the FFS OBA data.
- In Deliverable #4, we explored multiple sources and types of fire extent information, including landowner-provided fire atlas datasets and satellite based detections and extent maps, and we reviewed literature about the sensors and datasets.
- Deliverable #5.1 of the *Mapping Fires Across Florida* project focused on assessing the utility of the satellite-based BAECV product suite for identification of the spatial extents of fires in three pilot areas within Florida: Big Cypress National Preserve, Eglin Air Force Base, and the Apalachicola National Forest.
- Deliverable #5.2 of the *Mapping Fires Across Florida* project focused on extending the methodology and products across the entire state.
- Deliverables #6 and #7 (this Deliverable) include information on developing queries, fire metrics, and a general user guide (draft), as well as maintenance and update procedures (draft) for moving forward.

We expanded the BAECV-based fire products across the state based on previous evaluations of the products and derivatives within three pilot areas and facilitated meetings with fire managers at those locations. The methods used to develop these nationally scoped datasets are replicable, and we showed that it is possible to adapt them regionally to map the spatial extent of a range of fire sizes in Florida with some level of confidence. In addition, many smaller fires are mapped (~2.5 ac) as part of the protocol we developed for deriving the BAECV-based fire products, which is of benefit in Florida where many small fires prevail and where habitat-based analyses for those species with the greatest conservation needs are involved. We have determined that the BAECV-based datasets are quite useful as a first step for understanding fire regime characteristics in a spatial manner across the landscape within Florida, in spite of the known/documented limitations. We provide evaluations and suggestions for moving forward with identifying the spatial extents at a statewide level.

We believe that the automated portion of developing datasets and generating fire extents and perimeters using BAECV methodology can be useful for updating these datasets in a consistent fashion moving forward. As mentioned in previous Deliverables, we are exploring additional options to enhance this ability. The FFS OBA, BAECV, and landowner data combined can help focus and locate areas that have burned in prescribed fires and clarify fire characteristics across the state, perhaps better than any particular dataset alone – especially if there were simple standardized tracking and reporting options required that did not burden landowners with extra work. The next steps for this database include finalizing the processing and uploading of additional datasets (e.g., additional years, metrics, and ancillary data), and final User Guide and Update Methods. In addition, we will consult with FWC on exactly what data to upload into the final SQL Server database as ancillary data for queries and analyses.

Acknowledgements

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Appendices

Appendix A: Original Fire Regime Derivatives (2006-2016)

The following pages contain examples of the fire extent and fire regime derivatives from the original USGS BAECV data completed for previous work in the three pilot areas, as well as for each FFS District. Any location identified in these maps can be considered to have burned at least once between 2006-2016 (with 90-100% probability of the detection being a burn). An annual raster dataset indicating presence/absence of burning, and an annual 'area burned' vector dataset, exist and are loaded in the database for the entire state. We have included these maps to highlight the utility of the BAECV-based datasets. These images are for illustrative purposes only. Further examples are available upon request. Final datasets in the SQL database will have the most up-to-date version of the BAECV data (and all products derived thereof) and can be utilized for more current and accurate mapping.

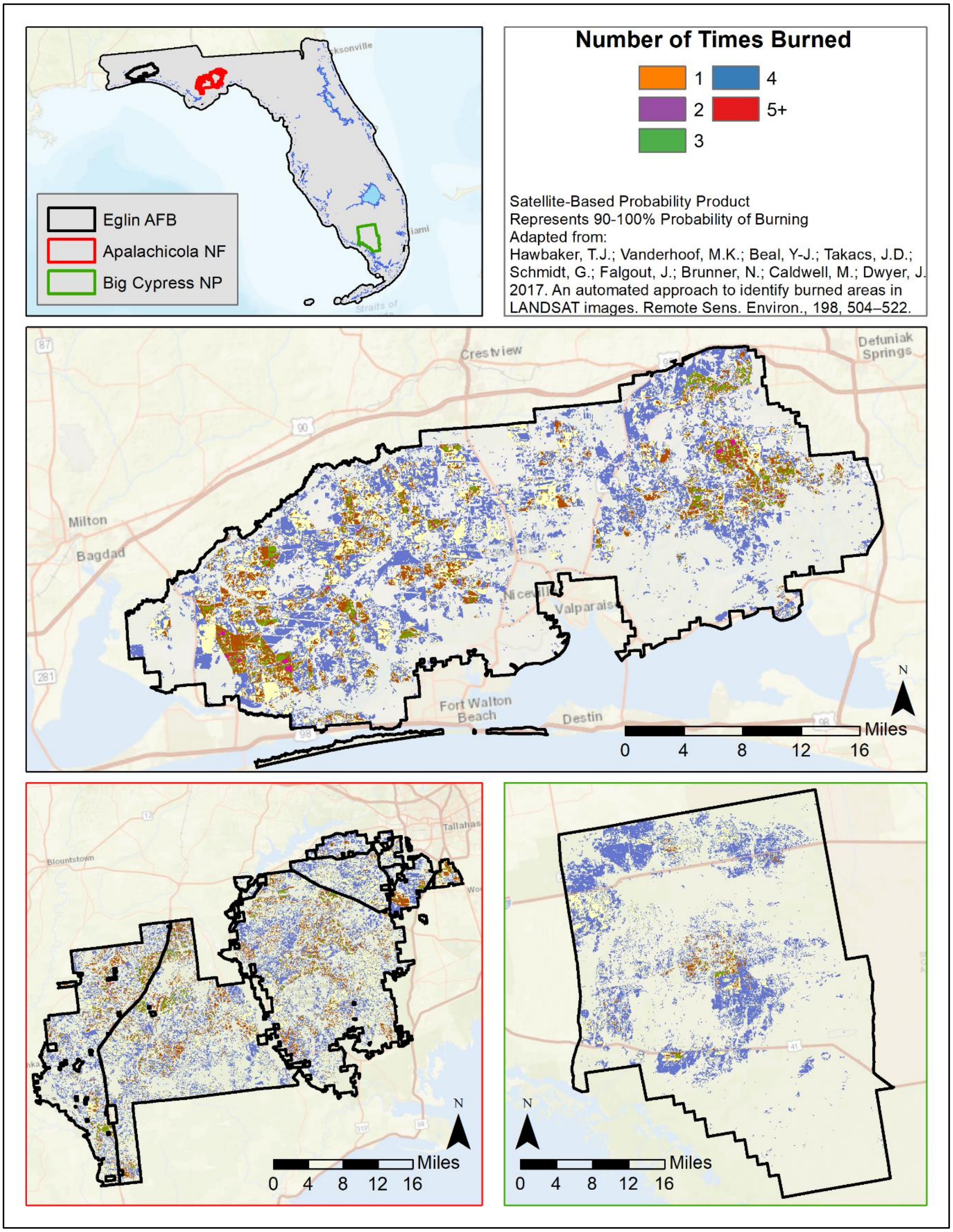


Figure A1: *Number of times burned between 2006 and 2016 in each of the three pilot areas based on annual composite 90-100% burn probability.*

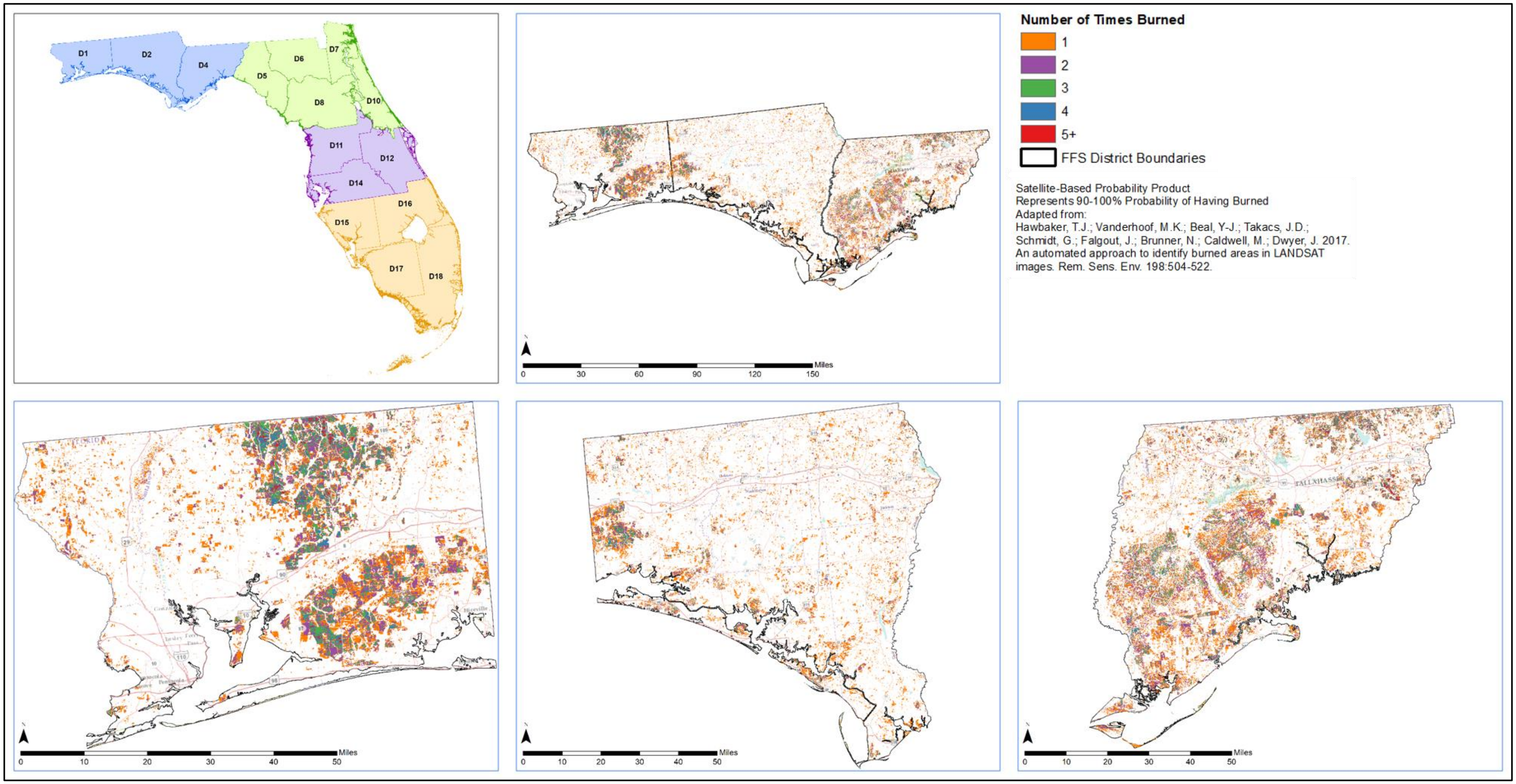


Figure A1.a: *Number of times burned between 2006 and 2016 based on annual composite 90-100% burn probability in FFS Districts 1-4.*

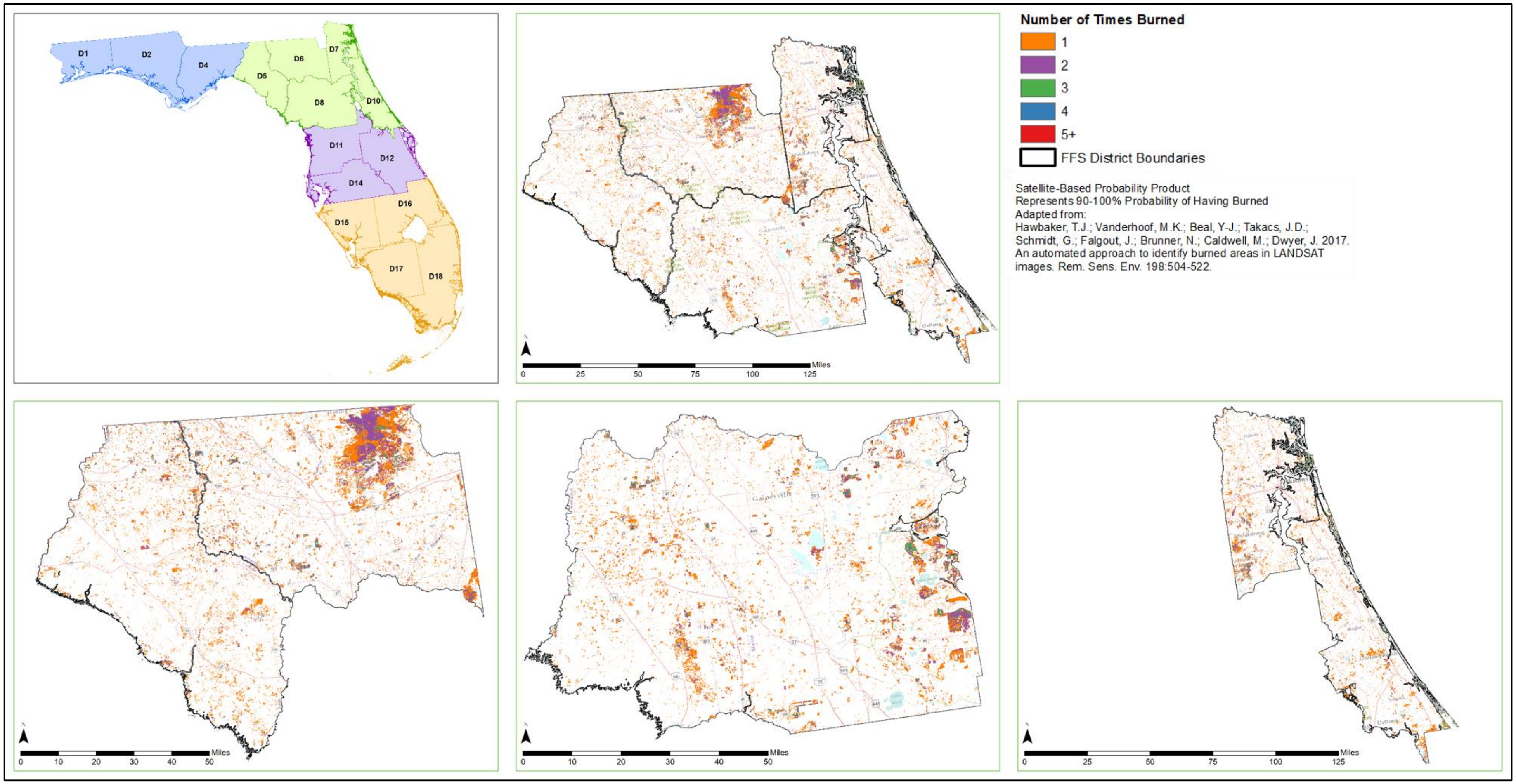


Figure A1.b: *Number of times burned between 2006 and 2016 based on annual composite 90-100% burn probability in FFS Districts 5-10.*

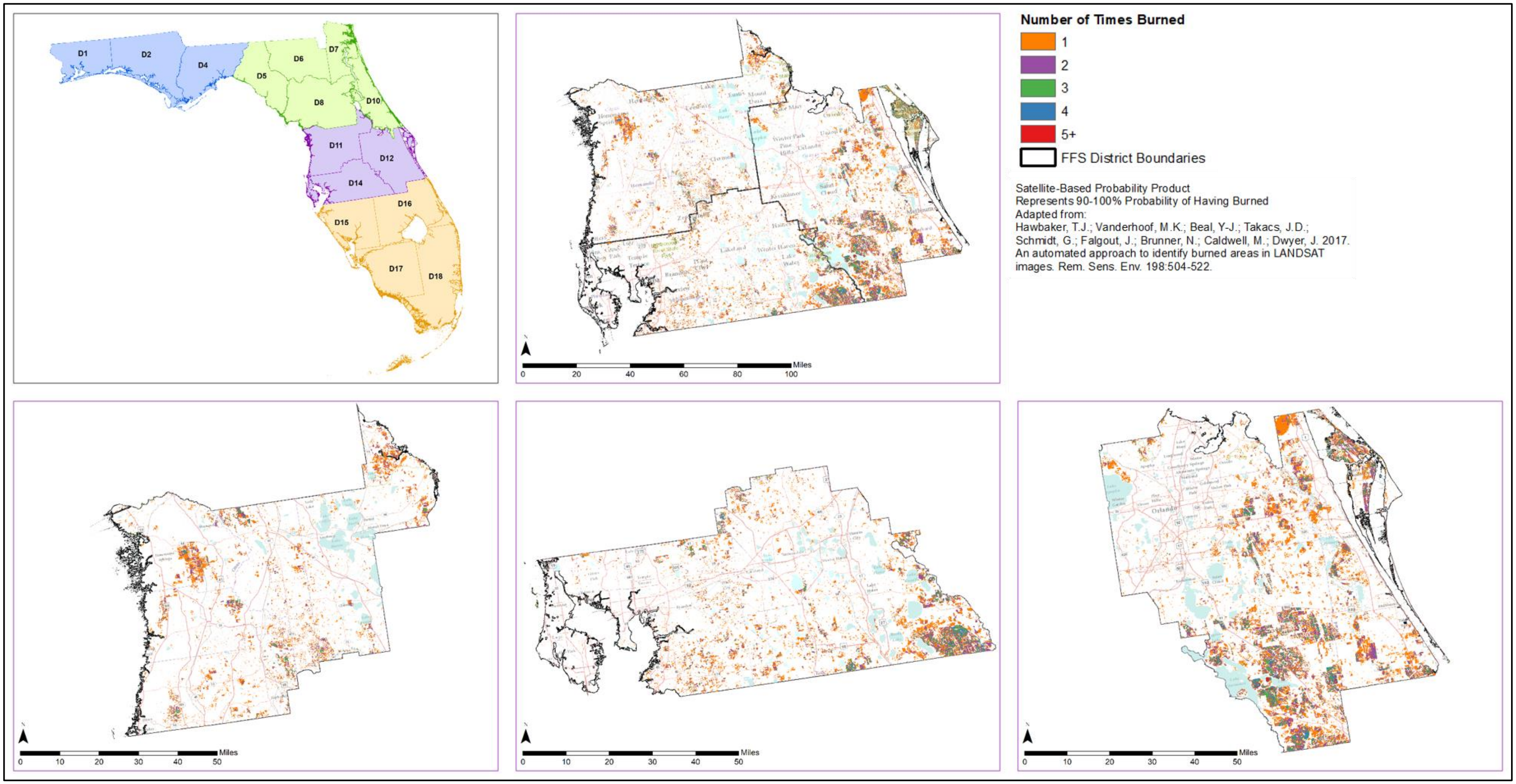


Figure A1.c: *Number of times burned between 2006 and 2016 based on annual composite 90-100% burn probability in FFS Districts 11-14.*

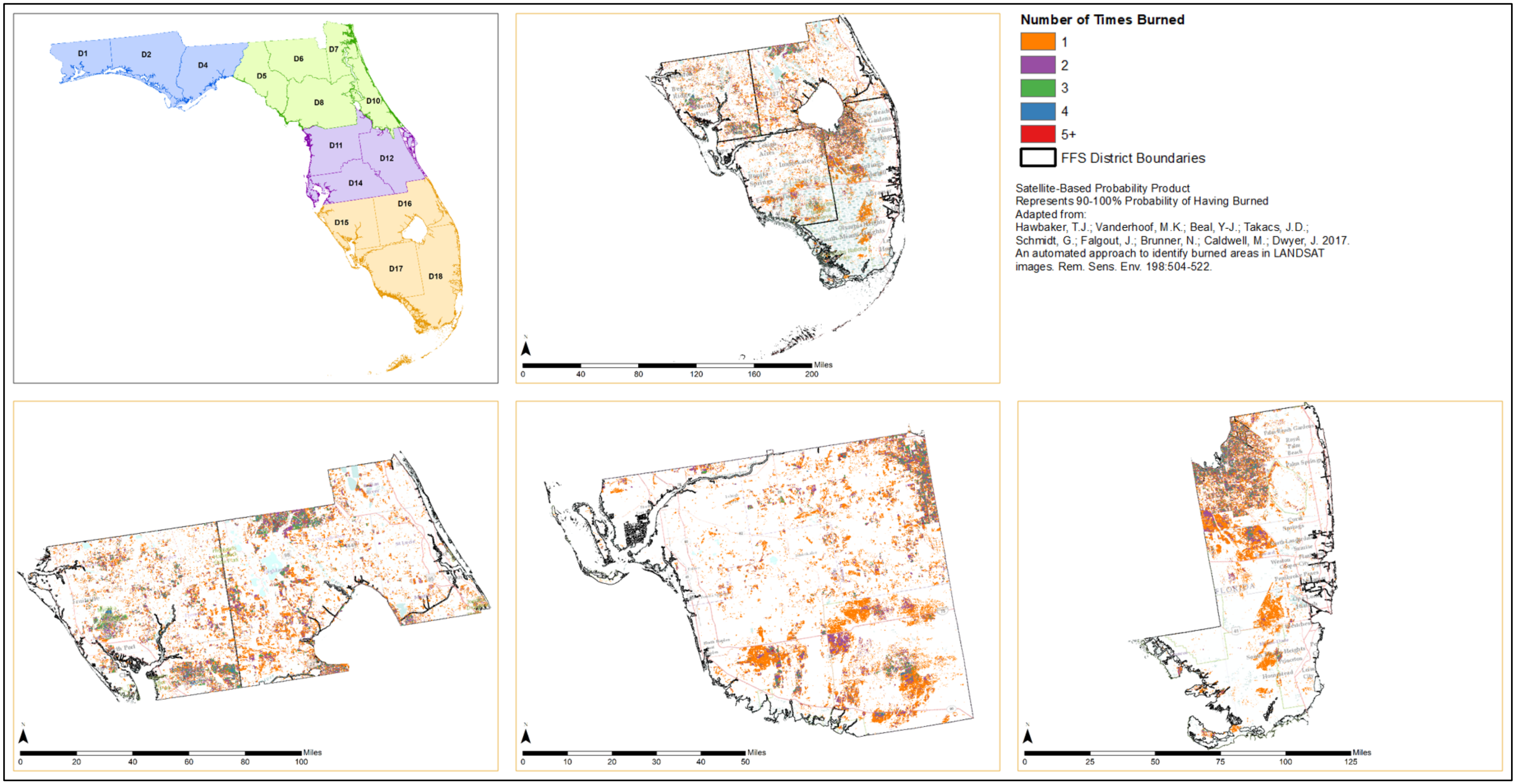


Figure A1.d: Number of times burned between 2006 and 2016 based on annual composite 90-100% burn probability in FFS Districts 15-18.

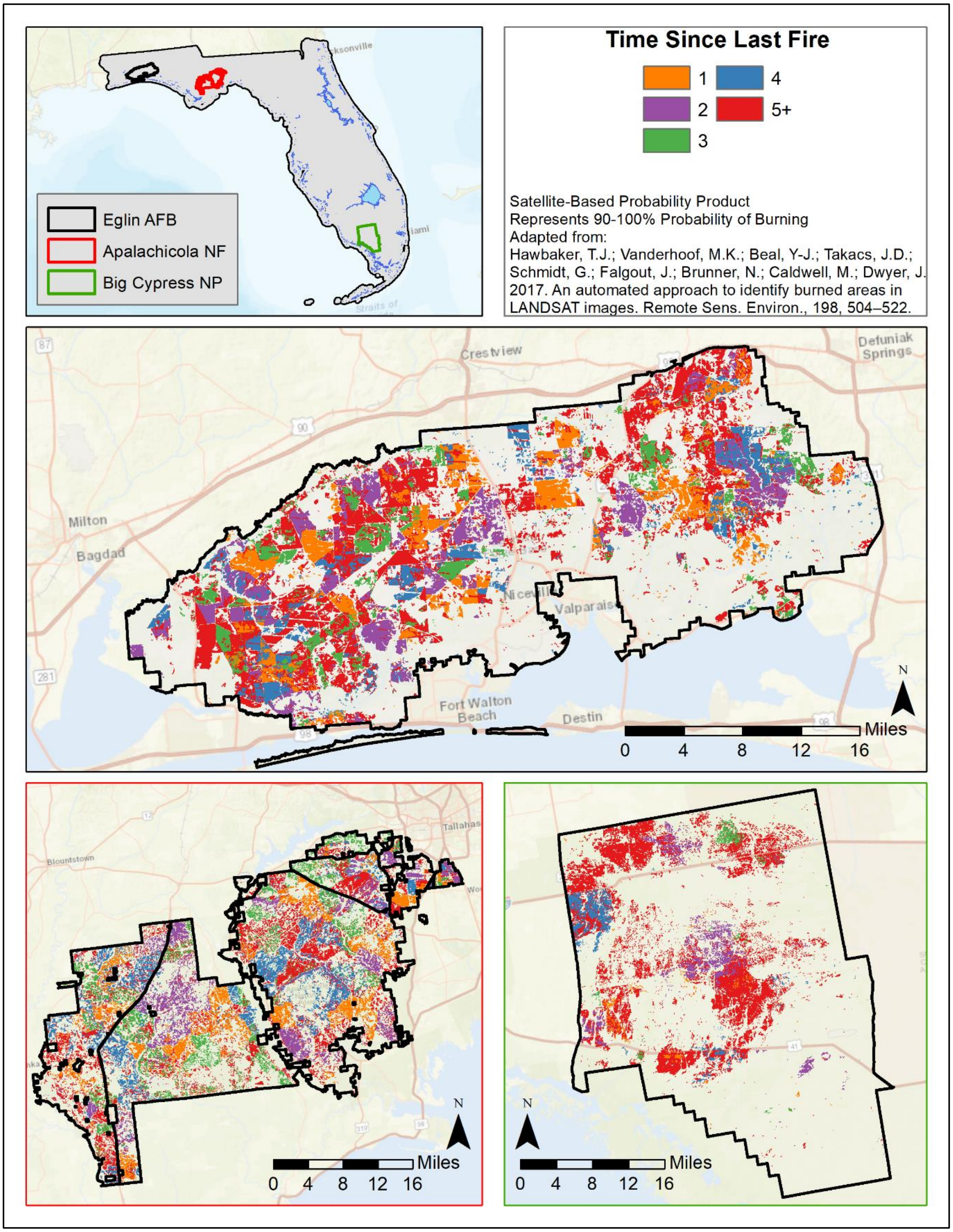


Figure A2: *Number of years since last fire (measured from 2017) in each of the three pilot areas for the time period 2006 - 2016 based on annual composite 90-100% burn probability.*

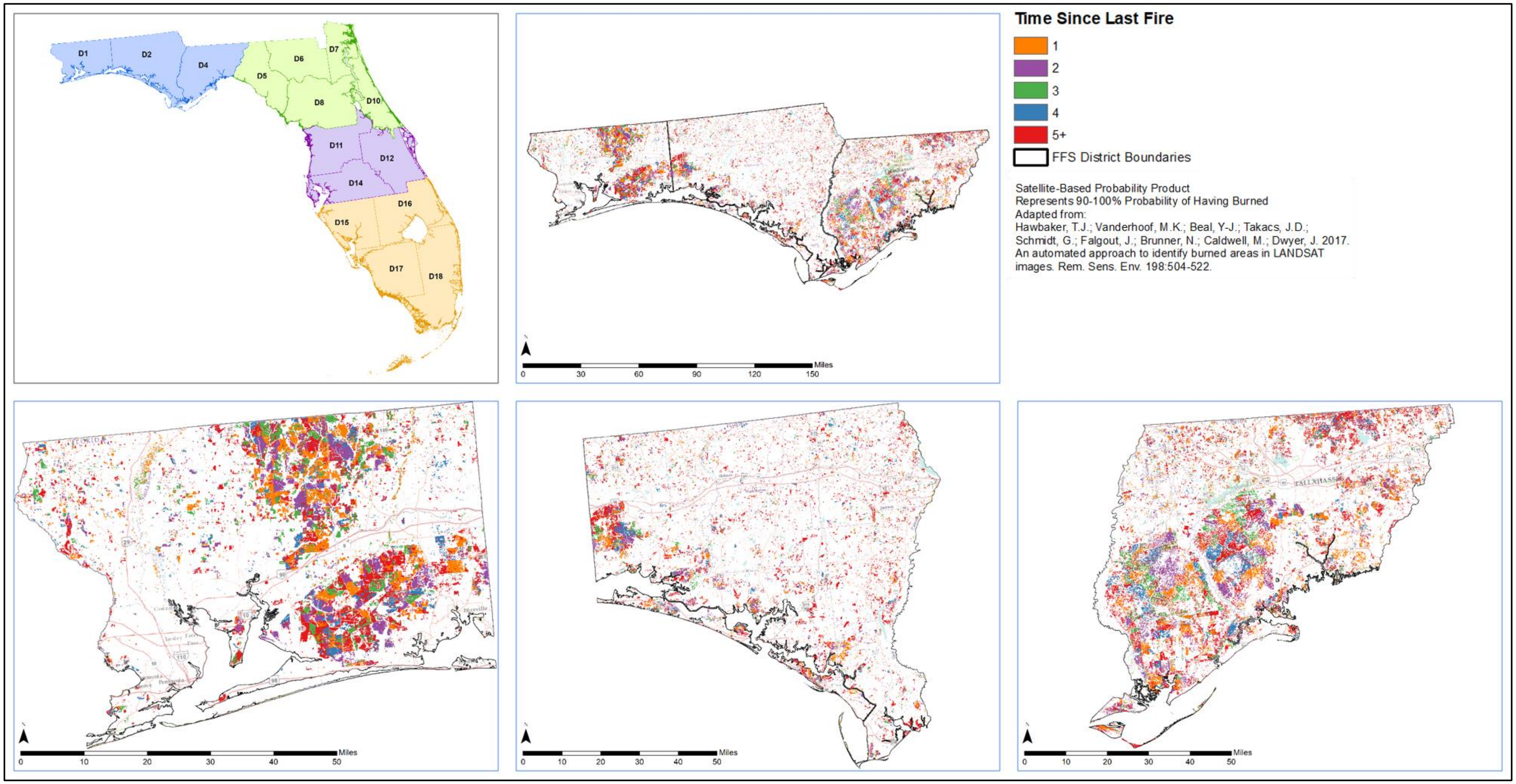


Figure A2.a: *Number of years since last fire (measured from 2017) for the time period 2006 - 2016 based on annual composite 90-100% burn probability, FFS Districts 1-4.*

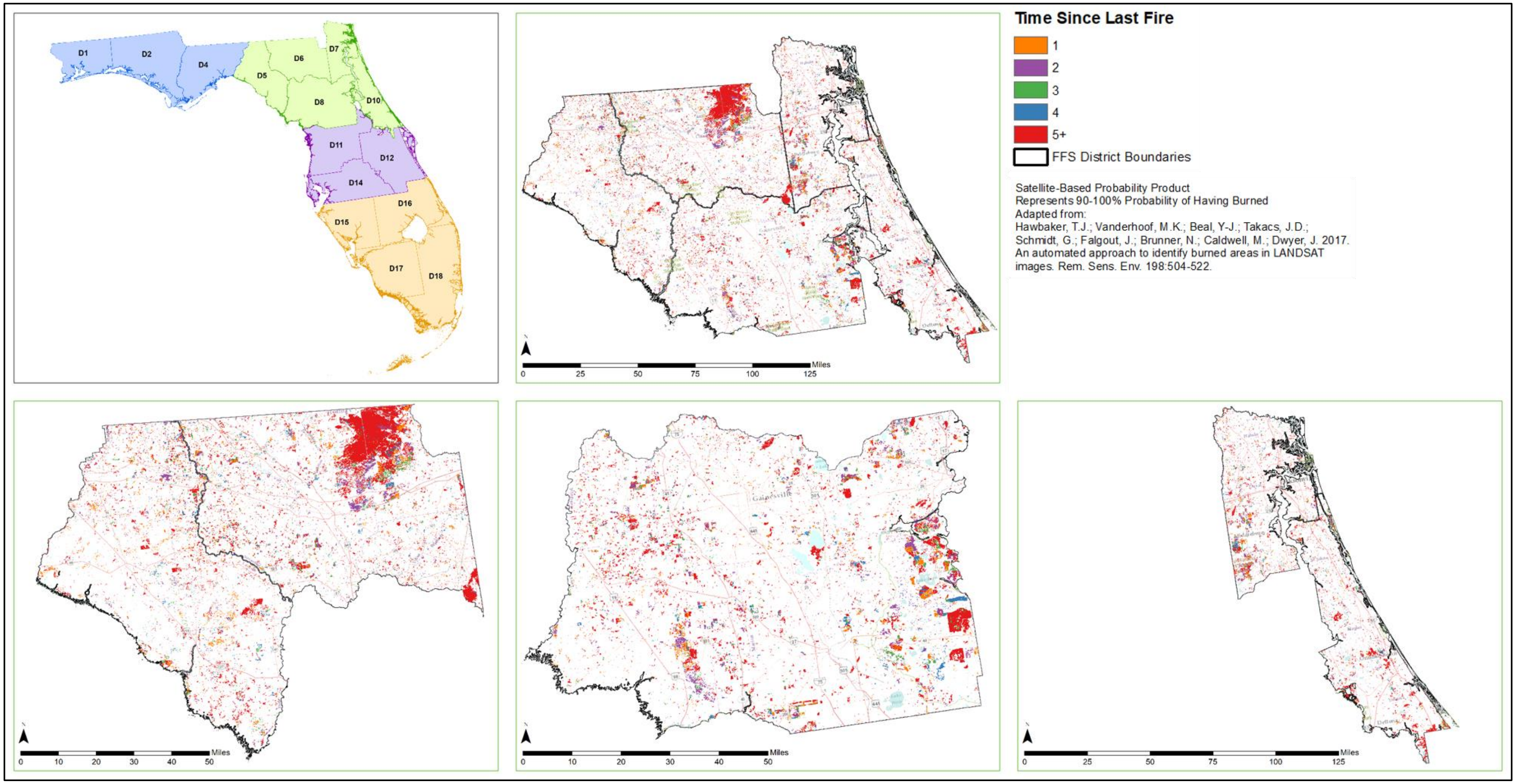


Figure A2.b: *Number of years since last fire (measured from 2017) for the time period 2006 - 2016 based on annual composite 90-100% burn probability, FFS Districts 5-10.*

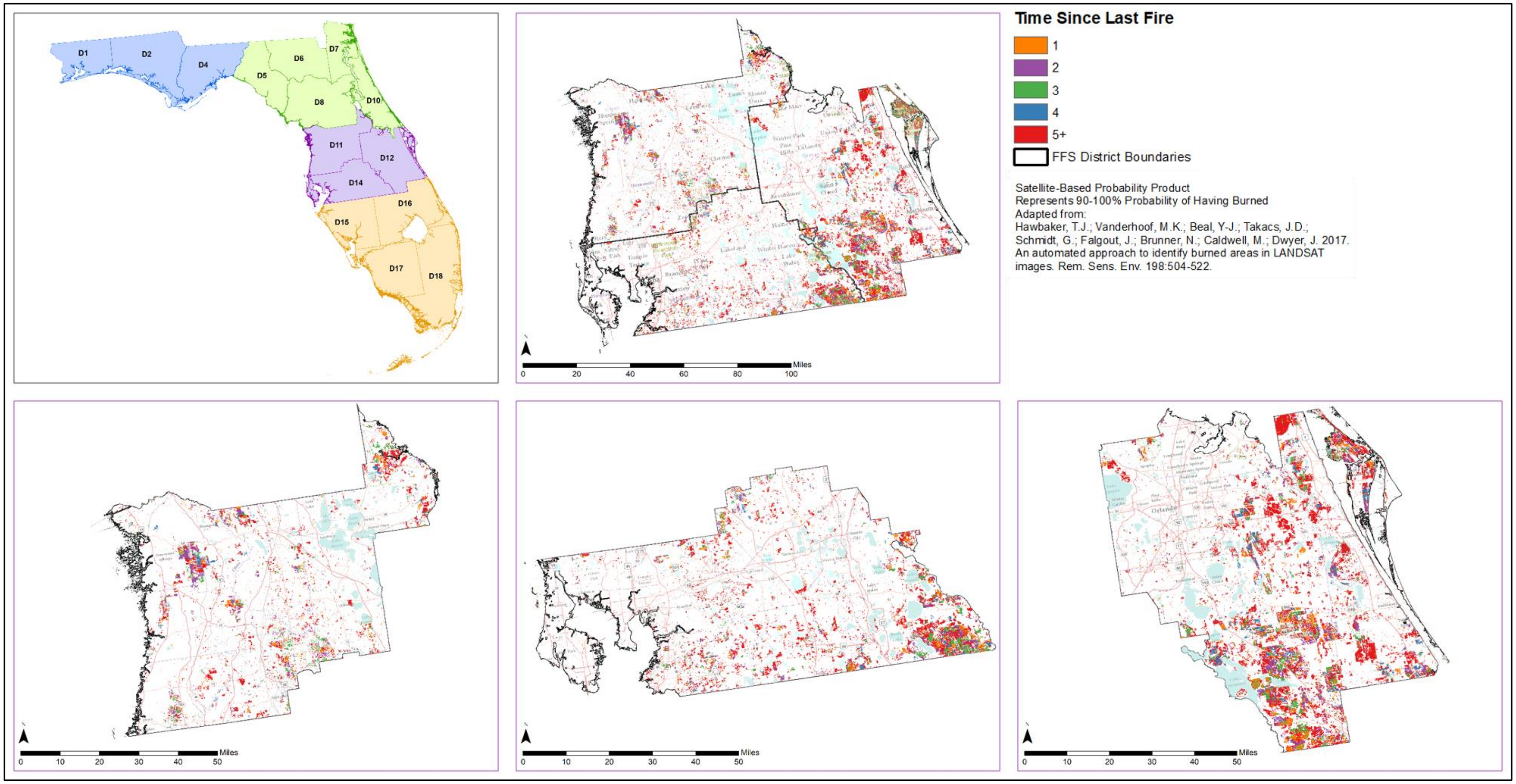


Figure A2.c: *Number of years since last fire (measured from 2017) for the time period 2006 - 2016 based on annual composite 90-100% burn probability, FFS Districts 11-14.*

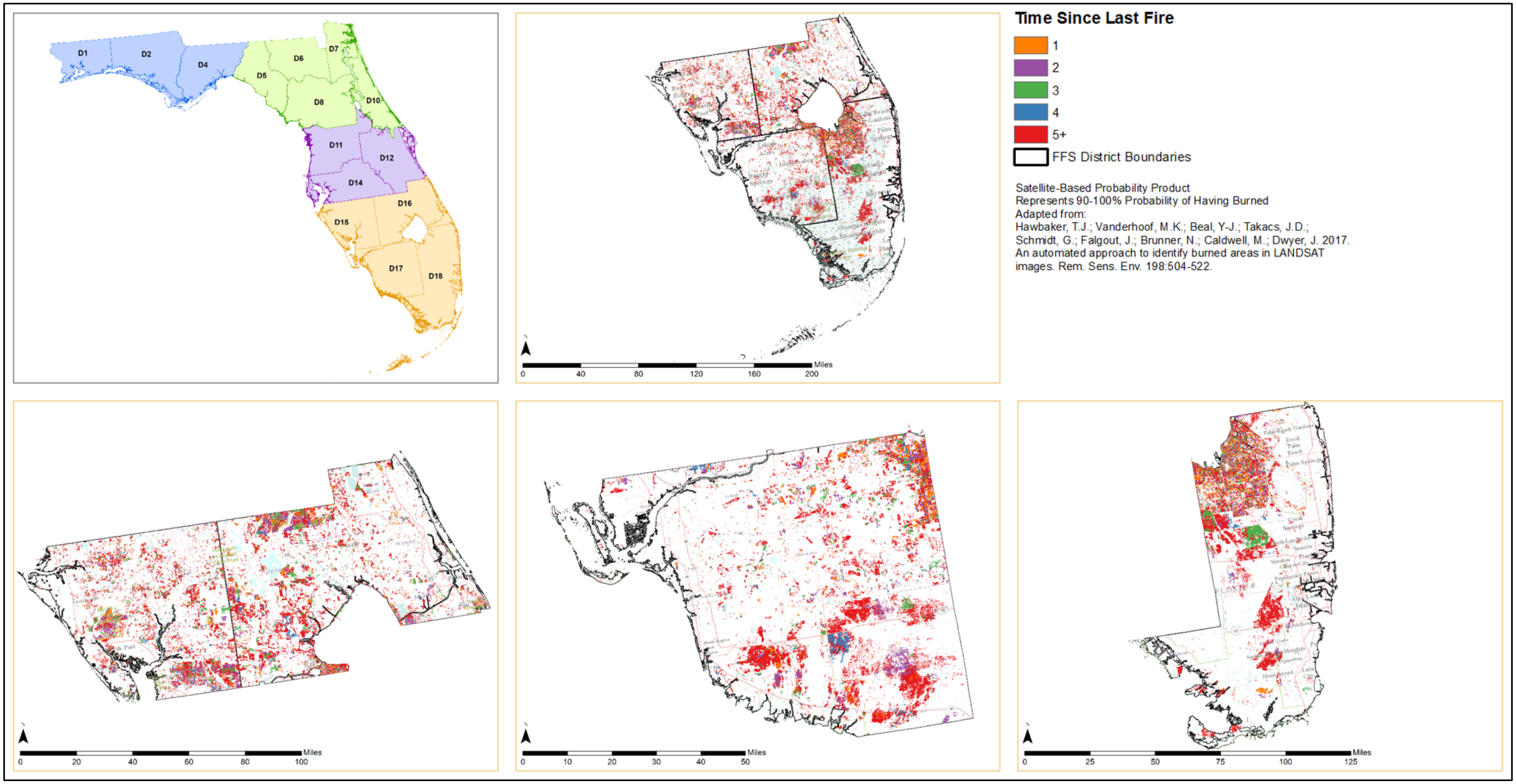


Figure A2.d: *Number of years since last fire (measured from 2017) for the time period 2006 - 2016 based on annual composite 90-100% burn probability, FFS Districts 15-18.*

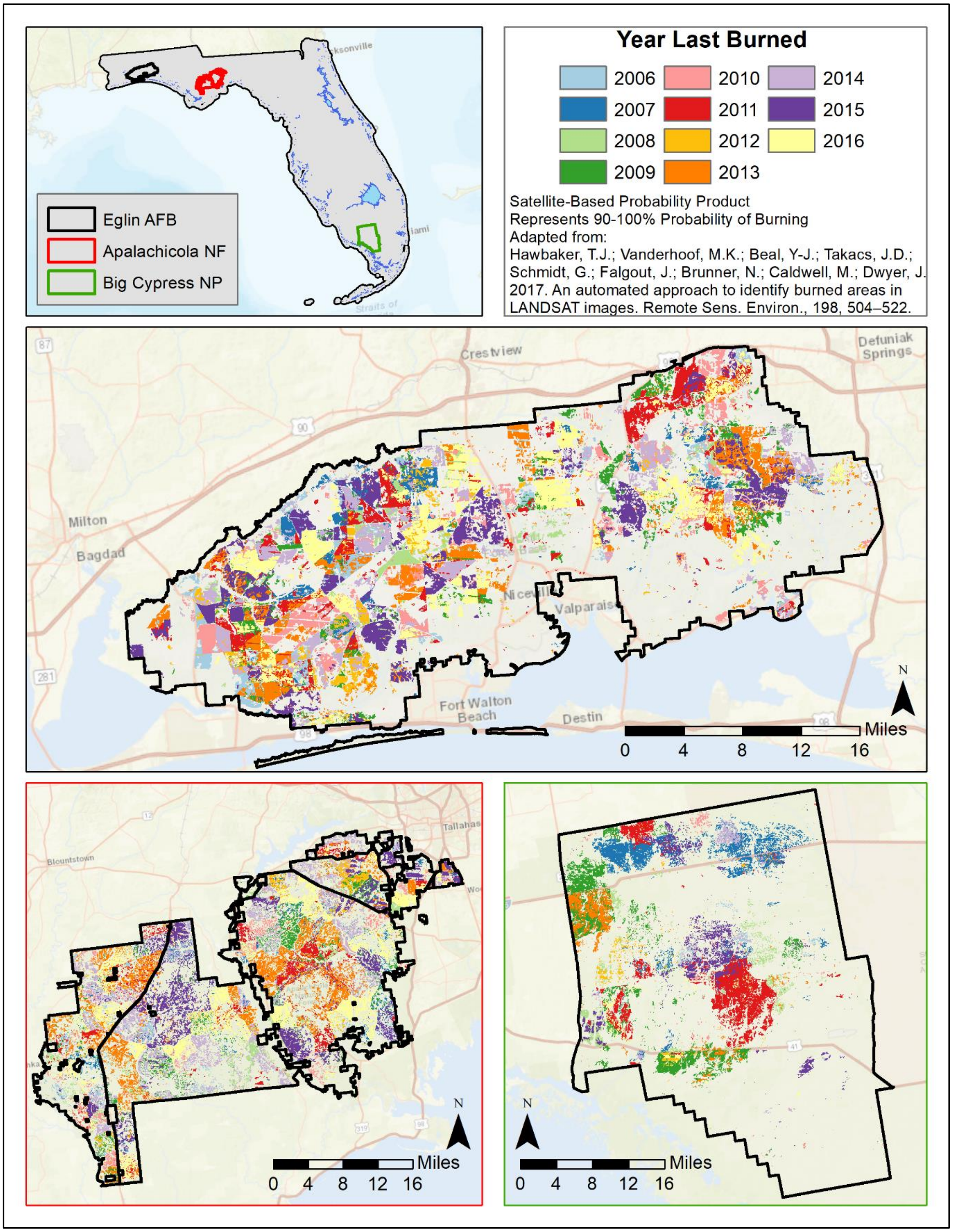


Figure A3: *Year most recently burned between 2006 and 2016 for each of the three pilot areas based on annual composite 90-100% burn probability.*

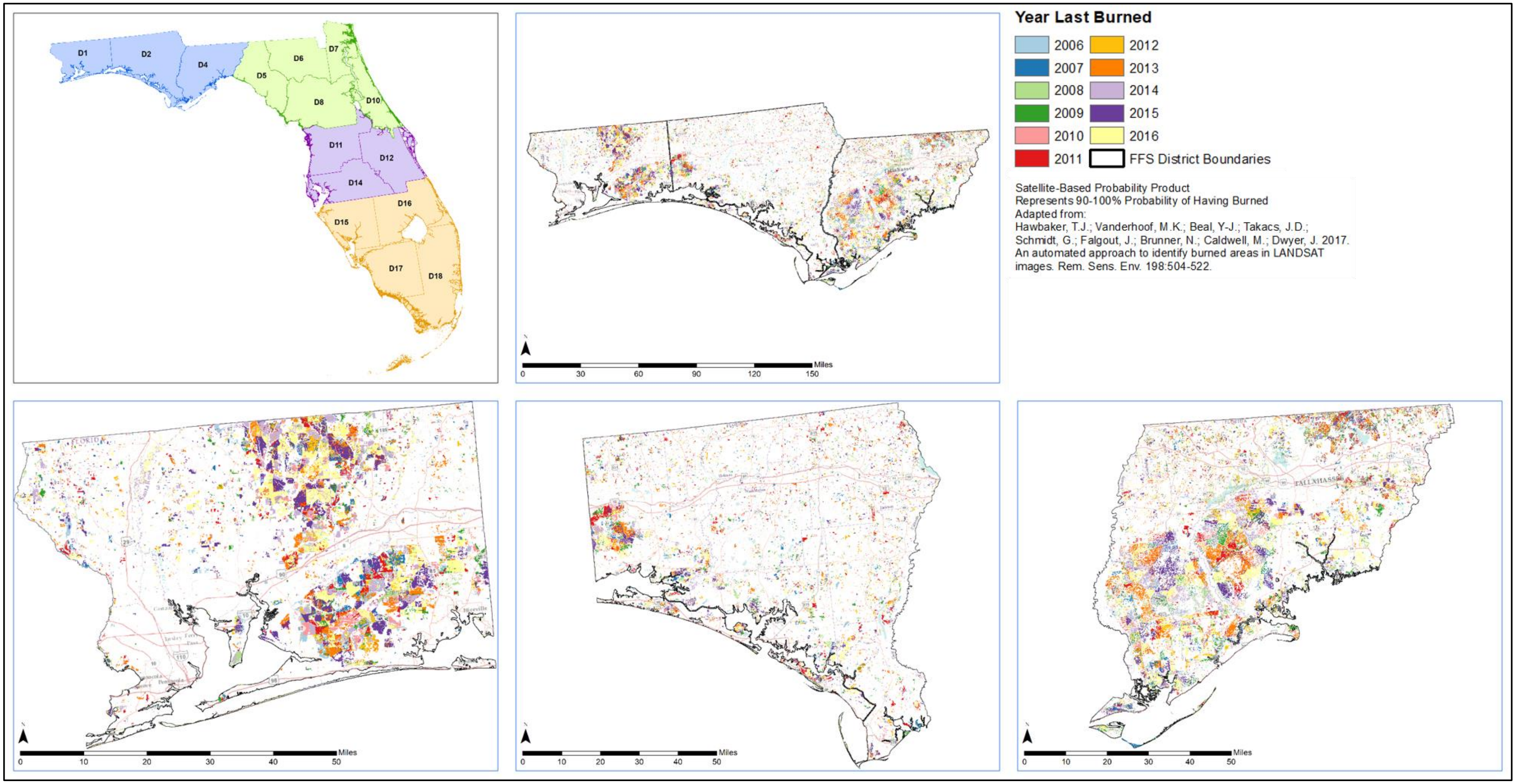


Figure A3.a: *Year most recently burned between 2006 and 2016 based on annual composite 90-100% burn probability for FFS Districts 1-4.*

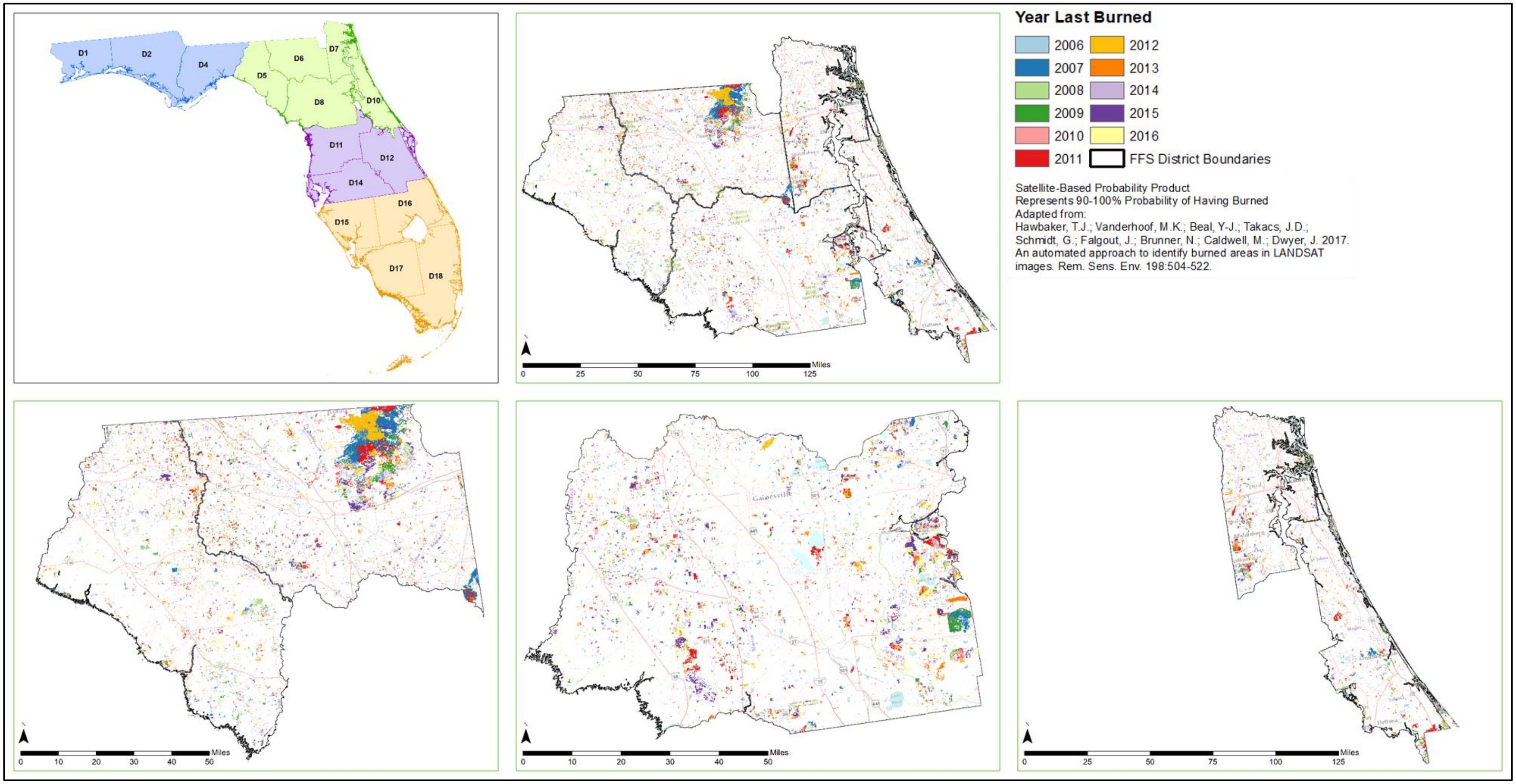


Figure A3.b: *Year most recently burned between 2006 and 2016 based on annual composite 90-100% burn probability for FFS Districts 5-10.*

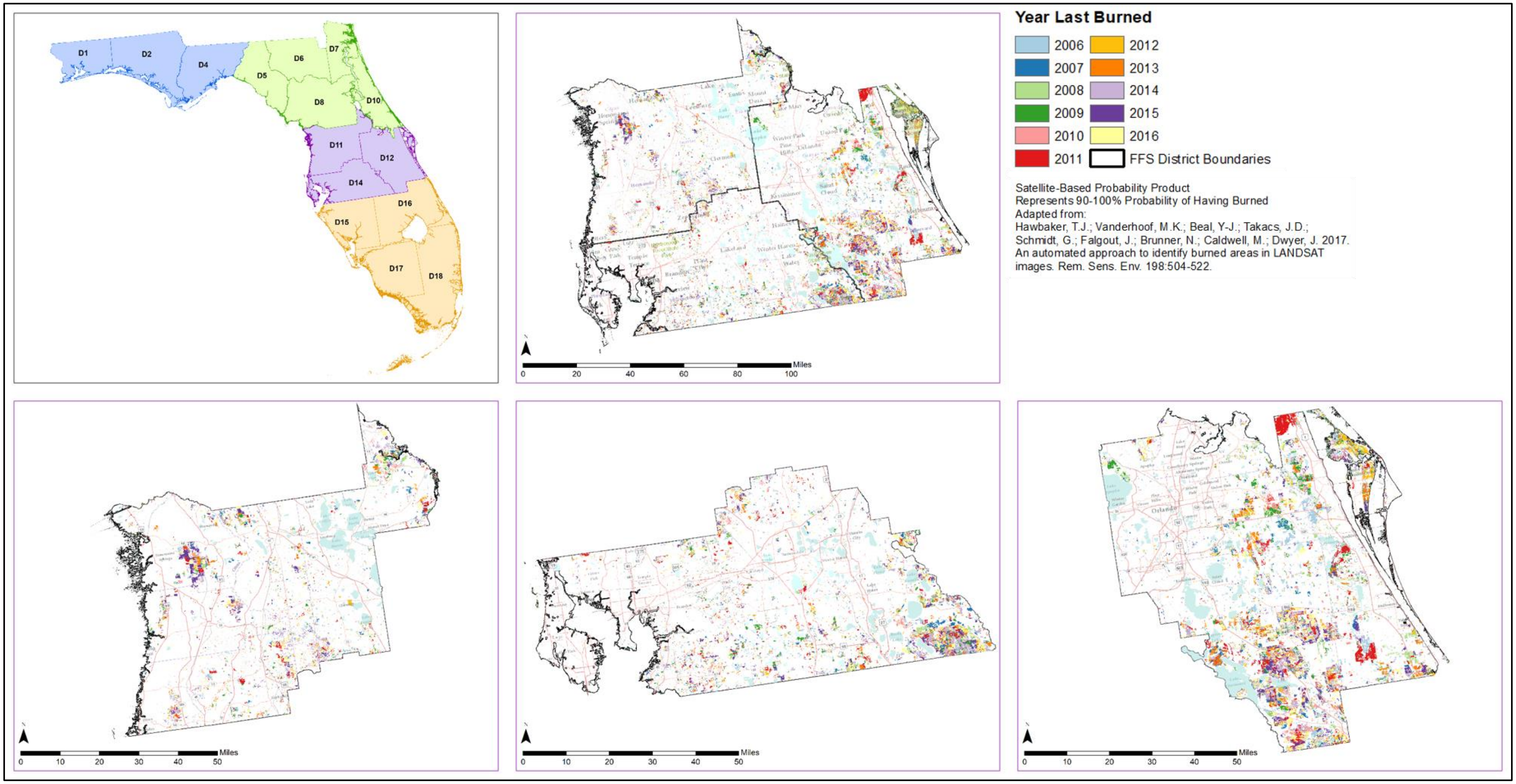


Figure A3.c: *Year most recently burned between 2006 and 2016 based on annual composite 90-100% burn probability for FFS Districts 11-14.*

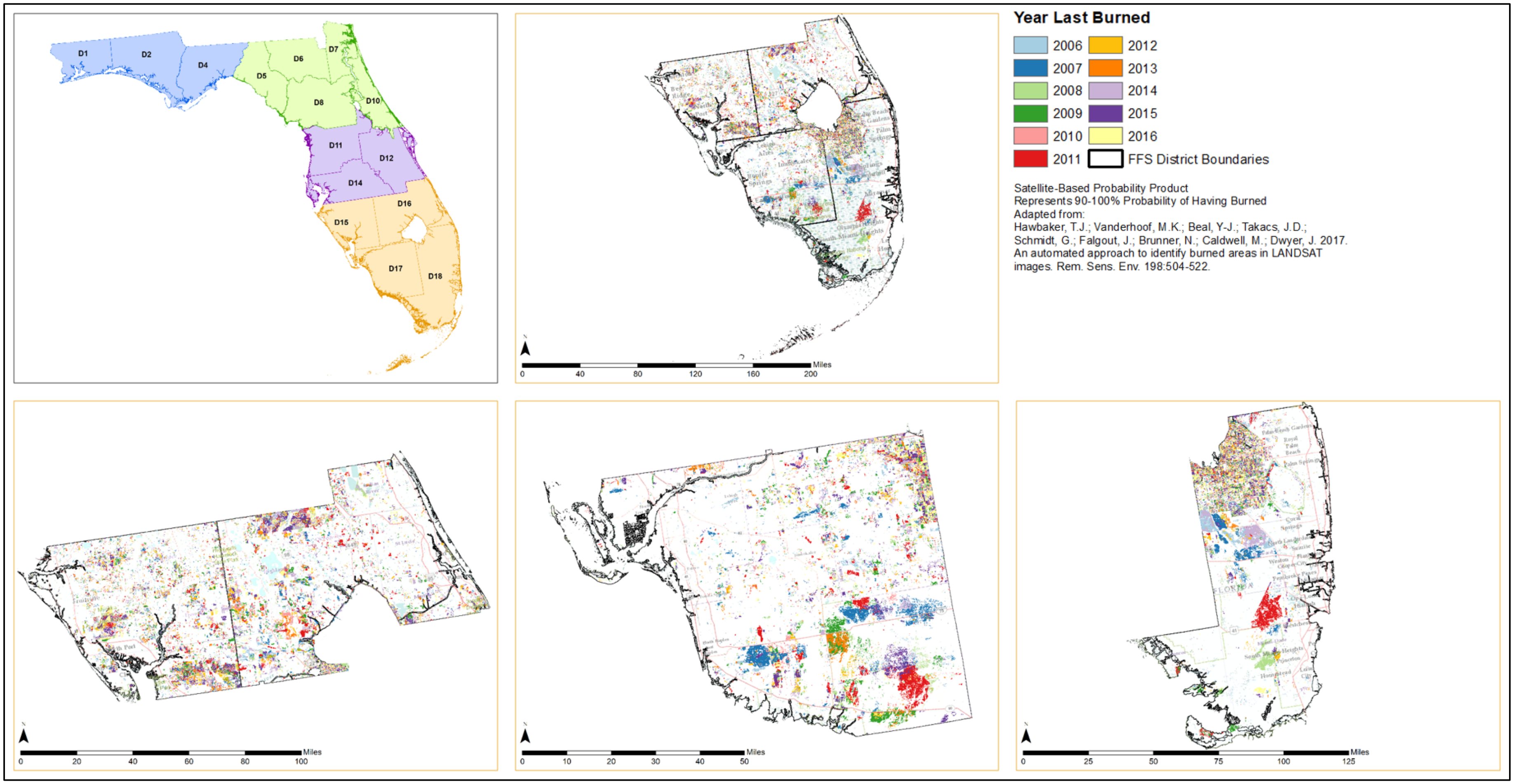


Figure A3.d: *Year most recently burned between 2006 and 2016 based on annual composite 90-100% burn probability for FFS Districts 15-18.*

Appendix B: Manager Meeting Notes

The following pages contain notes from meetings with fire managers at each of the three pilot areas. We briefed managers on the products and how we derived them, as well as what they illustrate. Managers provided feedback on the products, and we summarize those notes here. As a direct result of our update meetings with managers, the ANF and the Southern Fire Exchange and others have written USGS letters of support for continuation of BAECV development.

Table B1: Fire Manager meeting notes about the BAECV-based BP products for the three Pilot Areas.

Pilot Area	Notes
Apalachicola NF	• Seems to capture the patchiness of burning well • Low intensity fires may not be captured as easily • “Very impressed with this product and are hopeful that we can incorporate it into many different tools and workflows here on the NFs in FL” • “BAECV fills a critical niche because it is not dependent on data from disparate fire databases or on manual mapping of fire extents”
Big Cypress NP	• Think it is doing a good job given what fuel type we have • June through August burns seem to be difficult to capture due to seasonal cloud cover, rapid green up • November/December burns seem to appear in following calendar year • Seems to capture the patchiness of the fuels • May be easier to capture burns in drier years • Might consider a different threshold (70%) to better capture fire in these systems.
Eglin AFB	• Late season burns seem to show up in following year (e.g., burns in late Nov, Dec) • Burns may not be detected if burned after a treatment • Burns in low productivity sites not captured, but often hard to tell that they burned (i.e., fire is applied to unit, but may not carry well) • Cool burns, night burns, and burns in wet season seemed harder to detect • Burns leading into the summer season may not be detected (due to increased cloud cover during summer months) • First entry burns and burns early in the fire record may have burned more intensely than those later in record due to fire frequency reducing fuels (and thus intensity and detectability) • Just because we don’t have a record of it doesn’t mean it didn’t burn – we burn enough that we don’t get reports of fires due to folks thinking we are doing prescribed burn • May provide useful insight at a large scale, but we’d still have to ground truth at an individual fire scale if we were interested • Would be nice to be able to see these on a ‘fiscal year’ as opposed to a calendar year

Appendix C: Fire and Seasonality Metric Definitions

The following section defines and describes the fire metrics used in the database. Appendix D details how the actual values were derived.

General Fire Terminology

Many different terms are used when describing the spatial aspects of wildfires and prescribed fires. These can vary locally, regionally, nationally, and administratively, as well as vary between scientific and management communities. For the purposes of this project, the general fire terms we use are defined below so as to alleviate confusion.

Burn Unit (Burn Compartment, Burn Block)

Burn Unit refers to the area being burned, and generally has specific 'boundaries' defined in the form of roads/water/unburnable surfaces, etc. Other common synonymous usages include the terms *Burn Compartment* and *Burn Block*.

Fire Perimeter (Burn Perimeter)

Fire Perimeter refers to the perimeter delineating burned areas within a fire. It may or may not include unburned areas within a fire.

Burned Area Delineation

Burned Area Delineation refers to the all-encompassing area within a fire perimeter; it includes burned and unburned areas.

Fire History Metrics

Once the Annual Mosaic Burn Area Data are processed (Appendix D), fire history metrics can be determined. We list definitions here first. For this project, we are interested in where fires have burned between 2006 and 2018. Ultimately, the timing of the fires is important to assess things like effects due to seasonality and sub-annual burn characterizations. These definitions can be applied for different units of time or space, with minimal effort/change. For example, in this database, everything is done statewide on an annual basis for the time period 2006-2016. However, metrics can be calculated on a monthly level, or updated for a longer period of record, or subset to a specific area of interest and updated appropriately. Actual calculations are described in Appendix D.

Fire Frequency (Number of Times Burned)

Fire frequency refers to the total number of times a specific location has burned in the period of record (or for a given period of interest if a subset of total fire record). In a raster dataset, fire frequency is calculated at a pixel level; in a vector dataset, it is calculated at the geometric intersection where more than one polygon overlap. The burned area is categorically differentiated from the unburned areas in an area of interest. A tally is computed for the total number of occurrences of fire in a location (e.g., for a pixel or polygons and overlapping polygons). The value cannot be greater than the number of years in the fire history record.

Time Since Previous Fire (Time Since Last Fire, Time Since Last Burn)

Time Since Previous Fire (or *Time Since Last Fire*; TSPF or TSLF) is the measure of time from a specific date back in time to the last date of a detected or known fire. Units can be months, weeks, days, or years. In the database, since we used annual burned areas to populate the database, it is reported as the number of years from "present" to the last identifiable burn (where present = 2017 for 2006-2016 dataset, and 2018 for 2006-2017 dataset). This value cannot be greater than the number of years in the fire history record.

Year Last Burned (Year First Burned)

Year Last Burned (or *Year First Burned*) is the year of the last (or first) known fire/burn in a location; corresponds with the TSPF. In this database, the metric is reported as the actual year in YYYY format (e.g., YLB=2011 indicates that 2011 is the last year that a burn was recorded at a given location). This value cannot be outside the range of years in the fire history record.

Fire Free Interval (Longest or Shortest)

Fire Free Interval is the amount of time between two consecutive fires in a given area for a given period of time. In places where more than two fires have burned throughout time, the longest (or shortest) Fire Free Interval can be calculated as the maximum (or minimum) time period between two consecutive fires. In this database, the metric is reported as the longest fire free interval [LFFI] at an annual level and the unit is 'number of years' (e.g., LFFI=3 indicates that the LFFI for the period 2006-2016 is 3 years).

Seasonality

Seasonality refers to whether the burn occurred during growing season (March 15 - October 14) or dormant season (October 15 – March 14). Again, these classes are based on the BD product, and thus may be skewed in the October and March time frames due to limitations described above. Additionally, seasonality varies for individual years (i.e., 2019 growing season started in February, ~2 weeks earlier than 'normal'), and this variation is not reflected currently in the database as this date fluctuates across the state and through the years. Moving forward, this can be entered specifically for a given area/statewide, or re-entered with input from subject matter experts/local knowledge for individual years/locations.

Time of Year

Time of Year is the loose grouping of months into the four seasons (Spring, Summer, Fall, Winter). The first date of detection of high probability fire pixels was recorded in the BAECV Burn Date (BD) products as a Day of Year value. We used this date to categorize Time of Year into the four seasons. We recognize that there is a lag associated with Landsat-based detection data (on the order of 2 weeks), so a burn could have occurred in the end of May but not been detected until June thereby skewing Time of Year categories. Additionally, we understand the potential limitations of the ability to detect fires in a timely manner given the characteristics described previously (e.g., small, rapidly burning, low-intensity fires (often under a tree canopy), frequent cloud cover, and rapid green-up following fires). The detections of any satellite sensor used for imaging or detecting fires requires a cloud-free sky at the time of satellite overpass. When using satellite imagery to derive information about the extent and timing of fires, post-fire images occurring on cloudy days may not be suitable for deriving burned area, and low-intensity fires beneath a tree canopy may not be detectable. However, in the absence of correctly located permit data, this is the finest level of temporal detail for a surrogate that we could determine with these datasets.

Appendix D: User Guide – Development of Fire and Seasonality Metric Datasets

We used multiple GIS and remote sensing software packages to derive datasets for the first iteration of fire spatial database development, although we are working on streamlining and automating as much of the process as possible for future updates and endeavors based on what we learned. The basic workflow of getting BAECV-based data into a geodatabase is a multi-step process requiring a good plan for data organization and processing sequences before beginning. The general workflow we used for the first iteration is shown (Figure C.1).

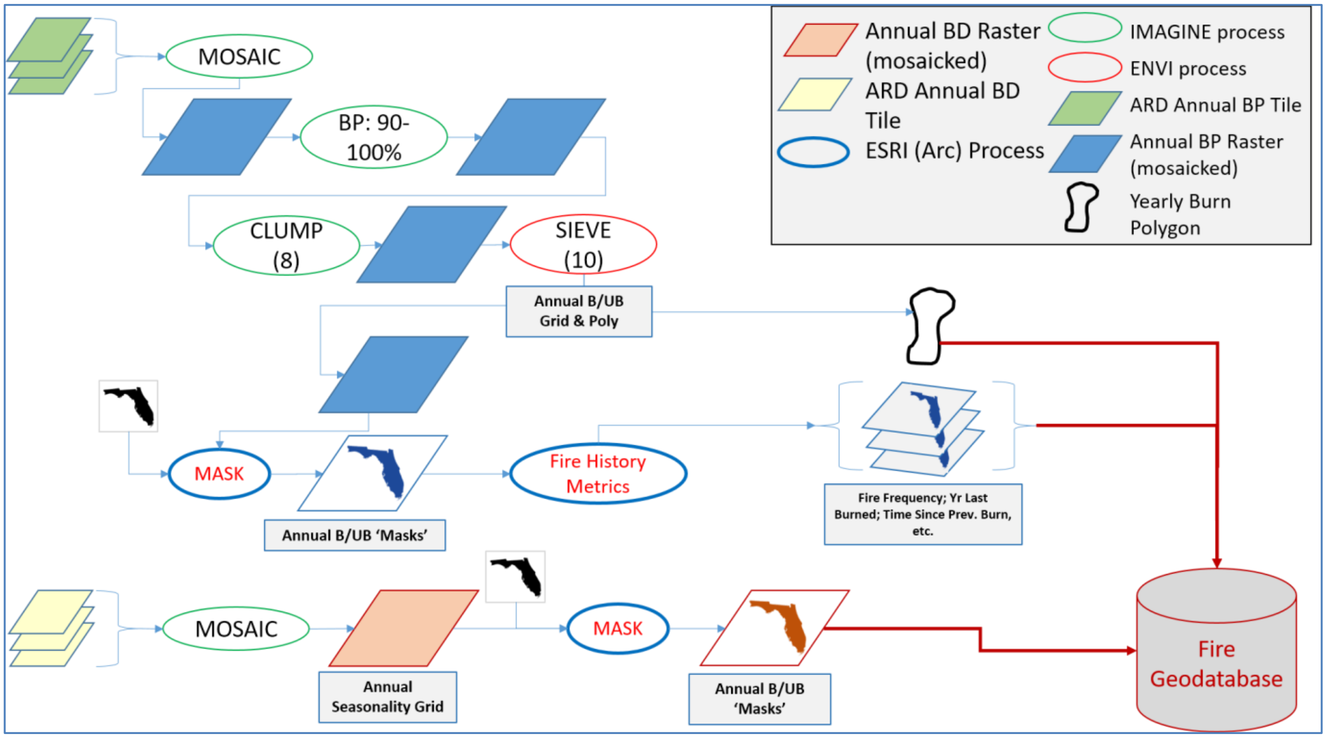


Figure D.1: General overview of processing steps to derive fire history data from BAECV.

The fire metrics calculations are developed for both raster and vector data; for vector data, we adapted fire metric calculation protocols from Wittkuhn and Hamilton (2010). The entire data development process is documented in the following pages.

ARD Tile Processing

The ARD tiles are similar to the WRS path/row scheme used for LANDSAT products, except that these tiles are 5000x5000 pixels (30m) and cross path/row boundaries and thus may include partial LANDSAT scenes that fall within them. U.S. Landsat ARD products are generated in the Albers Equal Area (AEA) Conic map projection, processed directly from Landsat Level-1 AEA scenes through Landsat Level-2 data products using the WGS84 datum. The Table below lists the U.S. Landsat ARD projection parameters. More information can be found here: https://landsat.usgs.gov/ard

Projection: Albers Equal Area Conic
Datum: World Geodetic System 84 (WGS84)
Output Format: Georeferenced Tagged Image File Format (GeoTIFF)

Table C.1: US LANDSAT ARD Projection Parameters.

	Conterminous U.S.	Alaska	Hawaii
First standard parallel	29.5°	55.0°	8.0°
Second standard parallel	45.5°	65.0°	18.0°
Longitude of central meridian	-96.0°	-154.0°	-157.0°
Latitude of projection origin	23.0°	50.0°	3.0°
False Easting (meters)	0.0	0.0	0.0
False Northing (meters)	0.0	0.0	0.0

USGS has processed LANDSAT-based BAECV products using this on-demand structure. BAECV rasters exist for entire state of Florida for each year – there are 20 tiles that cover all of Florida, filed by ARD Tile location (h###v###). Within the ARD Tile Folder, there are folders labeled by individual 'horizontal' and 'vertical' tiles (e.g., h024v016; Figure C.2.a). Within each of these ARD Tile Folders is a common structure (Figure C.2.b).

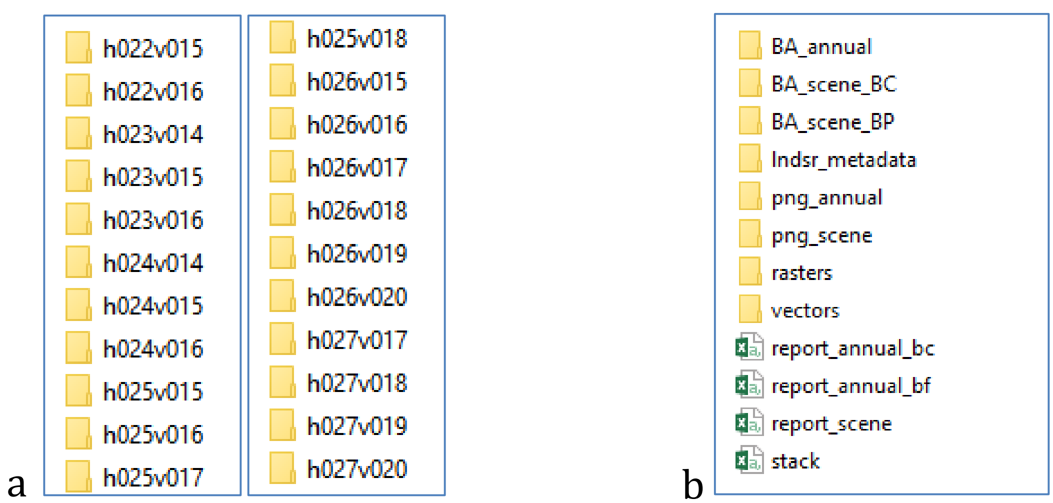


Figure C.2: General directory structure of individual ARD tiles (*a*) and within each directory (*b*) for BAECV products.

Within the **BA_annual** folder are annual rasters of burn dates (***BD.tif**) and burn probability (***BP.tif**). These are basically rasters of the scene dates that a burn was first detected (*BD.tif) and 'final' annual burn probabilities for a pixel to have burned within that year (*BP.tif). We ran the following processing sequence on each annual BP raster for the years 2006-2018. You can perform this method on an individual scene as it is processed as well, and clean up topology errors on an annual (or other unit-time) basis. We chose to perform this on annual products as a function of deriving locations of burns within Florida for a given year. For the burn date rasters, we simply mosaicked the annual rasters together (these coincided with the threshold used, >=90%BP), derived polygons from these rasters, and added the polygons to the geodatabase as feature classes. Step-by-step instructions for the entire process are described in this document. Figure C.1 shows how the overall process in general looks. The following instructions document how to get the annual burned area based on BAECV products.

1) **Data Organization:** As you can see, there are many steps for the process. It will be important to have a good data organization system in place before starting. The structure below is what we used for initial processing. (Note, the 'ARD' in the name signifies that the entire ARD tile was processed. Folders were named by the area of interest once processes to clip the rasters to a specific Area of Interest (AOI) were performed. For example, FL_* {instead of ARD*} would signify that the rasters in the folder would only pertain to the FL AOI).
    - **[ARD_YR_MOSAIX]**: folder containing the annual *BP.tif rasters for each year, mosaicked
    - **[ARD_YR_MOSAIX_BD]**: folder containing the annual *BD.tif rasters for each year, mosaicked
    - **[ARD_YR_MOSAIX_90BP++]:** main folder containing the outputs of the processing sequence described for 90-100%BP
        - **[IMAGINE_C8]:** sub-folder containing the outputs of the 'clump' process with 8 neighbors (3x3 window)
            - **[ENVI_S10]:** sub-folder containing the outputs of the 'sieve' process with minimum size of 10 pixels

Once initial processing outputs were deemed sufficient, the 'final' rasters and polygons were moved into a folder where the final GDB inputs were maintained:

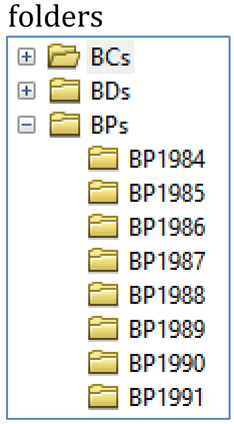
- **[Final_GDB_Inputs]:** main folder containing the final outputs of the processing sequence (eg., the files to be loaded into the GDB)
    - **[ALL_BP_MOSAIX]** ← this is the folder where the 'original' mosaicked BP rasters go
    - **[Rasters]** ← this is the folder where the sequence of BP processing rasters will go
    - **[Shapefiles/Geodatabases]** ← this is the folder where the final geodb of annual polygons (as feature classes) is located
    - **[FireMetrics]** ← this is the folder where the final fire metric products go
        - **[Annual_One_Grids]** ← subfolder containing annual grids where values are 1 (burned) and 0 (unburned)
        - **[Year_Grids]** ← subfolder containing annual grids where values are the year (in burned locations) and 0 (unburned)
        - **[BASE_Rasters_Masks]** ← subfolder containing rasters where the area of interest is masked. (used for masking and snapping to AOIs.)

        - ***Base Zero Grid***: This is the area of interest, but all values within the area of interest are 0.
        - ***Base One Grid***: This is the area of interest, but all values within the area of interest are 1.
        - ***Base TSPF/YLB Year Grid***: This is the area of interest, but all values within the area of interest are the year from which to derive the year last burned (YLB). For example, if the data are between 2006-2016, then the value within the area of interest for this grid would be 2017.
        - ***Area of Interest Mask Grid##***: This is the raster that you will use as a mask during processing. Anything outside of the area of interest will not be operated on, and will essentially turn into 'no data' values. The values within the area of interest can be anything but 'no data'.
    - **[FH_METRICS] ←** subfolder containing final fire metrics (YLB, FRQ, TSPF, LFFI, etc) rasters and polygons
    - **[FH_METRICS_FDEPAlbHARN] ←** subfolder containing final fire metrics (YLB, FRQ, TSPF, LFFI, etc) rasters and polygons in FL FDEP Albers HARN Projection
    - **[SEASONALITY] ←** subfolder containing annual rasters and feature classes with seasonality metrics

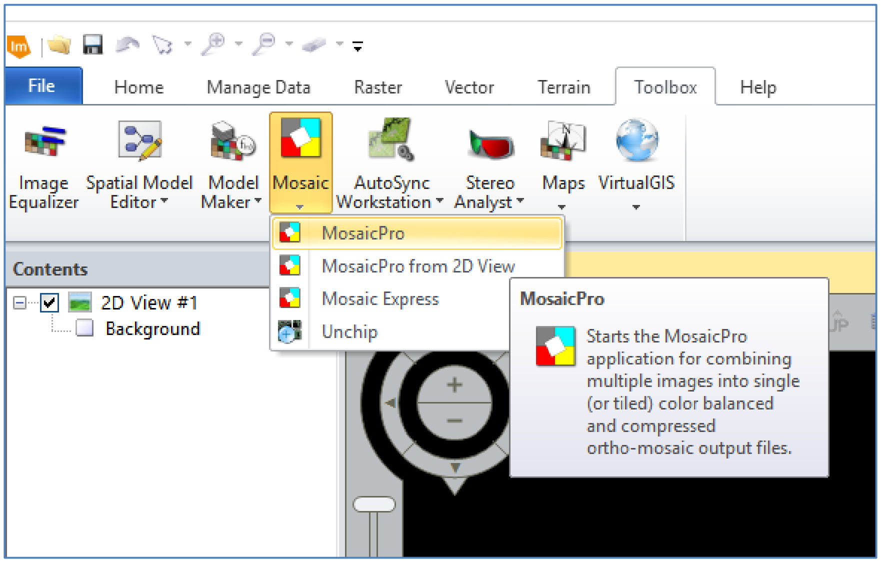
++**Note:** if you are using a different threshold, make a folder for that processing sequence. This will help keep things clean. For example, if you are interested in running a burn probability threshold for those pixels with BP>70, create a new folder named [**ARD_YR_MOSAIX_70BP**] and proceed in the same manner, but outputs would fall under this 'main' folder.

Once you have created your folder/file structure, you're ready to begin processing. To save a lot of time, it is recommended to copy or move the various ARD Tiles from their standard *H###V###* folders to a set of 'processing' folders as follows:

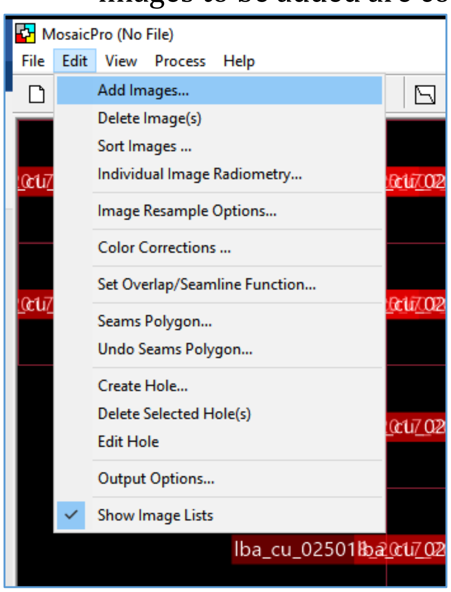
BC Datasets → moved to BC<YEAR> folders
BD Datasets → moved to BP<YEAR> folders
BP Datasets → moved to BD<YEAR> folders

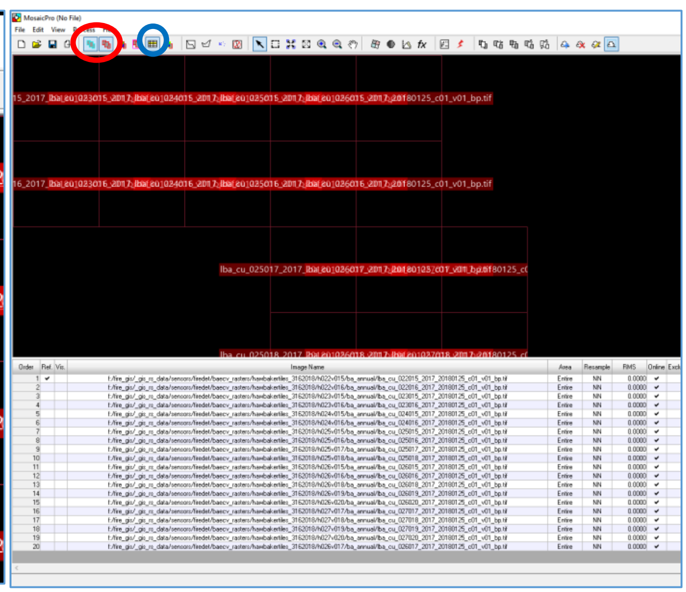


2) Open ERDAS IMAGINE 2018 (64-bit) | Toolbox | Mosaic | MosaicPro:

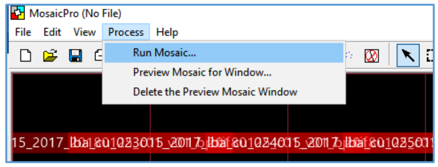


3) Mosaic the ARD tile BP tiles by adding the annual BP images.
   a. Edit | Add Images… (select the image(s) to add; in the case of FL, there are 20 ARD tiles for annual BPs that need to be added for every year of interest). As images are added, the outline of the boundary of the dataset appears (the turquoise & red boxes should be selected for this to occur; red circle below), and you can see the list of images to be mosaicked in the table view (the table button should be selected; blue circle below). In the image name field of the table, ensure that the images to be added are correct:





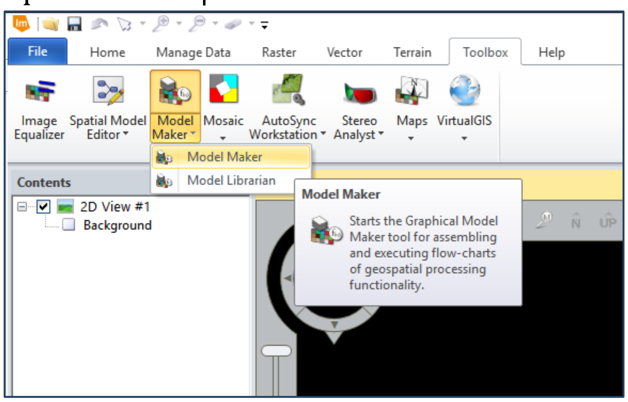
b. When the data to be mosaicked are all added, click on Process | Run Mosaic and save the file in the correct location, with appropriate format and naming convention:

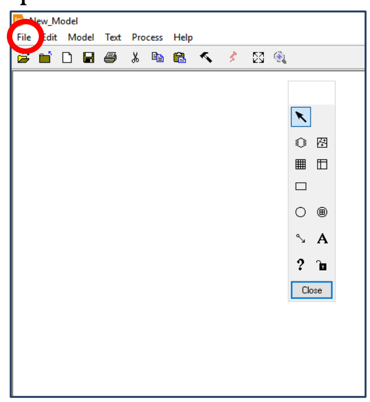


Steps 4 & 5 will select high probability pixels and perform a clump/sieve* operation on them. This is a process that operates on classified pixels and utilizes neighbor pixels to remove "salt and peppering" (e.g., remove individual pixels and fill in small holes within groups of pixels) for each annual mosaic BP raster derived in the previous step.

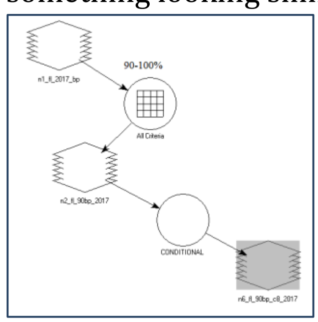
4) Isolate those pixels with >=90%BP (and their neighbors); this is still in IMAGINE:

a. Open Toolbox | Model Maker. A blank 'model' opens:

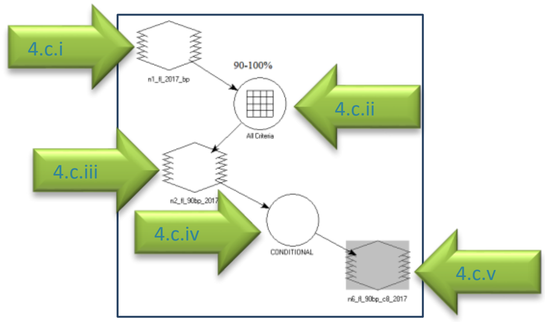




b. Select File | Open (red circle above) and choose the file named "90BP_ClumpingModel.gmd"; something looking similar to this will open:

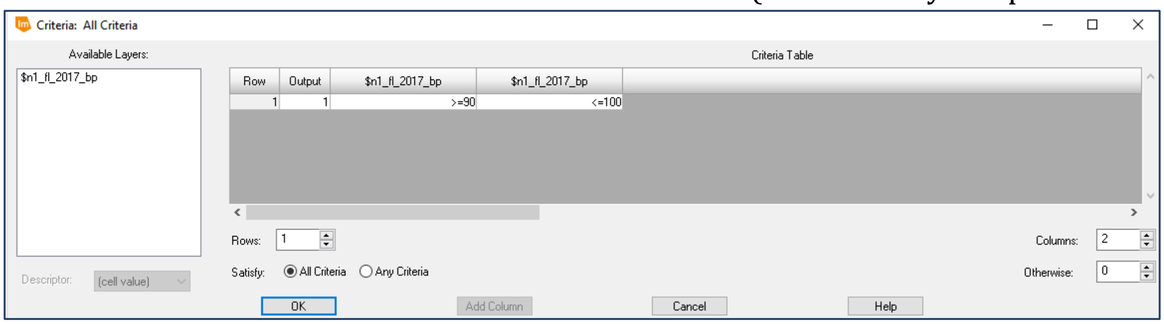


c. This model will need to be run for each Mosaicked Annual BP file that was created in Step 3. Double click on each part of the model to add appropriate information as follows:

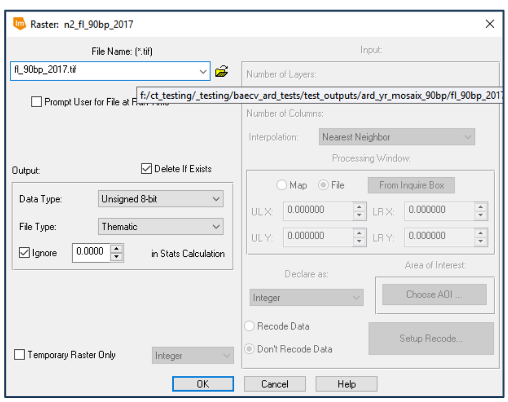


i. Select the input raster (output from step 3)

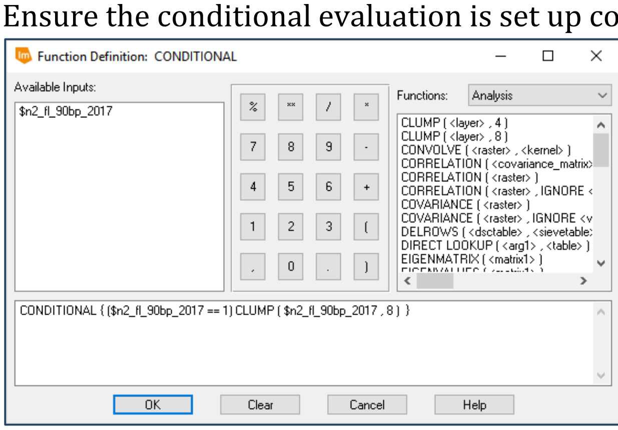
ii. Fill in the criteria table as follows (if not already completed correctly**):



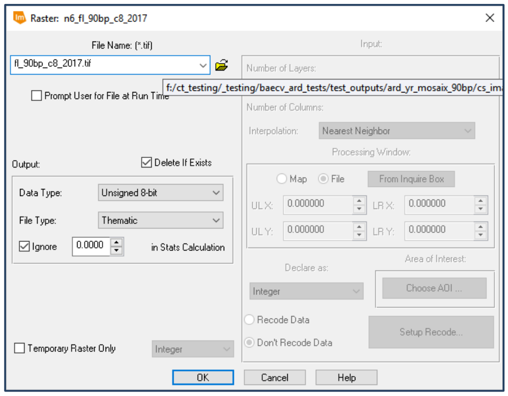
iii. Name the raster and save it in the appropriate folder; before clicking 'OK', ensure the checkboxes are filled in as follows:



iv. Ensure the conditional evaluation is set up correctly:

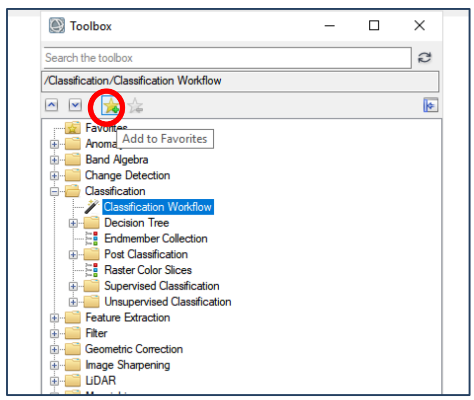


v. Save the raster in the appropriate folder with appropriate name, and ensure checkboxes are filled in as follows:

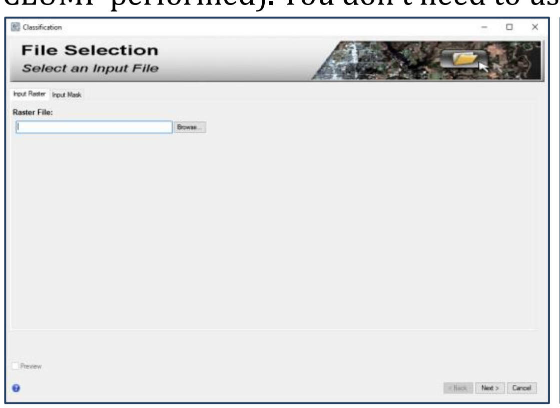


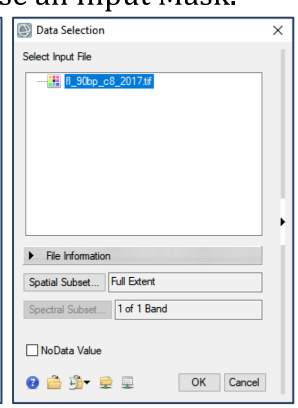
Once the classification and clumping are complete, you will need to perform a "sieve" process using ENVI for each annual mosaic raster derived in Step 4.c.v. This process removes clumps of pixels smaller than a given area (we chose to use 10 pixels = 2.24 ac; 10*900m^2).

5) Open ENVI 5.5 (64-bit)
   a. In ENVI, select Classification Workflow from the Toolbox (if you don't see it, search for it & add it to the favorites by clicking on the star with the green plus sign—red circle below; this will put it at the top of your toolbox under the 'FAVORITES' folder):



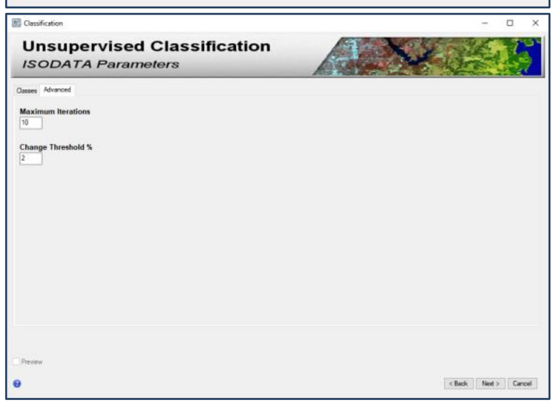
   b. A new window opens that will walk you through the Classification Workflow. Hit 'Next' after each screen to proceed to the next screen. The screens are as follows:
      i. *__File Selection:__* The input raster is the output from Step 4 (e.g., the output raster from Step 4.c.v → which is an annual classification that has had a CLUMP performed). You don't need to use an Input Mask.



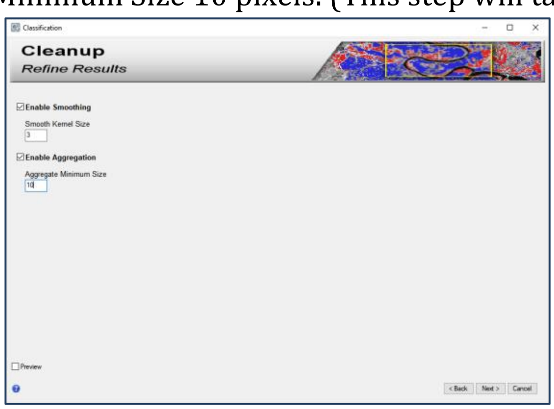


ii. *Classification Type:* No training Data.

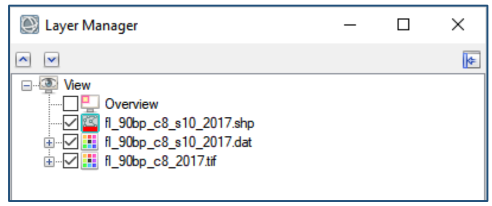
iii. *Unsupervised Classification ISODATA Parameters:* 2 classes. Advanced Tab: 10 iterations, 2% change threshold. (this will take a few minutes to run once you hit 'next'):



iv. *Cleanup Refine Results:* Smooth Kernel Size 3 pixels (i.e., 3x3) & Aggregate Minimum Size 10 pixels. (This step will take a few minutes as well)

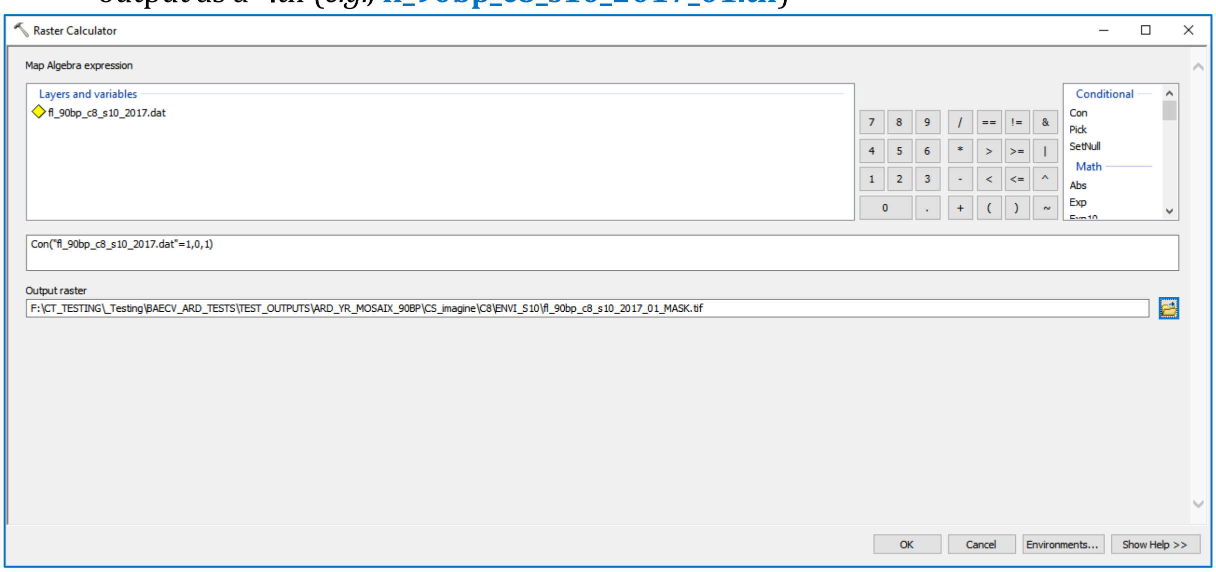


v. Save the raster and vector out to the appropriate locations you defined (*e.g.,* Step 1). (*Note: The only available 'format' for the raster is .dat, which is fine*). This will take a few minutes. You will see the final raster and vector show up in the Layer Manager when they are done saving. *If they appear with a name other than what you saved them as, you will have to click on the raster (or vector) & re-save the raster (or vector) appropriately. This doesn't happen often.*

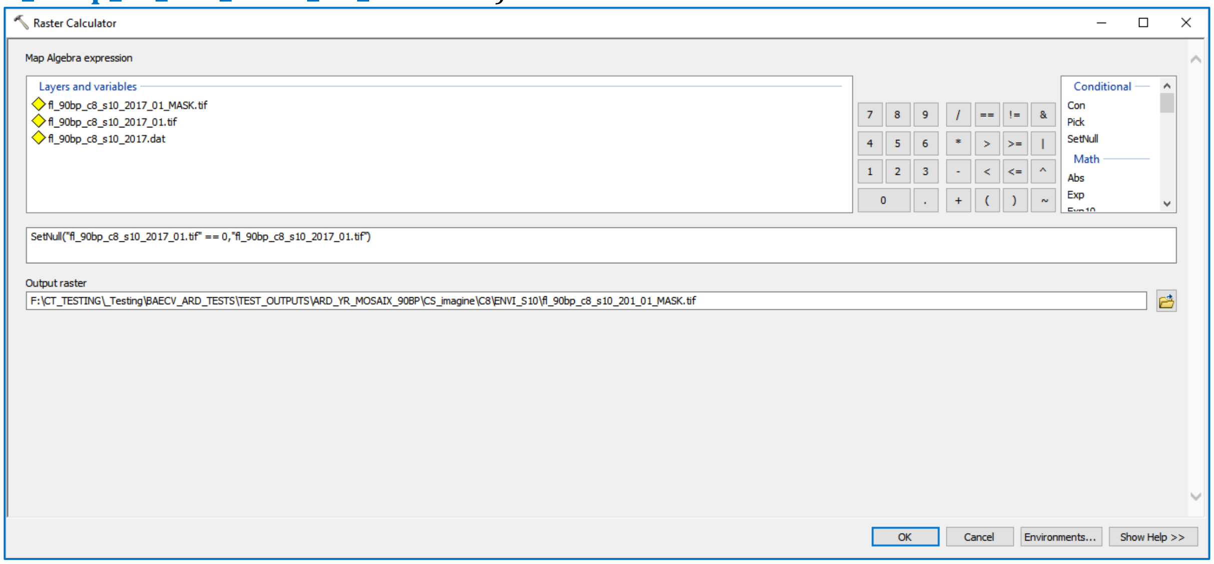


vi. ***Import all vectors to a File Geodatabase at this point to circumvent null vs. zero issues in SQL!!!***

6) Since the raster from 5.b.v saves out as *.dat, do the following in ArcGIS
   a. Build raster attribute table (the input is the raster from 5.b.v; this creates the *.vat for the raster)
   b. Use raster calculator to Create a '*01'.tif - (set the condition such that value =1, then 0 if true or 1 if false: **Con("fl_90bp_c8_s10_2017.dat"==1,0,1)**) ← if you get error, double check that you have '==' instead of '=', *as it won't work with just a single equal sign! Use the raster calculator buttons to ensure this is correct. Note: This raster is for when a future processing function requires a '0' (instead of a nodata value) to act on a cell location within a stack, it is available as an input. In these files, Class 2 (e.g., 2) is burned while Class 1 (e.g., 1) is unburned*. Save the output as a *.tif (*e.g.,* **fl_90bp_c8_s10_2017_01.tif**)



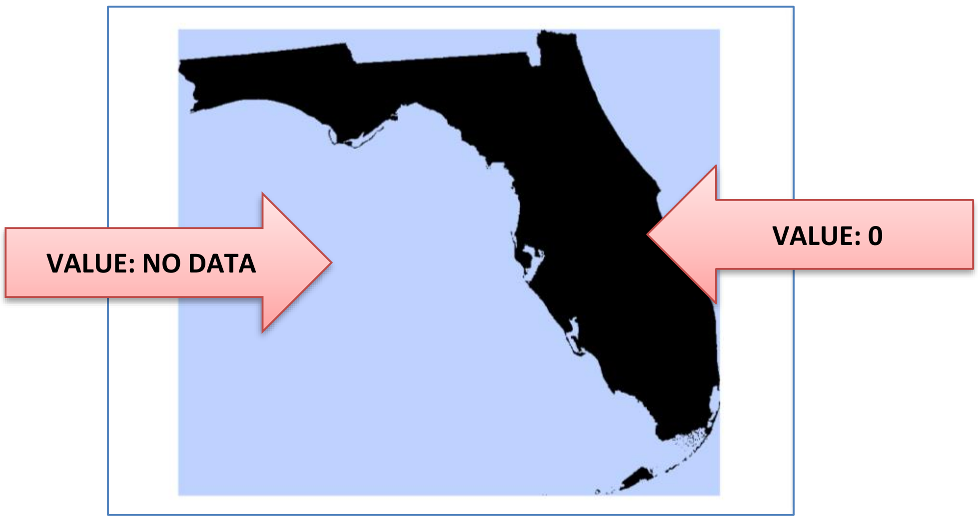
c. Use raster calculator to Create a *01_MASK.tif where only those 1 values are kept (*i.e.*, burned areas are kept, while the 0's are converted to NODATA values) within AOI (*e.g.,* FL, FFS District, etc.): (Set null value = 0, then 1 (orig raster) if false: **SetNull("fl_90bp_c8_s10_2017_01.tif" == 0,"fl_90bp_c8_s10_2017_01.tif")**). (*NOTICE the double equal sign – it won't work with just a single equal sign! Use the raster calculator buttons to ensure this is correct.*) Save the output as a *.tif (*e.g.*: **fl_90bp_c8_s10_2017_01_MASK.tif**)



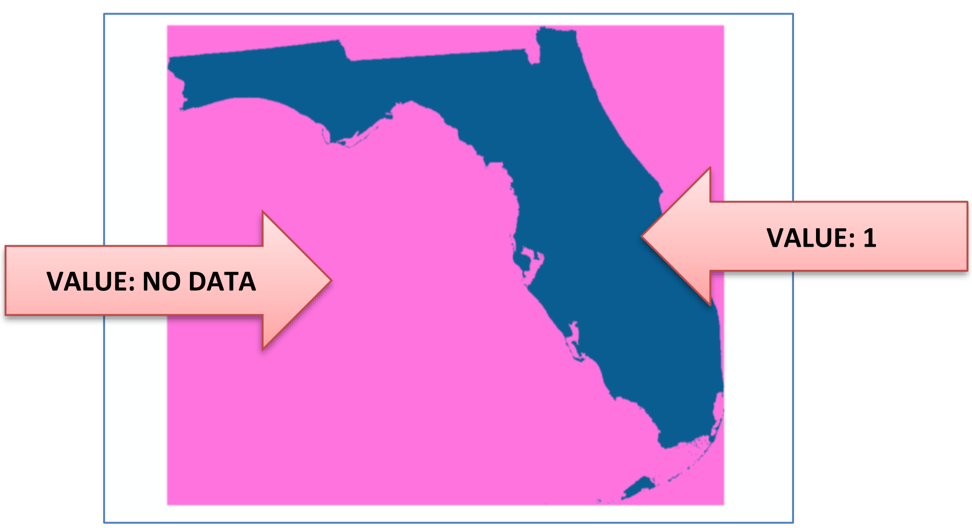
FIRE HISTORY METRIC CALCULATIONS

You have now mapped fire locations (or differentiated between burned and unburned areas) for a large area or your area of interest. It is now time to begin creating the datasets to calculate the metrics. In order to begin, you will need a minimum of 3 raster masks to utilize in the process. (we used 4 just to easily keep it straight– the masks were all spatially identical but had different values and names so we always knew where/how to use them!)

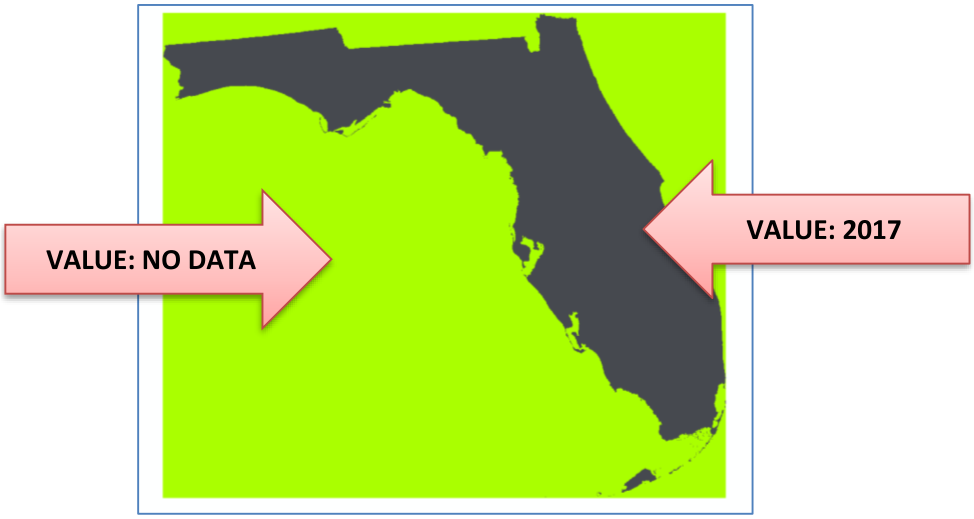
7) The 3 raster masks you will need are described and illustrated below, and the 4th one is optional (denoted by ##) but recommended for keeping things less confusing. These are all *.tif format. *In the examples below: FL is the AOI; ALL THESE HAVE THE SAME PROJECTION, EXTENT, & CELL SIZE!! These, and all other processing steps, are all snapped to the first raster created in 4.c.v*. The projection should match the data you are processing (*e.g.*, the .prj from 4.c.v raster):
    a. ***Base Zero Grid***: This is the area of interest, but all values within the area of interest are 0.



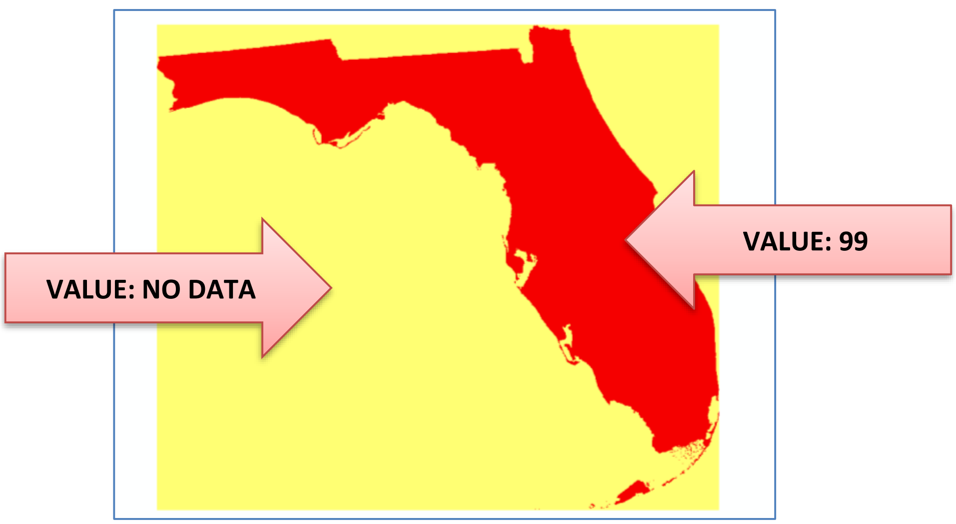
    b. ***Base One Grid***: This is the area of interest, but all values within the area of interest are 1.



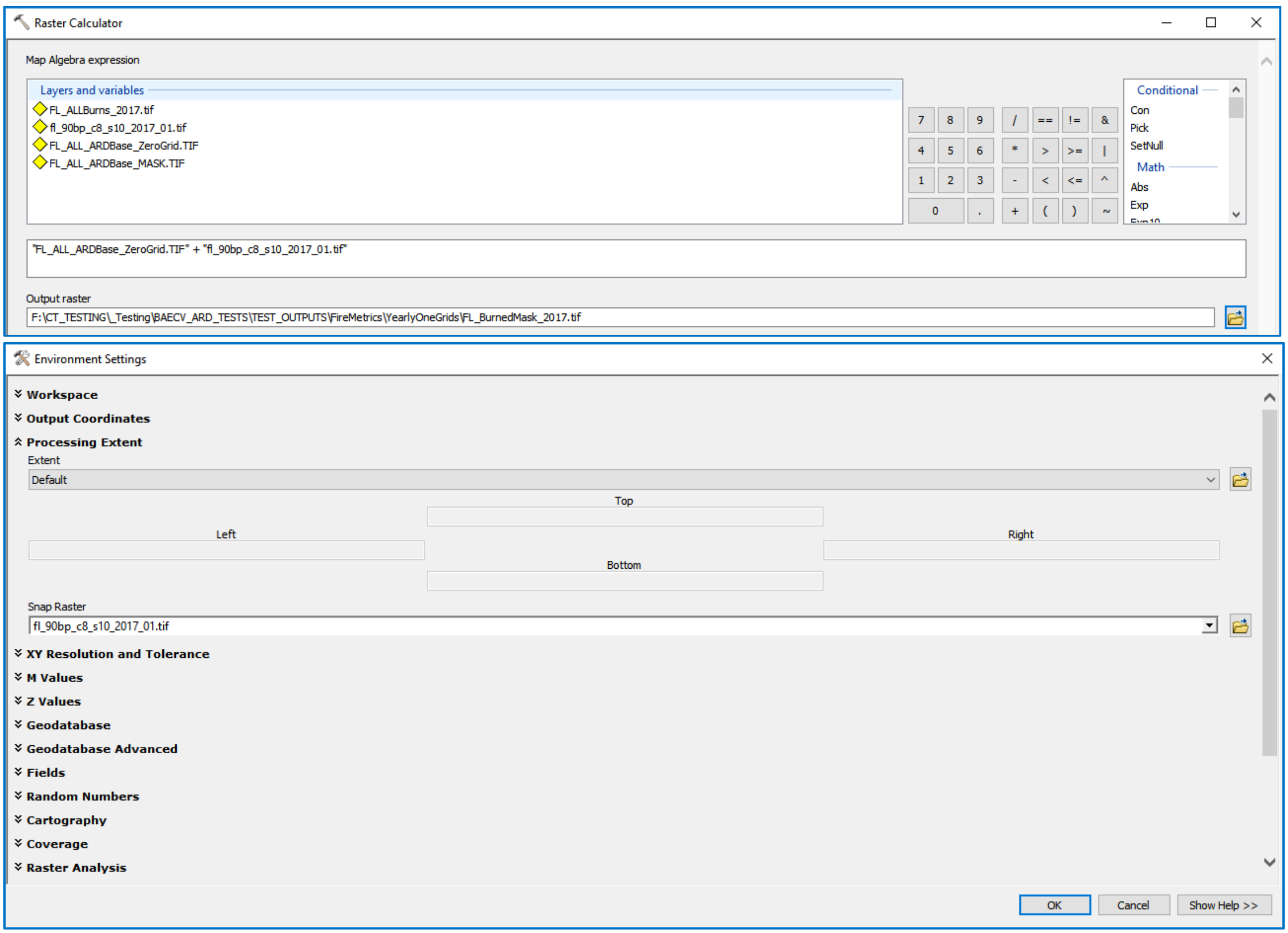
c. ***Base TSPF/YLB Year Grid***: This is the area of interest, but all values within the area of interest are the year from which to derive the year last burned (YLB). For example, if my data are between 2006-2016, then the value within the area of interest for this grid would be 2017.



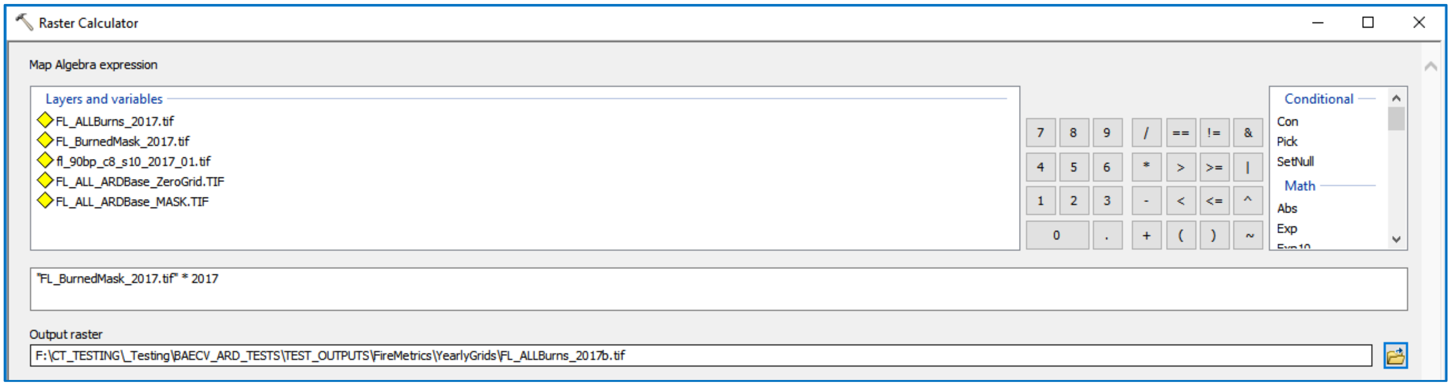
d. ***Area of Interest Mask Grid##***: This is the raster that you will use as a mask during processing. Anything outside of the area of interest will not be operated on, and will essentially turn into 'no data' values. The values within the area of interest can be anything but 'no data'.

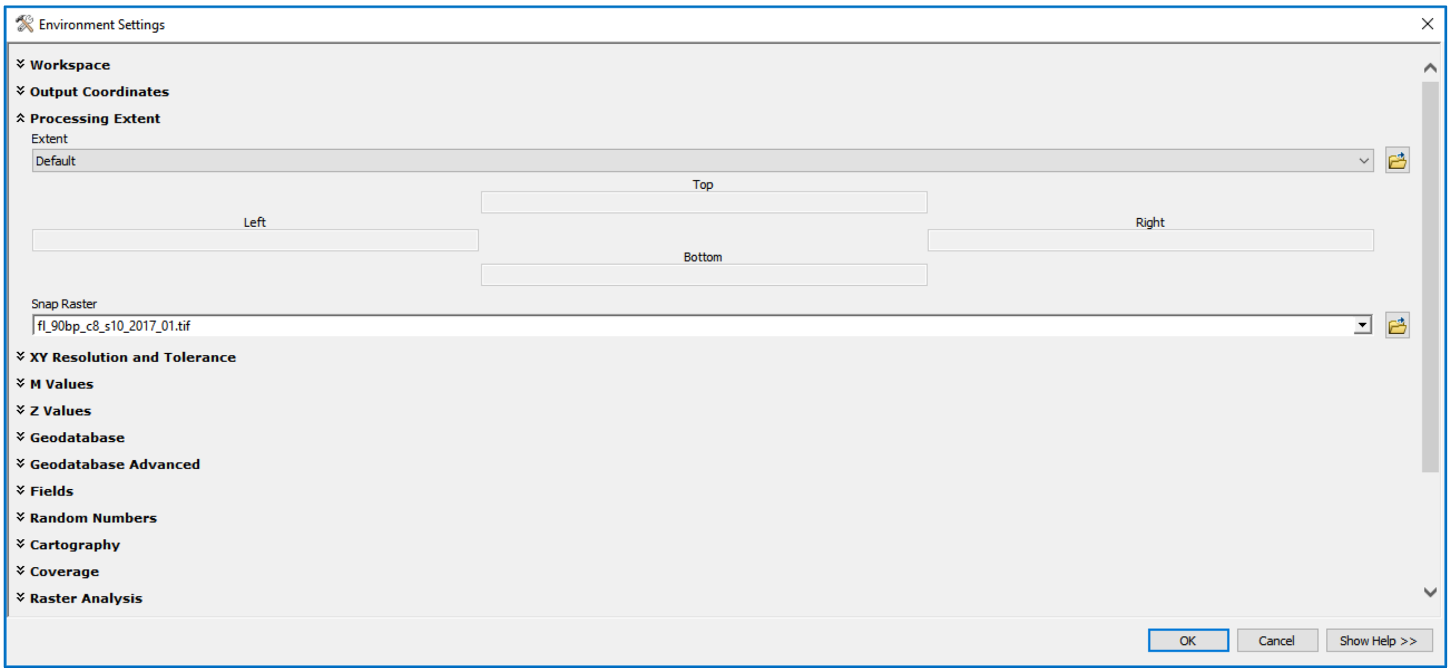


8) The next step is to create annual 'burn/unburned' rasters for the AOI (all in *.tif format). These will be used to derive fire metrics using the burned area outputs from Step 6.b and 6.c, the masked outputs from Step 7 and the following instructions.
   a. add the Base Zero Grid raster from 7.a to a new ArcMap Session.
   b. add the *<YEAR>_01.tif raster(s) from 6.c for each year in your time period to the same session.
   c. With Raster Calculator, do the following 2 calculations for *EVERY YEAR*:
      i. **Annual One Grid**: add the Zero Grid & each of the annual *<YEAR>_01.tifs together and save the output in an Annual_One_Grids Folder (e.g., *Zero_Grid.tif + *<YEAR>_01.tif = FL_BurnedMask_<YEAR>.tif). On the ENVIRONMENTS tab, make sure to set the Snap Raster to the *<YEAR>_01.tif raster. (← the extent should be exactly the same as the very first mosaic raster) *Note: if you have 16 years of fire data, you'd do this 16 times, and the value of <YEAR> would be the year the fires happened to create the burned area [ie, 1999, 2001, 2003, etc.]*). THIS RESULTS IN A RASTER WITH VALUES OF 0 AND 1, to be used in frequency calculations.



ii. **Annual Year Grid**: multiply the raster from 8.c.i by the appropriate <YEAR> and save the output in a Year_Grids Folder (e.g., for fires that occurred in 2017: **FL_BurnedMask_<YEAR>.tif * 2017 = FL_AllBurns_2017.tif**). THIS RESULTS IN A RASTER WITH VALUES OF THE YEAR BURNED, to be used in Time Since Previous Fire or Year Last Burned calculations.

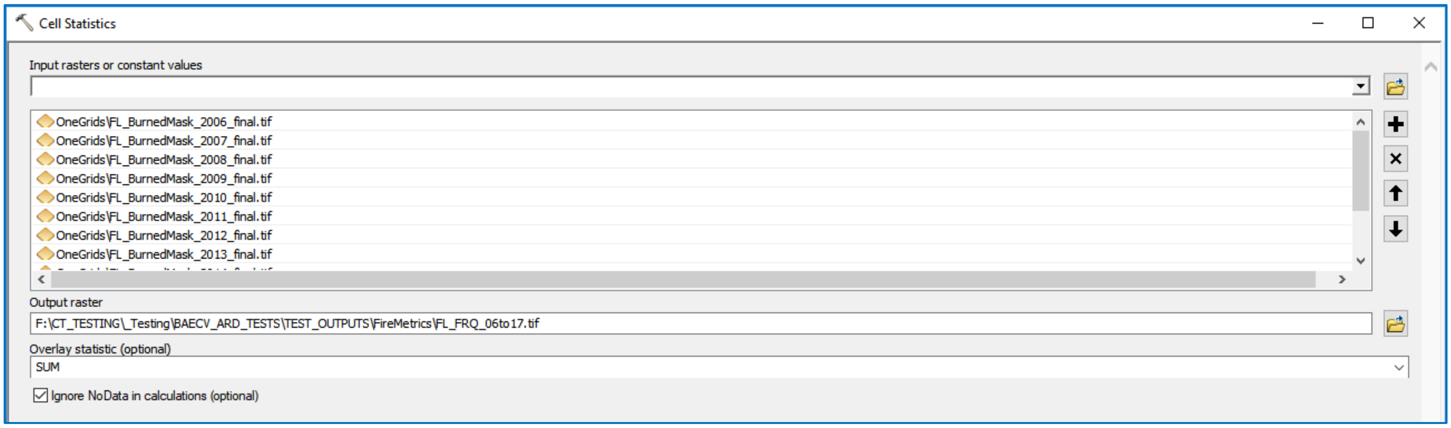




9) Calculate Fire Metrics in this order:

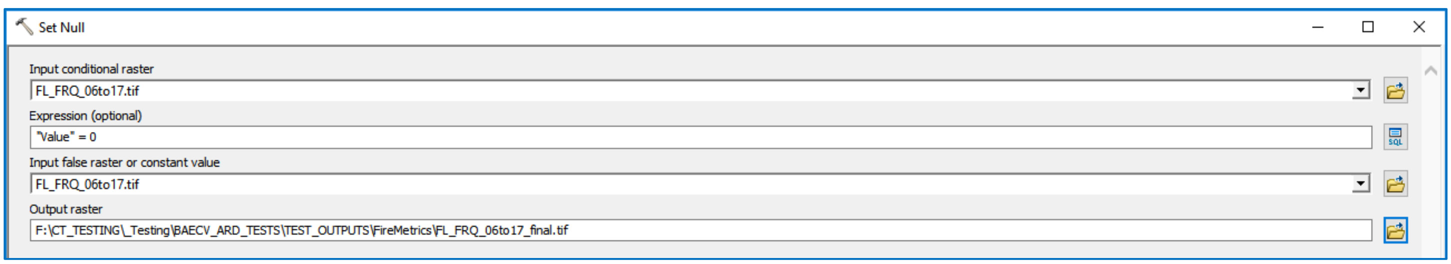
a. **Frequency:** This is a 2-step process. THIS RESULTS IN A RASTER WITH VALUES REPRESENTING THE NUMBER OF TIMES A PIXEL HAS BURNED THROUGH THE PERIOD OF RECORD FOR THE AOI.

i. **FRQ** = sum of the annual ***ONE GRIDS*** (e.g., sum all '*BURNEDMASK_<YEAR>.tif' rasters); using SUM in Cell Statistics; snap raster in environments to *BASE_MASK.tif.



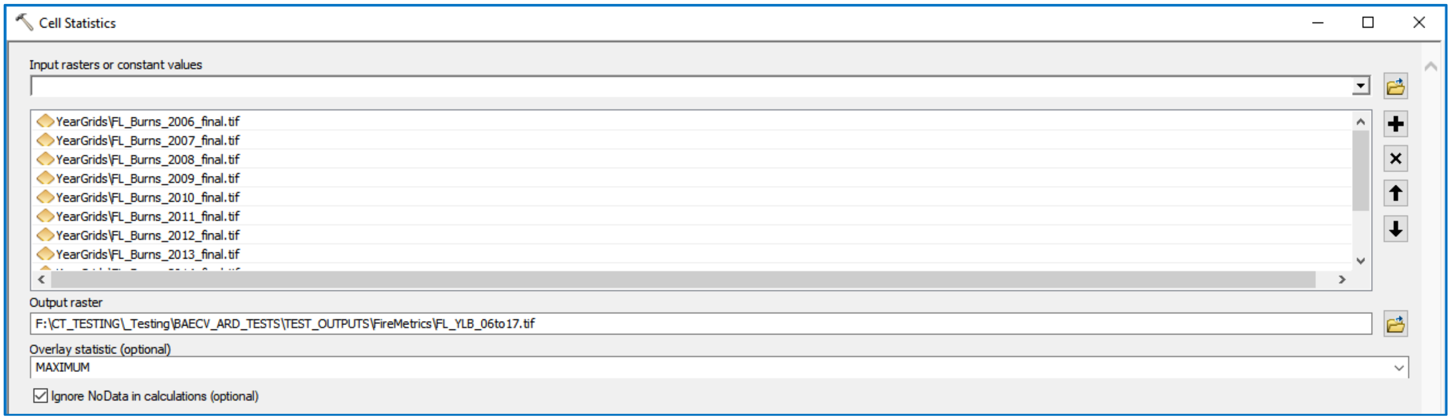
ii. **FRQ_FINAL:** Using Set Null, use the following:

- Conditional Raster = 9.a.i output
- Expression: "Value" = 0
- Input False Raster/Constant: 9.a.i output
- Output raster: *FRQ_Final.tif
- snap raster in environments to *BASE_MASK.tif



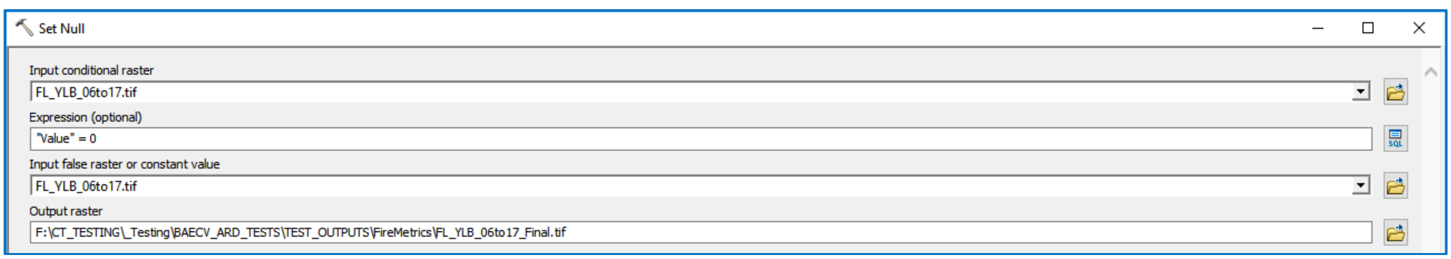
a. **YLB:** This is a 2-step process. THIS RESULTS IN A RASTER WITH VALUES REPRESENTING THE LAST YEAR THAT A PIXEL BURNED THROUGH THE PERIOD OF RECORD FOR THE AOI.

iii. **YLB** = maximum of the annual ***YEAR GRIDS*** from 8.c.ii (e.g., all ‘*BURNS_<YEAR>.tif’); using MAX in cell statistics; snap raster in environments to *BASE_MASK.tif. (*NOTE: this results in a raster with values of 0 or the year most recently burned. the second step will remove the 0 values).*

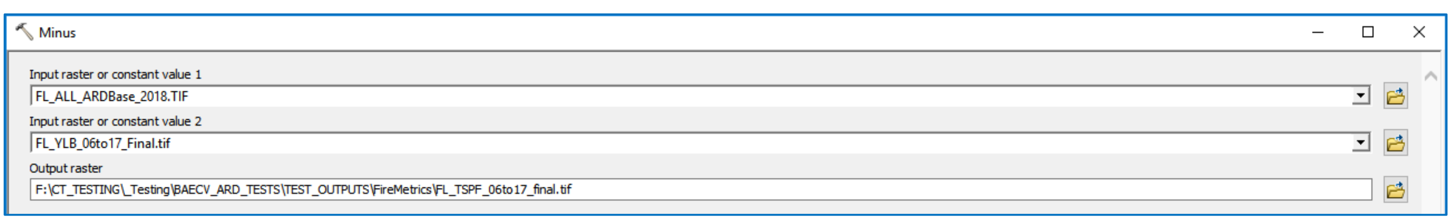


iv. **YLB_FINAL**: Using Set Null, use the following:

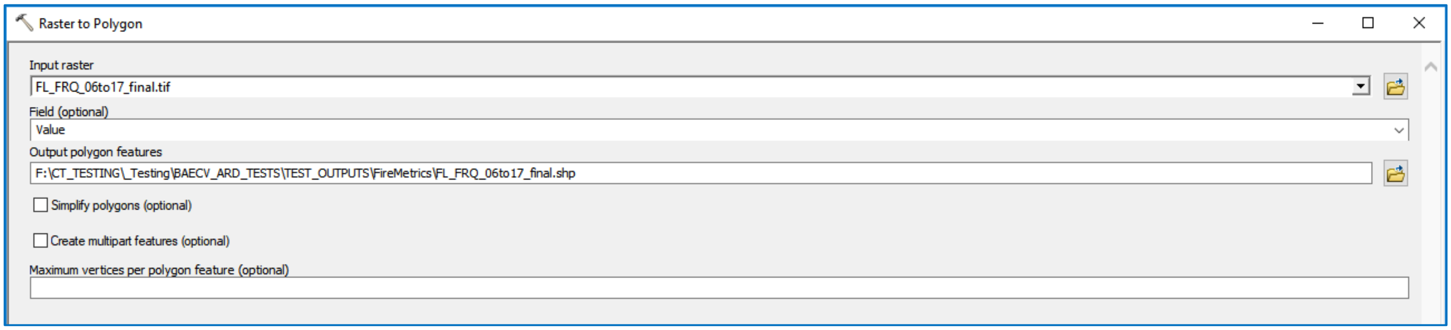
- Conditional Raster = 9.b.i output
- Expression: “Value” = 0
- Input False Raster/Constant: 9.b.i output
- Output raster: *YLB_Final.tif
- snap raster in environments to *BASE_MASK.tif



b. **TSPF** = the ***Base TSPF/YLB Year Grid*** raster (from 7.c) minus the **YLB_FINAL** raster (from 9.b.ii). This can be done in raster calculator or in the Minus tool; snap raster in environments to *BASE_MASK.tif. THIS RESULTS IN A RASTER WITH VALUES REPRESENTING THE AMOUNT OF TIME THAT HAS PASSED (FROM A SPECIFIC POINT IN TIME) SINCE A PIXEL HAS BURNED THROUGH THE PERIOD OF RECORD FOR THE AOI.



10) Convert Fire Metric Rasters to Polygons using the Raster to Poly tool for each of the 3 final rasters made in Step 9 (based on VALUE); simplify polygons & create multipart features should be UNCHECKED.

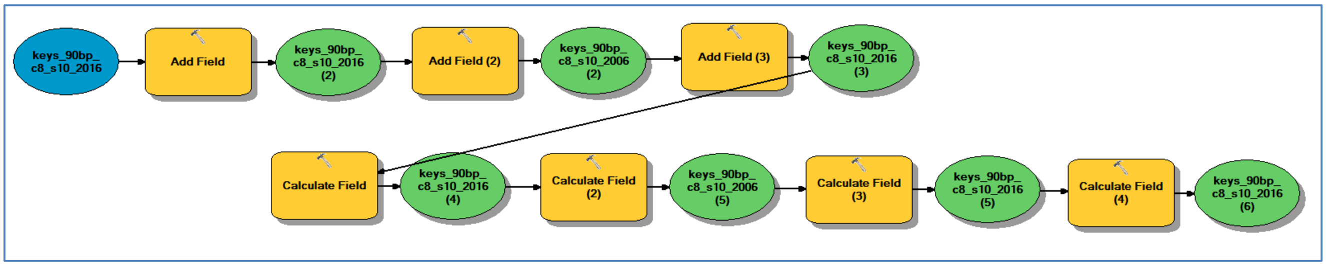


The next steps prepare the annual polygons for use in the fire metrics calculations and database.

11) To prepare the vector data for fire history metric analyses, do the following. You should complete all processing on the entire ARD area before clipping to an AOI if an AOI was not initially set:

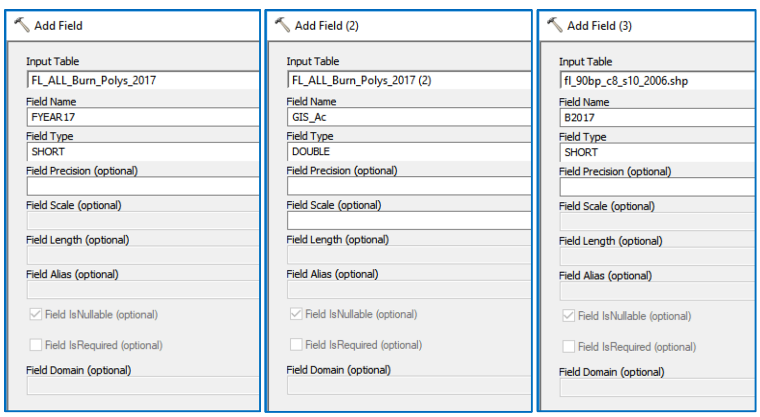
   a. Import all shapefiles created in 6.b.v into a file geodatabase if you did not already do this in step 5.b.vi
   b. Remove “Class 1” polys from the annual *BP feature classes & save. *(The ‘Class 1’ areas are unburned/nodata areas, but represented because of how polygon files were created from ENVI)*.

12) Add fields to and calculate Fields for annual burned area polys (use the python script or model: AddFireYr_and_Area_toPoly). First, select (*i.e.*, highlight) the model in the toolbox, then right click and select 'EDIT'. The model will appear as a graphic (see below).

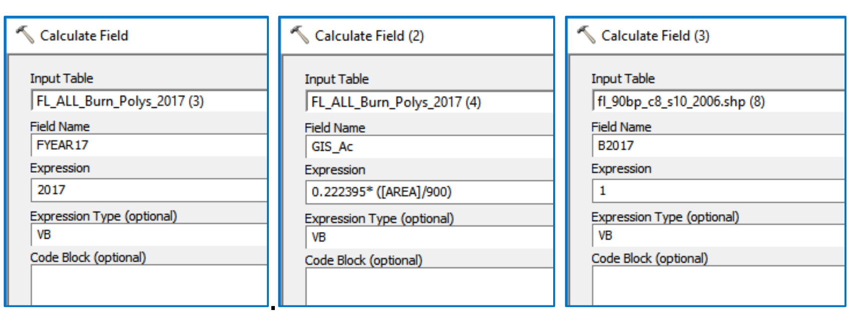


Double click on the blue circle and add the annual burned area polygon from step 11, and close. Double click on each of the yellow boxes, and add the information according to a and b below. This step will need to be replicated for each annual burned are polygon dataset you have:

a. ADD FIELDS (top row of model):
   i. B<YEAR>: Short (Precision=2, Nullable); ex: for 2017, the field would be B2017
   ii. FYEAR<YR>: Short (Precision=8, Nullable); ex: for 2017, the field would be FYEAR17
   iii. GIS_Ac: Double (Precision=16, Scale=2, Nullable)



b. CALC FIELDS (second row of model):
   i. B<YEAR> = 1 (need to make sure the <YEAR> matches the current year for dataset)
   ii. FYEAR<YR> = <YEAR> (need to make sure the <YEAR> matches the current year for dataset); ex: for 2017, FYEAR17 = 2017.
   iii. GIS_Ac: Expression Type is: VB and Expression is: 0.222395* ([AREA]/900)
   iv. CLASS_NAME=<YEAR> (need to make sure the <YEAR> matches the current year for dataset)



*****Fire Metrics Calculation Instructions based on:** Wittkuhn, RS & T Hamilton. 2010. Using Fire History Data to map temporal sequences of fire return intervals & seasons. Fire Ecology 6(2):97-114. Doi: 10.4996/fireecology.0602097

THIS SHOULD BE DONE IN A FILE GEODB TO PREVENT FILE SIZE LIMITATIONS AND NULL VALUE ISSUES. While some steps may appear at first to be 'combined', the individual layers created in each step are to be preserved for future processing.

1. Create FileGeoDB. Import all Annual Poly .shp into the GeoDB (FL_ALL_Burn_Polys_<YEAR>.shp → FL_ALL_Burn_Polys_<YEAR>)
2. Merge annual polys into a feature class (FL_ALL_Burn_Polys_<YEAR> → P01_FL_ALL_BurnPolys_2006to2016_merge)
    a. *These annual files should already have a **FYEAR<YR>** and **B<YEAR>** column; if not, add a field as follows for each polygon year in your fire history & calculate them accordingly (FYEAR07=2007; FYEAR08=2008, etc.....B2007=1, B2008=1, etc.):*
        i. *FYEAR06 = 2006*
        ii. *B2006 = 1*
3. Union the annual polys into a feature class (FL_ALL_Burn_Polys_<YEAR> → P02_FL_ALL_BurnPolys_2006to2016_union) –This step takes a few minutes!
    a. *JoinAttributes is set to ALL*
    b. *gaps allowed is checked*
    c. after running the UNION, DELETE all fields except the FID, AREA, FYEAR<YR> & B<YEAR> fields (← I did this by calling the FC *_Union1; then add to ArcMap; Select FC Properties | Fields, and uncheck all fields except FID, AREA, FYEAR<YR> & B<YEAR>.... It also helps to reorganize the fields here into FYEAR* and B<YEAR>* groups of fields (see below); Then export the data [not the table] and save as *_union & perform operations on that new table).

FL_ALL_Burn_Polys_2006_Union

FID *	Shape *	AREA	GIS_Ac	BurnYear	FYEAR06	FYEAR07	FYEAR08	FYEAR09	FYEAR10	FYEAR11	FYEAR12	FYEAR13	FYEAR14	FYEAR15	FYEAR16	FYEAR17
1	Polygon	12600.000001	3.113528	2006	2006	0	0	0	0	0	0	0	0	0	0	0
2	Polygon	21600	5.337476	2006	2006	0	0	0	0	0	0	0	0	0	0	0

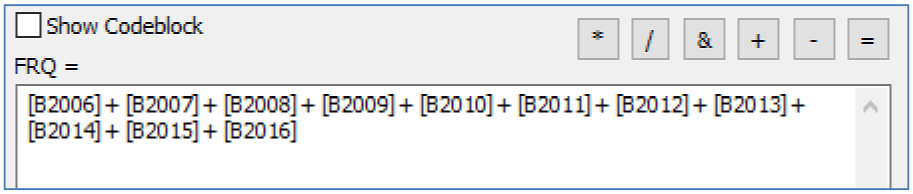
FID *	B2006	B2007	B2008	B2009	B2010	B2011	B2012	B2013	B2014	B2015	B2016	B2017
1	1	0	0	0	0	0	0	0	0	0	0	0
2	1	0	0	0	0	0	0	0	0	0	0	0

    d. Add a field **FRQ** (short integer)
    e. Add a field **YLB** (short integer)
    f. Add a field **TSPF** (short integer)
    g. Add a field **LFFI** (short integer)
    h. Add a field **RECNO1** (long integer) & calculate equal to OBJECTID (alias is FID)

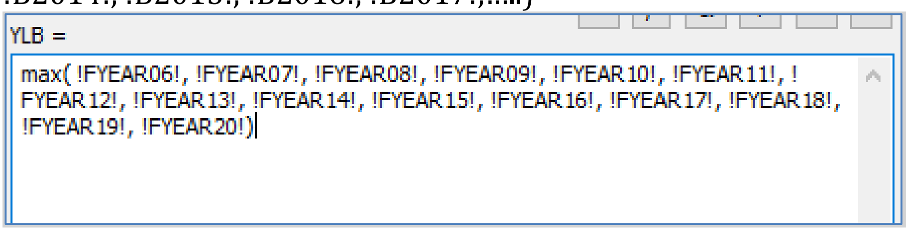
Add Field

	Input Table	Field Name	Field Type
1	FL_ALL_Burn_Polys_2006_Union	FRQ	SHORT
2	FL_ALL_Burn_Polys_2006_Union	YLB	SHORT
3	FL_ALL_Burn_Polys_2006_Union	TSPF	SHORT
4	FL_ALL_Burn_Polys_2006_Union	LFFI	SHORT
5	FL_ALL_Burn_Polys_2006_Union	RECNO1	LONG

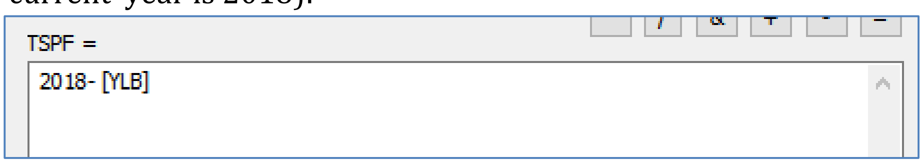
4. Export the Data from Step #3 to a new feature class (P02_FL_ALL_BurnPolys_2006to2016_union → P03_FL_ALL_BurnPolys_2006to2016) and then perform the following steps (in order):
    a. Calculate **FRQ** equal to [B2006]+ [B2007]+ [B2008]+ [B2009]+ [B2010]+ [B2011]+ [B2012]+ [B2013]+ [B2014]+ [B2015]+ [B2016] +….*(e.g, if B<YEAR>=1, it gets added, yielding a frequency of burning for a the unioned polygon; the example below shows how it looks when VB Script is selected (eg – uses [] instead of !))*



    b. Calculate **YLB** = Max(FYear[06-16])←determines the 'last yr burned' by finding highest yr. the example below shows how it looks when Python is selected instead of VB Script:
    max(!B2006!, !B2007!, !B2008!, !B2009!, !B2010!, !B2011!, !B2012!, !B2013!, !B2014!, !B2015!, !B2016!, !B2017!,…..)



    c. Calculate **TSP**F =2019-YLB ← use 'current' year to determine how many 'years' between burns (the example below is for fires between 2006-2017, so the 'current' year is 2018):



    d. Export the P03_FL_ALL_BurnPolys_2006to2016 Data Table to a comma-delimited file (can be .txt or .csv)
5. Run the PYTHON SCRIPT FOR LFFI.
    a. open LFFI_CALCULATIONS.py script
    b. change Line 12 to reflect the .csv created in 4.d above → replace the filename in parentheses with the full path/filename and the name of the file:

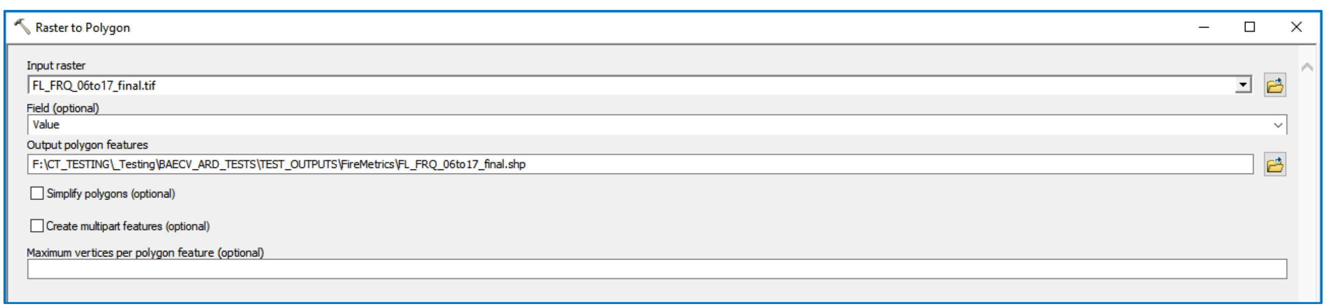
datatable = np.genfromtxt('F:\YOUR\FULL\PATH\HERE\P03_FL_ALL_BURNPOLYS_2006to2016_LFFI.txt' ,skiprows=1,delimiter=',')

    c. change Lines 19-21 to reflect the years and order of the B<YEAR> fields in your file. *Remember, python is 0-based, so start 'counting' at zero instead of 1 when determining which column is which.* Example: if B2006 is in the 7th 0-based column, the following values would change from [datatable[i,**1**] to [datatable[i,**6**]
    d. change Lines 40-43 to reflect the TSPF and LFFI column values (e.g., currently assumes TSPF is in 0-based column 15 and LFFI is in 0-based column 16)
    e. update Line 55 with a new filename→ replace the filename in parentheses with the full path/filename and the name of the file:

np.savetxt('F:\YOUR\FULL\PATH\HERE\P03_FL_ALL_BURNPOLYS_2006to2016_LFFI_**updated**.txt' ,skiprows=1,delimiter=',')

    f. change Lines 57-58 to reflect the years and order of the fields in your file.

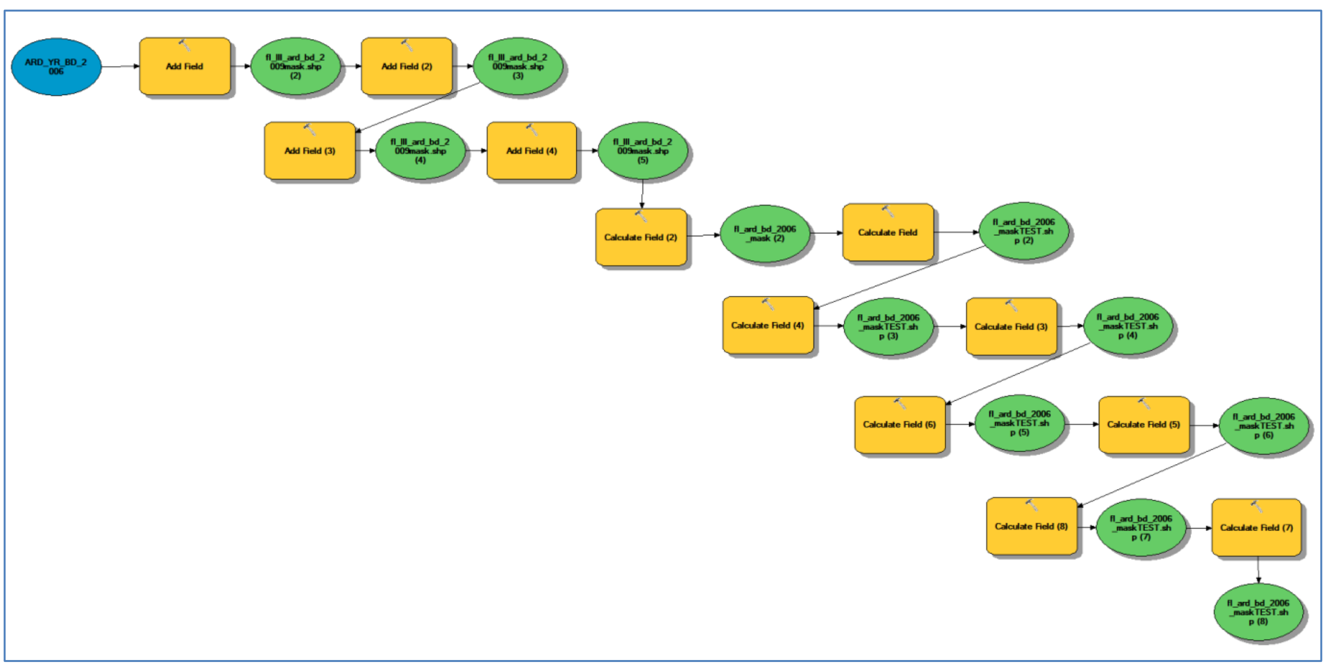
6. Once you have successfully run the LFFI_CALCULATIONS.py script and are satisfied with the results, you will need to:
    a. join the 'updated' file from 5.e above, using RECNO1 as the common field, back to your feature class P03_FL_ALL_BurnPolys_2006to2016
    b. You can then calculate the 'original' LFFI field (which should have all 'Null' values in it) equal to the 'joined' LFFI field (which should have all the LFFI values calculated in the python script). *THIS WILL LIKELY TAKE SOME TIME depending on the size of your dataset.*
    c. Once the calculation is complete, verify that there are not any 'Null' values remaining in the 'original' LFFI field, and then remove all joins.
7. A standalone LFFI raster and a standalone LFFI feature class can now be generated from this dataset:
    a. **LFFI:** Polygon to Raster:
        i. Input Features = P03_FL_ALL_BurnPolys_2006to2016
        ii. Value Field = LFFI
        iii. Output Raster Dataset = FL_ALL_LFFI_2006to2016.tif (choose appropriate name)
        iv. Cellsize = 30
        v. snap raster in environments to *BASE_MASK.tif
    b. **LFFI**: Raster to Polygon
        i. Input Raster = raster from 7.a
        ii. field = Value
        iii. Output Polygon Features: FL_ALL_LFFI_2006to2016poly
        iv. simplify polygons and create multipart features should be UNCHECKED



SEASONALITY

8. Mosaic all the *<YEAR>_BD.TIF rasters for each year together
9. Raster to Polygon (Feature Class) the mosaicked raster for each year if not done in ENVI (SEASONALITY_ALL_FC)
10. Add four columns to the new polygon layer (feature class) and rename the alias of the gridcode field:
    a. TimeOfYear (String, 20)
    b. TimeYrCode (Short, 4, null values allowed)
    c. DormGrow (String, 10)
    d. DG_Code (Short, 4, null values allowed)
    e. FYEAR<YR> (Short, 4, null values allowed)
    f. BYR<YR> (Short, 4, null values allowed)
    g. gridcode ALIAS = DayOfYear
11. Calculate the values for each year's seasonality metrics by running the SEASONALITY_FIELD_CALCS_FINAL.py python script or the SeasonalityFieldCalcs_Final model. Values are based on the GRIDCODE (DayOfYear) as follows:

GRIDCODE (Day Of Year)	***Dates***	***Time Of Year***	***Time Yr Code***	***Months***	***Dorm Grow***	***DG_Code***
>=60 & <152	3/1-5/31	Spring	1	Mar/Apr/May	-	-
>=152 & <244	6/1-8/31	Summer	2	Jun/Jul/Aug	-	-
>=244 & <335	9/1-11/30	Fall	3	Sep/Oct/Nov	-	-
>=335 or >=1 & <60	12/1-2/29	Winter	4	Dec/Jan/Feb	-	-
>=74 & <=288	3/15 – 10/14	-	-	-	Growing	1
>288 or <74	10/15-12/31;1/1-3/14	-	-	-	Dormant	2



12. Calculate FYEAR<YR> = Year Burned; BYR<YR> = 1

SPECIES

13) All species rasters need to be converted to presence/absence rasters with values of 0 and 1 (e.g., no Null or NODATA values) for the state. This can be done for each raster having null data in Raster Calculator using the conditional statements – similar to the following:
    a. input raster: RASTER_SPP1.TIF
    b. Raster Calculator Expression: con(isnull(RASTER_SPP1.TIF, 0,RASTER_SPP1.TIF))
    c. ouput raster: RASTER_SPP1_01.tif
14) Assign individual values to each species, and re-calculate the gridcode of each species by multiplying gridcode by the coded value in Raster Calculator. This results in a presence/absence raster of species with new values (0-24). The table below shows our Species Crosswalks:

Layer Name	Species	Species 6-Letter	Species Code
AMKE	American Kestrel	AMKE	1
BEAR	Bear	BEAR	2
CHBM	Choctawhatchee Beach Mouse	CHBM	3
CKMS	Cedar Key Mole Skink	CKMS	4
FLMOUSE	Florida Mouse	FLMOUS	5
FWSAL	Flatwood Salamander	FWSAL	6
GOPHTORT	Gopher Tortoise	GPHTRT	7
GPHRFRG	Gopher Frog	GPHFRG	8
GRSP	Grasshopper sparrow	GRSP	9
INDIGOSN	Indigo Snake	NDGSNK	10
NBOBWHITE	Northern Bobwhite	NBOBWT	11
PABU	Eastern Painted Bunting	PABU	12
PBTF	Pine Barren Tree Frog	PBTF	13
PINESNAKE	Pine Snake	PINSNK	14
RCW	Red Cockaded Woodpecker	RCW	15
RRCS	Rim Rock Crowned Snake	RRCS	16
SCJA	Scrub Jay	SCJA	17
SHFS	Sherman Fox Squirrel	SHFS	18
SHOGSNK	Southern Hognose Snake	SHGSNK	19
SSKINK	Sand Skink	SSKINK	20
STNEWT	Striped Newt	STNEWT	21
STSNAK	Short Tail Snake	STSNK	22
TIGERSAL	Tiger Salamander	TIGSAL	23
WILDTRK	Wild Turkey	WLDTRK	24

15) Once this is complete, use COMBINE to combine the reclassified species rasters into single rasters with all possible combinations of species overlap. *NOTE: Up to 20 rasters can be uploaded into a single combine; if you have more than this, you will have to perform this multiple times & join back on common fields (we had 24).*

   a. Input rasters: all species rasters that are in the presence/absence format (e.g., from step 14)
   b. Output raster: COMBO_SPP_<###>.TIF ← the <###> can help id the species rasters used (1-12,13-24, etc.)
   c. The fields will look something like this, where each column has the species code, and each value in that shows if that species is present or absent:

COMBO_SPP1to12.tif

OID	Value *	Count	amke_8b_20	bear_8b_20	chbm_8b_20	ckms_8b_20	flmouse_8b	fwsal_8b_2	gophtort_8
0	1	9629277	0	0	0	0	0	0	0
1	2	84867988	0	0	0	0	0	0	0
2	3	26701322	0	1	0	0	0	0	0
3	4	11533276	0	1	0	0	0	0	0
4	5	6987403	0	1	0	0	0	0	0
5	6	638666	0	0	0	0	0	0	1
6	7	20461740	0	0	0	0	0	0	0
7	8	8599960	0	0	0	0	0	0	0
8	9	99403	0	1	0	0	0	0	0

16) Finally, do one more COMBINE, and combine all individual 'COMBO_SPP_<###>.TIF rasters together in a logical order. For Example:

   a. Input Rasters: COMBO_SPP_1to12.TIF, COMBO_SPP_13to24.TIF
   b. Output Raster: COMBO_SPP_ALL.TIF

17) Add fields to the final combined raster of species presence/absence for further calculations in database using the Species 6-Letter code (step 14) as follows:

   a. <Species 6-Letter>, Long, Precision=5
   b. SPP_COUNT, Long, Precision=5

18) Calculate fields added in step 17:

   a. raster: COMBO_SPP_ALL.TIF
   b. jointable on VALUE based on 16.a inputs. (e.g., from COMBO_SPP2.TIF)
   c. Select by each of the fields that are present (i.e., see table from 15 -- if the value from COMBO_SPP1.TIF [field name AMKE_8b_20] is 1) and calculate <Species 6-Letter>=1 ← This essentially creates a bunch of 0s if species is not present, or 1s if species is present. Repeat for each species. *NOTE: if you have more than one COMBO_SPP#.TIF raster, only join/select/calculate on one set of joins at a time. Remove joins & repeat steps 18.b & 18.c for each set of combo rasters; do not go further until this is done!*

COMBO_SPP_ALL.tif

OID	Value *	Count	COMBO_SPP2	COMBO_SPP3	AMKE	BEAR	CHBM	CKMS	FLMOUS	FWSAL	GPHTRT	GPHFRG	GRSP	NDGSNK	NOBO
0	1	2009001	1	1	0	0	0	0	0	0	0	0	0	0	1
1	2	71882099	2	1	0	0	0	0	0	0	0	0	0	0	0
2	3	13822408	3	1	0	1	0	0	0	0	0	0	0	0	0
3	4	2441235	4	1	0	1	0	0	0	0	0	0	0	0	1
4	5	975319	1	2	0	0	0	0	0	0	0	0	0	0	1
5	6	3694951	2	2	0	0	0	0	0	0	0	0	0	0	0
6	7	1130792	4	2	0	1	0	0	0	0	0	0	0	0	1
7	8	914993	3	2	0	1	0	0	0	0	0	0	0	0	0

19) Convert the Raster to polygon:
    a. Input Raster: COMBO_SPP_ALL.TIF
    b. Output Polygon Features: COMBO_SPP_ALL_POLY
    c. Simplify Polygons & Create Multipart Features: UNCHECKED

20) Once the Fire, Seasonality, and Species layers have been created, a couple additional fields need to be added for easy queries once in database. Do the following:
    a. Add the following fields to P03_FL_ALL_BurnPolys_2006to2016:
        i. FIRE_BIN (Text, 50)
        ii. FIRE_DEC (Long)
        iii. FIRE_COUNT (Short)
        iv. FIRE_LAYERS (Text, 2000)
    b. Calculate the fields as follows using python in field calculator (or run a the BinaryCode__FireTables.py script):
        i. FIRE_BIN= str(!B2006!) + str(!B2007!) + str(!B2008!) + str(!B2009!) + str(!B2010!) + str(!B2011!) + str(!B2012!) + str(!B2013!) + str(!B2014!) + str(!B2015!) + str(!B2016!) + str(!B2017!) + str(!B2018!)
        ii. FIRE_DEC = int(!FIRE_BIN!,2)
        iii. FIRE_BIN= !FIRE_BIN!.count('1')
        iv. FIRE_LAYERS:

```
Expression:
Reclass(!FIRE_BIN!)

Code Block:
def Reclass(FIRE_BIN):
  layerlist =
['2018','2017','2016','2015','2014','2013','2012','2011','2010','2009','2008'
,'2007','2006']
  layerstr = ''
  myString = list(FIRE_BIN)
  id = len(myString) - 1
  firstflag = 1
  for i in myString:
    if i == '1':
      if firstflag == 1:
        layerstr = layerlist[id]
        firstflag = 0
      else:
        layerstr = layerstr + "," + layerlist[id]
    id = id -1
  return layerstr
```

c. Add the following fields to COMBO_SPP_ALL_POLY:
   i. SPP_BIN (Text, 50)
   ii. SPP_DEC (Long)
   iii. SPP_COUNT (Short)
   iv. SPP_LAYERS (Text, 2000)

d. Calculate the fields as follows using python in field calculator (or run a the BinaryCode__SpeciesTables.py script):
   i. SPP_BIN= str(!AMKE!) + str(!BEAR!) + str(!CHBM!) + str(!CKMS!) + str(!FLMOUS!) + str(!FWSAL!) + str(!GPHTRT!) + str(!GPHFRG!) + str(!GRSP!) + str(!NDGSNK!) + str(!NOBO!) + str(!PABU!) + str(!PBTF!) + str(!PSNK!) + str(!RCW!) + str(!RRCS!) + str(!SCJA!) + str(!SHFS!) + str(!SHGSNK!) + str(!SSKINK!) + str(!STNEWT!) + str(!STSNK!) + str(!TIGSAL!) + str(!WLDTRK!)
   ii. SPP_DEC = int(!SPP_BIN!,2)
   iii. SPP_BIN= !SPP_BIN!.count('1')
   iv. SPP_LAYERS:

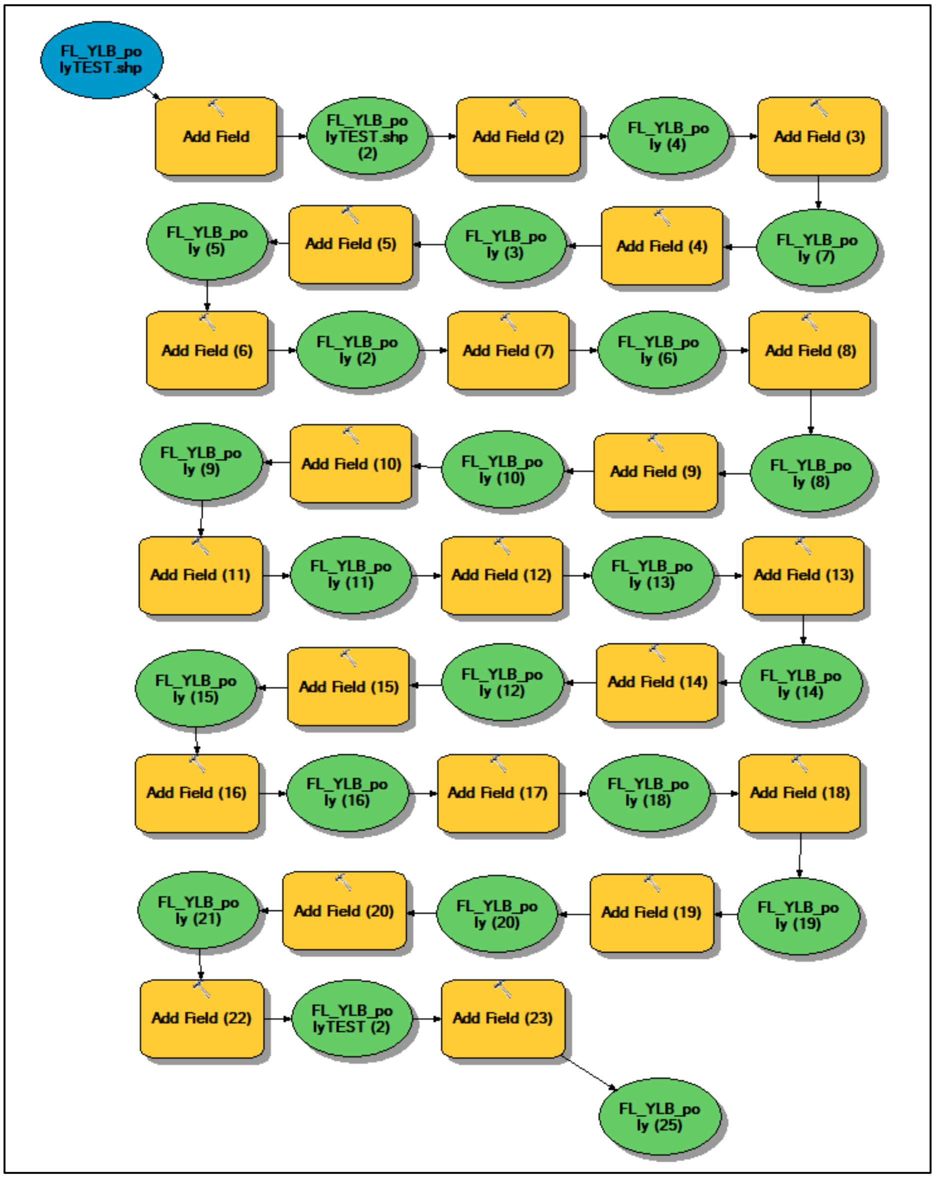
```
Expression:
Reclass(!SPP_BIN!)

Code Block:
def Reclass(SPP_BIN):
  layerlist = ['WLDTRK', 'TIGSAL', 'STSNK', 'STNEWT', 'SSKINK', 'SHGSNK',
'SHFS', 'SCJA', 'RRCS', 'RCW', 'PINSNK', 'PBTF', 'PABU', 'NBOBWT',
'NDGSNK', 'GRSP', 'GPHFRG', 'GPHTRT', 'FWSAL', 'FLMOUS', 'CKMS',
'CHBM', 'BEAR', 'AMKE']
  layerstr = ''
  myString = list(SPP_BIN)
  id = len(myString) - 1
  firstflag = 1
  for i in myString:
    if i == '1':
      if firstflag == 1:
        layerstr = layerlist[id]
        firstflag = 0
      else:
        layerstr = layerstr + "," + layerlist[id]
    id = id -1
  return layerstr
```

e. Add the following fields to SEASONALITY_ALL_FC:
    i. FIRE_BIN (Text, 50)
    ii. FIRE_DEC (Long)
    iii. FIRE_COUNT (Short)
    iv. FIRE_LAYERS (Text, 2000)
    v. DGSEAS_BIN (Text, 50)
    vi. TSEAS_LYR (Text, 2000)
    vii. DG_LYR (Text, 2000)

f. Calculate the fields as follows using python in field calculator:
    i. FIRE_BIN, FIRE_DEC, FIRE_COUNT, and FIRE_LAYERS: Calc as described in 20.b
    ii. DGSEAS _BIN = str(!DG_Code06!, !DG_Code07!, !DG_Code08!, !DG_Code09!, !DG_Code10!, !DG_Code11!, !DG_Code12!, !DG_Code13!, !DG_Code14!, !DG_Code15!, !DG_Code16!, !DG_Code17!, !DG_Code18!)
    iii. DG_LYR = !DGSEAS_BIN!.replace("1","Growing;").replace("2","Dormant;").replace("0","")
    iv. TSEAS_BIN = str(!TOY_Code06!, !TOY_Code07!, !TOY_Code08!, !TOY_Code09!, !TOY_Code10!, !TOY_Code11!, !TOY_Code12!, !TOY_Code13!, !TOY_Code14!, !TOY_Code15!, !TOY_Code16!, !TOY_Code17!, !TOY_Code18!)
    v. TSEAS_LYR = !TSEAS_BIN!.replace("1","Spring;").replace("2","Summer;").replace("3","Fall;").replace("4","Winter;").replace("0","")

21) Add field attributes to every raster and polygon layer that will be added to SQL dbase using the AddEventPyroFields model tool; if adding fields by hand, see table on next page for guidance on the fields & datatypes:



	A	B	C	D	E	F	G
1	**Column Name**	**Data type**	**Max Length**	**precision**	**scale**	**is_nullable**	**Primary Key**
2	OBJECTID	int	4	10	0	0	1
3	PYRO_ID	numeric	17	38	0	0	0
4	FUEL_TYPE	numeric	9	18	0	1	0
5	BURN_DATE	datetime2	8	27	7	1	0
6	CONTROL_DATE	datetime2	8	27	7	1	0
7	TYPE_BURN	numeric	9	18	0	1	0
8	CAUSE	numeric	9	18	0	1	0
9	USERNAME	nvarchar	60	0	0	1	0
10	RECORD_DATE	datetime2	8	27	7	1	0
11	BLOCK	numeric	9	18	0	1	0
12	LAST_RAIN	datetime2	8	27	7	1	0
13	MODEL_ID	numeric	9	18	0	1	0
14	BURN_OBJECTIVE_1	numeric	9	18	0	1	0
15	BURN_OBJECTIVE_2	numeric	9	18	0	1	0
16	EVENT_COMMENT	nvarchar	480	0	0	1	0
17	ENT_ID	numeric	9	18	0	1	0
18	PROPERTY_ID	numeric	9	18	0	1	0
19	MOD_DATE	datetime2	8	27	7	1	0
20	VALID_GEOM	nvarchar	2	0	0	1	0
21	ACRES	numeric	17	38	8	1	0
22	PLOTS_BURNED	nvarchar	2	0	0	1	0
23	GEOMETRY_SOURCE	numeric	17	38	8	1	0
24	SHAPE	geography	-1	0	0	1	0
25	GDB_GEOMATTR_DATA	varbinary	-1	0	0	1	0
26	RESPONSIBLE_AGENCY_ID	numeric	9	18	0	1	0
27	LANDCOVER_ID	numeric	9	18	0	1	0
28							

22) Clip the rasters & vectors to state of Florida (or the AOI of your choice) if not already done –initially the instructions were written for processing entire ARD mosaics (these mosaics will be in some sort of 'native' ARD PRJ; for FL FWC project, the files all need to be reprojected to the FL Albers HARN project [FDEP_ALB_HARN]. The easiest thing to do is to ensure that your AOI is projected to the same projection as the mosaic, clip all your vectors and rasters, and then reproject these 'smaller' datasets to the desired projection for your AOI)

23) Add to spatial database, with metadata as follows:

METADATA TEXT

This dataset is derived from the USGS Burned Area Products (Hawbaker *et al.* 2017). We used Burned Area (BA) version 2 products (USGS 2019). We evaluated the *annual*BAECV Burn Probability (BP) datasets –which are raster datasets – for evidence of burns. The annual datasets span an entire calendar year (*e.g.,*Jan 1 through Dec 31) and indicate the maximum BP within the year (0-100%). For each year between 2006 and 2018, we combined the annual datasets of interest within individual ARD Tiles into a single annual raster dataset (*i.e.,* we mosaicked the tiles) for further processing. We performed all additional processing steps on the annual mosaicked datasets as this provided statewide consistency. We identified pixels as burned or unburned according to their probability value; initially, we retained all pixels with an annual BP between 85-100% based on Hawbaker *et al.* (2017). Values between 90-100% were then converted to presence/absence rasters and we used image processing methods to remove 'speckling' (*e.g.,*fill in small holes within a burned area and remove groups of pixels less than a specified size/amount). This process resulted in annual rasters and vectors indicating burn presence (with 90-100% probability) for groups of pixels greater than ~2.24 acres (*e.g.,*10 30m pixels, in any arrangement). We also assigned dates from the Burn Date (BD) dataset to these same pixels as a surrogate for seasonality. We evaluated these products against fire records for three pilot areas. For each area, we held a meeting with fire managers, either in person or via web conferencing methods. We invited managers to inspect the data with us to evaluate their thoughts on the products. Through this process, managers provided many explanations for why no burn was detected and where/why fire detection was performing very well, as well as some ideas and suggestions for moving forward (all of which we relayed to USGS). Many of these comments reflect known limitations previously documented (see Hawbaker *et al.* 2017, Vanderhoof *et al.* 2017). Based on these meetings, we have applied the processing "logic" across the entire state at 90-100%BP. Fire regime metrics such as number of times burned, year last burned, and time since previous fire (as measured from 2019) are included in the dataset upload, and were derived using these annual presence/absence rasters and vectors.

References:

Hawbaker, T.J.; Vanderhoof, M.K.; Beal, Y-J.; Takacs, J.D.; Schmidt, G.; Falgout, J.; Brunner, N.; Caldwell, M.; Dwyer, J. 2017. An automated approach to identify burned areas in LANDSAT images. Remote Sens. Environ., 198, 504–522.

United States Geological Survey [USGS]. 2019. Landsat Level-3 Burned Area Science Product. < https://www.usgs.gov/centers/eros/science/usgs-eros-archive-landsat-landsat-level-3-burned-area-ba-science-product?qt-science_center_objects=0#qt-science_center_objects>. Digital Object Identification: doi.org/10.5066/F77W6BDJ

Vanderhoof, M. K.; N. Fairaux; Y-J. G. Beal; T.J. Hawbaker. 2017. Validation of the USGS LANDSAT Burned Area Essential Climate Variable (BAECV) across the conterminous United States. Remote Sens. Environ., 198, pp. 393-406.

Contact:

Casey Teske (cteske at talltimbers dot org) or Joe Noble (jnoble at talltimbers dot org) for more information.

Appendix E: Update Procedures

Software Requirements (Must be on machine prior to connecting to DB):

Must have SQL Server Manager installed on your machine in order to connect to SQL database through Arc

Software required to connect to SQL Server (http://desktop.arcgis.com/en/system-requirements/latest/database-requirements-sqlserver.htm)
Any client machines that connect directly to SQL Server must have a SQL Server client installed. SQL Server clients for Windows and Linux are distributed by Microsoft. SQL Server clients for Windows are also available on the ESRI site. You must install a client that is the same version or a newer version than the SQL Server database to which you want to connect. If you upgrade SQL Server, upgrade the SQL Server clients at the same time. When a version of SQL Server is no longer supported by ArcGIS, the corresponding SQL Server client library will no longer be supported either.
Supported SQL Server clients are as follows:

- SQL Server 2017
  - Microsoft ODBC Driver 17 for SQL Server
- SQL Server 2016
  - Microsoft ODBC Driver 17 for SQL Server

Note: When connecting from ArcGIS Server on Ubuntu 16.04.x to any version of SQL Server, you must install the Microsoft unixodbc-dev package on all ArcGIS Server machines in addition to the ODBC driver.

Connect to Microsoft SQL Server from ArcGIS
(http://desktop.arcgis.com/en/arcmap/latest/manage-data/gdbs-in-sql-server/overview-geodatabases-sqlserver.htm)

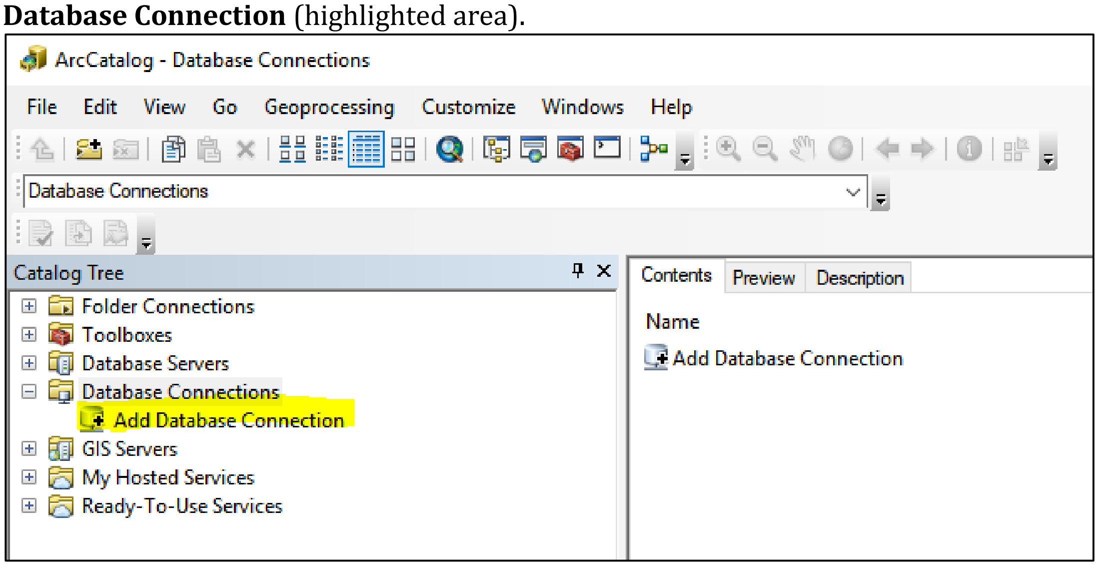
You can connect to Microsoft SQL Server from ArcGIS clients. To do so, install a supported Microsoft SQL Server ODBC driver on the ArcGIS client machine and connect to the database from the ArcGIS client. Next, create a connection file. To use the data stored in SQL Server in services published to an ArcGIS Server site, register the database or geodatabase with the site.

Install the ODBC driver for SQL Server
Obtain the Microsoft ODBC driver for SQL Server from the Microsoft Download Center or from ESRI. Be sure to get the Microsoft ODBC driver that is supported for the version of SQL Server to which you want to connect. Install the driver on all computers where ArcMap is installed. *NOTE: If you are installing the driver on a 64-bit operating system, run the 64-bit executable; it installs both 32- and 64-bit files. If you run the 32-bit installation on a 64-bit operating system, it will fail.*

Connecting to SQL geodatabase
First, be sure your SQL Server instance can accept connections from remote computers. You can connect to a database or geodatabase in SQL Server by adding a database connection under the **Database Connections** node in the Catalog tree in ArcMap or ArcCatalog or using the Create Database Connection tool. *Tip: If you have connection files that were created prior to ArcGIS 10.1, they will still work. However, if you need to create a connection to an older release geodatabase using an ArcSDE service, use the Create ArcSDE Connection File geoprocessing tool.*

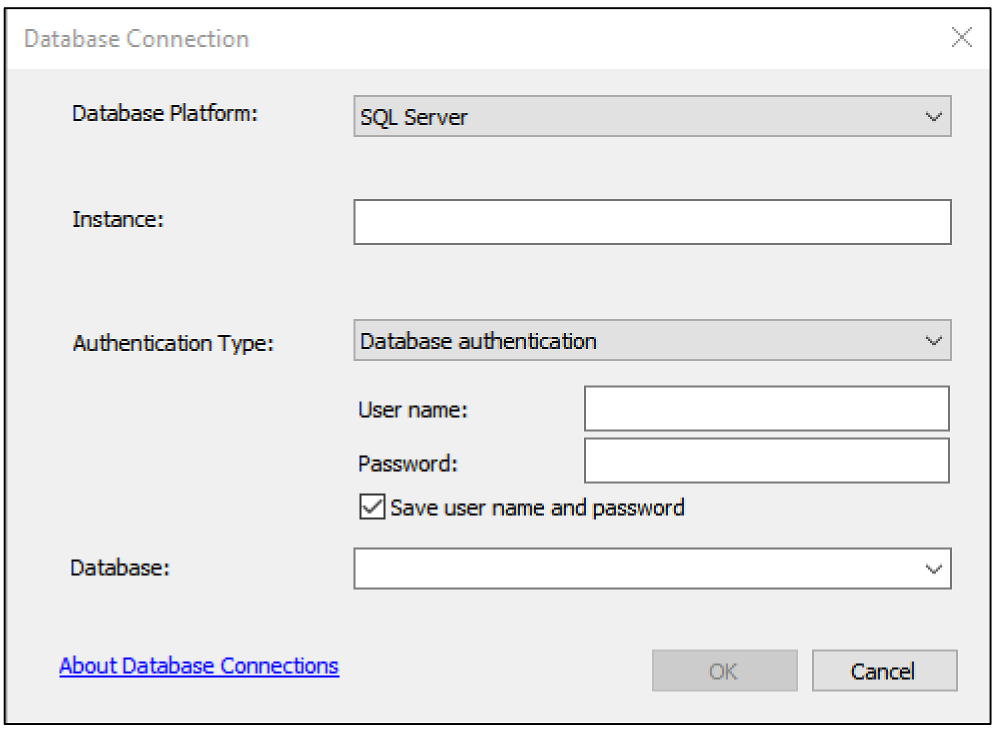
The following steps describe using the **Database Connection** dialog box.

1. Expand **Database Connections** in the Catalog tree in ArcMap or ArcCatalog and double-click **Add Database Connection** (highlighted area).

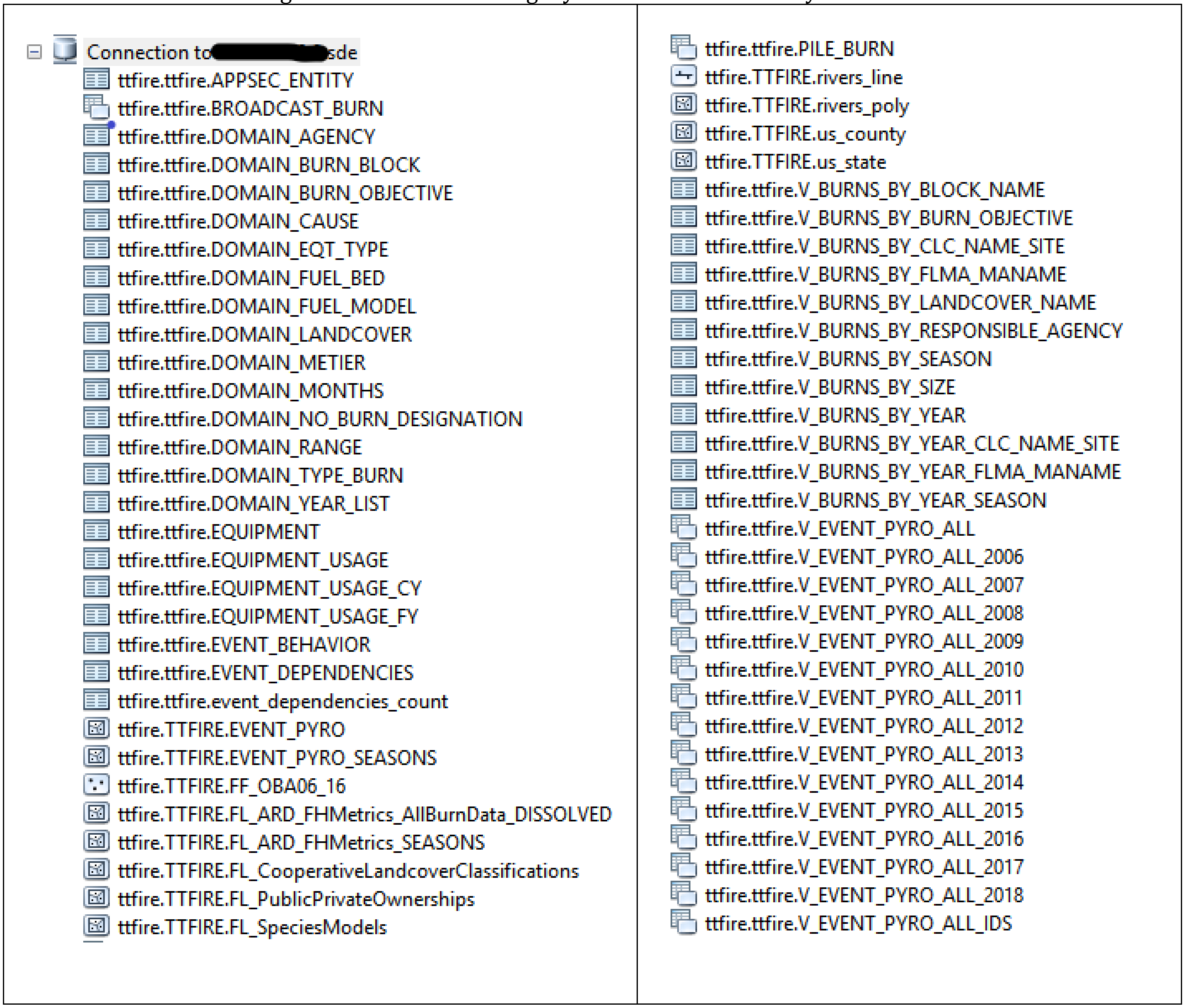


2. Choose **SQL Server** from the **Database Platform** drop-down list. **(*YOU CAN GET THE INFORMATION REQUIRED IN THE DATABASE CONNECTION SCREEN FROM YOUR DATABASE ADMINISTRATOR*)**
   - Type the SQL Server instance name in the **Instance** text box.

- Choose the type of authentication to use when connecting to the database: **Database authentication**.
    - If you choose **Database authentication**, you must provide a valid database user name and password in the **User name** and **Password** text boxes, respectively. User names can be a maximum of 30 characters.
    - Uncheck **Save user name and password** if you prefer not to save your login information as part of the connection; doing this can help maintain the security of the database. However, if you do this, you will be prompted to provide a user name and password every time you connect. Also note that **Save user name and password** must be checked for connection files that provide ArcGIS services with access to the database or geodatabase, or if you want to use the Catalog search to locate data accessed through this connection file.
- In the **Database** text box, type or choose the name of the specific database you want to connect to on the SQL Server or SQL Database instance. The database name is limited to 31 characters.
  Tip: The database name is required when connecting to SQL Database.
- Click **OK** to connect.

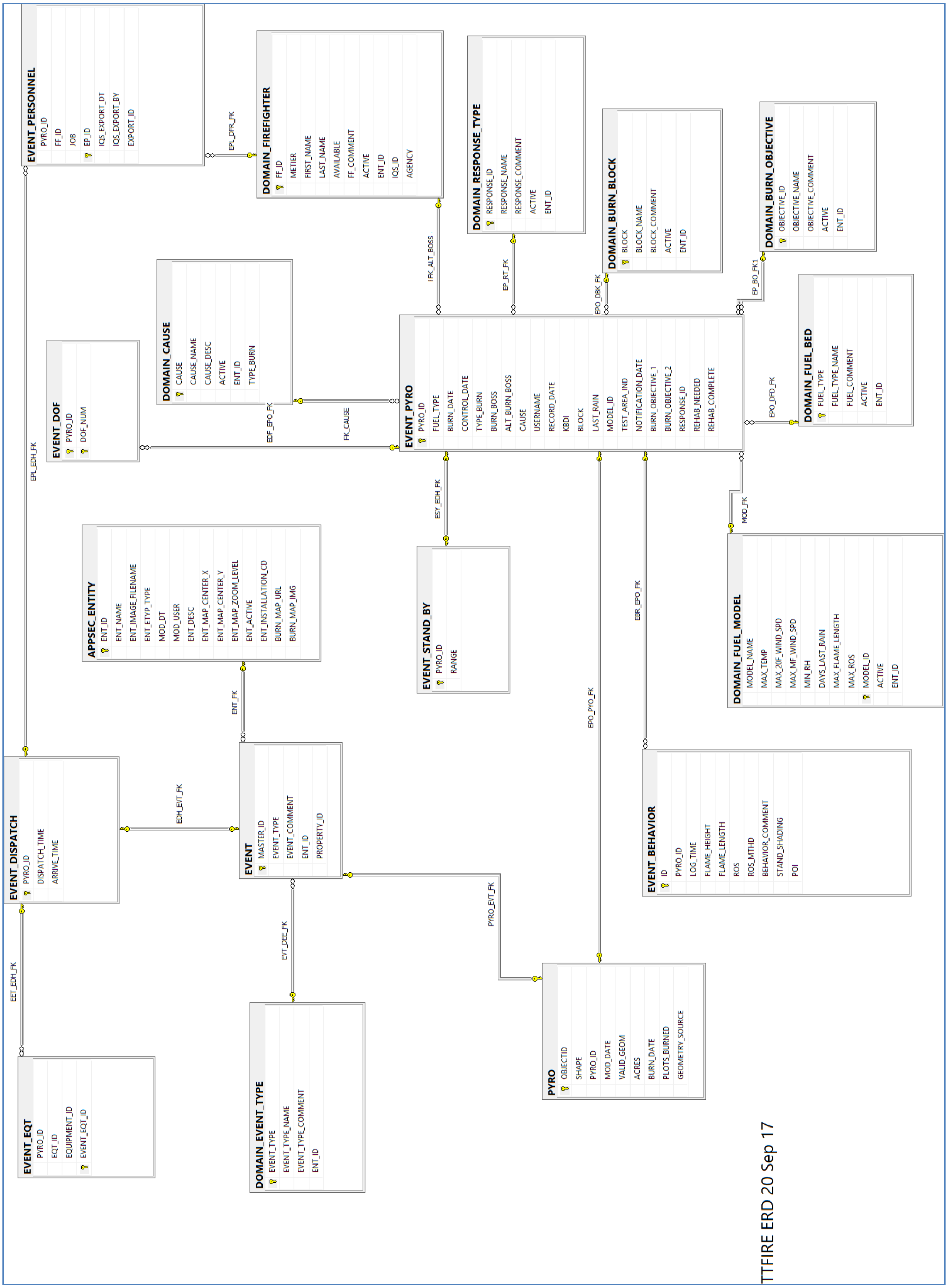


You will now see something similar to the following if you connect successfully:



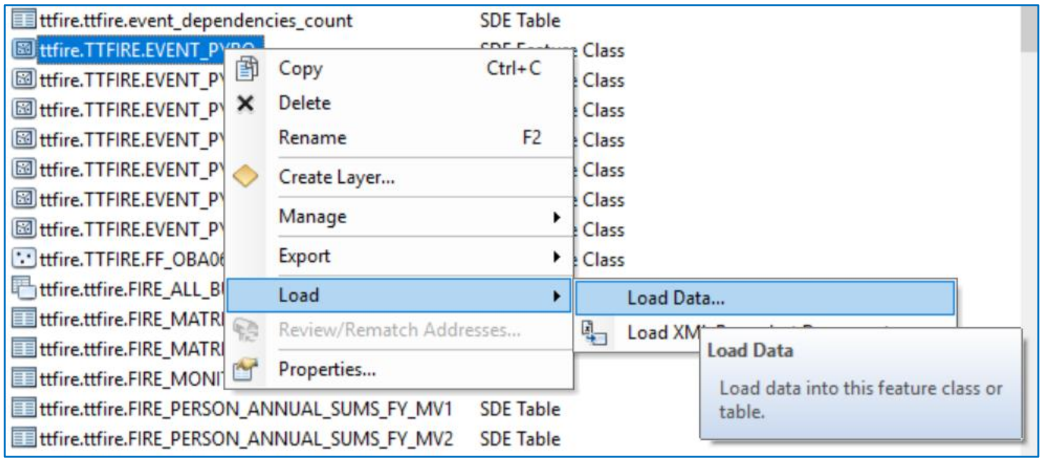
It is also possible to connect to a 'View Only' connection, or a SQL Server Management Studio. Specific login instructions for doing that have been provided to the Database Administrator as part of the final deliverable, but are not provided here for security purposes.

The following page shows the entity relational diagram for the SQL database.

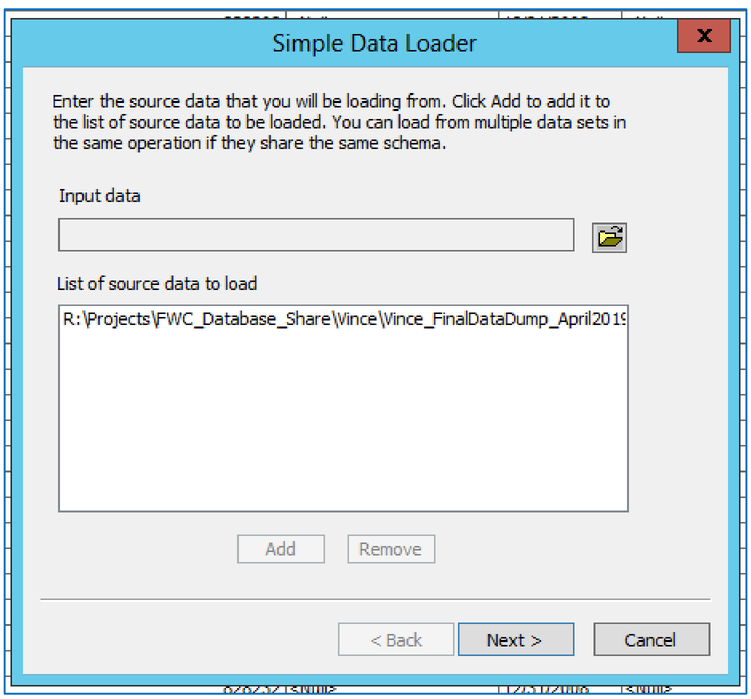

EVENT_PERSONNEL
PYRO_ID
FF_ID
JOB
EP_ID
IQS_EXPORT_DT
IQS_EXPORT_BY
EXPORT_ID
EPL_DFR_FK
DOMAIN_FIREFIGHTER
FF_ID
METIER
FIRST_NAME
LAST_NAME
AVAILABLE
FF_COMMENT
ACTIVE
ENT_ID
IQS_ID
AGENCY
DOMAIN_RESPONSE_TYPE
RESPONSE_ID
RESPONSE_NAME
RESPONSE_COMMENT
ACTIVE
ENT_ID
DOMAIN_BURN_BLOCK
BLOCK
BLOCK_NAME
BLOCK_COMMENT
ACTIVE
ENT_ID
DOMAIN_BURN_OBJECTIVE
OBJECTIVE_ID
OBJECTIVE_NAME
OBJECTIVE_COMMENT
ACTIVE
ENT_ID
IFK_ALT_BOSS
EP_RT_FK
EPO_DBK_FK
EP_BO_FK1
DOMAIN_CAUSE
CAUSE
CAUSE_NAME
CAUSE_DESC
ACTIVE
ENT_ID
TYPE_BURN
EVENT_DOF
PYRO_ID
DOF_NUM
EDF_EPO_FK
FK_CAUSE
EPL_EDH_FK
EVENT_PYRO
PYRO_ID
FUEL_TYPE
BURN_DATE
CONTROL_DATE
TYPE_BURN
BURN_BOSS
ALT_BURN_BOSS
CAUSE
USERNAME
RECORD_DATE
KBDI
BLOCK
LAST_RAIN
MODEL_ID
TEST_AREA_IND
NOTIFICATION_DATE
BURN_OBJECTIVE_1
BURN_OBJECTIVE_2
RESPONSE_ID
REHAB_NEEDED
REHAB_COMPLETE
EPO_DFD_FK
DOMAIN_FUEL_BED
FUEL_TYPE
FUEL_TYPE_NAME
FUEL_COMMENT
ACTIVE
ENT_ID
MOD_FK
ESY_EDH_FK
APPSEC_ENTITY
ENT_ID
ENT_NAME
ENT_IMAGE_FILENAME
ENT_ETYP_TYPE
MOD_DT
MOD_USER
ENT_DESC
ENT_MAP_CENTER_X
ENT_MAP_CENTER_Y
ENT_MAP_ZOOM_LEVEL
ENT_ACTIVE
ENT_INSTALLATION_CD
BURN_MAP_URL
BURN_MAP_IMG
EVENT_STAND_BY
PYRO_ID
RANGE
EBR_EPO_FK
DOMAIN_FUEL_MODEL
MODEL_NAME
MAX_TEMP
MAX_20F_WIND_SPD
MAX_MF_WIND_SPD
MIN_RH
DAYS_LAST_RAIN
MAX_FLAME_LENGTH
MAX_ROS
MODEL_ID
ACTIVE
ENT_ID
ENT_FK
EPO_PYO_FK
EDH_EVT_FK
EVENT_DISPATCH
PYRO_ID
DISPATCH_TIME
ARRIVE_TIME
EVENT
MASTER_ID
EVENT_TYPE
EVENT_COMMENT
ENT_ID
PROPERTY_ID
EVENT_BEHAVIOR
ID
PYRO_ID
LOG_TIME
FLAME_HEIGHT
FLAME_LENGTH
ROS
ROS_MTHD
BEHAVIOR_COMMENT
STAND_SHADING
POI
PYRO_EVT_FK
EVT_DEE_FK
EET_EDH_FK
EVENT_EQT
PYRO_ID
EQT_ID
EQUIPMENT_ID
EVENT_EQT_ID
DOMAIN_EVENT_TYPE
EVENT_TYPE
EVENT_TYPE_NAME
EVENT_TYPE_COMMENT
ENT_ID
PYRO
OBJECTID
SHAPE
PYRO_ID
MOD_DATE
VALID_GEOM
ACRES
BURN_DATE
PLOTS_BURNED
GEOMETRY_SOURCE
TTFIRE ERD 20 Sep 17

TO ADD NEW FIRE DATA (OR SEASONALITY DATA) TO DATABASE:

1. Appending new fires (or Seasonality feature classes).
   1.1. Invoke ArcCatalog and connect to the database using the ttfire user connection.
   1.2. In the **Contents** pane, locate the **ttfire.TTFIRE.EVENT_PYRO** table. (Use **ttfire.TTFIRE.EVENT_PYRO_SEASONS** for seasonality feature classes)
   1.3. Right click on the **ttfire.TTFIRE.EVENT_PYRO** table to invoke the context menu and select Load -> Load Data option. (Use **ttfire.TTFIRE.EVENT_PYRO_SEASONS** for seasonality feature classes)

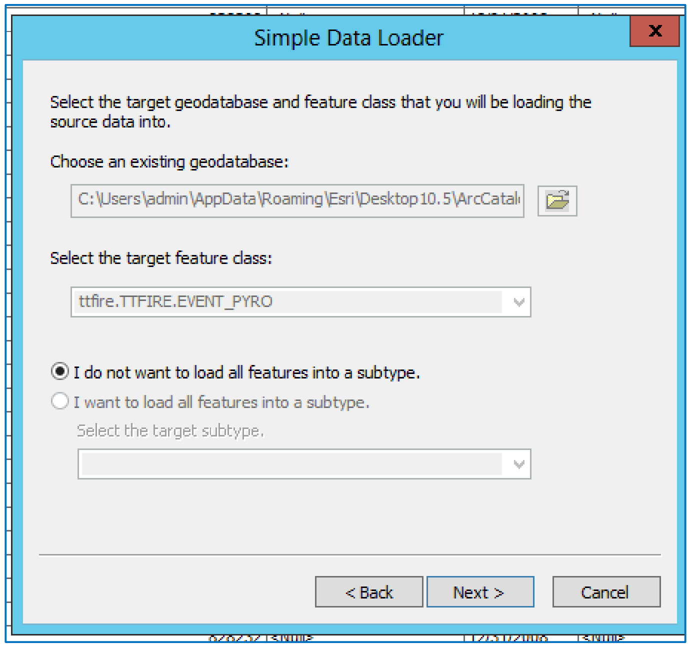


   1.4. In the **Simple Data Loader** window click the folder to the right of **Input data** and navigate to the new data and select.
   1.5. Click the **Add** button to add the data to the **List of source data to load**.



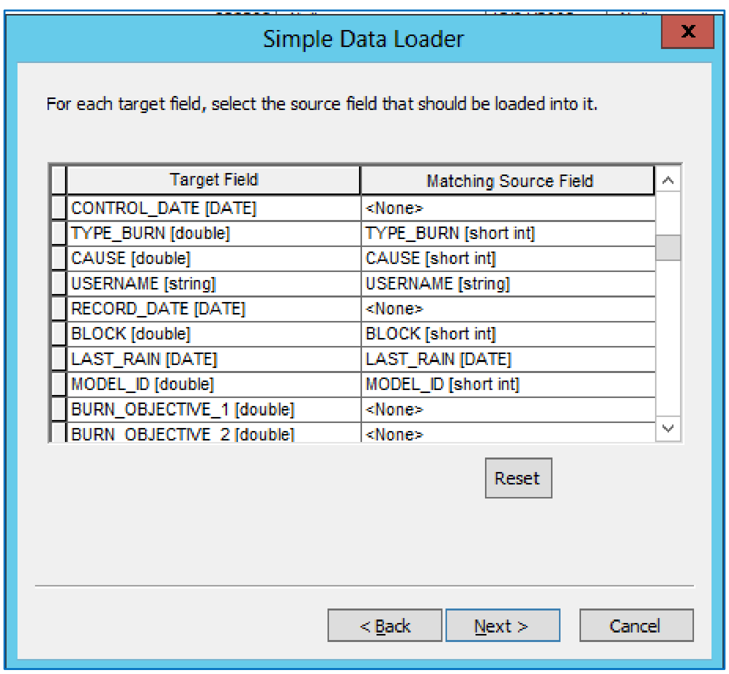
   1.6. Click Next

1.7. Leave the defaults options on the next window and click **Next**.

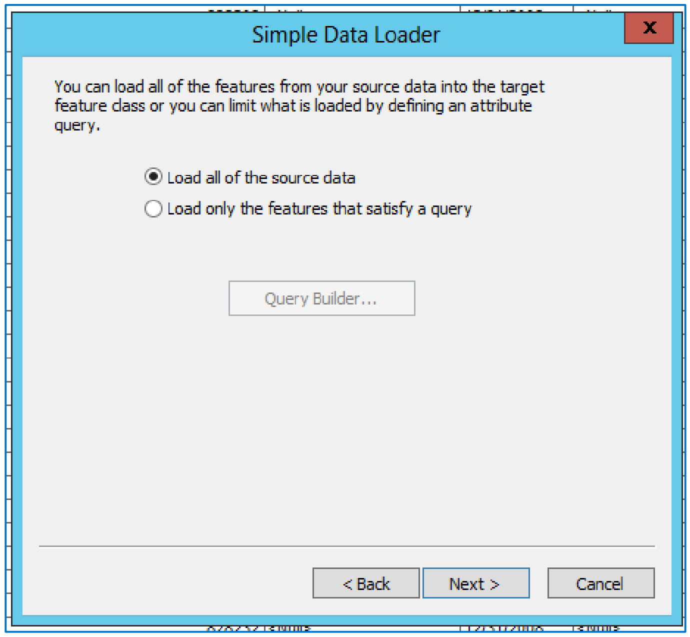


1.8. If your source data has different columns than event_pyro, use the next window to match the columns.

1.9. Once the columns are mapped properly, click next.



1.10. Choose Load all of the source data and Click Next.



1.11. Click Finish on the Summary window

1.12. Once the Simple Data Loader is complete, verify the load with ArcCatalog.

- You may need to calculate the BURN DATE (dec 31, <YEAR>) and GIS_AC (copy & paste this from the feature class). Then select OK.

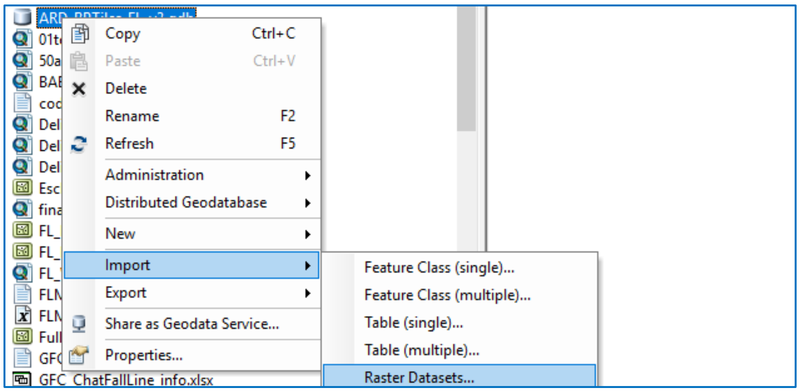
TO ADD NEW NON-FIRE DATA TO DB:

New Feature Classes

1.1. Invoke ArcCatalog
1.2. In the **Contents** pane, locate the database & feature class you want to add.
1.3. Right click on the feature class to invoke the context menu and select copy
1.4. Locate the database you want to add the feature class to
1.5. Right click on the database and click Paste
   - In the configuration keyword box (under Geodatabase Settings), select GEOMETRY
   - Click Ok

New Rasters

1.6. Invoke ArcCatalog
1.7. In the **Contents** pane, locate the database
1.8. Right click on the database to invoke the context menu and select Import ->



   - Add the raster(s) you want to add in the Input Rasters box
   - Click Ok

IF YOU SCREW UP:

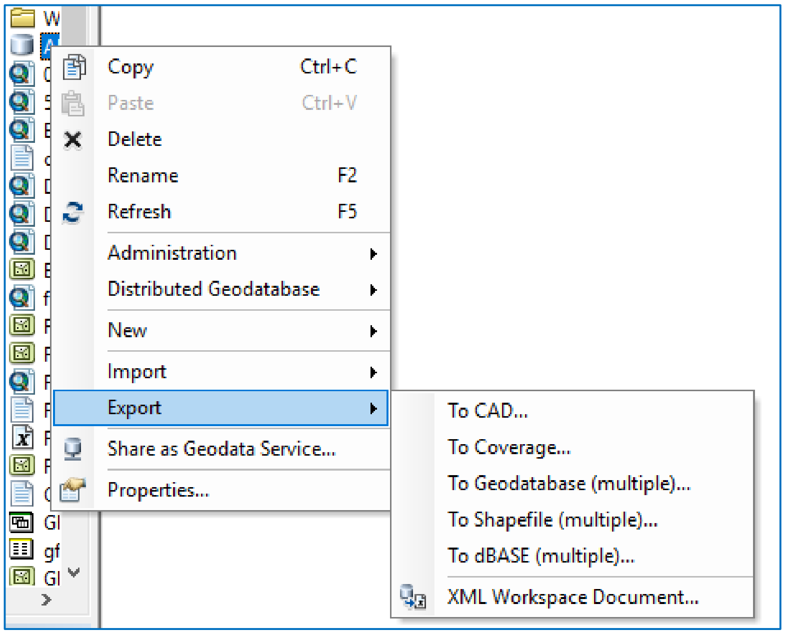
- Load data into Arcmap {TTFIRE_EVENT_PYRO]
- Select Editor | options| Versioning| uncheck edit a version, uncheck autosave change after edit.
  - Select by attributes, (then select the attributes that will get you the data you want to delete), ok
  - Then start editing (editor), choose layer to edit, continue, then open table & choose which to delete, save & stop editing

TO USE TEMPORARY DATA FOR FILTERING

1.1. Invoke ArcMap
1.2. Add feature classes you want to evaluate to the view (eg, FHMetrics*).
1.3. Add the data set you want to 'filter' with (ie, an ownership boundary; a geometric extent; a new landcover class; etc.)
1.4. Use 'CLIP' tool and clip the dataset from 1.2 with the dataset from 1.3.
1.5. Evaluate the new dataset as you would normally with Arc or add to a file geodatabase.

HOW TO DOWNLOAD SPATIAL DATA

1.6. Invoke ArcCatalog
1.7. In the **Contents** pane, locate the database
1.8. Right click on the database to invoke the context menu and select Export
1.9. Select the appropriate choice based on what you are interested in downloading



Appendix F: ESRI Web App Procedures

The following section describes the environments and process used to create an ESRI Web App that connected to the SQL Server database. A similar process was followed in preparation for the March 2019 workshop held at the FFS. Screens of the sample web app were presented there to help showcase the data and highlight a few of the available database queries.

ArcGIS Enterprise 10.6.1 Environment

The server environment used to create the sample web app consists of a base ArcGIS Enterprise deployment consisting of three VMs (OS – Microsoft Windows Server 2012 R2 Datacenter). The three servers are configured in the following roles: app server, web server and database server. The app server is installed with both ESRI's ArcGIS Server 10.6.1 and Portal for ArcGIS 10.6.1. The ArcGIS Server instance is federated with the Portal instance and acts as its hosting server. Two ESRI Web Adaptors are installed on the web server (IIS 8.5) – one for ArcGIS Server and one for Portal. ArcGIS Data Store is installed on the database server. The database server in the ArcGIS Enterprise deployment is running PostgreSQL 10.5.1/PostGIS 2.4.4 and is separate and distinct from the SQL Server machine hosting the fire spatial database. ArcGIS Desktop 10.6.1 (ArcCatalog and ArcMap) are installed on the app server to facilitate the sharing of services for web apps.

Laptop PC Environment

The laptop used to create the sample web app is a Dell Latitude E7450 running Microsoft Windows 10 Pro. It is configured with 16GB RAM and an Intel Core i5 Processor (i5-5200U/2.20Ghz). ArcGIS Catalog 10.6.1, ArcMap 10.6.1, and Google Chrome 73x were used to interact with the data, servers and the sample web app.

Web App Process Steps

The general steps to create an ESRI Web App connecting to the SQL Server are detailed below. Each step is elaborated in the continuing paragraphs.

1. Install SQL Server Client software on all connecting machines;
2. Create Database Connection file (.sde) in ArcCatalog;
3. Create registered Data Store in ArcGIS Server using .sde file;
4. Connect to database, add layer(s) and share map as service to Portal using ArcMap;
5. In Portal, add service as a layer to a Portal web map and save;
6. In Portal, share saved web map as an app using the Web App Builder and save; and,
7. Add and configure the query widget by building SQL queries using fire metrics, landowner, and/or seasonality attributes from the database.

1. Install SQL Server Client Software

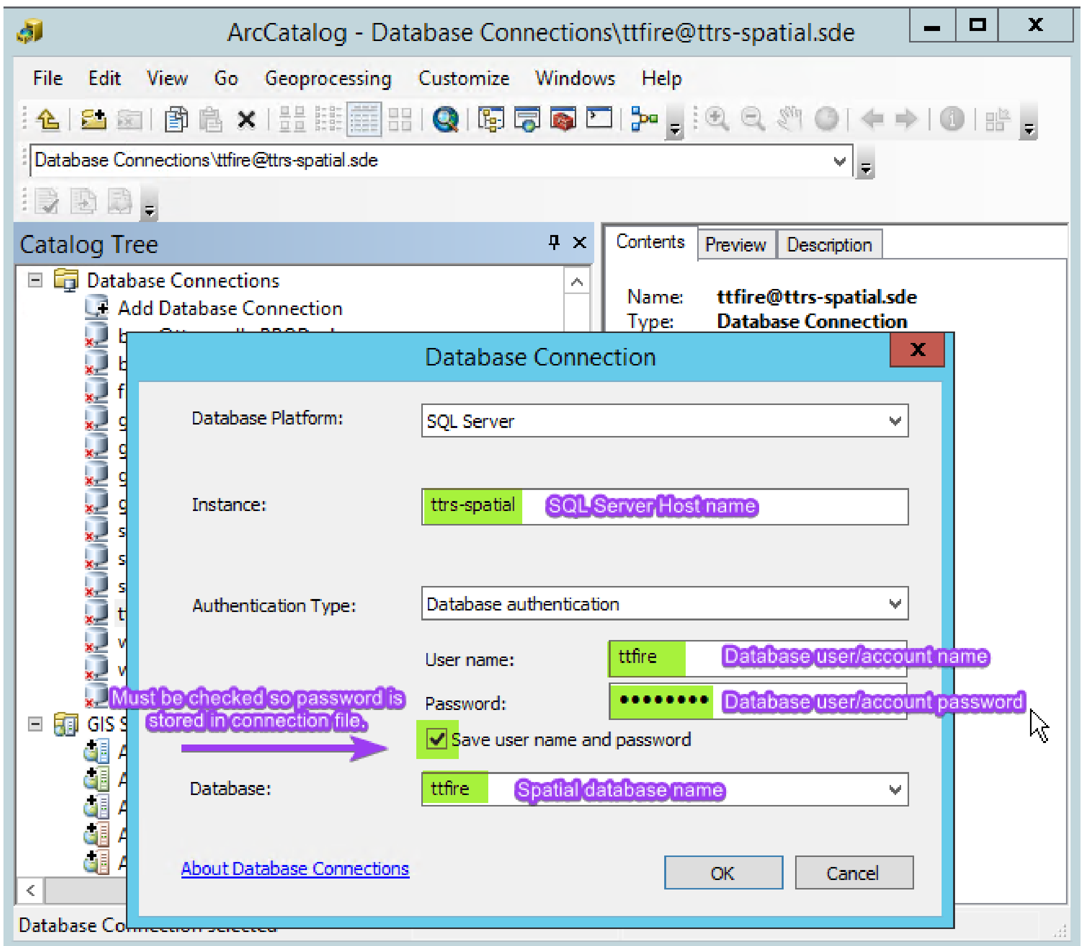
The SQL Server client software (Microsoft ODBC Driver 11 for SQL Server) was installed on the laptop and the app server. The installation file for the 64-bit version of the driver software was downloaded from ESRI's myesri support site. ArcCatalog and ArcMap require a 32-bit version of the client software. ArcGIS Server and Portal require the 64-bit version of the client software. The 64-bit installation file obtained from ESRI's site contains both the 32-bit and 64-bit versions. This file was used for both the laptop install and server install.

For specific information on supported SQL Server clients for ArcGIS 10.6.x, please see:
http://desktop.arcgis.com/en/system-requirements/10.6/database-requirements-sqlserver.htm

2. Create ArcCatalog Connection to SQL Server database

On the app server, a Database Connection was created to the SQL Server database using ArcCatalog. The first time ArcCatalog establishes a connection to a database, a .sde file is created on the client to store the properties required for communication with the database server. The .sde file is used each time a connection is established to the database. The default location for these files is within the Users folder on the client computer (\Users\<user_name>\AppData\Roaming\ESRI\Desktop<release#>\ArcCatalog).

The Database Connection dialog below displays the values supplied to create a connection to the SQL server database using ArcCatalog on the app server. In order to use the .sde file for establishing a Data Store with ArcGIS Server, the "Save user name and password" option must be checked so that this information is stored in the connection file (.sde). The .sde file used to create the sample web app was named using the database account name + "@" + SQL Server Host name. This file, ttfire@ttrs-spatial.sde, was coped to a network file share to simplify access for the next step, creating a registered Data Store in ArcGIS Server.



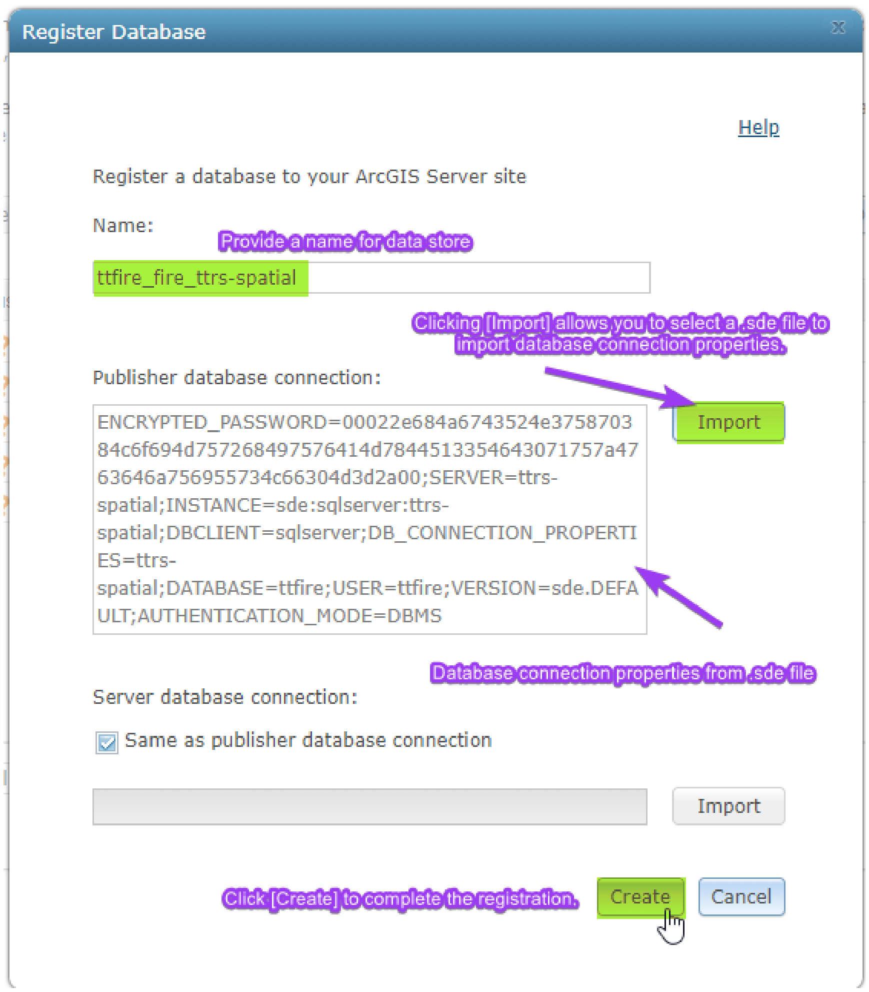
For more information on establishing Database connections in ArcMap, please see: http://desktop.arcgis.com/en/arcmap/10.6/manage-data/databases/database-connections-desktop.htm.

For specifics regarding connecting to Microsoft SQL Server from ArcGIS, please see: http://desktop.arcgis.com/en/arcmap/10.6/manage-data/databases/connect-sqlserver.htm

3. Create Registered Data Store in ArcGIS Server

After establishing a connection to the SQL server database, the resulting .sde file was used to create a registered Data Store on the ArcGIS Server. Registering the database as a Data Store establishes the needed information for ArcGIS Server to create appropriate references to the data used in services. The registration can be done in ArcGIS Server Manager or via ArcGIS Desktop.

ArcGIS Server Manager was used to register the Data Store in the creation of the sample web app. The Register Database dialog below displays the values supplied to establish the registration. The **Import** button was clicked and another dialog box displayed which allowed for browsing to the network location of the ttfire@ttrs-spatial.sde file. After selecting that file, the database connection properties were imported into the dialog and clicking the **Create** button completed the registration and creation of the Data Store.



For more information on registering a SQL Server database with ArcGIS Server, please see: http://enterprise.arcgis.com/en/server/10.6/publish-services/windows/register-sql-server-with-arcgis-server.htm

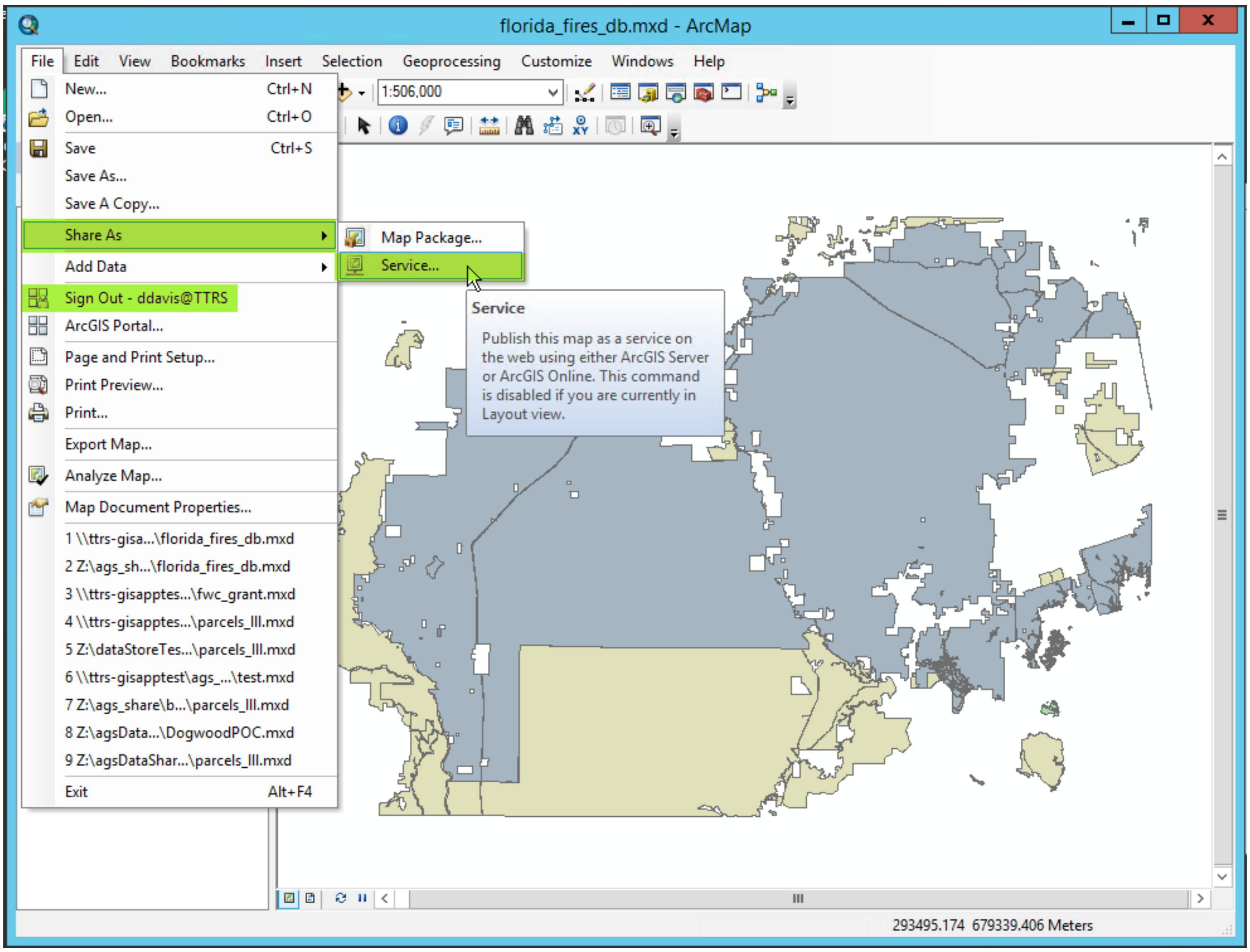
For more information on registering data with ArcGIS server using ArcGIS Desktop, please see: http://enterprise.arcgis.com/en/server/10.6/publish-services/windows/registering-your-data-with-arcgis-server-using-arcgis-for-desktop.htm

4. Share Map as Service to Portal

The next step after registering the database with ArcGIS Server is to use ArcMap to share a map as a service to Portal. In ArcMap, a connection was made to the database, data layers were added, symbolized and filtered. Then, after signing into the Portal, the map was published and shared as a Hosted Feature Service to the Portal.

The image below displays the mxd used to create the map service available in the sample web app. A selected area of FNAI's Conservation Lands (FLMA) data was clipped to the Apalachicola National Forest boundary to use as a focus area. A definition query was applied to the fire data to filter out any polygons not containing fire or species data. A scale threshold was set on the visibility of the fire data so that it did not display when the map was zoomed out beyond 1:24K.

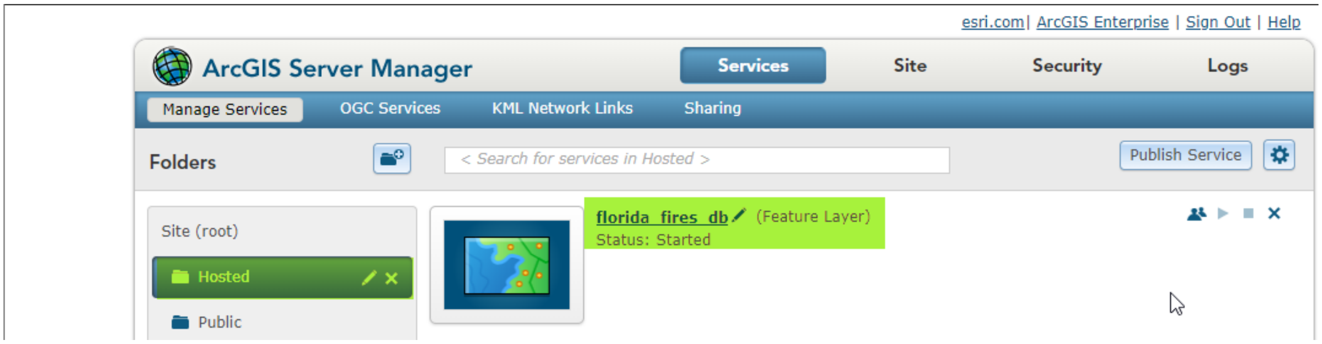
By default, ArcGIS Desktop connects to ArcGIS Online. The ArcGIS Administrator can be set, however, to connect to an ArcGIS Enterprise Portal, rather than ArcGIS Online. The **Sign Out** option indicates that the user was currently signed into an ArcGIS Enterprise Portal.

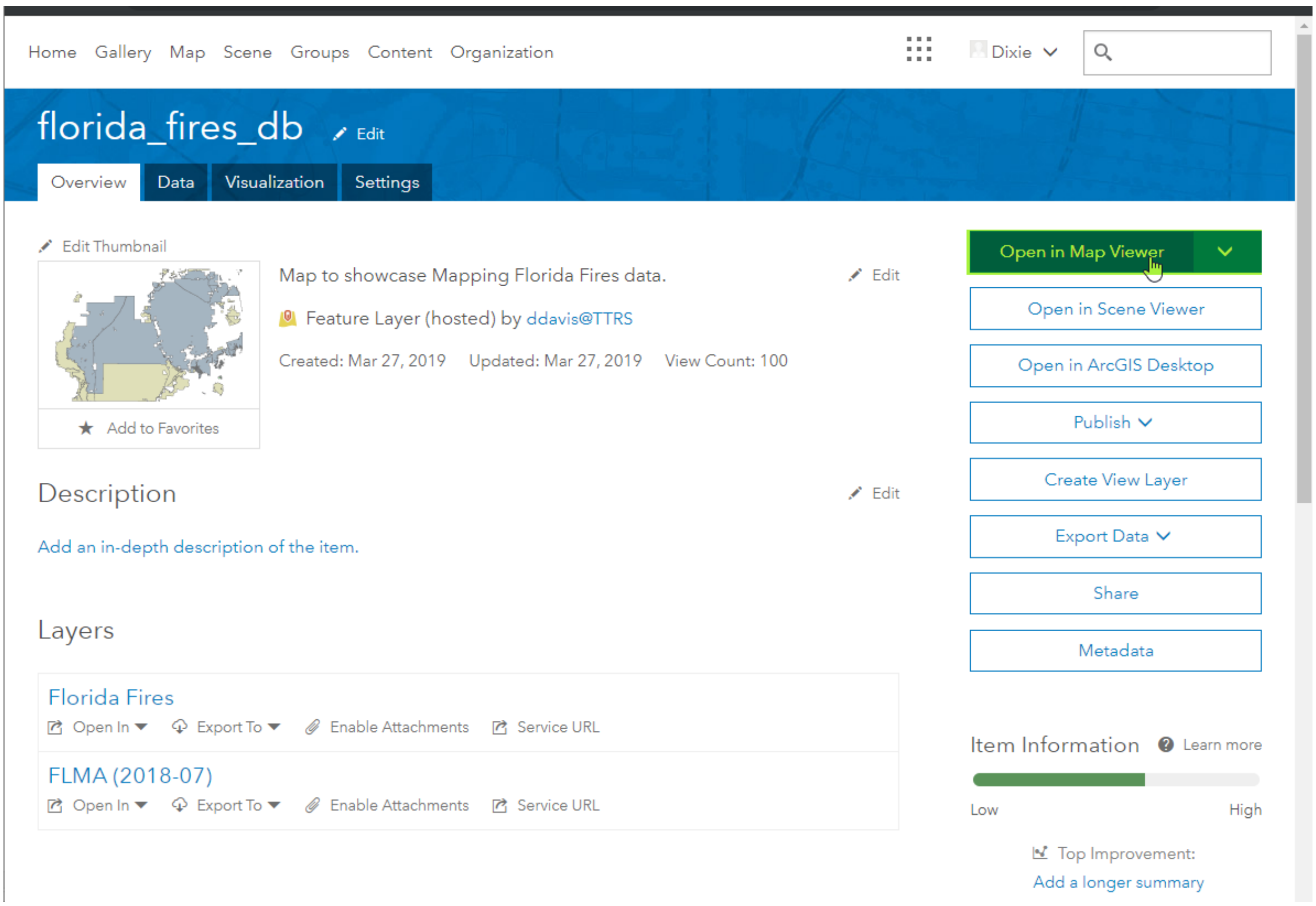


For more information on sharing a service using ArcMap, please see:
http://enterprise.arcgis.com/en/server/10.6/publish-services/windows/sharing-a-service-with-your-arcgis-organization-using-arcgis-for-desktop.htm

For more information on using the Manage Portal Connection tool in ArcGIS Administrator, please see:
https://desktop.arcgis.com/en/arcmap/10.6/get-started/administer/managing-portal-connections-from-arcgis-for-desktop.htm

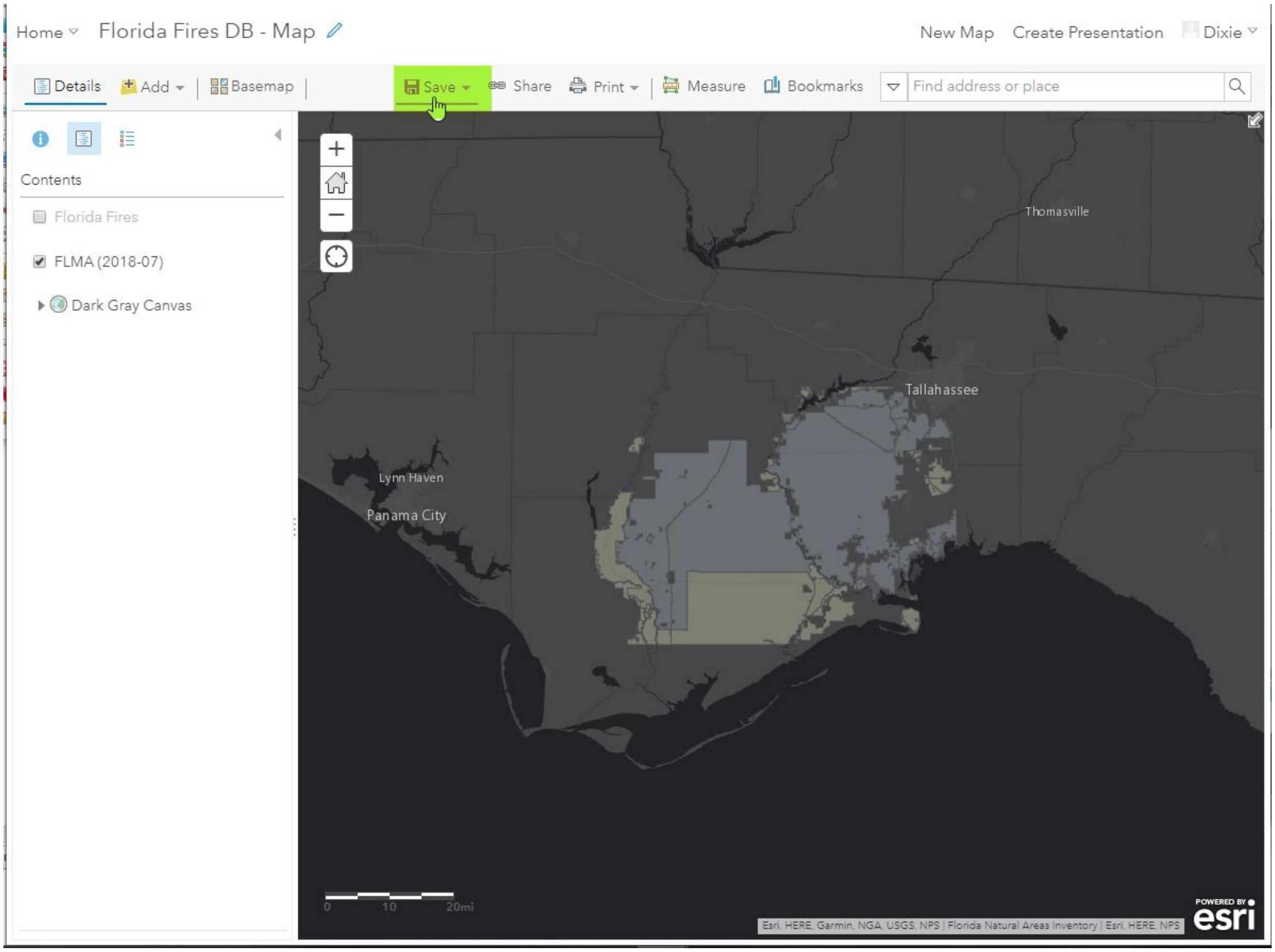
After the map was successfully published to Portal, a Hosted Feature Service (HFS) was available in ArcGIS Server Manager and a Hosted Feature Layer was available in the Portal. The images below display screen captures taken after logging into ArcGIS Server Manager and Portal, respectively.

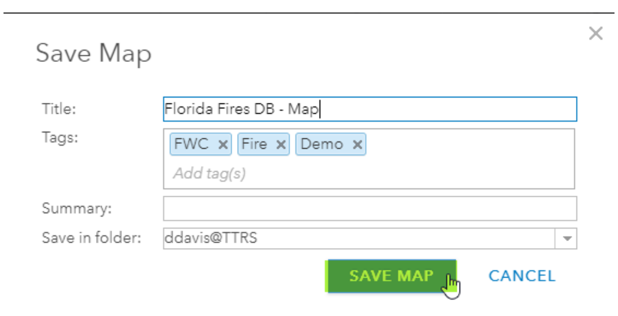




5. Create Web Map in Portal

The next step in creating the sample web app was to use the published service as a feature layer in a Portal web map. To create a web map, the feature layer must be added to the Portal's Map Viewer. The Map Viewer is the default mapping application available in the ArcGIS Enterprise Portal. After the feature layer was added, a Basemap was selected and the map was saved so it could serve as the web map for the sample web app.

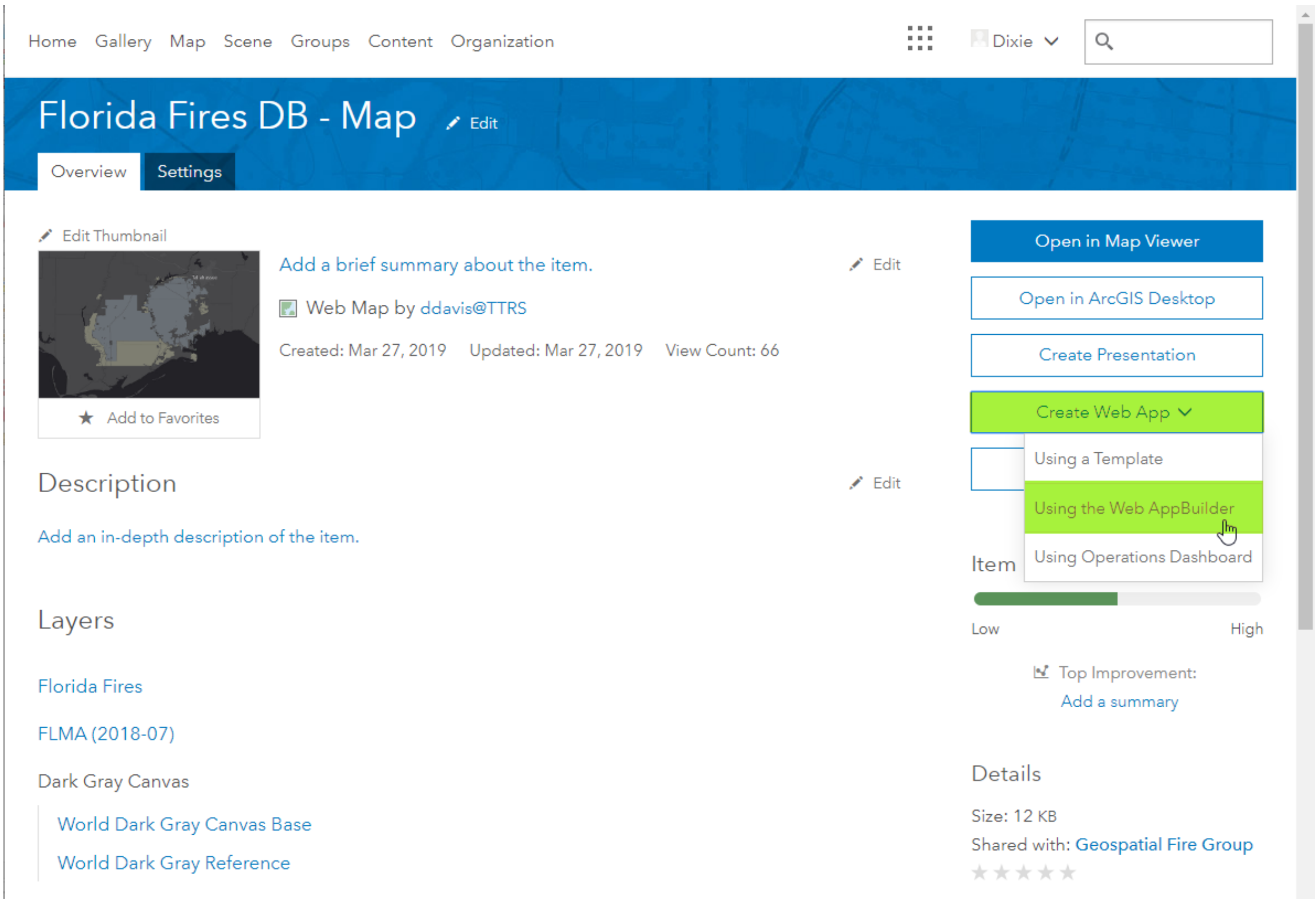


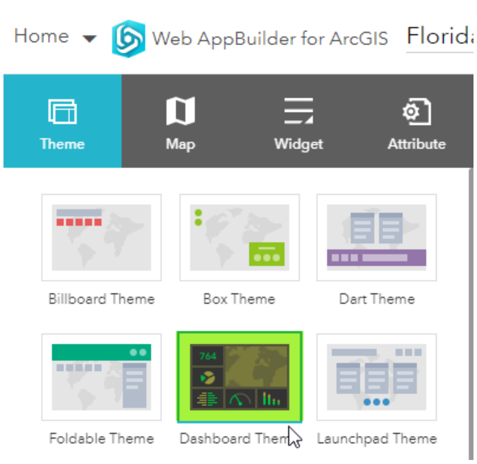


For more information on web maps, please see: https://enterprise.arcgis.com/en/portal/10.6/use/get-started-with-maps.htm

6. Create Web App in Portal using Web App Builder

Next, the web map was used to create a web app using the Portal's Web AppBuilder. The Web AppBuilder is a built-in Portal application that allows the end-user to select and configure a theme, a map and widgets to use in a custom web app. Launching the Web AppBuilder from a web map's Item page in Portal will automatically select it as the given map for the app. A Dashboard Theme was chosen as the theme for the sample web app.



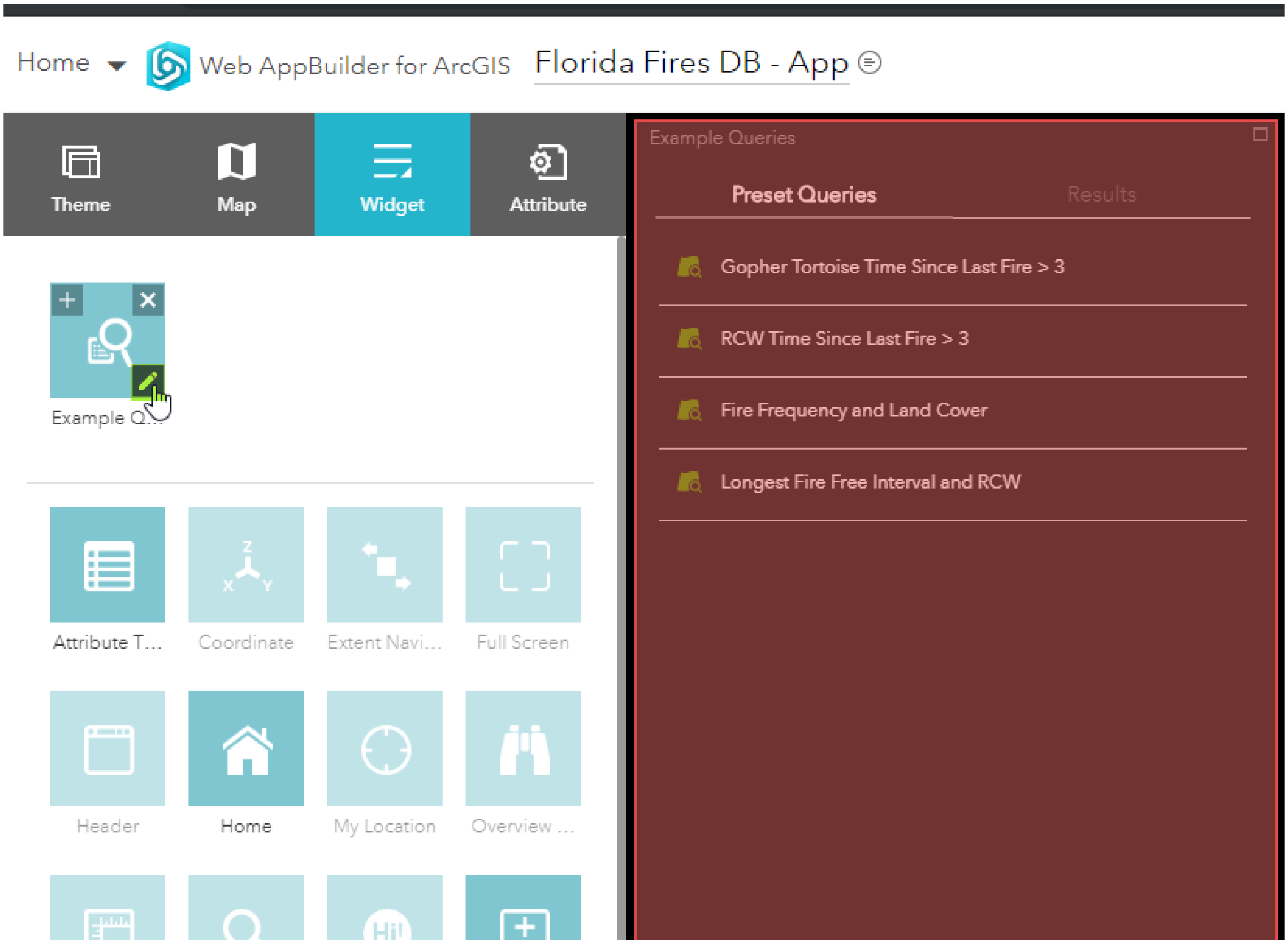


For more information on the Web AppBuilder for ArcGIS, please see:
https://enterprise.arcgis.com/en/portal/10.6/use/welcome.htm

7. Configure Queries using Query Widget

Finally, the Query Widget was added to the sample web app and several preset queries were defined as examples to be available as interactive tools in the sample web app. The Query Widget was added as an in-panel widget and then configured to create four distinct queries, each with different query filters to illustrate the fire metrics available in the database. Spatial filters were set to allow user-generated shapes or the current map extent.

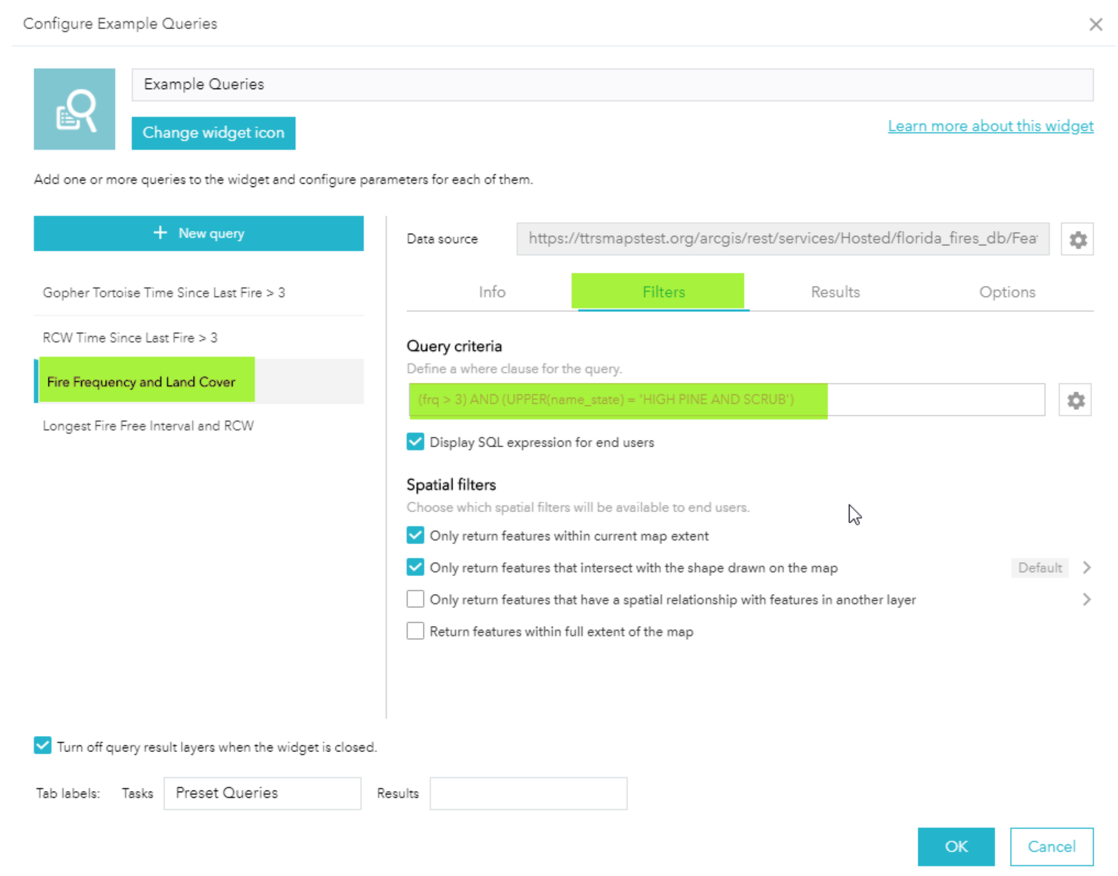
The image below displays selecting the Query Widget to configure preset queries.

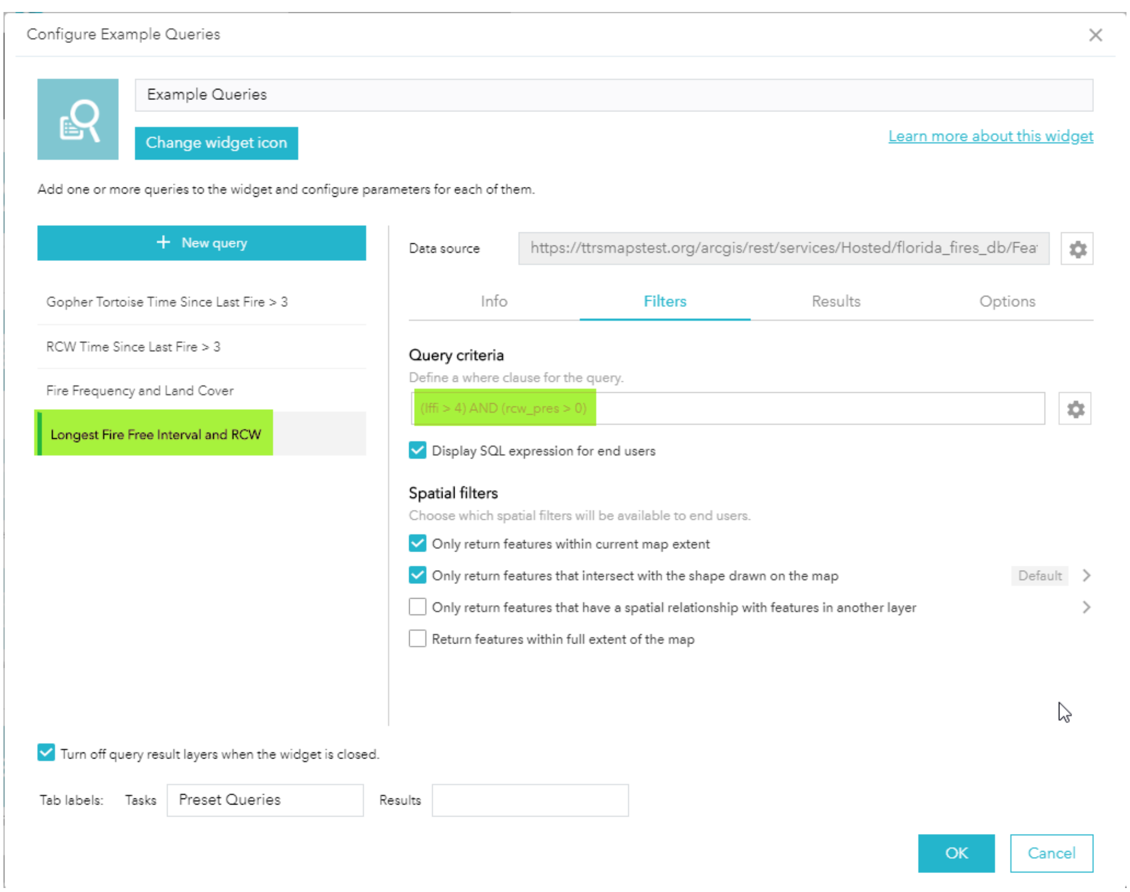


For more information on Web AppBuilder widgets, please see:
https://enterprise.arcgis.com/en/portal/10.6/use/widget-overview.htm

For specific information on the Query Widget, please see:
https://enterprise.arcgis.com/en/portal/10.6/use/widget-query.htm

The following images display the configuration screen for a selected preset query. The selected queries displayed are for: “Fire Frequency and Land Cover” and “Longest Fire Free Interval and RCW”.





Appendix G: Server & Workstation Size Requirements and Specifications

Server specifications are for the development environment. These specifications may vary depending on intended use and production environment. They are listed below.

General

Host Name	TTRS-SPATIAL.ttrs.local		
Description	TTRS_SPATIAL		
Online	Yes	Added	12/18/2017 12:19:12 PM
IP Address	192.168.20.8	Boot Time	4/26/2019 12:52:44 AM
MAC Address	7C:4C:58:7A:40:A7	Uptime	4.08:22:11
Current User	TTRS\admin (disconnected)		
Time Zone	(UTC-05:00) Eastern Time (US & Canada)		

Operating System

Name	Microsoft Windows Server 2012 Datacenter		
O/S	2012	Installed	9/20/2017 5:44:52 PM
Version	6.2.9200	Serial Number	00184-80005-49074-AA680
SP / Release		System Drive	C
Architecture	64-bit	Needs Reboot	No
PowerShell Version	3.0	IE Version	10.0.9200.22671
.NET Versions	4.0 Client, 4.0 Full, 4.7.1		

Active Directory

Path	Computers		
Description			
Domain	ttrs.local		
Location	IT		
Last Logon	4/30/2019 8:54:00 AM	Created	9/20/2017 10:55:05 PM

System

Manufacturer	Red Hat
Model	KVM
Processor	8-Core 1.7 GHz QEMU Virtual CPU version 2.3.0
Memory	24 GB
Chassis	Other
Serial Number	
BIOS Version	seabios-1.7.5-11.el7
BIOS Manufacturer	SeaBIOS
BIOS Asset Tag	
Family	Red Hat Enterprise Linux
Version	RHEL 7.2.0 PC (i440FX + PIIX, 1996)
SKU	

Scanning

Allow Scan	Yes		
Last Scan	9 minutes (4/30/2019 9:05 AM)	Last Scan Profile	Standard
Scan User	TTRS.LOCAL\admin		

Applications installed on the development server are listed below.

Application Name
Active Directory Authentication Library for SQL Server
ArcGIS Desktop 10.5.1
Browser for SQL Server 2017
Google Chrome
Microsoft .NET Framework 4.5 Multi-Targeting Pack
Microsoft .NET Framework 4.5.1 Multi-Targeting Pack
Microsoft .NET Framework 4.5.1 Multi-Targeting Pack (ENU)
Microsoft .NET Framework 4.5.1 SDK
Microsoft .NET Framework 4.5.2 Multi-Targeting Pack
Microsoft .NET Framework 4.5.2 Multi-Targeting Pack (ENU)
Microsoft Help Viewer 1.1
Microsoft Help Viewer 2.2
Microsoft MPI (7.0.12437.8)
Microsoft ODBC Driver 13 for SQL Server
Microsoft SQL Server 2008 Setup Support Files
Microsoft SQL Server 2012 Express LocalDB
Microsoft SQL Server 2012 Management Objects (x64)
Microsoft SQL Server 2012 Native Client
Microsoft SQL Server 2014 Management Objects
Application Name
Microsoft SQL Server 2016 (64-bit)
Microsoft SQL Server 2016 Setup (English)
Microsoft SQL Server 2016 T-SQL Language Service
Microsoft SQL Server 2016 T-SQL ScriptDom
Microsoft SQL Server 2017 (64-bit)
Microsoft SQL Server 2017 Policies RC1
Microsoft SQL Server 2017 RC1
Microsoft SQL Server 2017 Setup (English)
Microsoft SQL Server 2017 T-SQL Language Service RC1
Microsoft SQL Server Data-Tier Application Framework (x86)
Microsoft SQL Server Management Studio - 17.2
Microsoft System CLR Types for SQL Server 2012 (x64)
Microsoft System CLR Types for SQL Server 2014
Microsoft System CLR Types for SQL Server 2017 RC1
Microsoft Visual C++ 2010 x64 Redistributable - 10.0.40219
Microsoft Visual C++ 2010 x86 Redistributable - 10.0.40219
Microsoft Visual C++ 2013 Redistributable (x64) - 12.0.21005
Microsoft Visual C++ 2013 Redistributable (x86) - 12.0.21005
Microsoft Visual C++ 2015 Redistributable (x64) - 14.0.23506

Application Name
Microsoft Visual C++ 2015 Redistributable (x86) - 14.0.23026
Microsoft Visual Studio 2015 Shell (Isolated)
Microsoft Visual Studio Tools for Applications 2015
Microsoft Visual Studio Tools for Applications 2015 Language Support
Microsoft VSS Writer for SQL Server 2017
Scale Computing Guest Tools
Veeam Agent for Microsoft Windows
Veeam Backup Transport
Veeam CBT Driver
Veeam Installer Service
Webroot SecureAnywhere

Desktop specifications may not reflect minimum specifications to produce products, based on size of datasets processed and production methods used. They are listed below.

General

Host Name	GS-Desktop.ttrs.local		
Description	GS-Desktop-		
Online	Yes	Added	4/30/2019 9:06:26 AM
IP Address	192.168.21.137	Boot Time	4/28/2019 12:21:59 PM
MAC Address	00:1B:21:BE:FE:42	Uptime	1.20:51:50
Current User	TTRS\CTeske		
Time Zone	(UTC-05:00) Eastern Time (US & Canada)		

Operating System

Name	Microsoft Windows 10 Pro		
O/S	10	Installed	11/13/2018 5:49:18 AM
Version	10.0.17134.706	Serial Number	00331-20020-00000-AA124
SP / Release	1803	System Drive	C
Architecture	64-bit	Needs Reboot	No
PowerShell Version	5.1.17134.1	IE Version	11.706.17134.0
.NET Versions	4.0 Client, 4.0 Full, 4.7.1 (or later)		

Active Directory

Path	Computers		
Description			
Domain	ttrs.local		
Location			
Last Logon	4/28/2019 12:22:07 PM	Created	11/9/2018 8:40:34 PM

System

Manufacturer	System manufacturer
Model	System Product Name
Processor	32-Core 3.4 GHz AMD Ryzen Threadripper 1950X 16-Core Processor
Memory	96 GB
Chassis	Desktop
Serial Number	System Serial Number
BIOS Version	0808
BIOS Manufacturer	American Megatrends Inc.
BIOS Asset Tag	Default string
Family	To be filled by O.E.M.
Version	System Version
SKU	SKU

Scanning

Allow Scan	Yes		
Last Scan	6 minutes (4/30/2019 9:06 AM)	Last Scan Profile	Standard
Scan User	TTRS.LOCAL\admin		

Applications installed on the desktop are listed below. Not all applications are required for processing, depending on user needs.

Application Name
7-Zip 18.05 (x64)
AMD Ryzen Master
ArcGIS Desktop 10.6
ArcGIS Desktop Background Geoprocessing 10.6 (64-bit)
ArcGIS Pro
AURA
AURA Service
Cisco Webex Meetings
CloudCompare 2.9.1
Corsair LINK 4
CPUID CPU-Z 1.87
Enthought Canopy (64-bit)
ENVI 5.5.1
ERDAS IMAGINE 2018
Geospatial Licensing 2018
Google Chrome
Google Earth Pro
Intel(R) Network Connections 22.6.6.0
Leica Geosystems XPro SGM 6.4

Application Name
Microsoft .NET Core SDK 2.1.500 (x64)
Microsoft ODBC Driver 13 for SQL Server
Microsoft Office Professional Plus 2016
Microsoft OneDrive
Microsoft System CLR Types for SQL Server vNext CTP1.6
Microsoft Visual C++ 2008 Redistributable - x64 9.0.30729.17
Microsoft Visual C++ 2010 x64 Redistributable - 10.0.40219
Microsoft Visual C++ 2010 x86 Redistributable - 10.0.40219
Microsoft Visual C++ 2013 Redistributable (x64) - 12.0.21005
Microsoft Visual C++ 2013 Redistributable (x64) - 12.0.30501
Microsoft Visual C++ 2017 Redistributable (x64) - 14.16.27012
Microsoft Visual C++ 2017 Redistributable (x86) - 14.16.27012
Microsoft Visual Studio Installer
Notepad++ (64-bit x64)
NVIDIA 3D Vision Controller Driver 390.41
NVIDIA 3D Vision Driver 416.81
NVIDIA Graphics Driver 416.81
NVIDIA PhysX System Software 9.18.0907
Patriot Viper RGB

Application Name
Samsung Magician
Spatial Modeler Deep Learning Expansion Pack 2018
Update for Windows 10 for x64-based Systems (KB4023057)
Visual Studio Community 2017
Windows Driver Package - Corsair Components, Inc. (SIUSBXP) USB (07/14/2017 3.3)
Windows Mobile Connectivity Tools 10.0.15254.0 - Desktop x86
Windows SDK AddOn
Windows Setup Remediations (x64) (KB4023057)
Windows Software Development Kit - Windows 10.0.17134.12
WizTree v3.28

Fields in FL Burn data

FIELD NAME	VALUES	NOTES
B2006 – B2018	0 or 1	Presence/absence of a burn in a given year (e.g., if B2006 has a value of 1, there was a fire in 2006)
FRQ	1-13	Number of times burned between 2006-2018
YLB	2006-2018	Year last burned (measured from 2019) between 2006-2018 (actual year)
TSPF	1-13	Time since previous fire (measured from 2019) between 2006-2018 (yrs)
LFFI	1-13	Longest Fire Free Interval (2006-2018) in yrs
GIS_AC	**	Total Acres of polygon
FIRE_BIN	**	Binary string used for processing
FIRE_DEC	**	Code from binary string used for processing
FIRE_COUNT	**	Code from binary string used for processing
FIRE_LAYERS	**	List of years that a location burned
<all other fields are for querying within database, but not given a value here>		

Fields in FL SEASONS Data

FIELD NAME	VALUES	NOTES
Gridcode06 – Gridcode18	0 or 1	Presence/absence of a burn in a given year (e.g., if gridcode06 has a value of 1, there was a fire in 2006)
TOY_06-TOY_18	Spring, Summer, Autumn, Winter	Time of Year a fire was first recorded in a given year (from acquisition date of first image registering fire)
TOY_Code06 – TOY_Code18	1-4	Time of Year Code
DG_06 – DG_18	Dormant, Growing	Dormant or Growing season for a given year
DG_Code06 – DG_Code18	1, 2	Dormant/Growing Code
FYEAR06 – FYEAR18	2006 - 2018	Year that fire occurred
BYR06 – BYR18	0 or 1	Presence/absence of a burn in a given year (e.g., if gridcode06 has a value of 1, there was a fire in 2006)
FIRE_BIN	**	Binary string used for processing
FIRE_DEC	**	Code from binary string used for processing
FIRE_COUNT	**	Code from binary string used for processing
FIRE_LAYERS	**	List of years that a location burned
DG_SEAS_BIN	**	String of all DG_Code<YR> used for processing
TSEAS_Lyr	**	List of order of seasonality that a location burned
DG_Lyr	**	List of order of growing/dormant seasons that a location burned
<all other fields are for querying within database, but not given a value here>		

Florida Cooperative Landcover Classifications site and state codes can be found online:
https://myfwc.com/research/gis/applications/articles/cooperative-land-cover/

Land Cover Class Code	Land Cover Class	Description	Acres
1880	**Bare Soil/Clear Cut**	Areas of bare soil representing recent timber cutting operations, areas devoid of vegetation as a consequence of recent fires, natural areas of exposed bare soil (e.g., sandy areas within xeric communities), or bare soil exposed due to vegetation removal for unknown reasons	31494
1700	**Barren and Outcrop Communities**	Small extent communities in karst features or on exposed limestone	507
22132	**Basin Swamp**	Typically large basin wetland with peat substrate; seasonally inundated; still water or with water output; Panhandle to central peninsula; occasional or rare fire; forest of cypress/tupelo/mixed hardwoods; pond cypress, swamp tupelo	192634
2231	**Baygall**	Slope or depression wetland with peat substrate; usually saturated and occasionally inundated; statewide excluding Keys; rare or no fire; closed canopy of evergreen trees; loblolly bay, sweetbay, swamp bay, titi, fetterbush	111861
1214	**Coastal Scrub**	This scrub category represents a wide variety of species found in the coastal zone. A few of the more common components are saw palmetto, sand live oak, myrtle oak, yaupon, railroad vine, bay bean, sea oats, sea purslane, sea grape, Spanish bayonet and prickly pear. This cover type is generally found in dune and white sand areas.	19554
1640	**Coastal Strand**	Stabilized coastal dune with sand substrate; xeric; peninsula; rare fire; marine influence; primarily dense shrubs; saw palmetto in temperate coastal strand or seagrape and/or saw palmetto in tropical coastal strand.	6703
1600	**Coastal Uplands**	Mesic or xeric communities restricted to barrier islands and near shore; woody or herbaceous vegetation; other communities may also occur in coastal environments	16570
1850	**Communication**	Airwave communications, radar and television antennas with associated structures are typical major types of communication facilities that will be identified in this category. When stations are associated with a commercial or governmental facility, they will be included in either of those specific categories when located within their bounds and will not be listed as separate elements.	4084
18331	**Cropland/Pasture**	Agricultural land which is managed for the production of row or field crops and improved, unimproved and woodland pastures.	1038495
5300	**Cultural - Estuarine**	Communities that are either created and maintained by human activities, or are modified by human influence to such a degree that the physical conformation of the substrate, or the biological composition of the resident community is substantially different from the character of the substrate or community as it existed prior to human influence.	5366

Code	Land Cover Class	Description	Acres
3200	**Cultural - Lacustrine**	Communities that are either created, and maintained by human activities, or are modified by human influence to such a degree that the trophic state, morphometry, water chemistry, or biological composition of the resident community are substantially different from the character of the lake community as it existed prior to human influence	414335
2400	**Cultural - Palustrine**	Communities that are both created and maintained by human activities, or are modified by human influence to such a degree that the physical conformation of the substrate, the hydrology, or the biological composition of the resident community is substantially different from the character of the substrate, hydrology, or community as it existed prior to human influence.	367976
4200	**Cultural - Riverine**	Communities that are either created and maintained by human activities, or are modified by human influence to such a degree that stream flow, morphometry, water chemistry, or the biological composition of the resident community are substantially different from the character of the stream community as it existed prior to human influence	79951
1800	**Cultural - Terrestrial**	Includes communities that are both created and maintained by human activities, or are modified by human influence to such a degree that the physical conformation of the substrate, or the biological composition of the resident community is substantially different from the character of the substrate or community as it existed prior to human influence.	19794
2211	**Cypress**	Dominated entirely by cypress, or these species important in the canopy; long hydroperiod.	637310
2210	**Cypress/Tupelo (incl Cy/Tu mixed)**	Dominated entirely by cypress or tupelo, or these species important in the canopy; long hydroperiod	92145
22131	**Dome Swamp**	Small or large and shallow isolated depression in sand/marl/limestone substrate with peat accumulating toward center; occurring within a fire-maintained community; seasonally inundated; still water; statewide excluding Keys; occasional or rare fire; forested, canopy often tallest in center; pond cypress, swamp tupelo.	48862
1310	**Dry Flatwoods**	Non-hydric flatwoods.	2459
1330	**Dry Prairie**	Flatland with sand soils over an organic or clay hardpan; mesic-xeric; central peninsula; annual or frequent fire (1-2 years); treeless with a low cover of shrubs and herbs; wiregrass, dwarf live oak, stunted saw palmetto, bottlebrush threeawn, broomsedge bluestem.	155891

Code	Land Cover Class	Description	Acres
5000	**Estuarine**	Deepwater tidal habitats and adjacent tidal wetlands that are usually semi-enclosed by land but have open, partly obstructed, or sporadic access to the ocean, with ocean-derived water at least occasionally diluted by freshwater runoff from the land. The upstream and landward limit is where ocean-de rived salts measure less than .5 ppt during the period of average annual low flow. The seaward limit is (1) an imaginary line closing the mouth of a river, bay, or sound; and (2) the seaward limit of wetland emergents, shrubs, or trees when not included in (1)	1619174
7000	**Exotic Plants**	Upland and wetland areas dominated by non-native trees that were planted or have escaped and invaded native plant communities. These exotics include melaleuca, Australian pine, Brazilian pepper, and eucalyptus. This class includes sites known to be vegetated by non-native but for which the actual species composition could not be determined.	66089
1870	**Extractive**	Encompass both surface and subsurface mining operations. Included are sand, gravel and clay pits, phosphate mines, limestone quarries plus oil and gas wells. Industrial complexes where the extracted material is refined, packaged or further processed are also included in this category	256978
2123	**Floodplain Marsh**	Floodplain with organic/sand/alluvial substrate; seasonally inundated; Panhandle to central peninsula; frequent or occasional fire (ca. 3 years, much less frequent in freshwater tidal marshes); treeless herbaceous community with few shrubs; sawgrass, maidencane, sand cordgrass, and/or mixed emergents	49974
2215	**Floodplain Swamp**	Along or near rivers and streams with organic/alluvial substrate; usually inundated; Panhandle to central peninsula; rare or no fire; closed canopy dominated by cypress, tupelo, and/or black gum.	421270
2200	**Freshwater Forested Wetlands**	Floodplain or depression wetlands dominated by hydrophytic trees	2676694
2100	**Freshwater Non-Forested Wetlands**	Herbaceous or shrubby palustrine communities in floodplains or depressions; canopy trees, if present, very sparse and often stunted	138786
1822	**High Intensity Urban**	Residential density > 2 dwelling/acre, commercial, industrial, and institutional	2252895
1200	**High Pine and Scrub**	Hills with mesic or xeric woodlands or shrublands; canopy, if present, open and consisting of pine or a mixture of pine and deciduous hardwoods.	290829
2232	**Hydric Hammock**	Lowland with sand/clay/organic soil over limestone or with high shell content; mesic- hydric; primarily eastern Panhandle and central peninsula; occasional to rare fire; diamond-leaved oak, live oak, cabbage palm, red cedar, and mixed hardwoods.	240562

Land Cover Class Code	Land Cover Class	Description	Acres
183313	**Improved Pasture**	This category in most cases is composed of land which has been cleared, tilled, reseeded with specific grass types and periodically improved with brush control and fertilizer application. Water ponds, troughs, feed bunkers and, in some cases, cow trails are evident.	3056264
2121	**Isolated Freshwater Marsh**	--	276763
2213	**Isolated Freshwater Swamp**	--	74557
52111	**Keys Tidal Rock Barren**	Flatland with exposed limestone in supratidal zone; restricted to Keys; no fire; open, mainly herbaceous vegetation of upper tidal marsh species and stunted shrubs and trees; buttonwood, christmasberry, perennial glasswort, saltwort, seashore dropseed, shoregrass.	8519
3000	**Lacustrine**	Wetlands and deepwater habitats (1) situated in a topographic depression or dammed river channel; (2) lacking trees, shrubs, persistent emergents, emergent mosses, or lichens with greater than 30% areal coverage; and (3) whose total area exceeds 8 hectares (20 acres); or area less than 8 hectares if the boundary is active wave-formed or bedrock or if water depth in the deepest part of the basin exceeds 2 m (6.6 ft) at low water. Ocean- derived salinities are always less than .5 ppt.	388970
1821	**Low Intensity Urban**	Less than two dwelling units per acre. Areas of low intensity residential land use (generally less than one dwelling unit per five acres), such as farmsteads, will be incorporated into the rural structures category.	1302061
5250	**Mangrove Swamp**	Estuarine wetland on muck/sand/or limestone substrate; inundated with saltwater by daily tides; central peninsula and Keys; no fire; dominated by mangrove and mangrove associate species; red mangrove, black mangrove, white mangrove, buttonwood.	571710
6000	**Marine**	Open ocean overlying the continental shelf and coastline exposed to waves and currents of the open ocean shoreward to (1) extreme high water of spring tides; (2) seaward limit of wetland emergents, trees, or shrubs; or (3) the seaward limit of the Estuarine System, other than vegetation. Salinities exceed 30 parts per thousand (ppt).	7841740
1650	**Maritime Hammock**	Stabilized coastal dune with sand substrate; xeric-mesic; statewide but rare in panhandle and Keys; rare or no fire; marine influence; evergreen closed canopy; live oak, cabbage palm, red bay, red cedar in temperate maritime hammock; gumbo limbo, seagrape, and white or Spanish stopper in tropical maritime hammock.	29654
2120	**Marshes**	Long hydroperiod; dominated by grasses, sedges, broadleaf emergents, floating aquatics, or shrubs.	2435732

Land Cover Class Code	Land Cover Class	Description	Acres
1311	**Mesic Flatwoods**	Flatland with sand substrate; mesic; statewide except extreme southern peninsula and Keys; frequent fire (2-4 years); open pine canopy with a layer of low shrubs and herbs; longleaf pine and/or slash pine, saw palmetto, gallberry, dwarf live oak, wiregrass.	1325011
1120	**Mesic Hammock**	Flatland with sand/organic soil; mesic; primarily central peninsula; occasional or rare fire; live oak, cabbage palm, southern magnolia, pignut hickory, saw palmetto.	126285
1400	**Mixed Hardwood-Coniferous**	Mix of hardwood and coniferous trees where neither is dominant	1329657
3100	**Natural Lakes and Ponds**	Includes inland lakes and ponds in which the trophic state, morphometry, and water chemistry have not been substantially modified by human activities, or the native biota are dominant	550976
4100	**Natural Rivers and Streams**	Streams in which the stream flow, morphometry, and water chemistry have not been substantially modified by human activities, or the native biota are dominant.	80295
2300	**Non-vegetated Wetland**	Hydric surfaces on which vegetation is found lacking due to the erosional effects of wind and water transporting the surface material so rapidly that the establishment of plant communities is hindered or the fluctuation of the water surface level is such that vegetation cannot become established. Additionally, submerged or saturated materials often develop toxic conditions of extreme acidity. Intermittent ponds are the main components of this category	13828
18332	**Orchards/Groves**	This class is for active tree cropping operations that produce fruit, nuts, or other resources not including wood products	907991
18335	**Other Agriculture**	--	138533
2220	**Other Coniferous Wetlands**	Coniferous forested wetlands that are not dominated by cypress, tupelo, or a mix of cypress/tupelo	26800
2230	**Other Hardwood Wetlands**	Dominated by a mix of hydrophytic hardwood trees; cypress or tupelo may be occasional or infrequent in the canopy; short hydroperiod	23022
1340	**Palmetto Prairie**	These are areas in which saw palmetto is the most dominant vegetation. Common associates of saw palmetto in this cover type are fetterbush, tar flower, gallberry, wire grass and brown grasses. This cover type is usually found on seldom flooded dry sand areas. These treeless areas are often similar to the pine flatwoods but without the presence of pine trees.	21131
1300	**Pine Flatwoods and Dry Prairie**	Mesic pine woodland or mesic shrubland on flat sandy or limestone substrates, often with a hard pan that impedes drainage	105838
1320	**Pine Rockland**	Flatland with exposed limestone substrate; mesic-xeric; southern peninsula and Keys; frequent to occasional fire (3-7 years); open pine canopy with mixed shrubs and herbs in understory; south Florida slash pine, palms, mixed tropical and temperate shrubs, grasses, and herbs	16866

Land Cover Class Code	Land Cover Class	Description	Acres
2110	**Prairies and Bogs**	Short hydroperiod; dominated by grasses, sedges, and/or titi	1736441
4000	**Riverine**	All wetlands and deepwater habitats contained within a channel except those wetlands (1) dominated by trees, shrubs, persistent emergents, emergent mosses, or lichens, and (2) which have habitats with ocean-derived salinities in excess of .5 ppt.	164993
1130	**Rockland Hammock**	Flatland with limestone substrate; mesic; southern peninsula and Keys; rare or no fire; closed canopy of evergreen mixed tropical hardwoods; gumbo limbo, pigeon plum, stoppers.	19320
1830	**Rural**	--	1581448
5240	**Salt Marsh**	Estuarine wetland on muck/sand/or limestone substrate; inundated with saltwater by daily tides; statewide; occasional or rare fire; treeless, dense herb layer with few shrubs; saltmarsh cordgrass, needle rush, saltgrass, saltwort, perennial glasswort, seaside oxeye	378678
1670	**Sand Beach (Dry)**	Beaches are constantly affected by wave and tidal action. The fine clays and silts are washed away leaving sand. However, in protected bay and marsh areas, fine soil particles from surface drainage may settle out. The beach areas also are subject to water and wind erosion	24386
1213	**Sand Pine Scrub**	Found on ridges throughout the state; rare fire (20-80 years); canopy of sand pine and an understory of the three shrubby oaks, myrtle oak, Chapman's oak, sand live oak, or less commonly, Florida rosemary.	220967
1240	**Sandhill**	Upland with deep sand substrate; xeric; panhandle to central peninsula; frequent fire (1-3 years); open canopy of longleaf pine and/or turkey oak with wiregrass understory.	775755
1210	**Scrub**	Upland with deep sand substrate; xeric; statewide except extreme southern peninsula and Keys, mainly coastal in Panhandle; occasional or rare fire; open or dense shrubs with or without pine canopy; sand pine and/or scrub oaks and/or Florida rosemary.	159788
5252	**Scrub Mangrove**	Areas sparsely vegetated with small, stunted mangroves. Found in extreme south Florida only	42388
1312	**Scrubby Flatwoods**	Flatland with sand substrate; xeric-mesic; statewide except extreme southern peninsula and Keys; occasional fire (5-15 years); widely scattered pine canopy over saw palmetto and scrub oaks; longleaf pine, sand live oak, myrtle oak, Chapman's oak, saw palmetto, wiregrass.	93619

Land Cover Class Code	Land Cover Class	Description	Acres
1500	**Shrub and Brushland**	This association includes a variety of situations where natural upland community types have been recently disturbed through clear-cutting commercial pinelands, land clearing, or fire, and are recovering through natural successional processes. This type could be characterized as an early condition of old-field succession, and various shrubs, tree saplings, and lesser amounts of grasses and herbs dominate the community. Common species include wax myrtle, saltbush, sumac, elderberry, saw palmetto, blackberry, gallberry, fetterbush, staggerbush, broomsedge, dog fennel, together with oak, pine and other tree seedlings or saplings.	342184
1140	**Slope Forest**	Steep slope on bluff or in sheltered ravine within the Apalachicola drainage; sand/clay substrate; mesic-hydric; central panhandle; rare or no fire; closed canopy of mainly deciduous species; American beech, Florida maple, white oak, Ashe's magnolia, southern magnolia, spruce pine, Shumard's oak.	5875
2214	**Strand Swamp**	Broad, shallow channel with peat over mineral substrate; situated in limestone troughs; seasonally inundated; slow flowing water; vicinity of Lake Okeechobee southward in the central and southern peninsula; occasional or rare fire; closed canopy of cypress and mixed hardwoods; cypress, pond apple, strangler fig, willow, abundant epiphytes	44236
1833121	**Sugarcane**	--	618200
5220	**Tidal Flat**	A community of quiet waters, with substrates composed of silt or sand that is rich in organic matter and poorly drained at low tide. The substrate may be covered with algae	43950
1840	**Transportation**	Transportation facilities are used for the movement of people and goods. Highways include areas used for interchanges, limited access rights-of-way and service facilities. The Transportation category encompasses rail-oriented facilities including stations, round-houses, repair and switching yards and related areas. Airport facilities include runways, intervening land, terminals, service buildings, navigational aids, fuel storage, parking lots and a limited buffer zone and fall within the Transportation category. Transportation areas also embrace ports, docks, shipyards, dry docks, locks and water course control structures designed for transportation purposes. The docks and ports include buildings, piers, parking lots and adjacent water utilized by ships in the loading and unloading of cargo or passengers. Locks, in addition to the actual structures, include the control buildings, power supply buildings, docks and surrounding supporting land use (i.e., parking lots and green areas)	1610733
18333	**Tree Plantations**	--	4485132
9100	**Unconsolidated Substrate**	--	3050

Land Cover Class Code	Land Cover Class	Description	Acres
1720	**Upland Glade**	Upland with thin clay soils over limestone outcrops; hydric-xeric; central panhandle only; sparse mixed grasses and herbs with occasional stunted trees and shrubs that are concentrated around the edge; black bogrush, poverty dropseed, diamondflowers, hairawn muhly, Boykin's polygala, red cedar.	34
1110	**Upland Hardwood Forest**	Upland with sand/clay and/or calcareous substrate; mesic; Panhandle to central peninsula; rare or no fire; closed deciduous or mixed deciduous/evergreen canopy; American beech, southern magnolia, hackberry, swamp chestnut oak, white oak, horse sugar, flowering dogwood, and mixed hardwoods.	224388
1231	**Upland Pine**	Upland with sand/clay substrate; mesic-xeric; longleaf pine and/or loblolly pine and/or shortleaf pine.	164839
1860	**Utilities**	Include power generating facilities and water treatment plants including their related facilities such as transmission lines for electric generation plants and aeration fields for sewage treatment sites. Small facilities or those associated with an industrial, commercial or extractive land use are included within these larger respective categories.	113620
18334	**Vineyard and Nurseries**	Includes tree nurseries, sod farms, and three classes of ornamentals. Miscellaneous uses that would belong include vineyards and nurseries other than for trees.	135882
2221	**Wet Flatwoods**	Flatland with sand substrate; seasonally inundated; statewide except extreme southern peninsula and Keys; frequent fire (2-4 years for grassy wet flatwoods, 5-10 years for shrubby wet flatwoods); closed to open pine canopy with grassy or shrubby understory; slash pine, pond pine, large gallberry, fetterbush, sweetbay, cabbage palm, wiregrass, toothache grass.	761947
1150	**Xeric Hammock**	Upland with deep sand substrate; xeric; primarily eastern Panhandle to central peninsula; rare or no fire; closed canopy of evergreen hardwoods; sand live oak, saw palmetto.	24211