SE FireMap Scoping Report

July 15, 2020

<u>Executive Summary</u>:

Tall Timbers Research, Inc. is pleased to present the July 15th Interim Report for the scoping agreement of the SE FireMap to the U.S. Endowment for Forestry and Communities and the USDA Natural Resources Conservation Service. The overall purpose of the scoping phase is to develop an improved, cohesive system to track both prescribed fire and wildfire on public and private lands. The development of a comprehensive spatially explicit map of fire occurrence remains one of the most critical needs for conservation in the Southeastern US. Knowledge of recent fire history is a key consideration for land management decisions supporting fire dependent communities. As more sophisticated models and tools for prescribed fire planning and fire risk analysis become available, the more important it is that current landscape conditions are accurately portrayed in these models. The SE FireMap will provide baseline information to ensure land management decisions are based on the most current information available. Fire occurrence on public and private lands in the SE is currently tracked by approximate location through various permitting systems or burn unit mapping that is done by some federal, state, and limited private ownerships. In the case of permitting, these systems do not record perimeter data or include assessments regarding which burns are actually completed. Relying solely on these system results in documented data gaps when estimating the size, location and effectiveness of managed fires on a regional scale. Prescribed fires and wildfires mapped by either permit data or agency burn records miss the majority of burned areas on private lands which represent 87% of the land ownership in the Southeastern US.

Tall Timbers Research, Inc., as part of the scoping phase for the SE FireMap is addressing these needs by assessment of advanced remote sensing techniques in order to make recommendations to track both prescribed fire and wildfire on both public and private lands.

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

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

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

Fire Information for Resource Management System (FIRMS) distributes Near Real-Time (NRT) active fire data within 3 hours of satellite observation from both the Moderate Resolution Imaging Spectroradiometer (MODIS) and the Visible Infrared Imaging Radiometer Suite (VIIRS).

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.

GOES-17 (formerly **GOES-S**) is the second of the current generation of weather satellites operated by the National Oceanic and Atmospheric Administration (NOAA). The four satellites of the series (GOES-16, -17, -T, and -U) will extend the availability of the GOES (Geostationary Operational Environmental Satellite system) until 2036

Google Earth Engine (GEE) a cloud-based platform for planetary-scale environmental data analysis

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 Fire Occurrence Reporting Modules (InFORM) provides a single, nationwide system of record for both federal and state agencies to report wildfires. InFORM will eliminate redundant data entry, improve the quality and completeness of fire data, and make it easier to access.

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.

LANDFIRE (LF) Landscape Fire and Resource Management Planning Tools, is a shared program between the wildland fire management programs of the U.S. Department of Agriculture Forest Service and U.S. Department of the Interior, providing landscape scale geo-spatial products to support cross-boundary planning, management, and operations.

LANDFIRE Disturbance products are developed to help inform updates to LANDFIRE (LF) data to reflect change on the landscape caused by management activities and natural disturbance including both vegetation and fuel.

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.

LANDSAT Burned Area product is designed to identify burned areas across all ecosystems (e.g. forests, shrublands, and grasslands) for Landsat 4-8 data. The Landsat Burned Area product contains two acquisition-based raster data products that represent burn classification and burn probability. Landsat Burned Area is generated from U.S. Landsat Analysis Ready Data (ARD) Surface Reflectance and Top of Atmosphere Brightness Temperature data. The Landsat Burned Area product is processed to 30-meter spatial resolution in Albers Equal Area (AEA) projection using the World Geodetic System 1984 (WGS84) datum and gridded to a common tiling scheme.

Moderate Resolution Imaging Spectroradiometer (MODIS) is a key instrument aboard the Terra and Aqua satellites. The instruments capture data in 36 spectral bands ranging in wavelength from 0.4 μm to 14.4 μm and at varying spatial resolutions (2 bands at 250 m, 5 bands at 500 m and 29 bands at 1 km). Together the instruments image the entire Earth every 1 to 2 days. They are designed to provide measurements in large-scale global dynamics including changes in Earth's cloud cover, radiation budget and processes occurring in the oceans, on land, and in the lower atmosphere.

MODIS Burned Area Product contains burning and quality information on a per-pixel basis. Produced from both the Terra and Aqua MODIS-derived daily surface reflectance inputs, the algorithm analyzes the daily surface reflectance dynamics to locate rapid changes, and uses that information to detect the approximate date of burning, mapping the spatial extent of recent fires only. It provides varied quality assessment information and a single summary quality assessment score for each pixel. The algorithm improves on previous methods by using a BRDF model-based change detection approach to handle angular variations in the data and uses a statistical measure to identify change probability from a previously observed state.

Monitoring Trends in Burn Severity (MTBS) is 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. This includes all fires 1,000 acres or greater in the western United States and 500 acres or greater in the eastern Unites States. The extent of coverage includes the continental U.S., Alaska, Hawaii and Puerto Rico.

NatureServe Prescribed Fire Geodatabase developed in partnership with South Atlantic Landscape Conservation cooperative this database contains contributions from over 12 managing agencies totaling more than 1600 records with standard attribute fields.

Risk Management Assistance (RMS) Dashboard a series of links to products to help line officers, agency administrators, fire managers, incident management teams, area commands, geographic area coordination centers, and multi-agency coordination groups make more risk-informed decisions.

Sentinel-2 the Copernicus Sentinel-2 mission comprises a constellation of two polar-orbiting satellites placed in the same sun-synchronous orbit, phased at 180° to each other. It aims at monitoring variability in land surface conditions, and its wide swath width (290 km) and high revisit time (10 days at the equator with one satellite, and 5 days with 2 satellites under cloud-free conditions which results in 2-3 days at mid-latitudes) will support monitoring of Earth's surface changes. The coverage limits are from between latitudes 56° south and 84° north.

Sentinel-3 the main objective of the Sentinel-3 mission is to measure sea surface topography, sea and land surface temperature, and ocean and land surface color with high accuracy and reliability to support ocean forecasting systems, environmental monitoring and climate monitoring. The Sentinel-3 Mission Guide provides a high-level description of the mission objectives, satellite description and ground segment. It also covers an introduction to heritage missions, thematic areas and services, orbit characteristics and coverage, instrument payloads and data products.

Sea and Land Surface Temperature Radiometer (SLSTR) is a key instrument onboard the Sentinel-3 satellites. The sensor measures in nine spectral channels and two additional bands optimized for fire monitoring. The first six spectral bands cover the visible and near-infrared (VNIR) spectrum as well as the short-wave infrared (SWIR) spectrum; VNIR for bands 1 to 3, and SWIR for bands 4 to 6.[14] These 6 bands have a spatial resolution of 500 m (1,600 ft), while bands 7 to 9 as well as the two additional bands have a spatial resolution of 1 km (0.6 mi).

Visible Infrared Imaging Radiometer Suite (VIIRS) is an instrument onboard the Suomi National Polar-Orbiting Partnership (S-NPP) and NOAA-20 satellites. The VIIRS instrument follows the legacy of, and improves upon, the measurements made by the NOAA AVHRR and the MODIS instruments on Aqua and Terra. VIIRS observes Earth's entire surface twice each day. The VIIRS instrument collects imagery of the land, atmosphere, oceans, and cryosphere across 22 spectral bands, ranging in wavelengths from 0.41 to 12.5 microns, and at two native spatial resolutions: 375m (I-bands) and 750m (M-bands).

Wildland Fire Management Application (WFMAP) web based application that allows users an

Army DOD installations to input and analyze fire data.

<u>Background:</u>

For over a decade, resource managers across the SE have recognized the importance of tracking and monitoring the use of prescribed fire. Many species in the SE are dependent on fire for maintenance of appropriate habitat conditions. Measurements, such as seasonality and time 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.

There are numerous sources for detailed landcover, species, and habitat suitability datasets for the Southeast. However, there is a critical missing component for all of these datasets - 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 and wildfire *extents* regionally does not exist, which means that there is not a comprehensive knowledgebase about fire regimes across the SE. 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).*

Summary:

The overall aim of the Scoping process for the SE FireMap is to develop a robust understanding of the data sources and reporting capabilities that are available for advanced monitoring of prescribed fires on private lands. This report aims to enhance our understanding of using remote sensing techniques to map fires across the SE United States. (The pilot area used for analysis is Florida Forest Service District 4). To recap accomplishments so far on this project:

1. We address Active Fire detection methods and the feasibility of using these products for prescribed fire tracking. We discuss methods to validate active fire products by comparing active fire locations to prescribed burn authorization records obtained from the Florida Fire Management Information System.
2. We address Burned Area detection methods and the feasibility of using these products for prescribed fire tracking. We discuss methods to validate burned area products by comparing burned area locations to prescribed burn records obtained from private land owners and public agencies. Furthermore, we examine the various ways these collaborators map prescribed fire and wildfire on their lands and examine some of the challenges of using these data for validation of remotely sensed fires.
3. We explore the feasibility of using novel processing platforms (i.e. Google Earth Engine) to replicate a number of operational fire mapping techniques.

Dataset Exploration:

Understanding fire regime characteristics across the Southeastern US 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 region exists, particularly in terms of a regional spatial database that includes individual fire perimeters for prescribed fires and for any fires occurring on private lands. We explored multiple datasets to determine how the spatial extent of fires is represented. Table 1 lists the datasets that we evaluated for their utility to illuminate our knowledge of the spatial extent of fires in the region. In general, the datasets evaluated include prescribed fire information, wildfire information, or both. Data types include point, polygon, and raster data. Specifically, we are interested the extents for fires >5-10 acres. This section provides descriptions and evaluations of these datasets.

Table 1: Datasets evaluated for the SE FireMap, including spatial and temporal characteristics (including update availability, period of record, and data coverage timeframe) pertinent to this project.

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 - 2020	P	• Prescribed Fire Authorization Database • Updated Daily
Fire Data by Landowner	Point, Polygon	Varies	Varies	W, P, or WP	• Characteristics vary by landowner and their policies and procedures • See Table 3
MTBS	Polygon	30m	1984 - 2017	WP	• 500ac+ fires only (in SE) • 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.
LANDFIRE Disturbance	Raster	30m	1999 - 2014	WP	• Updated Annually with a 2-yr time lag following disturbance
Landsat Burned Area (BAv2)	Raster	30m	1984 - 2020	WP	• Can be derived for known fires using standardized methods and tools available. • Can be updated every ~2 weeks
MODIS MCD64A1	Raster	500m	2000 - 2020	WP	• Updated Monthly
MODIS Fire CCI51	Raster	250m	2001 - 2019	WP	• Updated Monthly
MODIS Active Fire MCD14DL	Point	Footprint: 1km	2000 - 2020	WP	• Updated Twice Daily
VIIRS M-Band Active Fire	Point	Footprint: 750m	2012 - 2020	WP	• Updated Twice Daily
VIIRS I-Band Active Fire	Point	Footprint: 375m	2012 - 2020	WP	• Updated Twice Daily
GOES-16 Fire/Hot Spot Characterization	Point	Footprint: 2km	2018 - 2020	WP	• Updated 12 times every hour
Sentinel-3 SLSTR Active Fire	Point	Footprint: 1km	2016 - 2020	WP	• Updated Daily

Table 2: 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.

Fire Data by Landowner	Data Type	Spatial Characteristics	Record Availability	Wildfire (W), Prescribed Fire (P), or Both (WP)	Source, notes, description
US Forest Service – Apalachicola National Forest	Polygon	Burnable Vegetation within Burn Unit	1970-2020 (Wildfire FOD) 1993-2020 (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
Florida Wildlife Conservation Commission	Polygon		1998-2020	WP	• Source: FWC GIS Dept. • Includes date/time of burns, rx burn purpose, and notes on burn
US Fish and Wildlife Service – St. Marks National Wildlife Refuge	Points, Polygon	Entire Burn Unit	2002-2018 (points) 1963-2020 (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
Tall Timbers Research Station	Polygon		1990-2016	P	• Source: Tall Timbers R.S. GIS Dept. • Details include burn date, landcover

Florida Forest Service Open Burn Authorizations (FFS OBA)

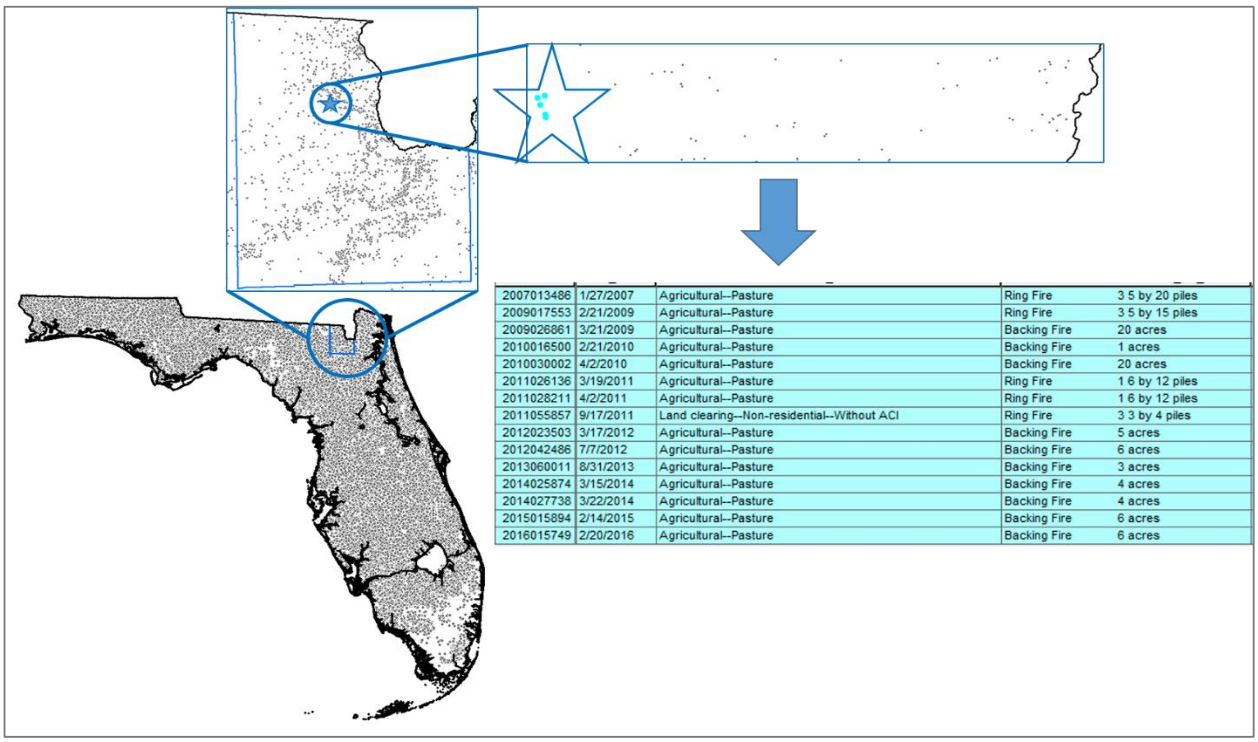
Currently, without a statewide spatial database of fire occurrence in Florida, the FFS OBA database can be used as a surrogate. This is an Oracle database (maintained by the FFS) where information required for an open burn authorization is recorded, and includes all open burns (e.g., broadcast burns and pile burns larger than 8 feet in diameter) authorized within the state. These records exist for the time period 1981 to present. 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. Additionally, there is currently not a mechanism in place to 'close' a permit and track how many acres were actually burned once the burning is completed. However, we feel the FFS OBA data still has merit for data exploration and analysis purposes, but the limitations must be recognized.

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, 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, there is no verifiable spatial accuracy of the point locations.

Known issues and limitations of the FFS OBA that are pertinent to this report include:

- 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 lat/long reporting procedures implemented; Figure 1);
- Single points representing multiple burn units (including non-contiguous units that can be up to ~10km away [Nowell *et al.*, 2018]; Figure 2);
- 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 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 to 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 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.

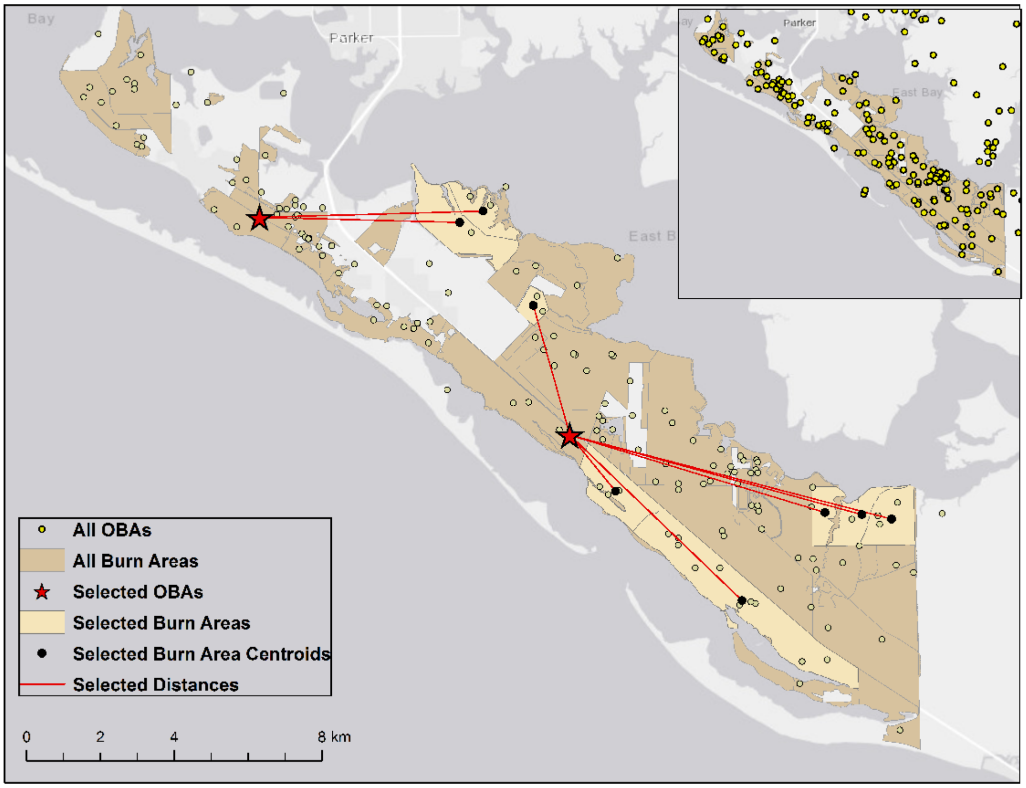


Figure 2: Example of single OBA representing multiple burn units. Here, two authorizations (red stars) for February 9, 2006 and the multiple units (yellow polygons) burned that day at Tyndall AFB are shown. Black dots indicate the centroids of burn units, and these are linked by red lines to the closest authorization issued on that date. Authorizations issued on other days are represented by yellow dots.

Fire Datasets by Landowner

Fire information in the form of fire occurrence databases and fire perimeters for both prescribed and wildfires were acquired from multiple landowner sources across the state. Landowners included public (*i.e.*, USFS, USFWS, FWC), and private landowners (Tall Timbers Research Station). Table 2 describes the 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 area that actually burned differs or the burn is not complete; 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 (Figures 6-11).

These datasets can be used 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 wildfires had been recorded by the different landowners in order to find fires for our BAv2 validation effort. If a fire perimeter was 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 a fire occurrence point was 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 should be used with caution and a complete understanding of what they 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 region-wide data call with specific reporting requirements be developed and utilized. This may also necessitate some automation to process data from each individual ownership in a standardized way in order to be incorporated into the database.

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, smaller burned areas are mapped 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 doesn't 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 Southeast Fire Map; 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 most 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. Overall, the MTBS dataset is a good ancillary dataset for investigation of spatial extents of larger fires in the Southeast.

LANDFIRE Disturbance

LANDFIRE (LF) Disturbance data depict locations on the landscape where a change occurred (Figure 3). They 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 LF Disturbance products are derived from a combination of fire management program data, satellite image processing methods, and other ancillary data.

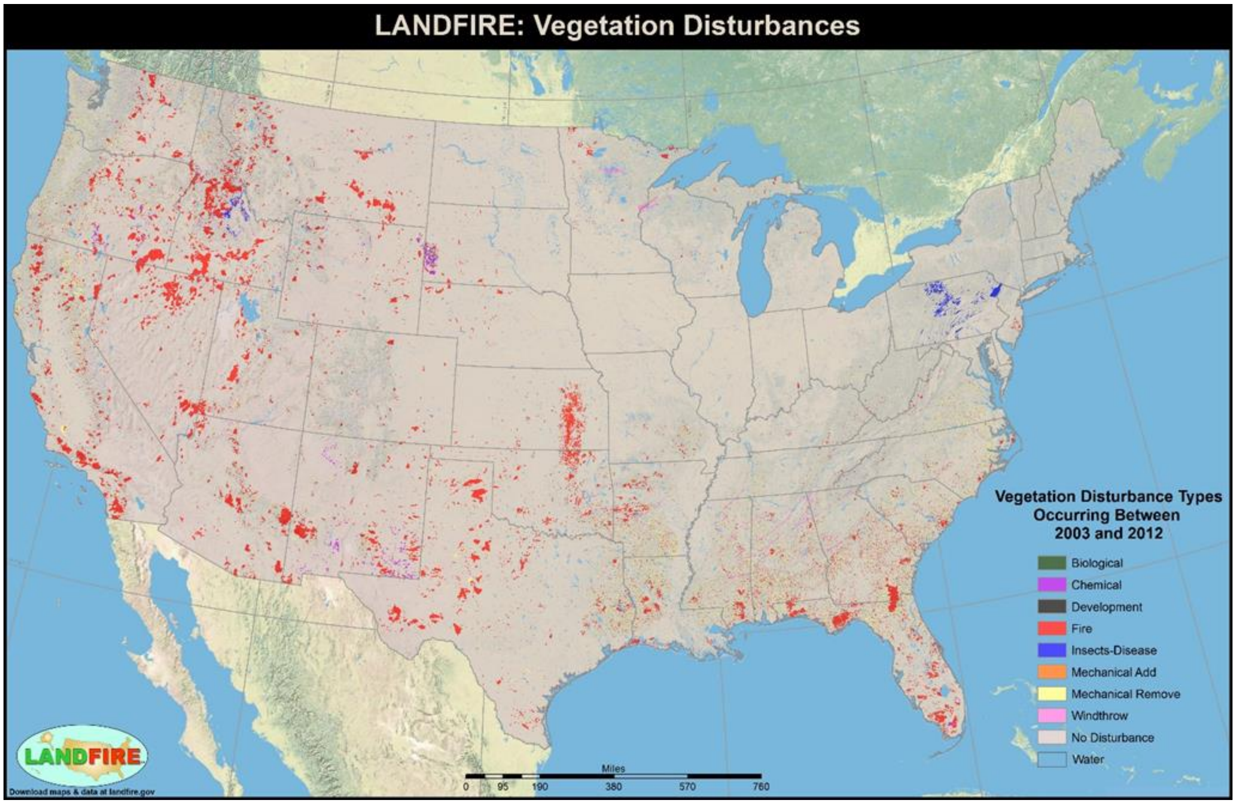


Figure 3: Example of the LF Disturbance dataset, indicating the prevalence of fire across the US including Florida. The data are provided as 30m rasters for the US, but are only current through 2014.

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 up to date and will always have a 1-2 year post-fire availability lag as a result of processing times and algorithm requirements. Furthermore, dataset generation is dependent on some of the datasets we have chosen not to use as primary fire location sources (e.g., MTBS). Thus, the LF Disturbance dataset can provide ancillary information, but will not be a primary source for identifying fires' spatial extents.

Landsat Burned Area v2

The Landsat Burned Area Products (version 2; BAv2) are a revised version of the Landsat Burned Area Essential Climate Variable (BAECV) products developed and validated by the USGS (Hawbaker *et al.* 2017a, b; Vanderhoof *et al.* 2017a, b), to incorporate Landsat 8 data and the new Analysis Ready Data (ARD) format. The BAv2 data show promise for systematically monitoring the geospatial extents of fires independent of any type of fire reporting system. This national product uses gradient boosted regression models with spectral indices summarizing present, historical and change in surface conditions derived from Landsat imagery as predictors to generate a burn probability surface. Categorical burned areas are identified in the burn probability surfaces using thresholds and region growing. The resulting Landsat burned area products have 30-m spatial resolution and are generated for every Landsat image with less than 80% cloud cover on record (*i.e.*, 1984-present), which is the longest consistent record of burned area information available. The BAv2 products were validated against independent reference datasets derived from high-resolution commercial satellite data (*e.g.*, QuickBird; Vanderhoof et al. 2017a) and with Landsat data (Vanderhoof et al. 2017b). Those studies indicated that the Landsat burned area products have a variety of omission and commission errors of depending on whether a national or regional perspective was assessed. However, the potential suitability of these products for mapping fire footprints across the state of Florida is worth exploring.

It is possible that BAv2 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 12). Given that more than a million acres of prescribed fire alone burn across Florida annually, but many of these fires are difficult to detect post-fire using traditional burn scar mapping protocols, it seems that the BAv2 methods could be used to locate burned areas in an automated and systematic way.

However, there are known limitations to the Landsat BA 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.* 2017). The aim is to help improve BAv2 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.

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. BAv2 and MTBS products are derived using 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. 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, the Sentinel-2 dataset 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 BAv2 products (Figure 4).

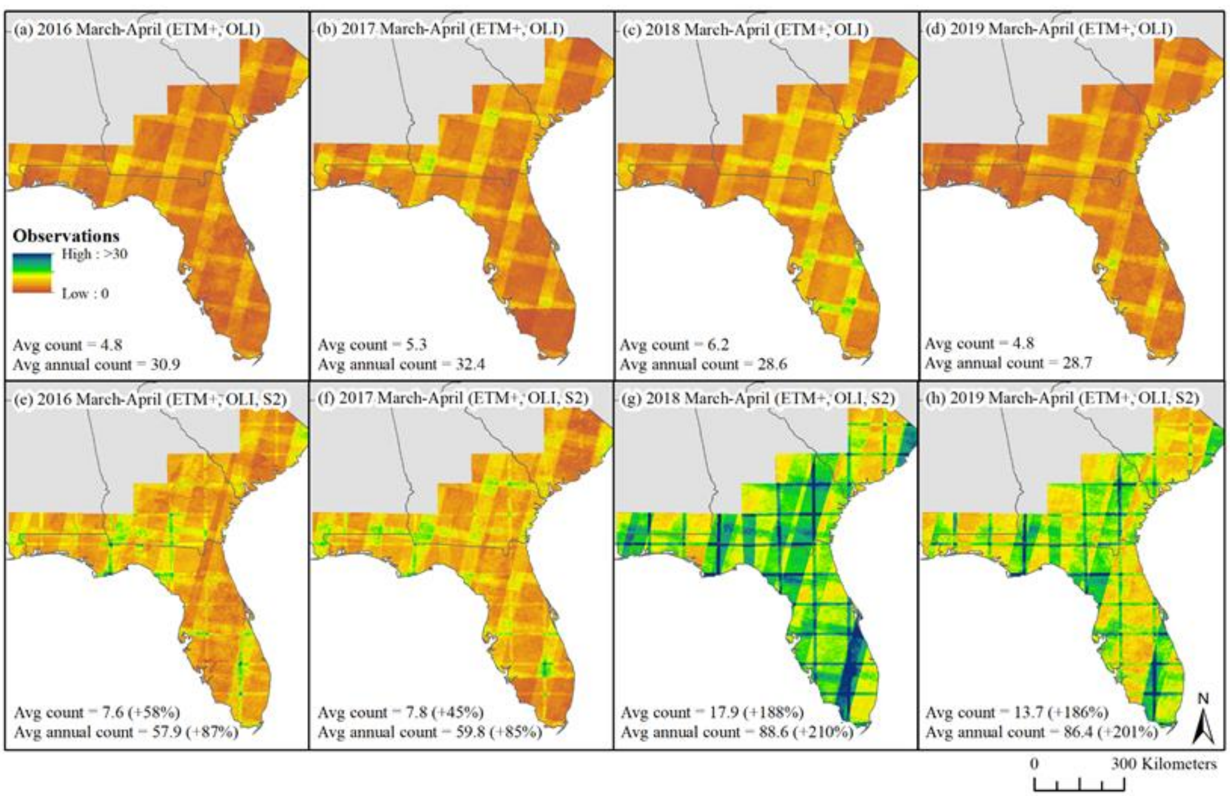


Figure 4: Available clear sky observations over the fire season (March-April) from 2016-2019 when using only Landsat imagery (top), and when including Sentinel 2 imagery (bottom) [Produced by Melanie Vaderhoof, USGS]

We have acquired BAv2-derived fire perimeters from 1994-2019 for Florida. As mentioned previously, these data do not encompass all fires, but hold promise in terms of identifying fire extents in locations where fires are not currently mapped.

MODIS Burned Area Products (MCD64A1 and Fire CCI51)

A number of MODIS Burned Area products are also available and were examined alongside the Landsat Burned Area product for comparison (Figure 5). The Terra and Aqua combined MCD64A1 Version 6 Burned Area data product is a monthly, global gridded 500 meter (m) product containing per-pixel burned-area and quality information. The MCD64A1 burned-area mapping approach employs 500m surface reflectance imagery coupled with 1-kilometer (km) MODIS active fire observations. The algorithm uses a burn sensitive Vegetation Index (VI) to create dynamic thresholds that are applied to the composite data (Giglio et al. 2018).

Furthermore, the FireCCI51 product employs a similar approach by coupling Terra MODIS 250m daily surface reflectance data with 1km MODIS active fire observations. The algorithm has two steps, the first one aiming to reduce commission errors by selecting the most clearly burned pixels (seeds), and the second one targeting to reduce omission errors by applying contextual analysis around the seed pixels (Chuvieco et al. 2018).

Although both products are derived from change detection algorithms and having areal extent properties, we felt that their coarse spatial resolution did not meet the minimum fire size requirements of this project. Figure 5 shows the spatial agreement between the burn scars identified in a Sentinel 2 reference image and satellite derived burned area products. While the MODIS BA products are capable of detecting burned areas for large fires, it is apparent that resolution is a limiting factor for being able to distinguish a burned area mosaic from unburned areas within an area of interest.

MODIS Active Fire Product

We explored the MODIS Active Fire Product to determine feasibility for use in identifying burned locations. The MODIS Active Fire 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 are represented as the centroid of a 1km fire detection pixel (*e.g.*, 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 being derived from thermal anomalies, the point-based data are difficult to use for mapping the extent of fires in the Southeast *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 the Southeast quite well. Secondly, the data are point based, which means that an extent is not inherently associated with them and would have to be derived 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 (*i.e.*, 3x3 pixels = 9km^2, or ~2225ac) is the minimum mapping unit that we require to detect and identify fire extents while accounting for error. 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 can be used as ancillary data representing possible presence/absence of fires if desired; however, we have chosen not to utilize them to identify the extents of fires in this project.

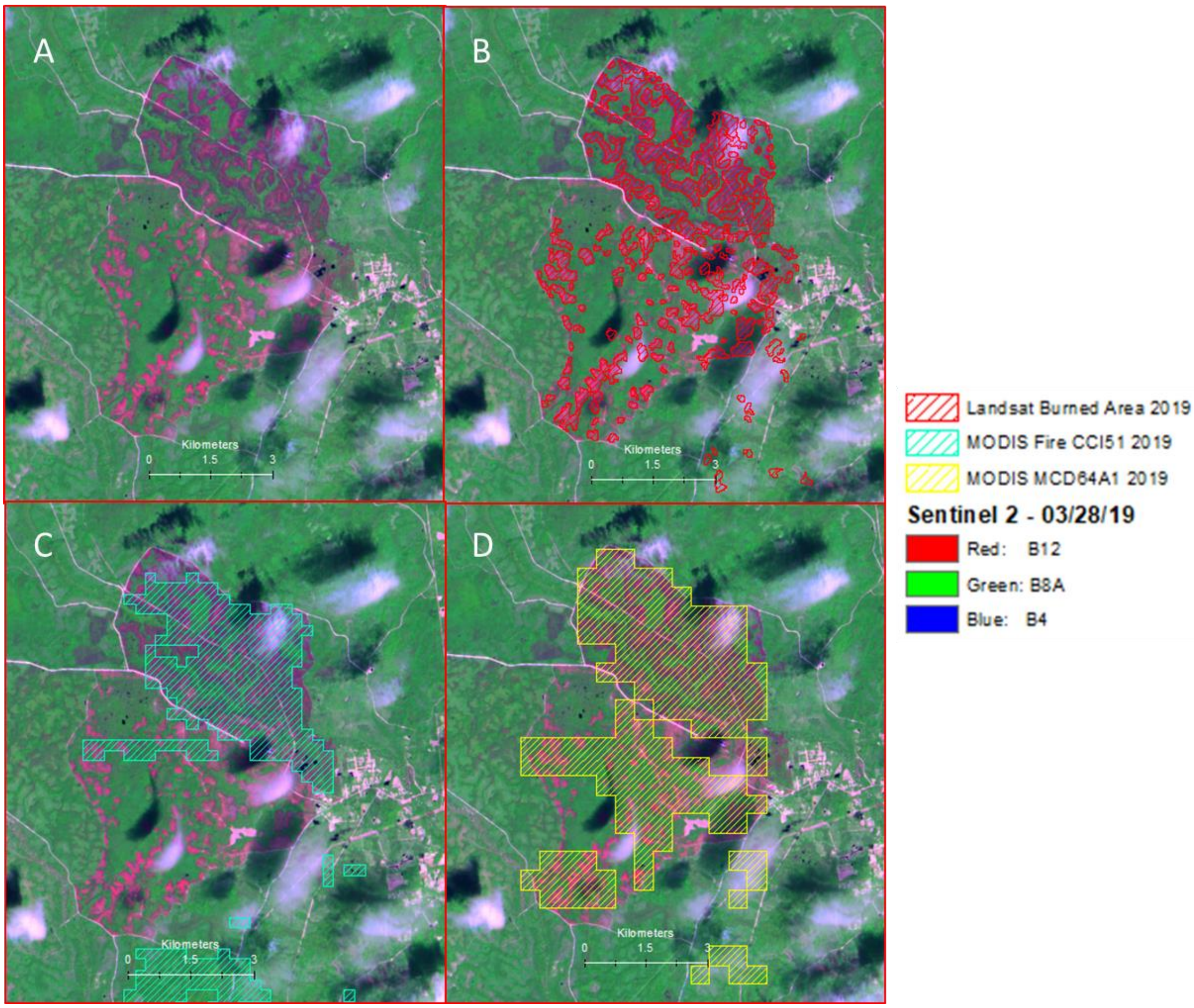
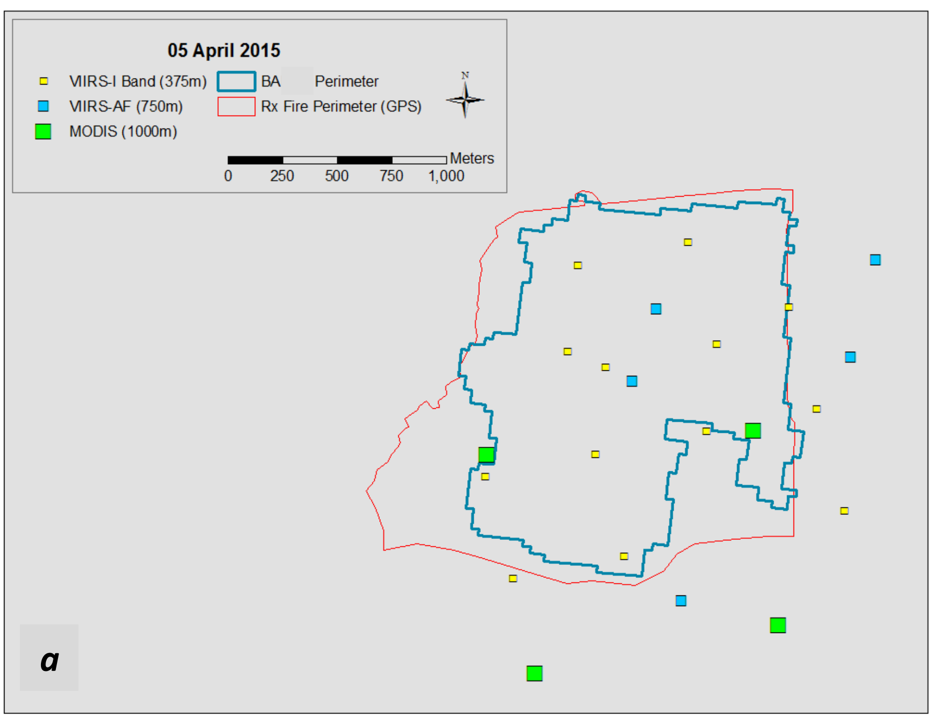


Figure 5: This example shows the spatial agreement between (A) the burn scars identified in a Sentinel 2 reference image and satellite derived burned area products: (B) Landsat Burned Area, (C) MODIS FireCCI51, (D) MODIS MCD64A1. It is evident that differences in sensor resolution and algorithm specifications result in different spatial arrangements for the same burned area.

VIIRS-M Band and VIIRS-I Band Active Fire Products

The VIIRS-M Band (750m; 2012-present) and VIIRS-I Band (375m; 2012-present) data products were also investigated as possibilities for helping to identify fire locations. The VIIRS detections of thermal anomalies are similar to the MODIS Active Fire products (but the processing algorithms are modified). Diurnal fire characteristics can be captured as the satellite that VIIRS sensors reside on revisits places every 12 hrs. The spatial resolution of both the VIIRS-AF and VIIRS-I bands are finer than MODIS, which allows for 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 can be imported into the database if needed; however, they are not included for the purposes of this project.

Examples of the different data types as compared to a GPS'd perimeter are shown in Figure 6. Note that even if lines were drawn connecting the outermost centroids of the MODIS (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 a fire event being mapped incompletely, 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.



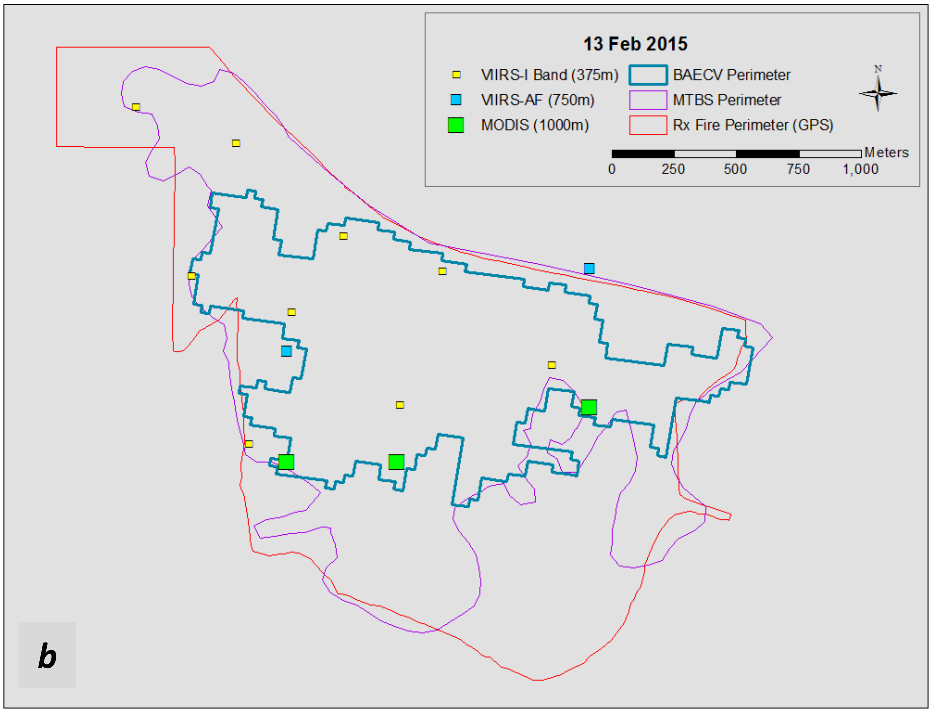


Figure 6: *(a)* 5 April 2015 fire detection center points for MODIS, VIIRS-AF, VIIRS-I band overlaid on the BAECV burned area (blue) and the actual GPS'd prescribed fire perimeter (red) of a prescribed fire on Eglin AFB. MTBS did not pick up a burn here, possibly due to this being a prescribed fire not reported in a national fire occurrence database. *(b)* 13 Feb 2015 fire detection center points for MODIS, 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.

GOES-16 Fire/Hot Spot Characterization

The GOES-R Series Advanced Baseline Imager (ABI) is capable of detecting heat signatures with improved time and space resolution, including smaller fires, compared to the previous GOES imager. With the ability to deliver high-definition images as often as every minute over CONUS, this means a much more detailed look at fire conditions, faster detection of hot spots, and the ability to track fire progression and spread in real time to detect changes in a fire's behavior and predict a fire's motion. The GOES-R fire detection and characterization (FDC) data product uses both visible and infrared (IR) ABI spectral channels to locate fires and retrieve fire characteristics. The FDC product looks for hot spots, attempts to determine the background temperature without fire present, corrects for solar contamination and water vapor attenuation, and provides fire characteristics for the detected fires. Once a fire is detected, fire size and temperature can be estimated. Radiative power is also calculated for the fire. While there is much promise for this new geostationary satellite series in real time tracking of active fires, the relatively coarse resolution (2 km) makes it challenging to detect small, low intensity fires which are prevalent across the Southeast.

Sentinel Satellite Products

Sentinel-3 is a multi-instrument ESA mission to measure sea-surface topography, sea- and land-surface temperature, ocean color and land color with high-end accuracy and reliability. Sentinel-3A was launched on 16 February 2016 and Sentinel-3B on 25 April 2018. Considering the relatively short imagery record, future work aims to mesh MODIS and SLSTR data into a single compatible time-series for long-term trend analysis. Similar to MODIS and VIIRS AF products, there is the Sentinel-3

SLSTR Active Fire product where individual pixels containing active fires are detected based on the identification thermal channel signals characteristic of active fires. Signals in the sensors solar reflective channels are used to decrease the probability of false alarms from features such as sun glint from small water bodies. This product has a 1km spatial resolution and a recent study showed that the algorithm offers an improved capability to detect smaller fires than MODIS (Xu et al. 2020).

Sentinel-2 is another satellite pair that have been used for fire mapping. Sentinel 2A and 2B capture land changes every five to ten days, offering increased temporal resolution over Landsat satellites. Furthermore, the Sentinel-2 Multispectral Instrument (MSI) captures data in 12 spectral bands, ranging from 10-60m in resolution. It is possible that the higher resolution color and NIR bands could improve the ability to map smaller fires across the Southeast. While there are no operational Sentinel 2 BA product for CONUS, Sentinel 2 BA products have been developed for other regions of the world, and results showed significant improvement compared to the MCD64A1 product, particularly in detection of small fires (See Workflow and Discussion Section 4). Given the spatial and temporal improvements that these satellites/sensors offer, there is much interest in integrating Sentinel 2 into existing fire mapping workflows. Additional research is required to determine the feasibility of these novel approaches.

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 this to be done by end users 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 time periods with the FMT. Installation of the tool and the dependent packages for require advanced computer skills. Furthermore, while the user interface makes it easier to understand what is going on, there are still many steps involved in mapping an individual fire, and these steps must be repeated for each fire of interest.

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 BAv2 raster data). 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. The ability to automatically identify probable burn locations and generate perimeters is of interest for our efforts moving forward with the BAv2 data products.

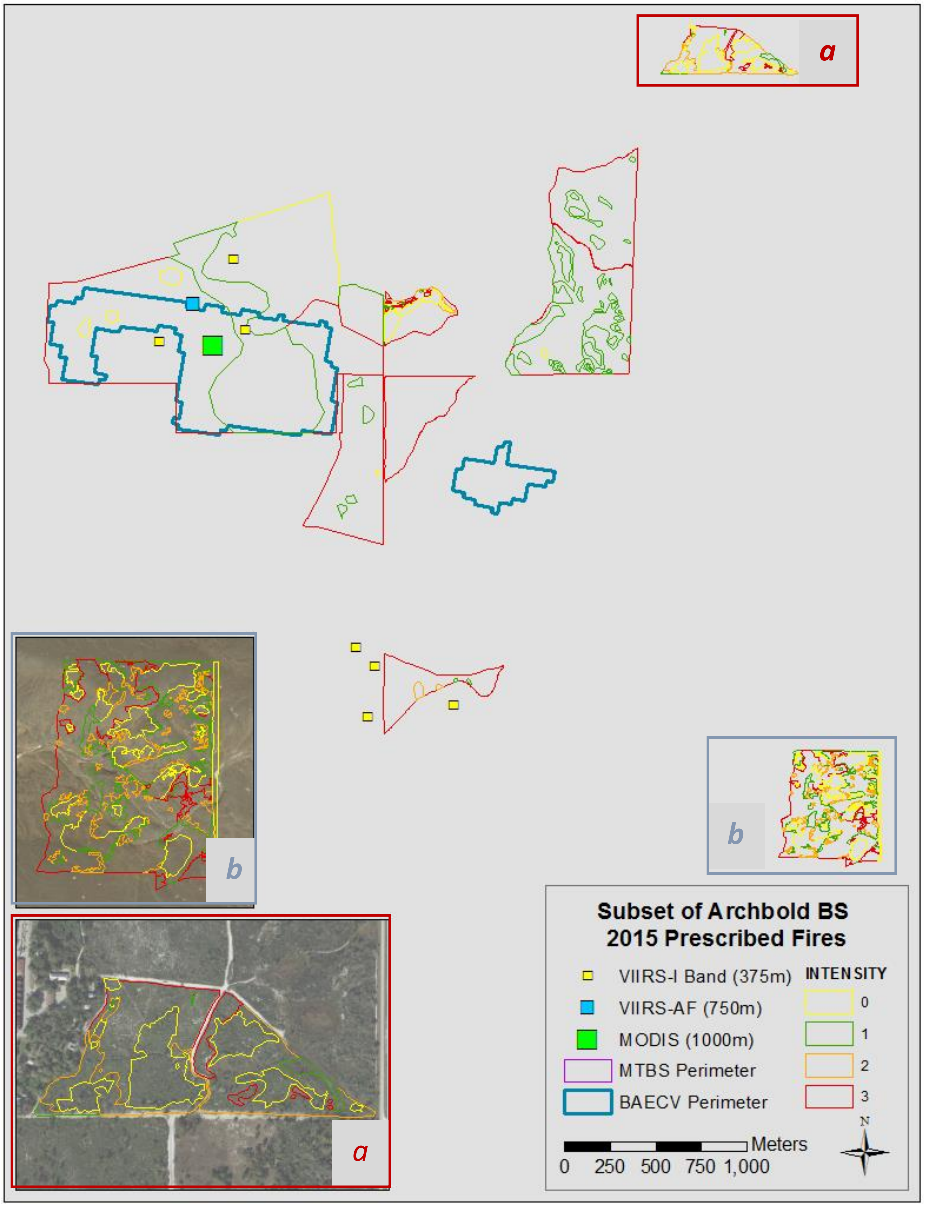


Figure 7: This image illustrates one of the different ways that landowners record fire data. A subset of 2015 prescribed fire perimeters (as mapped by Archbold Biological Station [BS]) is shown. Notice that Archbold details the interior variation related to the fire effects resulting from the fire intensity (*a*,*b*) within their perimeters. All of the 2015 VIIRS-I band, VIIRS-AF, and MODIS 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). No MTBS fires were mapped for the area.

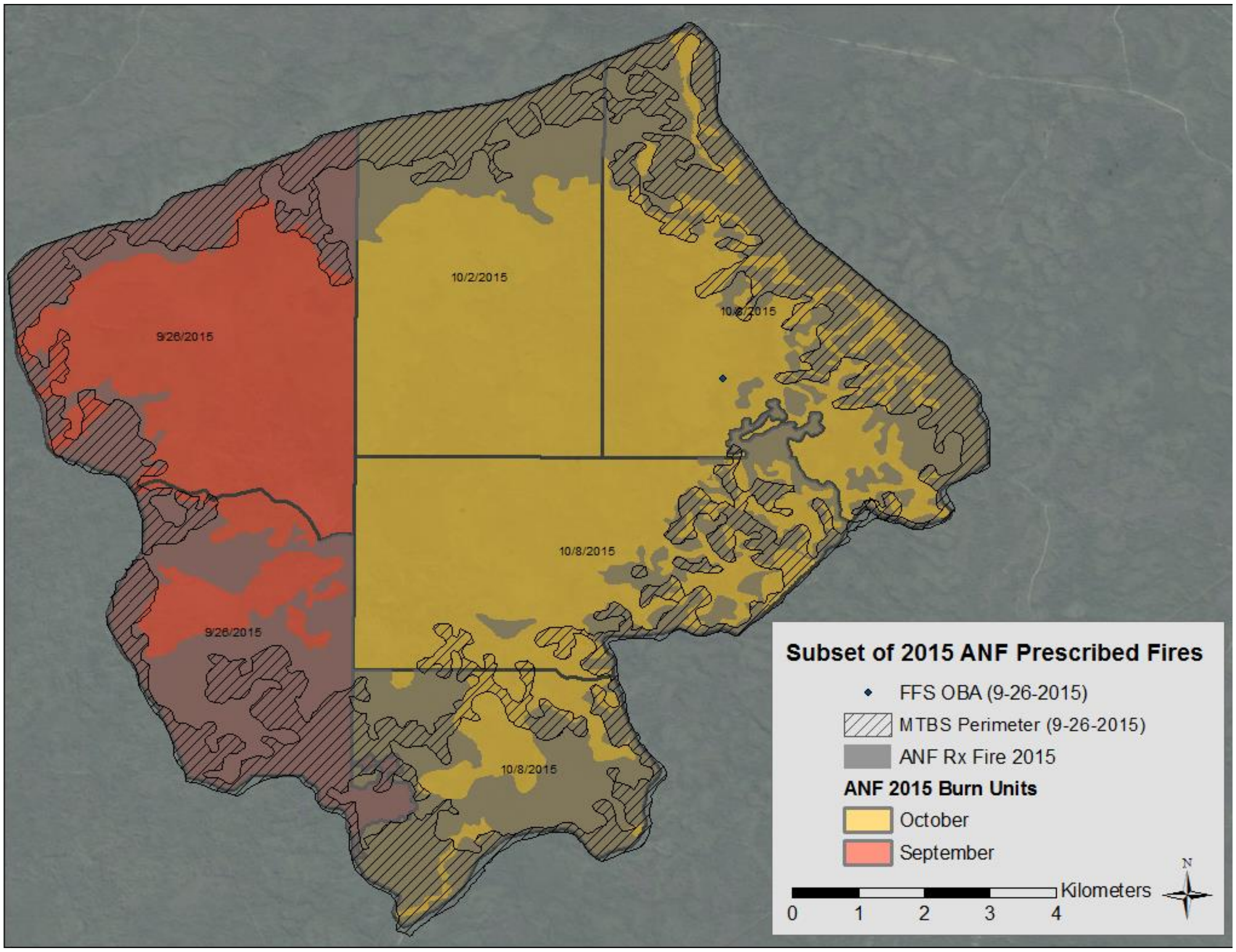


Figure 8: Prescribed fire perimeters as mapped by the Apalachicola National Forest (ANF) for a group of 6 burn units, encompassing ~24,500 acres. The burn units are colored by the month and labeled by the date that fire was applied to the unit. The total area identified by the ANF as burned in the 6 units is 10,120 acres (grey area in map). To get this data, ANF records the burn unit where fire is applied and subsets the burnable vegetation to report the total acres burned by prescribed fire. In the example above, a FFS OBA permit was requested for 11,500 acres on September 26, 2015, and is nearly 4.5 miles away from the center of the northwestern-most unit. The two western burn units were identified by the ANF 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).

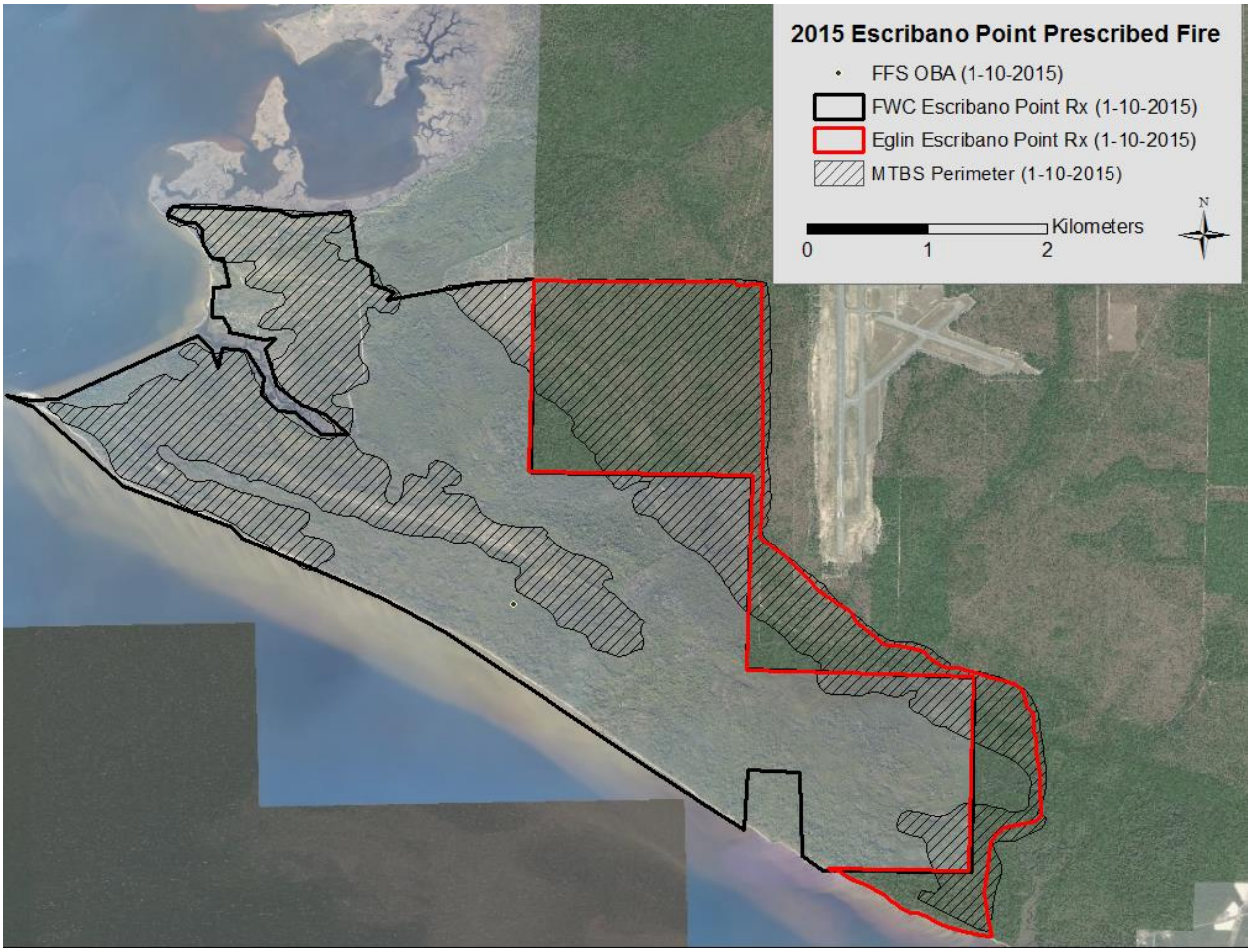


Figure 9: Prescribed fire perimeters for the Escribano Point burn that occurred on January 10, 2015. The burn encompasses two ownerships: FWC and Eglin AFB. Each owner recorded the area that fire was applied to in their respective units. FWC recorded nearly 3350 acres and Eglin recorded nearly 1100 acres, which correspond to the size of the burn units themselves. The FFS OBA point for the burn was for ~4500 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.

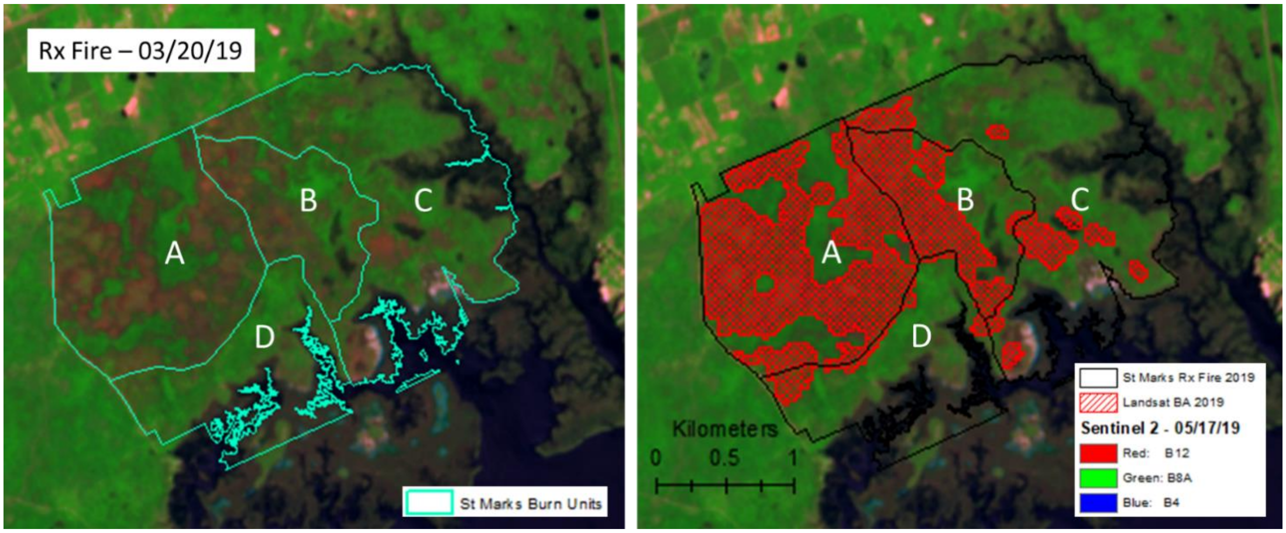


Figure 10: This example shows how the spatial footprints of prescribed fires at St. Marks National Wildlife Refuge are reported as the entire burn unit. Subsequently, the acreage of the reported burn is also equal to the size of the burn unit. However, it is evident from the reference Sentinel-2 image that the burn was patchy and does not encompass the entire burn unit. This is reflected in the Landsat BA product, that shows a mosaic of burned area within each burn unit.

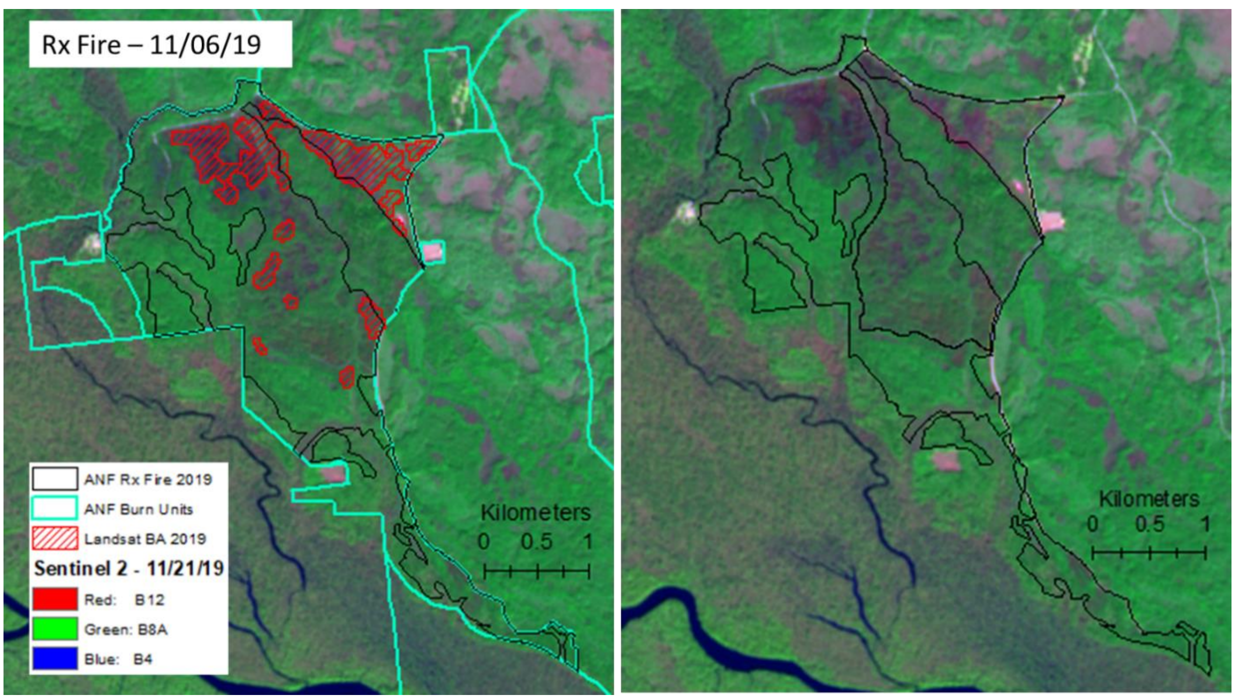


Figure 11: This example shows how the spatial footprints of prescribed fires at Apalachicola National Forest are reported as the burnable vegetation within the burn unit. Subsequently, the acreage of the reported burn is also equal to the size of the burnable vegetation polygons. However, it is evident from the reference Sentinel-2 image that even within the burnable vegetation there are green spots where no burn is apparent. This is reflected in the Landsat BA product, that shows a mosaic of burned area within each burn unit.

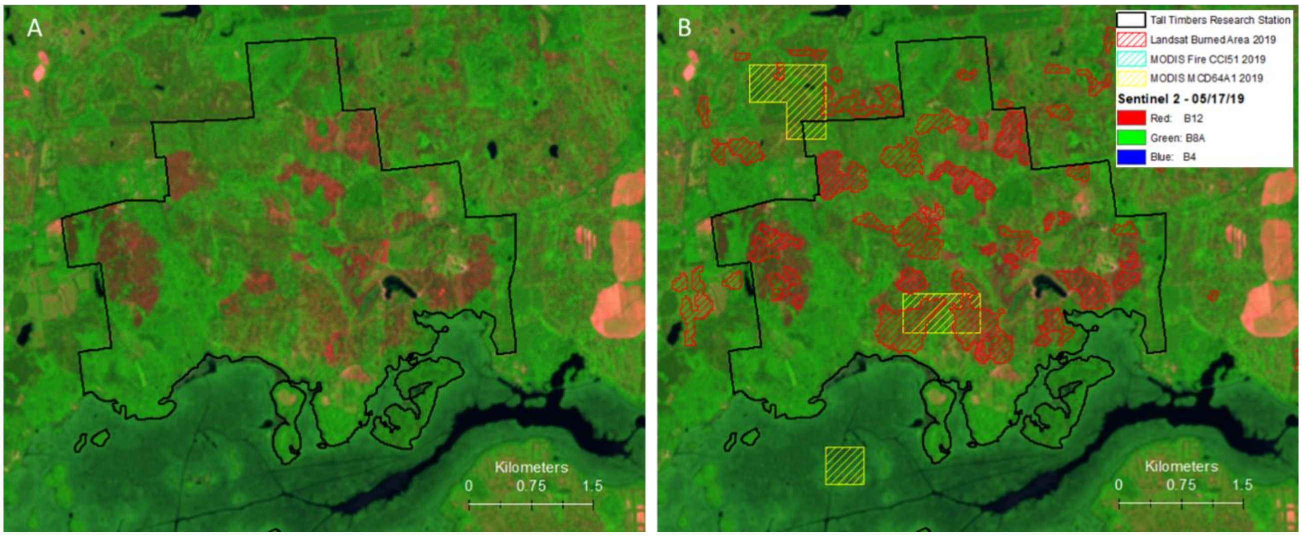


Figure 12: This example shows (A) burn scars at the Tall Timbers Research Station, as seen through a Sentinel 2 reference image captured on 05/17/2019, and (B) the spatial mosaic of each burned area product over the same area. There are no burned areas identified by the MODIS Fire CCI51 product within this extent.

Workflow and Discussion Section 1:

Evaluation and Analysis of Active Fire (AF) detection products in pilot area (FFS District 4) using Open Burn Authorizations (OBA) to evaluate MODIS, NOAA20, SUOMI-NPP, GOES-16, and Sentinel-3 AF detection sensors.

Despite the accessibility and widespread use of AF products, we felt there was a need to better understand their strengths and weaknesses in prescribed fire detection. For this exercise, we used open burn authorizations (OBAs) obtained from the Florida Forest Service (FFS) Fire Management Information System (FMIS) to help validate the suite of AF products listed below.

Satellite(s)	Sensor	Temporal Resolution	Years Active	Spatial Resolution	AF Products
Suomi-NPP NOAA-20	VIIRS	Once Daily	2012-2020 2017-2020	375 m	I-Band AF
Terra Aqua	MODIS	Once Daily	2000-2020 2002-2020	1000 m	MCD14DL
Sentinel-3A Sentinel-3B	SLSTR	Once Daily	2016-2020 2018-2020	1000 m	SLSTR AF
GOES-16 GOES-17	ABI	12x/hr (CONUS)	2018-2020	2000 m	FHS

OBA data were used as a proxy for the locations of prescribed fires (Figure 1). Regarding this data source, we recognize a number of limitations exist that must be taken into consideration (See Dataset Exploration). However, for the purposes of this exercise, we treated all OBA data as confirmed fire occurrence unless stated otherwise.

OBA and AF data were evaluated during Florida's fire season, from March 1st to April 3rd, 2020. A number of key attributes for each dataset were noted and used in the analysis. The start date and day of detection attributes were used to determine the timing of the OBA and AF respectively. AF data were filtered spatially and temporally to match the OBA prior to analysis. For each day that OBA records were obtained, a visual assessment was performed at each available OBA point. If active fire points were detected in the general vicinity of the burn permit (Figure 2), the fire was confirmed and additional information related to the satellite detection was recorded (e.g. number of AF points, sensors that detected the AF, flyover time). We considered active fire points within ~2km of an OBA as potential detections to account for the locational error reported for the OBA data unless the reported acreage of the OBA allowed for increased distance (Nowell et al. 2018).

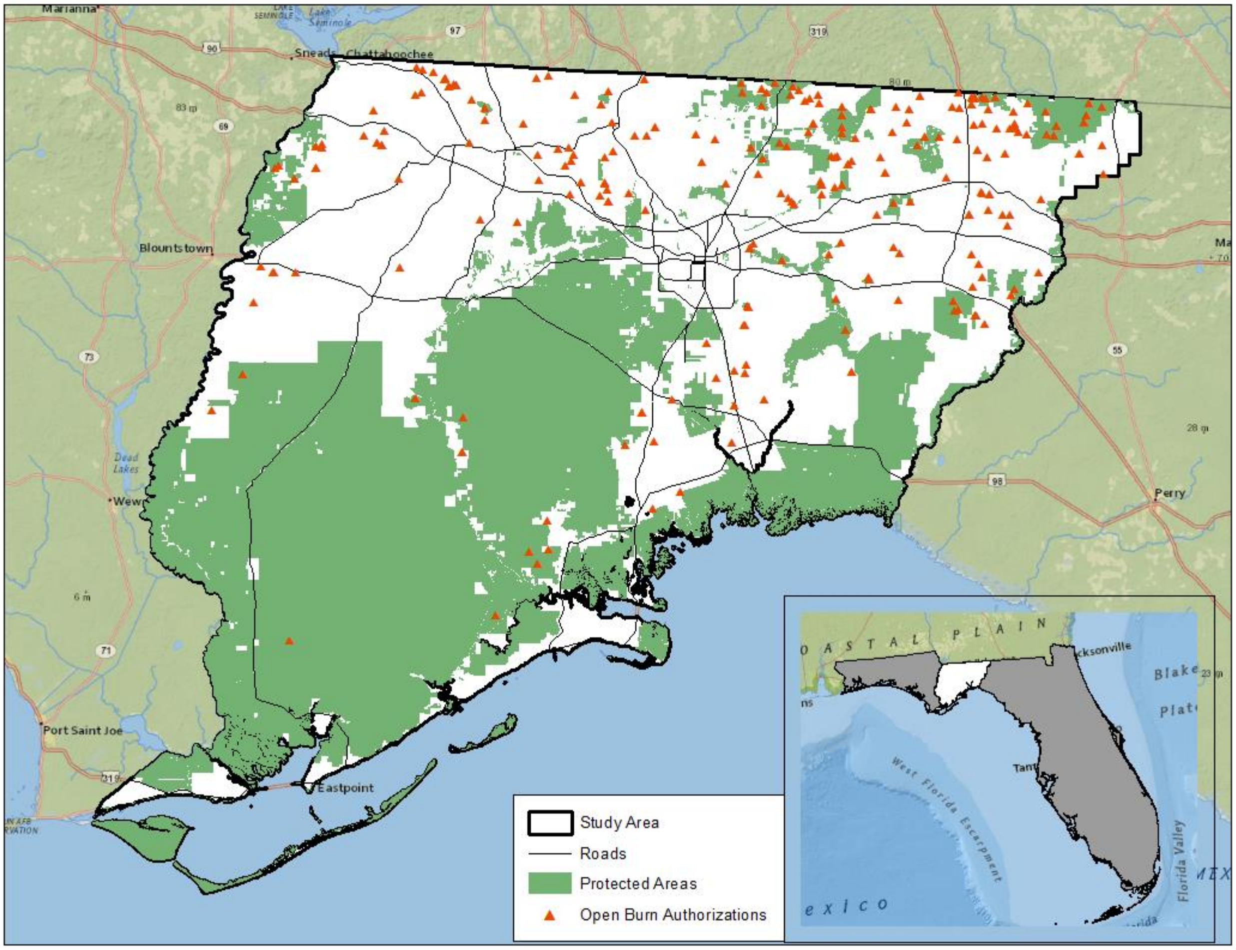


Figure 1 – Study Area (District 4 of the Florida Forest Service) within which active fire products and OBA records (n = 276) were assessed. Records span March 1st – April 3rd, 2020.

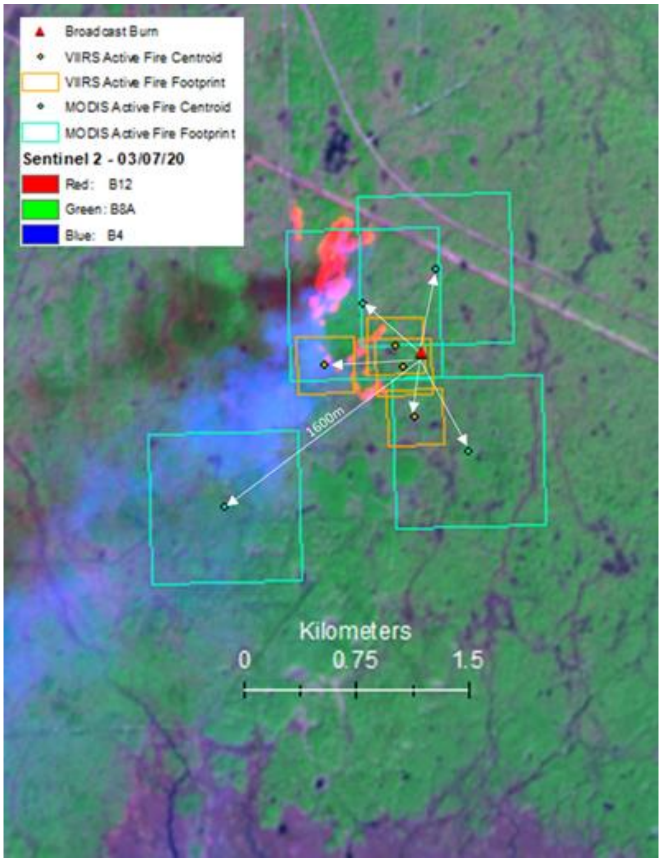


Figure 2 – A confirmed fire occurrence (3/7/2020) based on the proximity of the AF detections (n = 8) to the OBA

Roughly 28 % of the burn permits were detected by the active fire products (Figure 3). There were several instances where certain burns were detected by multiple satellites/sensors. The VIIRS sensor, onboard SUOMI-NPP and NOAA-20, was the most effective for detecting prescribed fires and pile burns within the study area. When combined, the two satellites were able to detect roughly 22% (n = 62) of the burn permits. It is evident that the increased resolution of the VIIRS sensor, at 375m, makes it superior for detecting smaller active fires. A number of factors could explain the low detection rates across all of the sensors such as the prevalence of small, rapidly burning, low-intensity fires or frequent cloud cover in the study region. In recognizing the limitations of the OBA data, it is possible that some of the burn permits used in this exercise were not actually implemented. Therefore, actual detection rates may be underreported. (See Appendix A for full report)

	OBA Metrics		Number of OBAs Detected By Satellite				
Sample Metrics	Sample Size	# OBAs Detected	MODIS	NOAA20	SUOMI	GOES-16	Sentinel-3
Total	276	76	21	33	45	17	3
% of Sample	100	**27.5**	7.6	12.0	16.3	6.2	1.1

Figure 3 – Validation Metrics Table

Workflow and Discussion Section 2:

Analysis of Burned Area (BA) detection products in pilot area (FFS District 4) using public and private burn polygon records to evaluate LANDSAT BA, MODIS MCD64A1, and MODIS Fire CCI51 products.

Despite the accessibility and widespread use of BA products, we felt there was a need to better understand their strengths and weaknesses in prescribed fire detection. For this exercise, we used fire perimeter data obtained from various collaborators to help add context to the suite of BA products listed below (Table 1). We also explore the limitations of these data in remote sensing applications.

BA Products	Temporal Resolution	Product Availability	Product Resolution	Satellites	Sensors
MCD64A1	Monthly	2000-2020	500 m	Terra Aqua	MODIS
Fire CCI51	Monthly	2001-2019	250 m	Terra	MODIS
Landsat 8	Annual	1984-2019	30 m	Landsat 5 Landsat 7 Landsat 8	TM ETM + OLI

Table 1 – Operational Burned Area products assessed

Prescribed and wildfire polygons were obtained from a number of federal, state, and private lands organizations: (1) Apalachicola National Forest, USFS (2) St. Marks National Wildlife Refuge, USFWS (3) Florida Fish and Wildlife Conservation Commission and (4) Tall Timbers Research Station. It is important to note that methods for documenting prescribed fire differ by agency/organization. In this case, the two approaches taken are by either listing the entire burn unit as burned or by listing all “burnable” vegetation within the burn unit as burned. In both scenarios, assumptions are made about the amount of area burned within the burn unit, and no real ground trothing is performed to delineate burned from unburned vegetation.

However, as this was the best prescribed fire data that we had available, we treated all fire polygon data as a confirmed presence of burned area. Prior to analysis, a random sample of 2500 points were generated from each data source to represent “observed” fires. Another 2500 points were randomly selected, within areas where no fire polygons were documented, to represent areas of “observed” fire absence. These points were combined to represent the final validation set for each data source (n = 5000).

To perform our validation assessment of the BA products, we extracted the predicted fire presence and absence values for each product to the validation point samples. We then compared the “observed” fire presence and absence values to the predicted values. This process was done separately for each validation dataset and resulted in confusion matrices which outline the following detection performance metrics: true positive, true negative, false positive, false negative.

Sensitivity (i.e. presence accuracy) varied by product and by validation dataset (Table 3). Across the products, sensitivity was highest for the Apalachicola National Forest. The BAv2 product generally performed the strongest across all of the validation datasets, with the exception of the USFWS (St. Marks) data where the Fire CCI51 product had a higher presence accuracy.

An investigation of burns on private lands (i.e. Tall Timbers Research Station) showed that the MODIS products were relatively incapable of detecting any fire related activity whereas the Landsat BA product was able to detect over 40 % of documented fires (Table 3). Tall Timbers provides an interesting case study because the data represents private lands burns which are more representative of the burns occurring across the state of Florida. These burns are smaller and less intense than fires prescribed on federal lands like ANF. (See Appendix B for full report)

Burned Area Product	Validation Dataset	Sensitivity (Presence Accuracy)	Specificity (Absence Accuracy)	Confusion Matrices			
				TP	TN	FP	FN
Landsat Burned Area Essential Climate Variable (BAECV)	Apalachicola National Forest	50.92 %	99.28 %	1273	2482	18	1227
				50.92 %	99.28 %	0.72 %	49.08 %
	St Marks National Wildlife Refuge	25.24 %	99.92 %	631	2498	2	1869
				25.24 %	99.92 %	0.08 %	74.76 %
	Florida Fish and Wildlife	27.80 %	99.32 %	695	2483	17	1805
				27.8 %	99.32 %	0.68 %	72.2 %
	Tall Timbers Research Station	42.08 %	98.80 %	1052	2470	30	1448
				42.08 %	98.8 %	1.2 %	57.92 %
MODIS Terra/Aqua Burned Area Monthly Grids (MCD64A1)	Apalachicola National Forest	41.84 %	96.68 %	1046	2417	83	1454
				41.84 %	96.68 %	3.32 %	58.16 %
	St Marks National Wildlife Refuge	29.84 %	99.28 %	631	2498	2	1869
				25.24 %	99.92 %	0.08 %	74.76 %
	Florida Fish and Wildlife	8.96 %	99.88 %	224	2497	3	2276
				8.96 %	99.88 %	0.12 %	91.04 %
	Tall Timbers Research Station	5.64 %	98.16 %	141	2454	46	2359
				5.64 %	98.16 %	1.84 %	94.36 %
ESA MODIS Fire CCI v5.1	Apalachicola National Forest	43.56 %	96.32 %	1089	2408	92	1411
				43.56%	96.32 %	3.68 %	56.44 %
	St Marks National Wildlife Refuge	41.32 %	97.56 %	1033	2439	61	1467
				41.32 %	97.56 %	2.44 %	58.68 %
	Florida Fish and Wildlife	19.32 %	99.72 %	483	2493	7	2017
				19.32 %	99.72 %	0.28 %	80.68 %
	Tall Timbers Research Station	0.00 %	100.00 %	0	2500	0	2500
				0 %	100 %	0 %	100 %

Table 2 – Validation Results

It is important to note that while we treat all fire polygon data as a confirmed presence of burned area, there are instances where our “observed” fires are not actually observed in reality. For example, Figure 1 shows how USFWS documents prescribed fires at the burn unit scale at St. Marks National Wildlife Refuge, however it is clear from the reference image that burns are patchy and not wall to wall. These are instances where a “true positive” is misleading and inherently adds error to the validation results. Therefore, true sensitivity rates are likely being underestimated in this exercise. A validation of the Landsat BA product against independent reference datasets derived from high-resolution commercial satellite data (QuickBird) showed 45% omission error and 37% commission error in the Eastern US (Vanderhoof et al. 2017a). On the other hand, there are instances where burn units/and or burnable vegetation match the burn scar quite well, arguably better than a satellite product (Figure 3). As a result, there is a need to assess agency derived datasets in more detail to determine how they perform compared to true validation datasets.

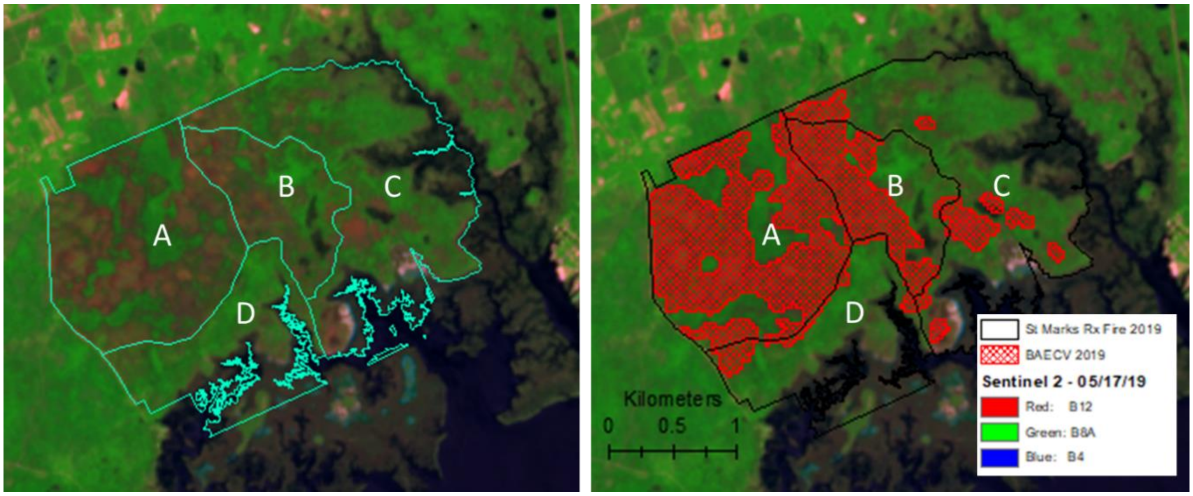


Figure 1 – St. Marks burn units (A – D), where prescribed fire was applied in 2019, overlaid onto a Sentinel-2 post-fire reference image

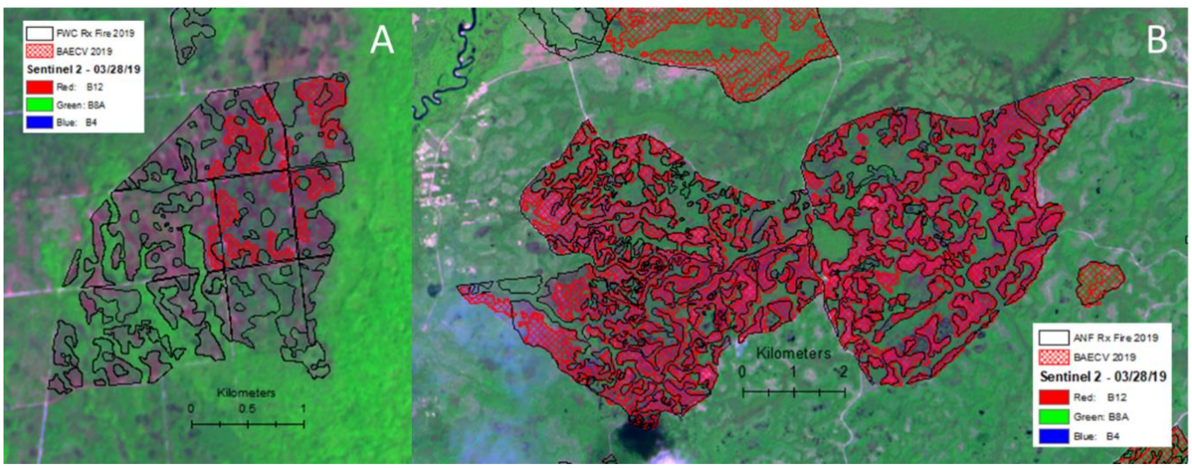


Figure 2 – Examples of burnable vegetation within the burn unit for FWC (A) and ANF (B) burns. On the right, there is considerable agreement between the burnable vegetation polygons and the BA v2 product, whereas on the left, the burnable vegetation polygons appear to capture the burn scar mosaic more accurately.

Workflow and Discussion Section 3:
Replication of fire mapping methods (MTBS and Landsat BA) using Landsat 8 and Sentinel 2 imagery in Google Earth Engine.

We investigated a novel image processing platform called Google Earth Engine (GEE) to determine if operational fire mapping techniques could be automated in a more efficient and user-friendly way. GEE is a web-based integrated development environment that combines a multi-petabyte catalog of satellite imagery and geospatial datasets with planetary-scale analysis capabilities and makes it available for researchers to detect changes, map trends, and quantify differences on the Earth's surface. By acquiring imagery and applying processing techniques in a cloud environment, users can perform entire workflows quickly and easily without having to download any data. Some proficiency in coding (i.e. JavaScript, Python) is required to use the platform. Processes to call imagery and run geospatial analyses are executed through a command line, however ample documentation is provided (https://developers.google.com/earth-engine).

Figure 1 shows how FMT methods can be replicated within GEE. In this exercise, the same Landsat imagery used with the FMT was pulled into the GEE environment with just a couple lines of code. Normalized Burn Ratios (NBR) were calculated for the pre and post fire imagery and then differenced to produce the delta NBR (dNBR). The same thresholds calculated within the FMT were applied to the dNBR in GEE to produce the burn severity product. A simple manipulation of the code required to produce this analysis would allow a user to assess other fires without having to redo the entire processing workflow. It is likely that the same FMT algorithm used to calculate the appropriate thresholds for the dNBR imagery can be re-written for GEE. This could potentially reduce the time and effort required to obtain these types of products for an area of interest.

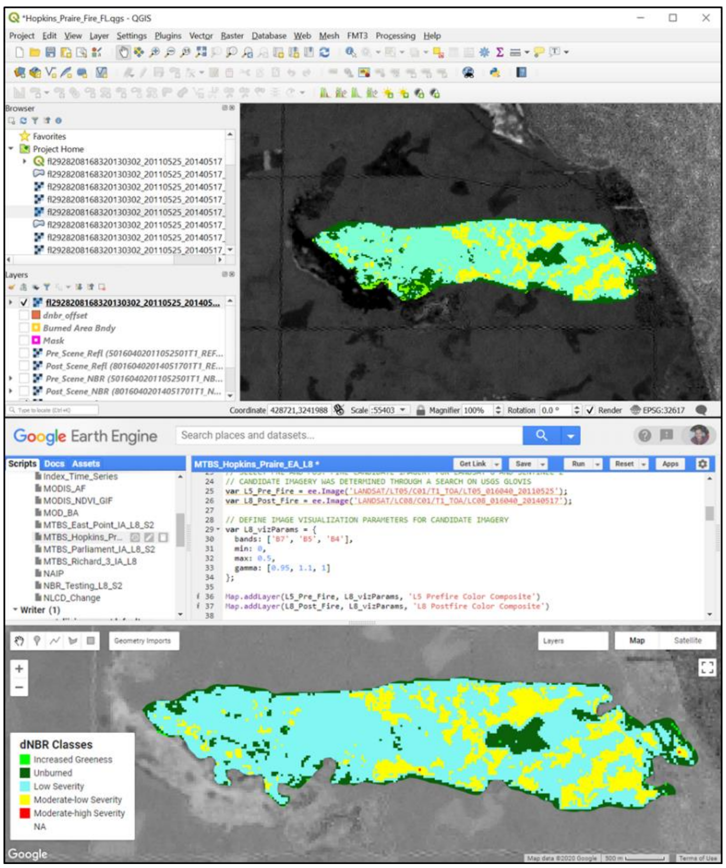


Figure 1 – Mapping burn severity with the FMT in QGIS (top) vs replicating the process in GEE

Image classification techniques within GEE were also explored; a number of supervised classification algorithms are available through the platform (Random Forest, Support Vector Machine, Maximum Entropy). For this exercise, we used the Random Forest algorithm on a single Sentinel-2 image, captured after the Florida fire season (05/17/2019). To train the algorithm, we generated 100 polygons that equally represented burned and unburned areas through visual assessment of the imagery. Spectral information (bands) were extracted to these training points and used to produce spatial predictions of burned and unburned areas within the image. The burned area map visually matched up quite well to the Landsat BA product (Figure 2). With the cloud processing power of GEE, it is possible to perform image classifications such as this on large collections of imagery and generate annual composites that are comparable to the Landsat BA product. The analysis presented has not been refined or validated at this time, however it is clear that GEE has enormous potential for mapping fires in a systematic and efficient way.

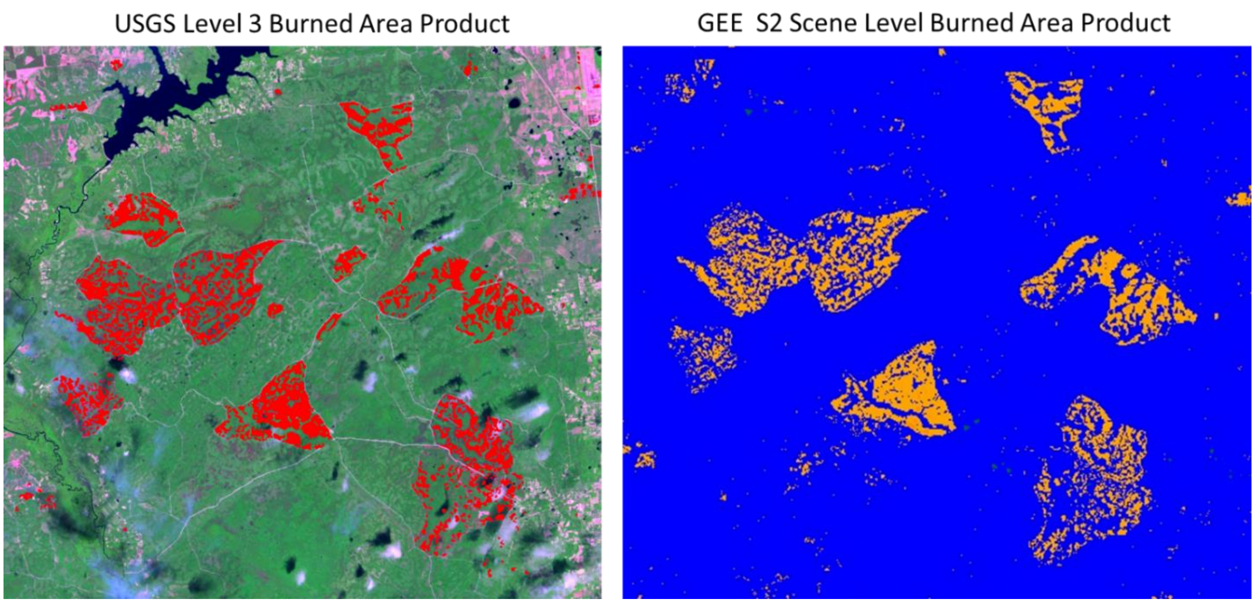


Figure 2 – USGS Landsat annual burned area composite (left) and Sentinel 2 scene level product produced in GEE (right)

Workflow and Discussion Section 4:
Initial reporting of improvements/enhancements to existing BA mapping products and discussion of those products under development.

1. Enhancements continue to be made to the Landsat BA product. The annual BA v2 composites initially showed some large and obvious commission errors. Some appeared to be caused by artifacts not masked in the Landsat quality assurance bands, but in other areas, were likely caused by misclassification from the algorithm. To remove these excessive commission errors, Hawbaker et al. (2020) visually examined results for each Landsat scene and flagged them for removal when they contained large commission errors. This step ranked scenes from high to low by the percentage of clear pixels that were classified as burned. Scenes with >1.0% burned (n=11,625) were visually assessed, starting with the highest percentage burned and working down. Each scene was flagged as acceptable or not based on visual analysis of the original Landsat scene and the corresponding burn probability and burn classification products. After all

scenes were assessed, annual composites were regenerated excluding any scenes flagged as unacceptable.

2. Wildfires and prescribed fires are common in wetland ecosystems across the southeastern U.S. However, burned area detection can be particularly difficult in wetland ecosystems as it can be challenging to spectrally distinguish open water or saturated soil from a wetland burned area. Consequently, very few efforts have focused on techniques to map wetland burned area extent, leading to a reliance on generalized algorithms used to produce national and global burned area products. Melanie Vanderhoof, with the U.S. Geological Survey, in collaboration with Tall Timbers scientists, are currently working to develop machine learning algorithms using Landsat OLI and Sentinel-2 image collections in cloud-based platforms to map wetland burned area extent for 2016-2019 across Florida and the coastal southeastern U.S.

3. Roteta et al. (2019) have recently developed a multitemporal two-phase BA algorithm using as inputs Sentinel-2 MSI reflectance measurements in the short and near infrared wavebands plus the active fires detected by Terra and Aqua MODIS sensors. An initial burned area map is created in the first step, from which tile dependent statistics are extracted for the second step. The whole Sub-Saharan Africa (around 25 M km^2) was processed with this algorithm at a spatial resolution of 20 m, from January to December 2016. The area was selected as existing BA products account it to include around 70% of global BA. Validation of this product was based on a two-stage stratified random sampling of Landsat multitemporal images. The accuracy of this BA product (26.5% omission and 19.3% commission error) significantly improved that obtained from coarse resolution sensors (MODIS MCD64A1 500m BA product – 59.6% omission and 20.4% commission error) particularly in detection of small burns (<100ha).

4. Additional advancements are being made in the wildfire community. Orora Technologies is a private company based in Germany that has developed the first global wildfire intelligence service, including risk assessment, early detection, real-time monitoring, and damage analysis. Orora Tech's wildfire service currently receives data from a variety of existing satellites; however, they are also developing their own satellite constellation. Due to the miniaturization of technology in the last few years, it is now possible to put a camera, an image processing unit, and the necessary support electronics into a 3-unit CubeSat with the size of 30x10x10 cm^3. The so-called New Space movement enables the launch of standardized nanosatellites. They are built with commonly available off-the-shelf components, and are relatively cheap compared to old large satellites, allowing the establishment of larger constellations. By developing their own CubeSat constellation, Orora Technologies will be able to speed up detection times significantly. The first step will be the launch of several complementary satellites. Even the first few will increase the number of revisits, creating greater coverage of the earth's surface and detecting wildfires earlier. The long-term constellation specifications are:

- 600 km sun-synchronous orbit
- Up to 7 orbital planes, launched in several steps
- Multiple revisits every hour
- Launched on ad-hoc rideshare missions as well as dedicated launches

Orora Technologies reached out to Tall Timbers Research to evaluate their active fire product. We were able to provide feedback through a summary report and discuss ways to continue our collaboration.

Background

Federal, state, and private land managers that apply annual prescribed fire plans typically have a method for documenting and tracking acres of prescribed fires each year. While these methods provide a historical record of fire occurrence, there are inconsistencies in how prescribed fire is tracked across agencies and private lands managers. 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. This makes it challenging to accurately quantify the acreage of prescribed fire occurring at state-wide to national scales.

Burned Area (BA) products generated from satellite remote sensing techniques provide a historical record of fire occurrence both spatially and temporally and are collected using a standardized methodology, independent of prescribed fire records. One benefit to looking at burned areas via satellite is that the spatial extent of a past fire can be delineated to a higher degree of detail than other ancillary data such as burn units and burnable vegetation. On the other hand, common 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). Despite the accessibility and widespread use of BA products, there is a need to better understand their strengths and weaknesses in prescribed fire detection. For this exercise, we use fire perimeter data obtained from various collaborators to help validate the suite of BA products listed below (Table 1). We also explore the limitations of these data in remote sensing applications.

BA Products	Temporal Resolution	Product Availability	Product Resolution	Satellites	Sensors
MCD64A1	Monthly	2000-2020	500 m	Terra Aqua	MODIS
Fire CCI51	Monthly	2001-2019	250 m	Terra	MODIS
Landsat 8	Annual	1984-2019	30 m	Landsat 5 Landsat 7 Landsat 8	TM ETM + OLI

Table 1 – Operational Burned Area products assessed

Fire Perimeter Data

Prescribed and wildfire polygons were obtained from a number of federal, state, and private lands organizations: (1) Apalachicola National Forest, USFS (2) St. Marks National Wildlife Refuge, USFWS (3) Florida Fish and Wildlife Conservation Commission and (4) Tall Timbers Research Station. It is important to note that methods for documenting prescribed fire differ by agency/organization. In this case, the two approaches taken are by either listing the entire burn unit as burned or by listing all "burnable" vegetation within the burn unit as burned. In both scenarios, assumptions are made about the amount of area burned within the burn unit, and no real ground trothing is performed to delineate burned from unburned vegetation. Agency/organization documentation methods are shown below (Table 2).

Agency/Organization	Type	Prescribed Fire Documentation Method
Apalachicola National Forest, USFS	Federal	Burnable vegetation w/in burn unit
Florida Fish and Wildlife	State	Burnable vegetation w/in burn unit
St Marks National Wildlife Refuge, USFWS	Federal	Entire burn unit
Tall Timbers Research Station	Private	Entire burn unit

Table 2 – Fire data source and documentation method

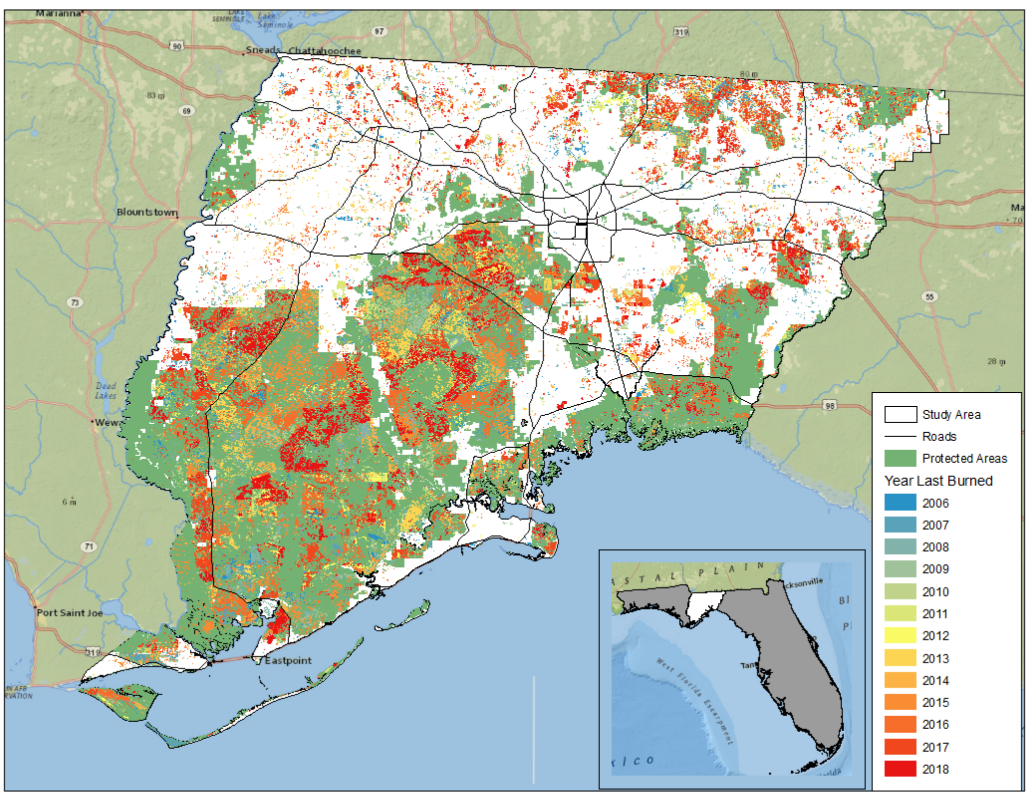


Figure 1 – Study Area (District 4 of the Florida Forest Service) within which burned area products were assessed. Fire history is displayed using a Level 3 Burned Area Product from the USGS (Hawbaker et al. 2017).

Validation Methodology

1.1 Fire Perimeter Data

For the purposes of this exercise, we treat all fire polygon data as a confirmed presence of burned area. Prior to analysis, all fire polygon data were projected to the Albers equal-area projection, rasterized at 30m, snapped to a reference grid, and clipped to an area of interest (Figure 1). Furthermore, the raster data were converted to points and a random sample of 2500 points from each data source were selected to represent "observed" fires in our validation datasets. Another 2500 points were randomly selected, within areas where no fire polygons were documented, to represent "observed" areas of fire absence. These points were combined to represent the final validation set for each data source (n = 5000).

1.2 Burned Area Products

BA products were processed into binary (presence/absence) fire maps using different methodologies. That data used represents burned areas detected in 2019.

1.2.1 Landsat BA

We identified pixels as burned or unburned according to their probability value, with the assumption that probabilities from 90 – 100% represent burn presence. Burn Probability values were then reclassified to presence/absence raster layers 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 a raster product that indicates burn presence (with 90-100% probability) for groups of pixels greater than ~2.24 acres (*e.g.,* 10 contiguous 30m pixels, in any arrangement).

1.2.2 MODIS Products

The classified MCD64A1 and Fire CCI51 products were used in this analysis. These products come in a monthly format where each burned pixel is labeled by the Julien date of the spectral change detection. To stay consistent with the annual composite format, MODIS monthly products were combined to obtain all burned area detected for a given year and then reclassified into binary (presence/absence) fire products. Finally, the MODIS annual composites were resampled and snapped to the BAECV resolution and extent.

1.3 Confusion Matrices

To perform our validation assessment of the BA products, we extracted the predicted fire presence and absence values for each product to the validation point samples. We then compared the "observed" fire presence and absence values to the predicted values. This process was done separately for each validation dataset and resulted in confusion matrices which outline the following detection performance metrics: true positive, true negative, false positive, false negative.

Validation Results

Sensitivity (i.e. presence accuracy) varied by product and by validation dataset (Table 3). Across the products, sensitivity was highest for the Apalachicola National Forest. The BA v2 product generally performed the strongest across all of the validation datasets, with the exception of the USFWS (St. Marks) data where the Fire CCI51 product had a higher presence accuracy.

Tall Timbers provides an interesting case study because the data represents private lands burns which are more representative of the burns occurring across the state of Florida. These burns are smaller and less intense than fires prescribed on federal lands like ANF. The results show that the MODIS products were relatively incapable of detecting any burns on the property whereas the BAECV was able to detect over 40 % of the documented fires.

Burned Area Product	Validation Dataset	Sensitivity (Presence Accuracy)	Specificity (Absence Accuracy)	Confusion Matrices			
				TP	TN	FP	FN
Landsat Burned Area Essential Climate Variable (BAECV)	Apalachicola National Forest	50.92 %	99.28 %	1273	2482	18	1227
				50.92 %	99.28 %	0.72 %	49.08 %
	St Marks National Wildlife Refuge	25.24 %	99.92 %	631	2498	2	1869
				25.24 %	99.92 %	0.08 %	74.76 %
	Florida Fish and Wildlife	27.80 %	99.32 %	695	2483	17	1805
				27.8 %	99.32 %	0.68 %	72.2 %
	Tall Timbers Research Station	42.08 %	98.80 %	1052	2470	30	1448
				42.08 %	98.8 %	1.2 %	57.92 %
MODIS Terra/Aqua Burned Area Monthly Grids (MCD64A1)	Apalachicola National Forest	41.84 %	96.68 %	1046	2417	83	1454
				41.84 %	96.68 %	3.32 %	58.16 %
	St Marks National Wildlife Refuge	29.84 %	99.28 %	631	2498	2	1869
				25.24 %	99.92 %	0.08 %	74.76 %
	Florida Fish and Wildlife	8.96 %	99.88 %	224	2497	3	2276
				8.96 %	99.88 %	0.12 %	91.04 %
	Tall Timbers Research Station	5.64 %	98.16 %	141	2454	46	2359
				5.64 %	98.16 %	1.84 %	94.36 %
ESA MODIS Fire CCI v5.1	Apalachicola National Forest	43.56 %	96.32 %	1089	2408	92	1411
				43.56%	96.32 %	3.68 %	56.44 %
	St Marks National Wildlife Refuge	41.32 %	97.56 %	1033	2439	61	1467
				41.32 %	97.56 %	2.44 %	58.68 %
	Florida Fish and Wildlife	19.32 %	99.72 %	483	2493	7	2017
				19.32 %	99.72 %	0.28 %	80.68 %
	Tall Timbers Research Station	0.00 %	100.00 %	0	2500	0	2500
				0 %	100 %	0 %	100 %

Table 3 – Validation Results

Fire Perimeter Data Limitations

It is important to note that while we treat all fire polygon data as a confirmed presence of burned area, there are instances where our "observed" fires are not actually observed in reality. For example, Figure 1 shows how USFWS documents prescribed fires at the burn unit scale at St. Marks National Wildlife Refuge, however it is clear from the reference image that burns are patchy and not wall to wall. These are instances where a "true positive" is misleading and inherently adds error to the validation results. Therefore, true sensitivity rates are likely being underestimated in this exercise. A validation of the Landsat BA product against independent reference datasets derived from high-resolution commercial satellite data (QuickBird) showed 45% omission error and 37% commission error in the Eastern US (Vanderhoof et al. 2017a). On the other hand, there are instances where burn units/and or burnable vegetation match the burn scar quite well, arguably better than a satellite product (Figure 3). As a result, there is a need to assess agency derived datasets in more detail to determine how they perform compared to true validation datasets.

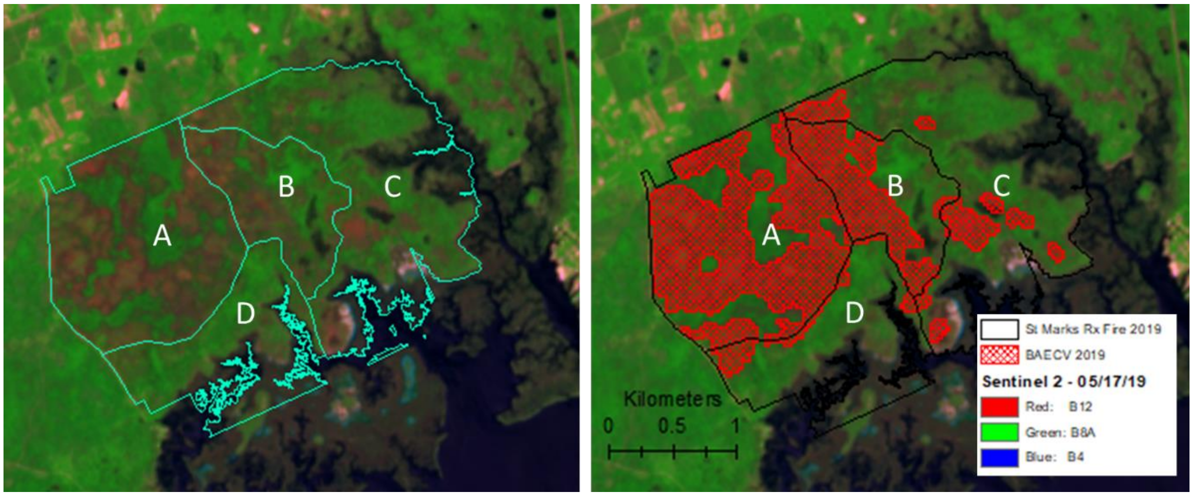


Figure 2 – St. Marks burn units (A – D), where prescribed fire was applied in 2019, overlaid onto a Sentinel-2 post-fire reference image

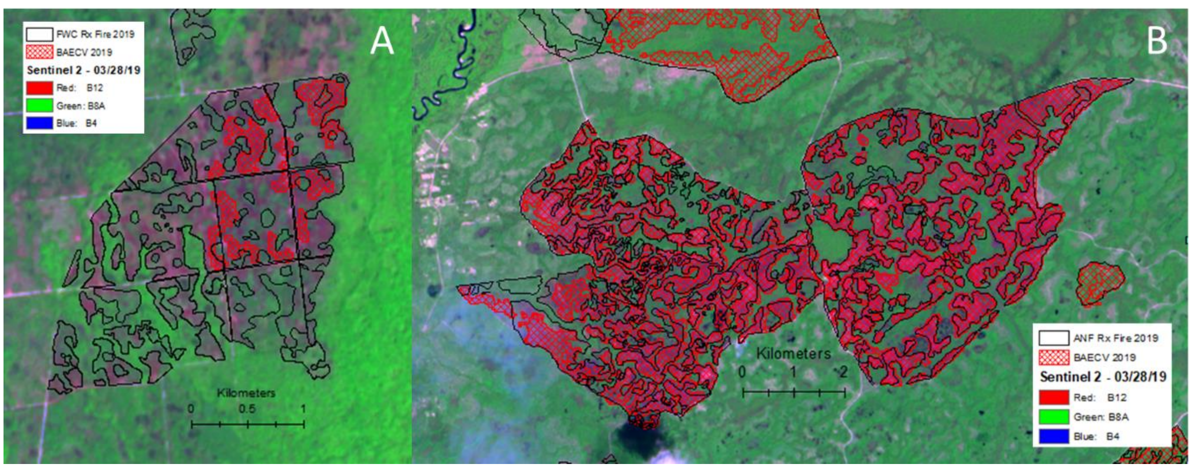


Figure 3 – Examples of burnable vegetation within the burn unit for FWC (A) and ANF (B) burns. On the right, there is considerable agreement between the burnable vegetation polygons and the BAECV product, whereas on the left, the burnable vegetation polygons appear to capture the burn scar mosaic more accurately.

Background

Active Fire (AF) products generated from satellite remote sensing techniques provide natural resource managers with near real-time detection and characterization of wildland fire conditions in a geospatial context across the globe.

AF products are delivered in a point based format and characterize daily fire detection data based on thermal anomalies. AF points represent the centroid of a fire detection pixel (i.e. the footprint) that signifies an active fire detection location at the time of the satellite overpass.

Several online platforms host a suite of AF products for ease of access:

1. NASA's Fire Information for Resources Management System (FIRMS)
2. The National Interagency Fire Enterprise Geospatial Portal (EGP)
3. Orora Technologies' Wildfire System

Despite the accessibility and widespread use of AF products, we felt there was a need to better understand their strengths and weaknesses in prescribed fire detection. For this exercise, we used open burn authorizations (OBAs) obtained from the Florida Forest Service (FFS) Fire Management Information System (FMIS) to help validate the suite of AF products listed below.

Operational Active Fire Products Assessed

Satellite(s)	Sensor	Temporal Resolution	Years Active	Spatial Resolution	AF Products
Suomi-NPP NOAA-20	VIIRS	Once Daily	2012-2020 2017-2020	375 m	I-Band AF
Terra Aqua	MODIS	Once Daily	2000-2020 2002-2020	1000 m	MCD14DL
Sentinel-3A Sentinel-3B	SLSTR	Once Daily	2016-2020 2018-2020	1000 m	SLSTR AF
GOES-16 GOES-17	ABI	12x/hr (CONUS)	2018-2020	2000 m	FHS

Once Daily = day-night (2 image) composites

Florida Forest Service Open Burn Authorizations

OBA data from the FFS FMIS include all open burns (e.g. broadcast burns and pile burns larger than eight feet in diameter) authorized within the state and serve as a proxy for locations of prescribed fires (Figure 1). While this is a rich dataset that can be used to further our understanding of prescribed fire occurrence and characteristics, a number of limitations exist that must be taken into consideration (See Dataset Exploration). The data records are in a point format, which lacks precise spatial extent information. Therefore, it is challenging to confidently determine if, and to what degree, AF detections are aligned with an OBA point (Figure 2). Additionally, there is currently no mechanism in place to 'close' a permit and track how many acres actually burned once the burning in complete. As a result, there is no way to systematically confirm the implementation and/or actual size of each OBA. However, for the purposes of this exercise, we treat all OBA data as confirmed fire occurrence unless stated otherwise.

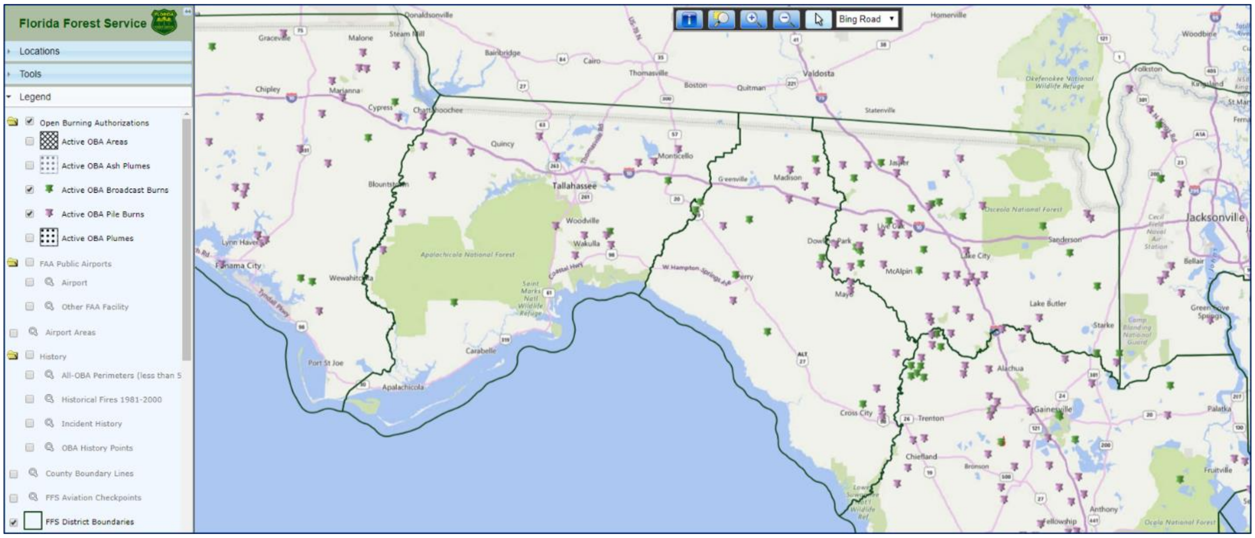


Figure 1 – Florida's Fire Management Information System (FMIS) portal: http://tlhforucs02.doacs.state.fl.us/fmis.dataviewer

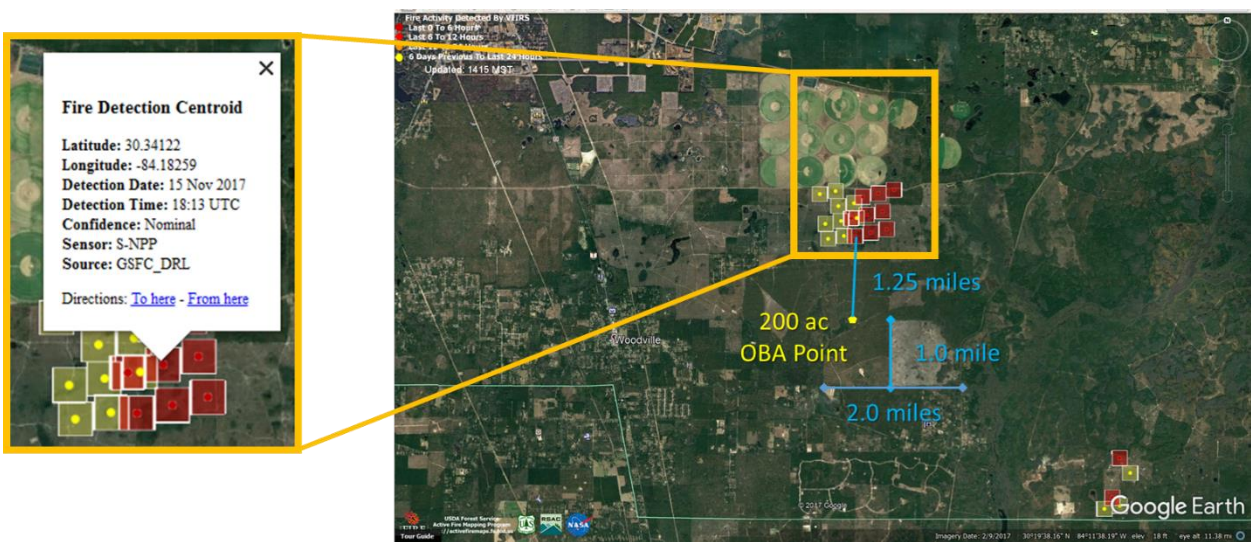


Figure 2 – AF detections captured through SUOMI-NPP VIIRS on November 15, 2017 as compared to an OBA point on the same day that was recorded to have 200 acres of land burned. Spatially, the AF pixels were detected approximately 1.25 miles (2 km) away from where the OBA point was recorded.

Validation Methodology

OBA data were provided weekly by colleagues at the FFS, in a custom Florida Albers equal-area conic projection, and subsequently clipped to an area of interest (Figure 3). A number of key attributes for each OBA were noted and used in the analysis (Figure 4). The start date attribute was used to determine the day of the OBA.

Using NASA's Fire Information Resource Management System (FIRMS), AF data representing the MODIS and VIIRS sensors were downloaded in 1 week intervals (https://firms.modaps.eosdis.nasa.gov/active_fire/#firms-shapefile), clipped to the study area, and temporally filtered to match the days of each OBA.

For each day that OBA records were obtained, a visual assessment was performed at each available OBA point. If active fire points were detected in the general vicinity of the burn permit (Figure 5), the fire was confirmed and additional information related to the satellite detection was recorded (e.g. number of AF points, sensors that detected the AF, flyover time). We considered active fire points within ~2km of an OBA as potential detections to account for the locational error reported for the OBA data unless the reported acreage of the OBA allowed for increased distance (Nowell et al. 2018).

In tandem with the FIRMS data, we partnered with a private company, Orora Technology, to assess their active fire detection portal. Active fire data from both the GOES ABI and the Sentinel 3 SLSTR were obtained. The same validation methods were used if active fire points were detected in the general vicinity of the burn permit.

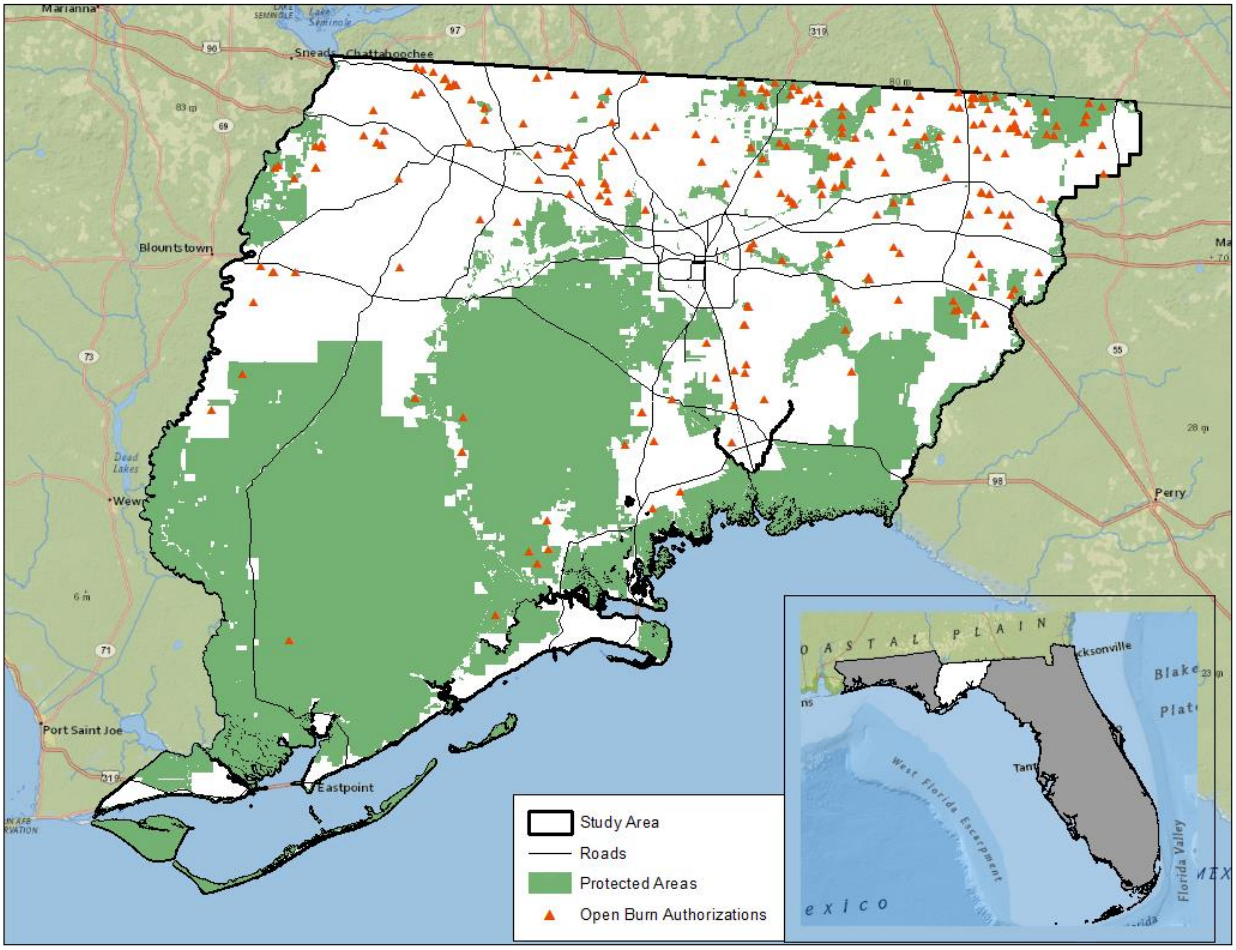


Figure 3 – Study Area (District 4 of the Florida Forest Service) within which active fire products and OBA records (n = 276) were assessed. Records span March 1st – April 3rd, 2020.

FID	START_DATE	ACRES	PILES	BURN_TYPE *	FIRING_TECHNIQUE *
0	3/3/2020	35	0	Silvicultural--Ecological	Backing Fire
1	3/3/2020	250	0	Silvicultural--Hazard removal	Backing Fire
2	3/3/2020	15	0	Land clearing--Residential--Without ACI	Backing Fire
3	3/3/2020	23	0	Silvicultural--Hazard removal	Backing Fire
4	3/3/2020	0	1	Land clearing--Residential--With ACI	Ring Fire
5	3/2/2020	0	1	Land clearing--Residential--Without ACI	Ring Fire
6	3/2/2020	0	20	Land clearing--Non-residential--Without ACI	Ring Fire

Figure 4 – Example of attributes provided for individual open burn authorizations

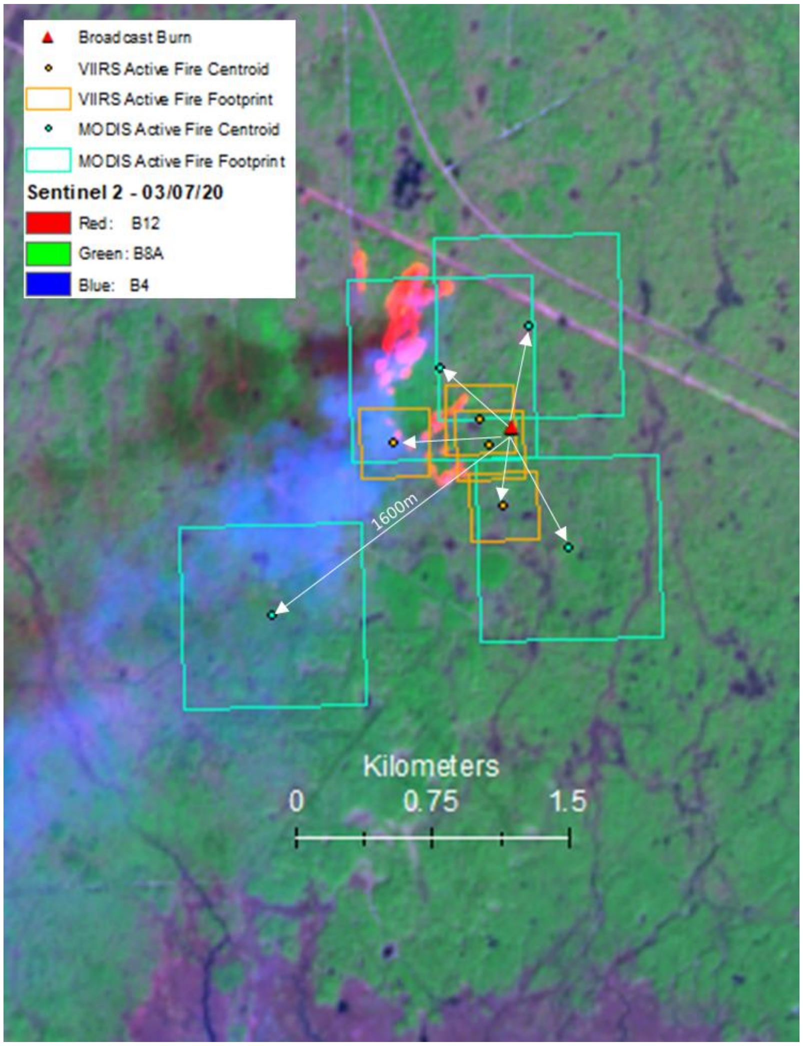


Figure 5 – A confirmed fire occurrence (3/7/2020) based on the proximity of the AF detections (n = 8) to the OBA

Results

Roughly 28 % of the burn permits were detected by the active fire products (Figure 6). There were several instances where certain burns were detected by multiple sensors. The VIIRS sensor, onboard SUOMI-NPP and NOAA-20, was the most effective for detecting prescribed fires and pile burns within the study area. When combined, the two satellites were able to detect roughly 22% (n = 62) of the burn permits. It is evident that the increased resolution of the VIIRS sensor, at 375m, makes it superior for detecting smaller active fires. A number of factors could explain the low detection rates across all of the sensors such as the prevalence of small, rapidly burning, low-intensity fires or frequent cloud cover in the study region. In recognizing the limitations of the OBA data, it is possible that some of the burn permits used in this exercise were not actually implemented. Therefore, actual detection rates may be underreported. While the VIIRS sensor represents a step forward in the ability to detect prescribed fires in near real time, there are still severe spatial limitations that exist with the active fire data that make it challenging to accurately represent a burned area mosaic across the landscape (Figure 7). As a result, we felt there was a need to explore the Landsat Burned Area product in more detail.

	OBA Metrics		Number of OBAs Detected By Satellite				
Sample Metrics	Sample Size	# OBAs Detected	MODIS	NOAA20	SUOMI	GOES-16	Sentinel-3
Total	276	76	21	33	45	17	3
% of Sample	100	**27.5**	7.6	12.0	16.3	6.2	1.1

Figure 6 – Validation Metrics Table

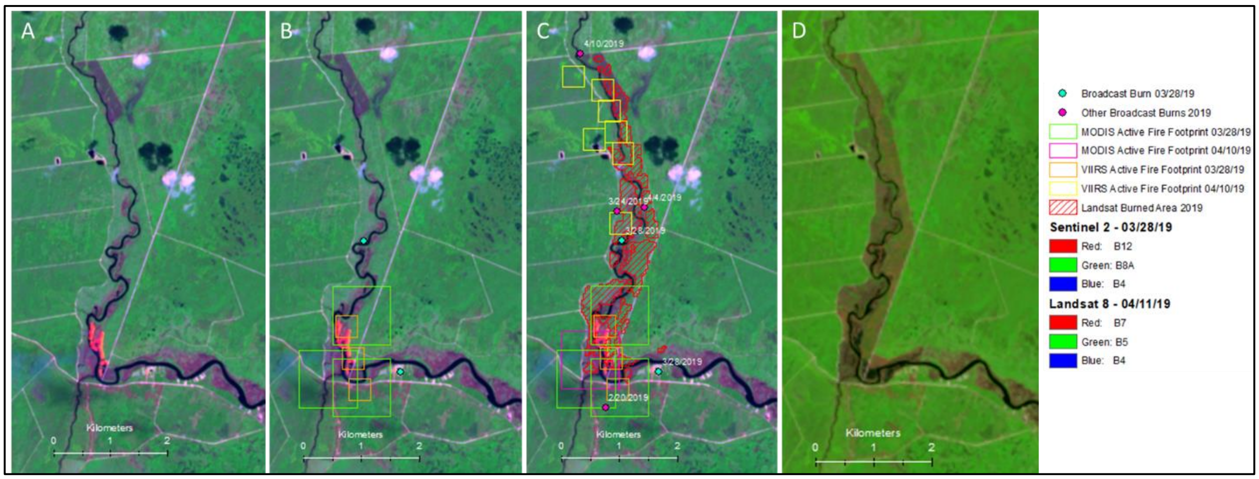


Figure 7 - (A) an active fire captured via Sentinel 2 (03/28/19), (B) the corresponding burn permit and active fire detections for the active fire, (C) All fire records (2019) along the river, and (D) the burn scar apparent after all of the fire activity, captured via Landsat 8 (04/11/19).

<u>Burned Areas</u>

Burned Area (BA) products generated from satellite remote sensing techniques differ from AF products in that they provide historical records of fire distribution as opposed to near real-time detections. One benefit to looking at burn scars is that the spatial extent of a past fire can be delineated to a higher degree of detail (Figure 8). In parallel with AF products, there is also a need to better understand the strengths and weaknesses of BA products in prescribed fire detection. That is why we also compared a number of burned are products against prescribed fire perimeters (See BA Validation Report).

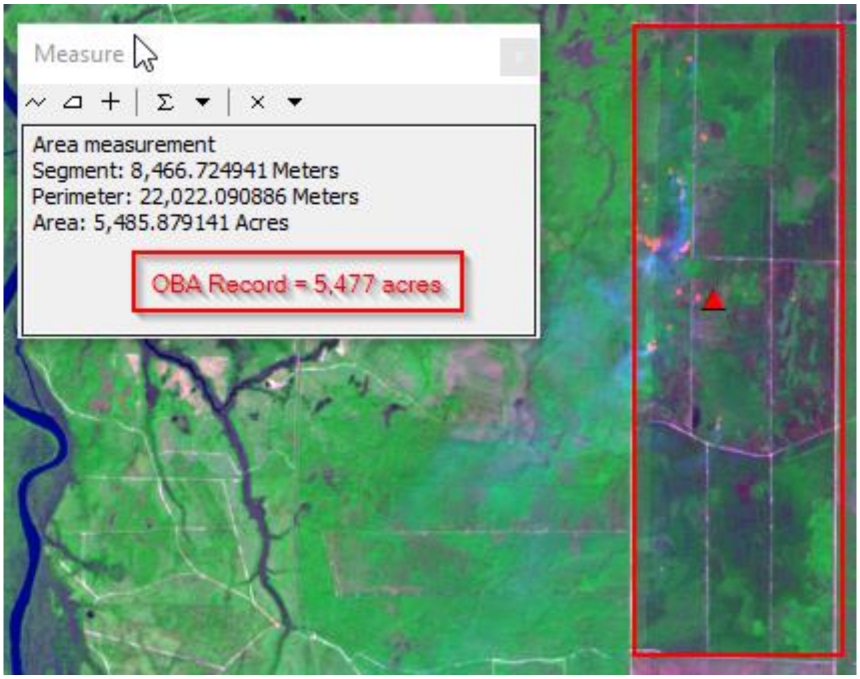


Figure 8 – Reference Sentinel-2 image, captured on 03/07/2020, four days after an OBA record (red triangle). Burn scars evident in the image can be used to delineate the actual area of the fire.

Southeast FireMap Scoping Webinar Meeting #1

Webinar Meeting Report

May 28, 2020

Hosts: Joe Noble, Tall Timbers Research Station

David Godwin, Southern Fire Exchange / University of Florida

Lucas Furman, Longleaf Alliance

Mary Nell Armstrong, Tall Timbers Research Station / Southern Fire Exchange

Speakers: Carl Nordman, NatureServe

Andy Beavers, Center for Environmental Management of Military Lands, Colorado State University

Introduction

The purpose of the scoping phase is to provide recommendations to ultimately build out the Southeast (SE) FireMap through a future request for proposals funding opportunity. The intent of this meeting and forthcoming meetings is to get an idea of some existing fire mapping projects so that the final SE FireMap product can built to best serve the various fire mapping and tracking needs of the region.

Presentation #1

Carl Nordman, Vegetation Ecologist, NatureServe

NatureServe

- a network connecting science with conservation and guiding conservation action where it's needed most
- produces information on ecosystems and rare species
- wants decision makers to understand the importance of science in identifying and protecting ecosystems, rare plants, and animals
- uses scientific expertise tools and data which are used to focus conservation actions and investments on most important places and help reduce the risk of impacts to biodiversity
- NatureServe partners with a network of programs across the United States, Latin America, and Canada
- collectively over 40 years of experience doing this type of work with partners such as Georgia Department of Natural Resources, South Carolina DNR, Florida Natural Areas Inventory at Florida State University, North Carolina Natural Heritage Program, South Carolina DNR Heritage Trust
- global footprint: some work overseas in Africa and Asia, but are focused in North America

- focused on biodiversity, rare species, ecosystems, where they are found, what are they, how they are doing, what actions will help, and then are the actions working – what they are doing with prescribed fire and getting better information about it will relate to actions that may help and if they are working
- NatureServe collects data, transform data into knowledge, and provide meeting to help guide decision making

Prescribed Fire Geodatabase

- developed in partnership with the South Atlantic Landscape Conservation cooperative
- covers the area from southern Virginia to north Florida (Carolinas; Georgia, but not blue ridge region, just piedmont and coastal plain)
- standard minimum data fields and domains. dozens on land managing agencies contribute data
- partners includes Florida Natural Areas inventory
- applied data schema with standard minimum data fields and applied standard domains
- contributions from over 12 lad managing agencies totaling more >20,000 polygon features representing prescribed fires and about 1600 records for each of the most recent years
- this work was part of larger project focused on southern open pinelands and the ecological integrity and rapid assessment metrics for assigning condition for wildlife in these ecosystems (primarily longleaf pine, but other southern yellow pines too)
- open southern pinelands can be great habitat for a lot of wildlife, but depend on prescribed fire to maintain the open conditions that which can regenerate longleaf pine
- fire benefits a variety of rare species and can also serve for hazardous fuel reduction. With a lot of extensive military lands in the region, fire is an important tool in maintaining military training areas

Spatial data pertaining to fire

- point location from burn permits are available from some state forestry agencies.
- some states have made a real effort to bring these together in spatial datasets
- point locations related to burn permits are problematic because just because it has a permit doesn't mean that it got burned, the location may not be accurate, acreage is just an estimate and may be on the high end to avoid penalty, and often an entire burn unit is not actually burned
- raster data is available globally: MODIS (1 km raster data of active fires), VIIRS (375 m raster data of active fares), MTBS (Monitoring Trends of Burn Severity)

- MODIS and VIIRS: fairly large pixels, geared towards big fires that are high intensity that go on for a number of days. Less able to detect prescribed fires in our region which may burn grasses and shrubs, and not a lot of trees. Small fires and fires with short durations likely won't be accounted for.
- MTBS is a nationwide dataset. The minimum burn size that they try to detect is 1,000 acres out West and 400 acres in the East. Is better at detecting the wildfires and higher intensity fires.
- Focused on polygons of prescribed burn areas.
- agencies keep records of prescribed fire activity
- more than 12 agencies contributed through the region– The data gathered is valuable regionally, and they emphasized the value of this data when they did outreach to agencies. Proper outreach was very important.
- Tried to work with agency staff point persons and accepted data on their schedules - didn't want to make demands on a person's schedule when they could be out burning. Don't want to demand unnecessarily)
- data came with various data fields as shape files or polygon feature classes
- Fire Spatial Footprint Geodatabase spreadsheet (and database) is available for download
- work with a lot of different datasets – used a minimum required field approach
- tried to crosswalk data to a standard schema
- See "Field Properties – Fire Spatial Footprint Geodatabase" table
- basics: required (whether or not the field was required or not), date, agency, domain (standard domains used by other agencies), type (not all fires were prescribed fires), cause (13 standard causes commonly used in other data sets that they use), year (some agencies describe year as federal fiscal year), GIS acres (used Albers Equal Area to calculate acres), percent burn estimate (not populated in many cases), control date (may be different than ignition date for a night prescribed burn), ignition time, fire severity, name of fire, comments, unique identifier for the polygon within the source dataset, name of the dataset provider, name of the source dataset, also assigned unique identifier pertaining to the treatment or disturbance in the original dataset

Summary:

- Nearly 20,000 polygon features, data spans >20 years, can be used for many purposes (keep in contact with groups with similar goals to compliment data), their focus is polygon data from various agencies and landowners that can contribute data, this data is mainly from public lands (many private landowners weren't interested in sharing their burned areas publicly), it is a file geodatabase. Partnership effort with funding from South Atlantic LCC. And funds from the US Fish and Wildlife Service Science Applications and Department of Interior Wildland Fire Program. Project partner was Florida Natural Areas Inventory Partner: TTRS (compared notes, made sure that efforts were complimentary) National Fish and Wildlife Foundation was particularly interested in this data, as they have been funding prescribed fire activity in the region

- See Data Download information (from Landscape Conservation Cooperative Network and NatureServe) and White paper (partnership with other agencies looking at the outcome of this project and direction)
- Data is also available on Data Basin, an independent conservation science, spatial data store
- Data also available on NatureServe website (search "NatureServe southern open pine")

<u>Post Presentation Discussion:</u>

1) Todd Hawbaker (USGS): How do end users feel about data and how well it tracks things like fire heterogeneity, if that's important to them? Have you considered addressing it by incorporating other data sets?
   >Carl Nordman: No. Haven't addressed burn heterogeneity. That's a level of data detail that they didn't get into. If someone is interested in that, they could look at the areas within the polygons themselves
2) Todd Hawkbaker: can you comment on the consistency of the data collection effort over the 20 years that your dataset spans. Can you use that data to look at trends?
   >Carl Nordman: Can use data to look at trends, but, now, it has not been consistent throughout the years. Has been more consistent in the past 10 years than from 2000-2005. For the project, we were focused on the most recent years, but also added data from earlier. Could break down data and look at fields like agencies to determine consistency.
3) Todd Hawbaker: You had to work with a ton of other agencies to pull all the data together. Can you comment on lessons learned in collecting data and how to potentially streamline the process going forward?
   >Carl Nordman: We tried to identify many different point people in different agencies and then ask them and then to identify other point people. We really tried to promote the utility of this database for science, for measuring the impact of prescribed fire management in the region and that funding agencies have an interest in knowing how much is getting done and how much needs to be done. Also that this data could be used to better advocate for funding in the future. We kept a spreadsheet of all contacts. Tried not to hammer same people over and over. Sometimes visited their offices at their convenience or talk to them on the phone or set up a WebEx or something. Tried to promote the value of their contributions to get them to latch on to the idea.

<u>Presentation #2</u>

Andrew Beavers, Wildland Fire Program Manager, Center for Environmental Management of Military Lands, Colorado State University

Center for Environmental Management of Military Lands

- supporting the military with wildland fire support for over 20 years now
- primarily what they do is fire management plans, water risk assessment, fire data acquisition, tracking fires

Wildland Fire Management Application WFMAP

- This came about because the military didn't have a way to track fires across their collective installations. Data varied wildly across installations (some had great data, some had none). Resulted in annual data calls that were probably quite inaccurate. Likely an undercount of fires and acreage.
- fire managers weren't able to advocate for their needs for this reason. It's impossible to advocate for wildland fire needs, in order to get funding, without the data to support the requests
- WFMAP is a website / web app that allows users at the installations to input and analyze data
- data includes information about the fires, doesn't require much training, and is very quick and easy

Fundamental Principles

- Think pretty hard at the beginning of your process: What is it that you are trying to do? What are you trying to accomplish? What are the requirements versus what might be nice to have?
- They think about different features and pieces of data that way: What do we have and what do we want to have? Trying to collect comprehensive, comparable quality data
- They wanted to ease reporting requirements of installations. Enter data as they go rather than input a year's collection of burns at one time. Then Installation Management Command, which oversees all army training installations, can simply look at that. Then they can make data driven decisions.

3 Key Factors: comprehensive, comparable, quality data

- comprehensive: wanted to know about all ignitions at every installation (no matter how small
- comparable: want to control data input in a way that is consistent and standardized. Basic database management is very important. Critical data is required and some data is optional.

- quality data: every fire goes through an automatic quality check in the database. If it gets flagged, it goes in front of a person and a person takes a look at it and if necessary, they may contact the user and talk with them about that specific fire

What do they collect?

- there is an element of "keep it simple, stupid" to this kind of project
- required information: where are the fires? How big are they? What type are they? When are they occurring? Why are they occurring?
- See figures selected from the website: David has copy of the slides and figures shown here.
- Login to WFMAP (housed on AWS which gives great connectivity, provides mirroring capability so that they can provide in different places as well, also provides backups so site will never go down) -> dashboard. Can set up for your particular preferences
- received data, from 2015 and earlier, in 2016 via an operational order data call that went out from INCOM to the installations
- big gap in data – WFMAP rolled out in FY 2020. Various installations joined at different times – it won't be a full mirror of data
- graphics react to the various ways of looking at fires: number of fires or total acres; average per year versus the total
- Area Of Interest: can view national data or view at installation level
- Fire Events Table is a listing of all fires (can sort) – can view full information from each fire, can export as PDF
- Throughout the site you can export data as a PDF or CDF (comma delimited file)
- Fire events charts – graphical representation of data (can use slider to view different years)
- One of the most powerful parts of the site is the search functionality
- Can use search tool to narrow data down

Analyses and reports

- one goal is to make sure that even the most basic user can look at fires and do simple analyses on their own. Did the work for them to make the site more usable and more valuable and to avoid user error
- There are many ways to view data
- Tried to put together info for users – what data is being input, what they are asking for (looking for that consistent data)
- burn objectives (tied to pots of funding), purpose of burn, what is the primary driver of the burn
- information includes rules of thumb for entering the data: where is the edge of fire? should spot be included? Those kinds of questions are answered

Map

- can select polygons and view fires that occurred there. If it is selected in map, then it's also selected in fire events table. And vice versa (if you select a fire from the table, it will be highlighted on the map)
- <u>Three ways to input data</u> 52:46
    - can digitize on screen by creating polygons (don't want end users to be doing a ton of on-screen digitizing because it can be time consuming).
    - They are asked to input property, fire type, cause (they use specific military cause codes), report date and time, when did the fire start and end (error catching is included – e.g. if recorded end date is before start date), who is in charge of the fire, who was on the fire (how many people and what agencies are they from), and equipment (who is providing the equipment, what it is)
    - can save and edit later, submit, or delete
    - submitted file goes through quality control
    - Other ways of inputting fires may be better/easier – can be created by prescribed burn unit, select burn units to create geometry of fire, then select the same kind of information as mentioned above
    - can also input data from a GPS file, .gpx is the standard file output from GPS units like a Trimble? or Garmin. Upload fire polygon from GPS unit or drag file from file explorer into WFMAP, click finish, then input same information
- Other layers are included in WFMAP (airfields, etc.)
- Additional use cases: Military oriented.
- develop use cases through scoping process

<u>Relevance to SE FireMap</u>

- many concepts of WFMAP are applicable to the SE FireMap project
- "the main thing is to keep the main thing the main thing" don't fall into the trap of "we are collecting this data, let's collect that data too"
- keep it simple, don't get too complicated. Too much complication may change the functionality of what is featured
- beware of the heavy back end – keep it simple and light – the back end can end up consuming a lot of your funding sources
- they use an open-source database software which requires virtually no effort to maintain
- Oracle is an expensive, complicated system that requires a very savvy database manager
- think about connectivity – users will be scattered throughout states and some may be rural. They are going to have connectivity issues and how you design this is going to be very important in their ability to use it effectively
- a data delivery tool like WFMAP could be very appropriate for SE FireMap's goals and objectives
- set it up so that novice users can slice and dice data as they like – in WFMAP, users can slide and dice the data as they like and then export that data only

- make user friendly and scalable (so that it could be built out of SE)
- Not all burn bosses will be willing to input data like WFMAP has the ability to require, but could create incentives

<u>Post Presentation Discussion:</u>

1) Lucas Furman (Longleaf Alliance): You had mentioned the minimum data fields or domains within the database, were any external stakeholders, non-income stakeholders involved in that decision process? Fish and Wildlife Service or some of the other agency folks that you work within DOD lands on a variety of projects, were any of those stakeholders engaged? Or is it duty specific?
   -Andy Beavers: It's largely DOD specific. Some of the participants involved with the initial scoping meetings of WFMAP were Fish and Wildlife Service and Forest Service had some involvement. The uniqueness of DOD is that the data is intended for only internal use, so it is pretty specific to DOD, but they did try to utilize industry standards (ex. For the cause standards) so that the data can be compared across property owners.

2) Lucas Furman: As far of the data, is this sharable to help inform or provide baseline data for SE FireMap? Understanding that INCOM, the US Army, they have a stake in sentinel landscapes and Army compatible use buffers and there's peripheral private lands components in support of this landscape initiative SE FireMap. Do you perceive there being any way to piggyback or crosswalk with WFMAP?
   -Andy Beavers: Security folks in DOD will likely say no to sharing data. There are a few installations that may be willing to share. Sharing on an installation by installation basis may be possible. INCOM-wide, sharing is probably not going to happen. Security folks are making those decisions, not the people in fire. Would have to refer you to income personnel.
   Tony Davis (INCOM): When it comes down to getting geospatial data, it must be requested through certain channels, G9, and we need to do that and get you the information. If you want me to request the data, I can do that also, but even myself, I have to go through them to get geospatial data for any installation. It will be scrutinized for why they are giving the information up
   -Andy Beavers suggests Tony and he to meet and also maybe Neil Kleinman to set up a meeting and discuss a potential way forward.
   -Tony Davis: If you are requiring the info, you will need to make a very good justification. It's going to be a formal request, it will need to go through the chain, and will take time to process. When you start asking for remote sensing multi-spectral data it is a security thing that we must be aware of. I will help and get with Neil Kleinman and go to G9 to request information.
3) Joe Noble to Andy Beavers: It's so important to be able to display, explore, and report on fire events. It's so challenging for a fire manager to measure any metric

of success without reporting and display tools – it is a critical component.
-Andy Beavers: there are so many sites that allow data download and then the buck stops there, mostly due to funding availability. That is only useful for professional managers and researchers – not the public.

4) Lucas Furman: It's important to get stakeholders who would be interested in SE FireMap involved. It's great to see snapshots of other similar projects.
5) Todd Hawkbaker to Andy Beavers: likes how they standardize data input. Great reporting tool. How often do end users enter spatial data?
-Andy Beavers: It varies. It's people's personal work habits. Some enter it once a week, some build up a bunch and then plug them all in. First roll out was in early November, so people are still getting used to it. They still play a large part in instructing people as to how to enter data. Some installations already have good fire tracking databases, so they are working together to minimize dual inputs. Historic data- that ship has sailed. They aren't trying to import past data. As of FY21- WFMAP will become central system and will make all data solid. INCOM is telling them that funding will be dependent on compliance. Data quality is important, so they prefer continually adding data as fires occur rather than waiting until the end of the year to input it all.
6) Andy Beavers: What are the exact goals and objectives of SE FireMap? What is driving the project? NRCS funding tracking?
-Bridgett Costanzo: has been very involved in Longleaf Council and SURPASS group which were promoting Rx burning and needed to know prescribed fire that is already on the ground and where it was. Within NRCS, data sharing is very restricted. Having SE FireMap, with remote sensing methodology, would allow us to view fire across the landscape (from themselves and partners) that would bypass restrictions and allow for landscape planning. Prescribes fire is primary practice for gopher tortoise and longleaf partnership initiative. In order to conduct landscape planning and assess outcomes- they need data and a map of prescribed fire that they can rely on.
-Lucas Furman: Variety of stakeholder groups have interest in this project, including supplementary data outside of public lands. Knowing: What are the minimum data fields? What are proposed use cases? With the thought that there will be a majority of overlap. Technical oversight team hopes to put our heads together within these working groups and webinars to come up with cohesive recommendations and best practices moving forward. What products are out there? What tools are out there to support? Ties back into funding. In addition to NRCS funding, there is potential of continued, long term funding for this product.
7) Andy Beavers: The challenge may be in private land burning. How to acquire private land data from landowners?
-Lucas Furman: Remote sensing products are promising and will likely be used to fill in the gaps.
-Andy: We looked at MODIS and VIIRS as well as LANDSAT. LANDSAT is great because it is long term consistent dataset, but it misses a lot small or short

duration fires. They used LANDSAT to look at >100 installations over a 10-year period of record to determine what fires were occurring on those installations.

8) Andy Beavers to Todd: Is there an intention within your world to move away from LANDSAT and try a new satellite product?
Todd: There are challenges to LANDSAT in detecting small or low severity fires or detecting fires under the canopy. Trend is how to incorporate LANDSAT and Sedna? sensors together to reduce the temporal lag between satellite collections, but there are some big challenges to doing that. ESA, that runs Sentinel?, they haven't been doing as good of a job as they have been doing with LANDSAT creating consistent geo-referencing in atmospheric correction. That can present some creates problems with time series analysis when the basic data aren't consistent themselves. There are other problems with Sentinel - it lacks the thermal bands that LANDSAT has that we found can be really helpful for finding burned areas. Within USGS they were involved with project to generate burned area products from the LANDSAT archive. There is a paper recently published covering the latest versions of those and they are being produced routinely by the Eros Data Center. We have validated them; they have documented accuracies. They are automated, so they're not perfect. Within USGS there are other teams looking at more sophisticated types of change analyses that find fires and also other types of land use and land cover change. This is a part of the ELSI Maps Project, which tries to fit a harmonic regression to the full time series data for every pixel to make a prediction for the next scene and then figure out if their prediction is different from what was observed. If it is different, then they try to consider whether or not it's some tye of change, and then classify the change. That is the framework that I see USGS throwing money at this right now. Will probably do a good job of noting large intensity fires that remove canopy, but it may not be successful picking up grassland fires in the Southeast where vegetation recovers quickly.
-Andy Beavers: Cloudy days can be a large problem too.
-Joe Noble: There are burned areas products that don't pick up low-severity fires under canopy and grassland fires. Started process a lot like NatureServe by calling, and tried to get data from private ownership lands. At some point they noticed they were missing fires, but many more fires were being mapped than previously done. As a part of this scoping effort, we want to look at other applications and the way other folks are doing it. We produced a very usable product that was better than what we had when they started.
-Andy Beavers: Something is better than nothing. We looked at it in the way that we are sampling fire, as you would in any study, knowing that there is a large fire bias to it. Not trying to detect every fire.
-Joe Noble: One thing we didn't look at that needs more investigations, some areas LANDSAT does well and in other places it doesn't. That is an area that really needs further investigation. That is something we can look at going forward and how we can threshold for those different ecosystems. [commenting on training areas] Used 4 areas in FL with good fire records as pilot areas. We took

the product and sat down with those fire practitioners and went through their records to determine what was missing and where was it doing well and they tried to look at the reasons for that. That did well to inform project and gave confidence that it was working well in some places.
-Andy Beavers: At the end of our attempts at trying to map and detect these fires, we felt like we needed to move on to whatever the next thing is going to be. I don't think it has arrived quite yet, but more and more satellite data arrives every day, more and more platforms, and the cost keeps going down. Our thought was to start thinking about 5-10 years from now and be ready to utilize satellite data that will be available and cost effective at that point. Because it's moving so fast, let's be ready for the future rather than looking only at what is available now.
-Joe Noble: The dashboard and reporting elements don't ever need to change, only inputs. Only the inputs. Use the best that you have today knowing that it can be improved over time with a standardized reporting interface.
-Todd Hawbaker: Look at how MTBS is used. Even though it is a remotely sensed product, they rely on original fire occurrence records to determine which fires to map and because they can attribute those fires with the start date. It's a great dataset if you're looking to model fires or relate fires to climate change across the country. It's important to tie remote sensing products back to things that we can relate to on the ground (like ignition causes or specific start dates). How a fire is portrayed on the ground may be different than how it is depicted in the imagery. A large western fire may start from multiple ignitions and end up burning together and mapped as one large perimeter. Do we count that as one fire or multiple? How to that communicate detail in whatever product or interface that you produce?
-Andy Beavers: I think what your product requires and what you are trying to achieve will change the answer to that. Maybe what you are really interested in is just the burned area. From a military perspective, they don't care if three fires grow to one, but if your objectives are different then you might care. There is a limit to what you can discern with satellite/remotely detected data.

Southeast FireMap Scoping Meeting #2

Meeting Report

June 30, 2020

Hosts: Joe Noble, Tall Timbers Research Station

David Godwin, Southern Fire Exchange / University of Florida

Lucas Furman, Longleaf Alliance

Mary Nell Armstrong, Tall Timbers Research Station / Southern Fire Exchange

Speakers: Josh Picotte, USGS Eros Center
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Todd Hawbaker, USGS Geosciences and Environmental Science Center
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Beth Stys, Florida Fish and Wildlife Conservation Commission
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Introduction

The purpose of the scoping phase is to provide recommendations to ultimately build out the Southeast (SE) FireMap through a future request for proposals funding opportunity. The intent of this meeting and forthcoming meetings is to get an idea of some existing fire mapping projects so that the final SE FireMap product can built to best serve the various fire mapping and tracking needs of the region.

Presentation #1

Josh Picotte, Contractor to the USGS Earth Resources Observation and Science (EROS) Center

Highlights from recent fire science research at USGS EROS

- Monitoring Trends in Burn Severity (MTBS) monitors all large fires in the US
  - In the East, in the US, MTBS maps anything 500 acres and above
  - 1,000 acres in the West
  - Does not map smaller fires except in special cases
- Problem: Burn severity is not mapped for most small fires (<10ha)
- They have helped other people map smaller fires using satellite imagery in a similar way to MTBS
- MTBS
  - Takes Landsat imagery or will also use Sentinel 2 imagery
    - They take the top atmosphere corrected, Landsat images or central images to get a pre-fire and post-fire image

        - Calculate the normalized burn ratio image, which is the difference between the near infrared and short wave infrared divided by the sum to calculate the normalized burn ratio
        - Difference the pre-fire and post-fire pictures together to get the normalized burn ratio image where you can see the fire scar very well (negating the speckling effects that were evident before combining the two)
    - MTBS creates two products
        - Burned Area Product – burn perimeter; a shapefile that covers the burned area of the fire
            - Usually a digitized representation
            - They typically don't automatically generate perimeters; they are all semi-solid
            - MTBS traces out the fire perimeter and also thresholds the burn severity product and creates a thematic image which contains classes including unburned (represented in dark green), low severity (mint green), moderate (yellow), high (red), areas that are masked out (white), areas of regrowth (light green)
        - Threshold Severity Product
            - There are some criticisms of this process because it is a visual process
            - People use the best data they can to designate burned areas and the burn classifications
        - These two products are distributed on the MTBS website
        - They produce other products too, that make up the two listed above
        - They are also looking into using TBI data
- QGIS Fire Mapping Tool (FMT)
    - Creates similar products using the QGIS (open source GIS software)
    - Uses an algorithm to record burn severity
    - Works well in forested systems; doesn't work as well in grassland or shrubland
    - Allows users to map fires
    - Step 1) Identify a fire using sensor detections or another data source
    - Step 2) Use QGIS tool to enter fire information and order fire imagery
    - Step 3) Identify the pre- and post-fire Landsat scenes
    - Step 4) Map fire perimeter and burn severity
    - Does not work with Sentinel yet
    - Creates the same products as MTBS (burned area and burn severity product) automatically using a fairly simple algorithm
    - Open source
    - Through USGS; allows one to order imagery and download it on databases; fire perimeters and spatial light

    - Automated image processing
    - Automated dNBR offset based on the entire image or unburned areas and calculates a median value and it also gives a standard deviation and break points)
    - Automated thresholding
    - Automated metadata (can track all mappings)
    - This algorithm has been tested against what MTBS analysts have done so that you can see the comparison (see figure in slides)
        - There is ~62% agreement (variability may not be due to the algorithm, but variability within the analysts.
    - Can use a "mask" (a vector file) to remove clouds or any other problem
    - FMT is currently available on the MTBS website under "tools"
- CBI: Assessing on the ground burn severity
    - Visually see differences in the ecosystem; how the ecosystem has been effected by fire; effects on canopy, ground vegetation, and soil
    - Averages effects on the 3 layers and gives a rating 0-3 (0 is unburned while 3 is severely burned); is a continuous index (ex. 2.1)
    - Five strata (substrates, herbs, low shrubs and trees, tall shrubs and trees, intermediate trees, and big trees)
        - 4-5 rating factors
        - Based on Ryan and Noste 1985
    - Each strata gets a rating, then the overall value is averaged across strata to get a single value that ranges between 0-3
    - CBI represents data on the plot level; can be scaled up to high resolution imagery
    - Breakpoints are based on CPU comparing CBI to dNBR
    - If a plot overlaps multiple pixels which have different dNBR values, average them all together
    - Overall goal was to develop radiative transfer models to estimate CBI values from the dNBR
- Radiative Transfer Model – Estimating CBI from dNBR
    - Methodology
        - Collect CBI plot data for Conterminous US (CONUS)
            - CBI data is freely available. Most is in the West, but we have some in the East (not much at all in the central US)
        - Collect pre- and post-fire NBR images to calculate dNBR
        - Regress dNBR (x) with CBI (y) to calculate regression model
            - Stratify CBI data by different subdivisions (vegetation based)
- Pre- and Post-Fire Information
    - They have assessed a total of 231 fires
    - 122 pre-fire NBR images
    - 124 post-fire NBR images
    - 227 total images

- 137 dNBR images
- Data is subdivided by ecoregion, LANDFIRE fire regime, biophysical groups, and national vegetation classification (NVC)
- In total, they tested 57 different regression equations (9 polynomial, 48 sigmoidal)
- Determined 3 most common models (linear, Sigmoid A, Sigmoid B)
- Determined best fit model per data subdivision
    - 1. Sigmoid B
    - Linear
    - Sigmoid A (rare, only 2% of NBR models)
- Important in order to calculate curve to fit over entire US
- Also shows where certain models work best
- This dataset is downloadable through ScienceBase
- They are also submitting a paper which will describe this and more; will also submit the different regression equations they calculated for the different subdivisions distributed
- In some locations dNBR works better, and in others NBR works best, in some places either work fine

- Legion Lake Fire
    - Dominant NVC Group: Northwestern Great Plains-Black Hills Ponderosa Pine Forest and Woodland (G216)
    - Much of the burn severity of that fire was in the northern section, so they collected data in the north
    - Rated low, moderate, and high burn severity in 34 plots
    - Compared regression equations amongst Legion Lake only and then NBC classification
    - Graphed various specifications to fit data models
    - Then apply dNBR to create CBI image comparison (CONUS, Legion Lake only, NVC G216 only)
- Some fires are large enough to meet MTBS thresholds, but still go undocumented
- How to apply machine learning models to get burned or unburned value images which can be vectorized to create burned area
    - Using a segmentation algorithm
    - Python scikit-image
        - 14 algorithms
    - Felzenszwalb algorithm (an algorithm that can break apart images by similarity)
        - Uses 3 bands
            - Landsat OLI 6, 4, 3
        - Examines pixel similarity
        - Can change level of pixel similarity (smoothing; e.g. 100)
        - Can change minimum mapping unit (e.g. 5)
    - Picks out images that are similar

- Then dropped some points
- Intersected the smaller point files with the segments and got a much larger sample with 342,000 sample points for the burned areas or unburned areas
- In the training data only (with only 90 points) vs the segmented training data you can see much less speckling
- Did this for fire severity as well

- **Conclusions**
  - FMT can be used anywhere in the world to map fires
  - FMT could be used to process imagery and obtain the data necessary for all applications mentioned
  - CONUS CBI dataset has been completed
  - dNBR/CBI regression models are available at different scales
  - Each regression model has its own accuracy limitations
  - CBI regression model could be used to convert MTBS dNBR to CBI images
  - CBI burn severity output imagery should be easier to interpret because It relates to ground collected data
  - CBI image outputs can be applied to local conditions
  - This is all available open source in python libraries
  - Felzenszwalb segmentation process is easily adjustable for different applications and processing is relatively efficient
  - Segment data can be used to enhance training datasets for machine learning models

<u>Post Presentation Discussion:</u>

1) Todd Hawbaker: How well does the segmentation work in other systems outside of the Flint Hills
   -Josh: They can look really good. It depends on the imagery. You can get some problems in a mountainous region where you have a lot of hillshade. But, you can change the models to change the segmentation thresholds that allow you to group pixels, so that you can spread out that limit. In some areas you may get omission or commission errors based on the landscape and how good your burned area models are
2) Lucas Furman: Referring to segmentation and machine learning, have there been a lot of studies or examples of how utilizing those techniques can affect the final output resolution? Does it improve the 500 acre threshold?
   -Josh Picotte: Yes, it can get much lower. I would say the acreage cutoff is about 15 acres or so. We get reasonable representation. Each Landsat pixel is about 900 meters squared, so I wouldn't go less than 25 pixels or so. I haven't seen many papers that combine machine learning and segmentation
   -Todd Hawbaker: Comment on the machine learning methods, there have been a number of papers that compare random forest vs neural network (machine

learning model). There are differences, but they seem to be very minor. Results are determined by the predictors that you feed those models. Also found in the literature is the use of segmentation and region growing approaches; use machine learning to find pixels that we have a lot of confidence that they were burned and then we use segmentation and region growing to add in pixels that we have lower confidence in. That's been happening for at least 10 years now in the literature. If people are interested, I could dig up some of that. That idea has been around for a while. Almost every burned area mapping algorithm uses it to some extent.

Presentation #2

Todd Hawbaker, USGS Geosciences and Environmental Change Science Center

Mapping burned areas from the Landsat archive: monitoring of fire occurrence across the United States

- Our team at USGS has been working on burned area products from the Landsat archive for a long time now. Originally we called them the Landsat Burned Area Essential Climate Variable (BAECV) products, but more recently we have been referring to them as the Landsat burned area products
- Motivation
    - Our motivation for this is to come up with accurate and complete fire data that have been consistently collected over space and time
    - Accurate and complete fire data are critical for:
        - Quantifying fire occurrence patterns and trends
        - Characterizing drivers of fire and projecting future potential fires
        - Assessing impacts of fires on atmospheric, ecological, hydrological, social, and economic systems
    - Accuracy, completeness, and consistency of existing fire datasets are often uncertain
    - There are several great datasets out there: MTBS (maps large fires from agency records), Fire Program Analysis data (FPA) (forest service; has ignition locations for small and large fires across the country), MODIS active fire detections
    - They all tell different stories about fire occurrence across the country
    - MTBS and FPA datasets that rely on agency data suffer from inconsistent reporting levels over time, which adds uncertainty to the trends that we might pull from those datasets
    - MODIS data are coarse in resolution (1 km resolution at best) which makes them challenging to use for on the ground management applications
    - So despite all the great datasets out there, we saw the need for improvement
- Landsat Burned Area Essential Climate Variable (BAECV)

  - Felt that remote sensing was the best mechanism to come up with spatially and temporally consistent burned areas dataset
  - Works in all major ecosystems
  - Consistently applied across the US (forests, grasslands, shrub lands, wetlands and across all ownership types)
  - Characterizes long-term patterns of burned area (1984-2015)
  - Spatial and temporal resolution appropriate for large-scale assessments and on-the-ground management applications
  - Published the first version of the algorithm in 2017 ("Mapping burned areas using dense time-series of Landsat data")
  - This year, an updated version was published ("The Landsat Burned Area algorithm and products for the conterminous United States") that bring the data up through 2019
    - Slight change to the algorithm and updated validation numbers
- Landsat Burned Area Products
  - Uses all Landsat 4, 5, 7, and 8 sensors (will use any image that has up to 80% cloud cover)
  - 3 main steps are applied to those images
    - 1) Pixel-level burn probabilities. Use a machine learning technique: gradient boosted regression model
      - Gradient boosted regression model
      - Trained using MTBS fires
      - Scene predictors: Landsat-derived spectral indices
      - Reference predictors: 3 year lagged means and standard deviations
      - Change predictors: between scene level and 3 year lagged means
      - Once we have trained the boosted regression model, we can apply it to the full Landsat image and generate burn probability images -> these images are the basis for the imaging and segmentation step
    - 2) Pixel-thresholding and segmentation (used to generate a burn classification image) (can also e used as a measure of confidence)
      - Use candidate burned areas with a high probability burn threshold (~97%)
      - Lump those pixels into patches of 5 acres or 22 pixels and toss out anything smaller to get rid of noise
      - Then use a region growing algorithm to add neighboring pixels that have a slightly lower probability
      - This produces a classification image
      - This image captures fire heterogeneity (unburned patches within burned areas)
      - They do this for every image within the Landsat archive
    - 3) Annual compositing

- Annual Landsat Burned Area Products
    - Summarize individual Landsat scenes across an entire yeat
    - 1) Maximum burn probability across all images in a year
    - 2) Burn classification count: Number of times a pixel was classified as burned across all images in a year
    - 3) Burn date: Day of year the first image a pixel was classified as burned (seasonality of detection, not necessarily when the fire occurred)
    - 4) Filtered burn classification and polygons (residual burned areas removed for select ecoregions)
        - Because some burn scars remain for years; don't want to recount these areas
        - Looks for overlapping burned areas between years
        - Attribute these polygons with summary statistics for burn probabilities, burn classification, and burn dates as well as a count of pixels in each national land cover database class, then assign to an ecoregion based on where the majority of the area burn is for each fire
    - Do this for every year

- Have mapped fires covering .4% of CONUS / year
    - Shows fires mapped in the great plains and the east that are not well represented in many other fire occurrence datasets
- Scene-level Landsat Burned Area Products
    - Acquisition (scene) based products available through USGS Earth Explorer (same place you would go to download Landsat data)
    - Complete for 198402019
- Annual products are available through USGS Science Base Catalog (search Landsat Burned Area)
    - Link in summary text takes you to site which has a directory for individual sensors. Each one of those has compressed files of the annual products
- Summary
    - Have found that it is possible to produce consistent, scene-level and annual burned area products derived from the Landsat archive
    - Validation results indicate lower error rates (omission and commission rates) than global, coarse-resolution products
    - Commission errors may limit use in agriculture and pasture/hay land cover
    - 35+ year long time series of 5+ acre burned areas
    - 180% greater burned area then existing fire data (MTBS)
    - Provide a new information source for understanding patterns and impacts of fire (especially for the Great Plains and the Southeast)
    - Our active and growing community of stakeholders will benefit from routine production of burned are layers delivered through the USGS Earth Explorer and USGS Science Base Catalog

- (Went over on time – saving questions for final Q&A)

<u>Presentation #3</u>

Beth Stys, Florida Fish and Wildlife Conservation Commission

<u>Florida Fire Database</u>

- Fire Occurrence Database: Fire data needs
    - Comprehensive, spatially explicit map of fire occurrence remains a critical need across Florida and the Southeast (is an area in restoration or maintenance condition?)
    - Many of Florida's endangered species and ecosystems rely on frequent fire
    - Fire risk and behavior modeling and prescribed fire planning rely on fire history
    - Current available data is too coarse and temporally insufficient
- Desired queries
    - Burn metrics (year last burned fire return interval, number of times burned since time "x")
        - By land cover type
        - By species
        - By land ownership/managing agency
        - Within a names land parcel
    - How many and size of fires by year and by season?
    - Ability to set up additional queries to the database based on selected fields
        - To properly allocate resources for future fires
- Solution
    - Create a comprehensive, spatially explicit dataset of fire extents in Florida with querying capabilities
    - Utilize advanced remote sensing techniques for consistent classification methods
    - Wanted to capture both prescribed and wildfire
    - Provide current, up to date data on a continuous, annual basis (minimum of 10 years)
    - Develop web-mapping tool
        - Query across years, by land cover type, species habitat, conservation area
        - Use to identify priority areas for prescribed fire
        - Use to track progress toward prescribed fire (fire return) indicators
    - Received funding from FWS with science applications and landscape conservation cooperatives, partnered and contracted with Tall Timbers to help develop this and build it out
- Partner workshop

- Wanted to work with a lot of partners. This is a large, landscape level product, so they hosted a partner workshop
- Attendees from 15 different partner organizations
- Shared project description/process
- Gathered information on:
  - Data availability and sharing
  - Project benefits
  - How fire data is currently being used
  - What reporting metrics would be most useful
  - Integration of data produced
  - Core fields of data needed
  - Non-fire data to associate with burn events
  - Intersection with FFS permitting data
  - Limitations and concerns:
    - Privacy issues
    - Long-term data management
    - Data validity, errors, accuracy, and metadata

- Available datasets and limitations
  - Florida Forest Service Open Burn Authorization (OBA) system via the fire management information system (FMIS)
  - FMIS represents one of the most advanced prescribed fire planning datasets in the country
    - But it has authorizations only. Does not record perimeter data or actual complete urns
  - Known limitations of OBA:
    - Duplicate locations (multiple authorizations using identical location)
    - Single points representing multiple burn units (burn boss could give point location of main shop, but not necessarily the burn unit)
    - No record of actual burn areas (e.g. 100 acres authorized, but only 78 actually burned, no standardized way to record difference)
    - Includes only authorizations, so it does not include wildfires
  - Final report of this project contains evaluation of how OBS could and could not help
- Florida does have a lot of data to use
  - Received Oracle Data Export from Eglin Air Force Base (AFB) (from tracking their fires and spatial footprint)
  - Started with this as database
  - Converted from oracle to SQL
  - Built tables, constraints, and triggers for tables
  - Simplified events and domains

        - Removed and changed certain boxes from the Eglin AFB database schema (some were more relevant to DOD, while some were important for this project)
        - Wanted:
            - Cooperative Land Cover Map (FWC)
            - Management Lands/Ownership (FNAI)
            - Species Habitat Models (FWC)
    - Modified Database Schema
- Remote Sensing Overview
    - What is already out there that could get at the type of information that they care about, with the right resolution, with the right level of accuracy, simple and straightforward enough that once it is built out it would be something that can be updates every year
    - Assess the feasibility of using satellite burn detections to identify fire extents
    - Remote sensing techniques and tools used to identify and delineate burned areas at 30 meter pixels
    - Fires mapped to minimum ~10-acre size (to account for small ecosystems like pine rocklands)
    - Minimum of 10 years
        - Updated annually
- Evaluation of datasets for mapping fires in Florida
    - FFC OBA, MTBS, LANDFIRE Disturbance, MODIS Active Fire (AF), VIIRS-AF, VIIRS I-Band, BAECV, Fire Data by Landowner
    - Decided on Burned Area Essential Climate Variable – BAECV
- BAECV
    - Burned Area Essential Climate Variable (Hawbaker et al. 2017)
        - Burned area products
    - Developed by USGS
        - TTRS and USGS worked together to calibrate products for the state of Florida
            - Mechanical and chemical treatments were showing up as burned areas
    - Utilizes regression models, change detection algorithms, spectral indices, and reference conditions
    - LANDSAT imagery (30m)
    - Probability surface
- Validation
    - Acquired known fire locations 2006-2016
    - Prescribed fires and wildfires
    - Developed scene selection methodology
        - Cloud cover/shadow <30% (Florida is often stormy and rainy)
        - Random points visually evaluated – cloud cover

    - Supervised evaluation
        - Selected 3 years: 2007, 2011, 2015
        - Created point/polygon feature classes of known fire burned areas for validation
        - Checked areas for cloud cover
        - Evaluated against the BAECV
- Burn Area Model Output to Final Burn Products
    - Get burn probability surface -> reclassified based on pixel clustering size and value thresholds -> produce burned area image
- Known issues and challenges
    - Rapid green-up following a burn
    - Cloud cover and shadows obscuring burn signatures (especially during thunderstorm season)
    - Difficulty detecting or differentiating a low intensity burn signature beneath tree canopies
    - Satellite product resolution might be too coarse to capture fine-scale differences or small burns
- Pilot Areas
    - 3 areas that had well tracked fires were used
    - Eglin AFB, Apalachicola National Forest, and Big Cypress Preserve
    - Compare known fire locations with BAECV derived spatial footprints of fires
    - Throughout 2006-2016-time frame
    - Used annual BAECV Burn Probability (Raster datasets)
    - Used 90-100% probability as burned
- BAECV Results from Pilot Areas
    - Common: overall, these datasets captured actual fire footprints relatively well (asked land managers from 3 pilot locations to look at results)
    - Where there were challenges:
        - Fires occurring in grass-dominated locations
        - The actual fire did not burn very hot and did not alter canopy characteristics
        - Fires occurring where days were more often cloudy then clear (July-August)
        - 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
        - Fire was at the end of calendar year, so was perhaps captured in the following years data (November-December)
    - Big Cypress
        - Some threshold adjustment was needed – lowered to ~70-80%
        - Systems are wetter
- Spatial database

    - Fire data from 2006-2018
    - Spatial and tabular queries are possible (can get the image and assess acreage)
    - Captured fires as small as 2.5 acres
    - Very recently updated data to 1994-2019
- Burned Area Products Metrics
    - Fire frequency – number of times burned (in years)
    - Year last burned
    - Time since previous fire (in years)
    - Longest fire free interval (in years)
- FL Fire History 1994-2019 Shapefiles available including:
    - Combination of all fire data
    - Individual years of data
    - Individual shapefiles for burned area product metrics:
        - Fire frequency – number of times burned
        - Year last burned
        - Time since previous fire
        - Longest fire free interval
- Babcock Ranch Preserve Results Example (see slides)
- All fire data polygons query example (see slides)
- Within the SQL Database, added ancillary datasets
    - Species potential habitat models
    - Conservation lands – ownership
    - Landcover types
- Moving forward, will be able to…
    - Assess fire frequency by
        - Land cover type
        - Species habitat
    - Identify key areas
        - Public and private lands
        - Meet indicator targets
    - Maintenance vs restoration
- All of this is available of the Florida Conservation Planning Atlas
    - Fire Map Viewer and tools
    - https://flcpa.databasin.org/
    - Metadata available
    - User manual

Q&A Session

- Josh Picotte: Beth, how much modification of the burned area perimeters do you do?
    - Beth: Not sure. That was TTRS side. Joe?

    - Joe Noble: The product that was delivered to FWC was the straight burned area polygons. Used a different method to clump and adjust geometry from the python scripts that you used, but those were the only modifications that we did.
- Lucas Furman: Beth, building on Josh's questions, I'm curious about the land cover type variants and how that effects the viability of the model. The pilot areas were used to update and improve some of those predictors to prevent things like mechanical and herbicide use areas from being picked up. Thinking in context of the SE FireMap and perhaps larger deployment, are there any baseline recommendations or concerns related to needing to circle back and do additional land cover analyses to see how the model may need to be changed. It's kind of a big question, but I'm just curious if there is any kind of guidance that could be included in discussion today.
    - Beth: Based on fire maintained systems that we have here and as we got further into south Florida in the wetter systems there were some differences being found. Topography throughout the Southeast may cause differences
    - Joe: What we did with our pilot process with the burn practitioners in those 3 pilot areas was to examine the known fire records from those pilot areas and compare to BAECV. We did this to try and understand where we were missing fires and where we were doing well. In the final report, that info went into developing user guides where limitations were highlighted where you may want to be aware of certain issues and limitations with the products. What we are speaking of with the thresholding, in Big Cypress we lowered the thresholding to known fires. We did not include that in the final product delivered to FWC. We have not broken out thresholding for individual land cover types. That could be something that we look into in the future, but we did not do that for this project.
- Lucas: Thanks Joe, that was something I had noted as a question for Todd after he presented, talking about those variances that, Todd, you've been seeing across CONUS and how that might play into this as we discuss the SE FireMap concept and what tools are out there to support this product that we are looking for. Pros and cons and recommendations from your work.
    - Todd Hawbaker: When we first developed out approach, we had tentatively planned to include land cover as a predictor, but we ultimately didn't because there was no land cover data set available for CONUS that reached back to the 80's. Was changed recently, USGS just released their first version of the LC map products, which have pretty coarse land cover classifications for the US and annual time step, but we didn't do it at the time because it wasn't available. Our approach, instead, was to rely on predictors and summarized pre-fire conditions. So we would take a 3-year average of NBR or NDBI and use that as a predictor in our model and maybe change NBR and NDBI to a given image that we were looking at.

Machine learning methods excel when you throw lots and lots of data at them. In theory, they can handle correlated predictors. The challenge we had was that if you derive 20 spectral indices and 23-year lag means and 23-year lag standard deviations, the processing power you would need to process that much stuff gets to be overwhelming. So we, in the latest version, did some forward variable selection, adding predictors if they improved the model up to a certain point. We were able to boil down our predictor set to 8 or 9 predictors. About half were pulled directly from the scene we were trying to map fires in and the other half were those 3-year lagged mean and standard deviations. None of the change predictors came out as being important. So for Southeast Fire Map, as long as you are accounting for pre-fire conditions and variability in pre-fire conditions in some way whether it is by taking historical summary of the satellite imagery or taking the land cover class, I think you'll improve your results. That being said, having more training data will get you better results than having a regional training data set. For our work we trained one algorithm, boost regression models for CONUS using all of our sample points in CONUS (somewhere between 100,000-250,000 training points). We did a quick test to see how the algorithm would change if we just included training points from the Southeast, and you still get decent results, but the accuracy metrics were lower. You wouldn't think that training points in California would help map fires in the Southeast, but they did.
The other thing that we found very helpful with the Landsat data was the thermal band. Historically, not many people have used the thermal band to help map burned areas. I think in part because there were not consistent corrective surface temperatures in the archive. That is something that has come about recently. At least half of the predictors that we used incorporate the thermal bands in some way. There is a variant of NBR that incorporates a thermal band and we included that one at the image level, it's 3-year lag mean and 3-year lag standard deviation. It's important to consider moving forward because there are numerous sensors available like the Sentinel sensors that have a higher resolution and can help us get more frequent image collection in areas in the Southeast where we have a lot of cloud cover, but they lack the thermal band. So there might be some challenges in developing some approaches that work across different sensors because of the differences in the bands.

- Slides will be shared in the shared work space from the Technical Oversight Team

SE FireMap –Scoping Phase Outline and Deliverables Update
7-8-20

Response to Key Deliverables:

1. **Up to 8 meetings, workshops, webinars or conference calls to convene partners and experts to discuss broadly the current data collection, technologies and/or mapping being conducted in the Southeast and elsewhere, with at least two such events focused outside the Southeast:** Host an initial planning web-meeting with project leaders and the Technical Oversight Team. Partner with Southern Fire Exchange to conduct 2-3 online web-meetings focused on updating and expanding the assessment done by the Southeast Regional Partnership for Planning & Sustainability (SERPPAS) Good Map committee in 2018. Conduct 2 meetings in western states focused on existing and proposed fire mapping efforts. These efforts would focus on federal partners at USGS and NIFC. Additional meeting with Western partners if needed to refine assessment of national mapping effort. Conduct wrap-up workshop at location to be determined to discuss findings.

Workflow and Discussion:

4/16/2020	Initial planning web-meeting with project leads and TOT
4/23/2020	Meeting updates to TOT
4/23/2020	Survey developed by TT and SFE to gain focus for future meetings
5/08/2020	TOT Meeting – Landscape Portal Intro & Scoping Review
5/28/2020	Webinar Meeting #1 (Carl Nordman, NatureServe and Andy Beavers CEMML
6/30/2020	Webinar Meeting #2 (Todd Hawbaker, USGS/Beth Stys, FFWC and Josh Picotte, USGS)
In-Planning	Panel Discussion (CONUS/Western focus) of Fire Mapping and BA Products by national experts.
In-Planning	Webinar or TOT presentation of InFORM , IFTDSS and Southern Fire Risk Assessment

The first two webinars intent is to update and expand the assessment done by the SERPPAS Good Map committee in 2018. Monitoring Trends in Burn Severity (MTBS) was included in the second webinar due to interest expressed by TOT in discussions and survey. Mapping Fire in Florida and the FFWS Fire Map were presented as a case study in how remote sensing and burned area mapping can be used to track fire on private lands where previous mapping has occurred.

Direction Forward:

In the primary phase of the scoping process, Tall Timbers is focused on evaluating relevant fire mapping efforts as well options for managing those data through a web interface that supports queries, reports and downloads. Since the primary focus of fire mapping is on private lands where spatial fire occurrence records are lacking, remote sensing solutions will be the focus. The goal of the webinar series is to bring relevant efforts to the attention of the TOT in order to frame the larger discussion of what is required for a successful SE FireMap. Much of the analysis of individual sensors and mapping efforts will be done by analysts at Tall Timbers and presented by written report to the TOT and discussed in monthly TOT as requested.

3. **A list with moderate detail describing the existing relevant mapping efforts, data collection and/or technologies reviewed as part of this Scoping Phase, including a brief assessment of their strengths and weaknesses as it pertains to the end-user (scale, coverage, accessibility, format, interface, etc.), and a contact person for each:** We will perform a standard assessment of all evaluated mapping efforts, this will include all data aggregations and fire detection remote sensing products currently in use. Assessment will focus on existing products as well as new technology approaches including but not limited to those using AI, Google Earth Engine and cloud computing. This assessment of both existing data collection efforts as well as remote sensing efforts and delivered in Excel spreadsheet. Minimum attributes for these data sets would include data source, type, spatial and temporal characteristics, period of record, type fire, format, accessibility and

contact. In addition, our team will make a qualitative assessment of the efforts assessed.

Workflow and Discussion:

Tall Timbers is in the process of assessing the following data aggregations and fire detection remote sensing products currently in use:

Data Aggregation and Analysis Products:

- NatureServe Prescribed Fire Geodatabase
- Wildland Fire Management Application WFMAP
- Interagency Fuel Treatment Decision Support System (IFTDSS)
- Integrated Reporting of Wildland-Fire Information (IRWIN)
- Summary RxFire Permitting (various states)
- LANDFIRE Disturbance
- InFORM
- Risk Management Assistance (RMA) Dashboard
- Southern Integrated Prescribed Fire Information System (SIPFIS)

Fire Detection Products:

- Hazard Mapping Systems (HMS)
- Global Fire Emissions Database (GFED)
- Monitoring Trends in Burn Severity (MTBS)
- GOES-16
- GOES-17
- MODIS Active Fire
- MODIS Burned Area 500m
- MODIS Burned Area 250m
- VIIRS M-Band AF
- VIIRS I-Band/NOAA-20 AF
- LANDSAT BA (BA v2)
- Sentinel 2 Burned Area
- Sentinel 3A AF
- Sentinel 3B AF
- Himawari-8 AF
- Meteosat-10/11

Workflow and Discussion:

Currently Tall Timbers is completing the following analysis for July 15, 2020 interim report:

1. Analysis of Active Fire (AF) detection products in pilot area (FFS District 4) using Open Burn Authorizations (OBA) to evaluate MODIS, NOAA20, SUOMI-NPP, GOES-16, and Sentinel-3 AF detection sensors.
2. Analysis of Burned Area (BA) detection products in pilot area (FFS District 4) using public and private burn polygon records to evaluate LANDSAT BA, MODIS MCD64A1, and MODIS Fire CCI51 products.
3. Replication of fire mapping methods (MTBS and Landsat BA) using Landsat 8 and Sentinel 2 imagery in Google Earth Engine.
4. Initial reporting of improvements/enhancements to existing BA mapping products and discussion of those products under development.

4. **Clear, detailed recommendations for building a scalable SEFireMap database that depicts fire occurrences in the Southeastern U.S. at various landscape scales through a web interface that supports simple queries, reports and downloads as either Excel spreadsheets, pdf(s) or shapefile(s). Recommendations will include how to expand the SEFireMap to help ensure seamless fire planning at larger geographies of the U.S. (especially Western states, if there is interest in doing so):** Recommendation for a SEFireMap application will be broken down into the logical components of mapping products, database structure, web interface, query and reporting and update schedule. Several mapping products may be used to create the best spatial representation of fire on both public and private lands with the goal of using standardized methods. The Technical Oversight Team should provide continuing direction with regards to query and reporting needs as it will dictate database/end user application design. Understanding these requirements will be critical in the scoping phase as existing databases are evaluated with clear criteria in mind.

Workflow and Discussion:

Recommendation will be made based on those data aggregation and analysis products examined during the scoping process. Emphasis will be given to recommendation from the TOT as to what type of query and reporting needs will be required to meet the needs of the SE FireMap. Many of the webinars and TOT presentations are focused on this end user interface as it should remain somewhat constant over time regardless of the remotely sensed fire datasets and traditional fire polygon records it may consume. It is expected that data inputs will change and improve as new technology becomes available but the database/end user application design should be designed in a manner to accommodate those changes.

5. **An approximate cost range for developing the SEFireMap as described above: An approximate cost range will be developed for building the SEFireMap as recommended:** Understanding that there may be multiple contractors who are recommended for specific tasks, the cost estimate will be based on information provided by those contractors.

Workflow and Discussion:

Tall Timbers has produced fire history maps and metrics for the entire state of Florida 1994-2019 as well as the Long Leaf Legacy Landscape which includes portions of southern Georgia and Alabama. For the Mapping Fires across Florida, Tall Timbers provided a rewrite of the USAF Wildland Fire Database from Oracle to SQL Server to include all events, domains, queries updated for FWC partners. For the Longleaf Legacy Landscape, Tall Timbers has produced ESRI Web Mapping Applications that allow for viewing, query and reporting of fire history metrics.

Accurate cost estimation is dependent on detailed needs assessment which we hope to gain through feedback and recommendations from NRCS and the TOT throughout the process.

Deliverables Due to Endowment:

4/23/2020 Interim Report
7/15/2020 Interim Report
10/15/2020 Interim Report
11/30/2020 Final Report

Support Meetings

2/06/2020 Presentation of Web Portal w/Costanzo, Hessmiller, Fawcett, Furman, Noble
3/11/2020 Launching a New Wildland Fire Portal (Raleigh, NC)
4/14/2020 SE FireMap Portal Testing
5/05/2020 SE FireMap TOT Agenda Questions Meeting
5/27/2020 SE FireMap GoToMeeting Overview and Testing