**NASA DEVELOP National Program**



NASA John C. Stennis Space Center

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Texas Disasters

Utilizing NASA Earth Observations to Assist the Texas Forest Service in Mapping and Analyzing Fuel Loads in the Texas Grasslands

 **Technical Report**

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# I. Abstract

[Placeholder - do not put anything here until the final draft submission. The abstract in the project summary is where the working draft of the abstract should “live”]

**Keywords**

Remote Sensing, Fuel Load, Wildfires, MODIS, Landsat, STARFM

# II. Introduction

**Background:**

In recent years, the risk of severe wildfires in Texas has been increasing due to sequences of wet and drought years and urban expansion into woodland areas that are vulnerable to wildfire. During the year 2010, Texas experienced higher amounts of rainfall, which produced more fuel for fires in the following year. In 2011, the state of Texas declared a state of emergency due to the uproar of fires. There were record-breaking high temperatures, very low humidity, and precipitation changes as a result of La Niña in the winter of 2010, all of which contributed to a devastating wildfire season. La Niña, which triggers extreme changes in climate, caused a major drought due to the high water temperatures in the tropical Pacific during the winter season. During the fire season of 2011, wildfires scorched nearly 4,000,000 acres of Texas grasslands, forests, and urban areas destroying 2,947 homes, and costing homeowners over $100 million. Wildfires and drought caused farms to raise prices due to low crop yields. The combined economic damages in Texas caused by wildfires and droughts in 2011 totaled over $5.2 billion (Smith, date).

Many studies and methodologies have been utilized to try to understand and mitigate risks and damages caused by wildfires. Two main factors used in assessing fire risk are vegetative fuel types and fuel loading. A map that displays fuel types shows the distribution of different types of vegetation and how they react to wildfire. Fuel load maps estimate the amount of combustible vegetation.

**Project Objectives:**

The focus of this project was to create fuel type and fuel load maps for the state of Texas. Some of the challenges inherent in creating these types of maps are the large spatial scale combined with the variable temporal characteristics of natural fuels. NASA Earth observations provide a platform for evaluating wildfire fuels across a range of temporal and spatial scales. The suite of Landsat satellites provides the necessary spatial resolution (30m) to detect the various types of vegetation, but each scene covers a small area and lacks the temporal resolution to adequately record changes over time. MODIS (Moderate Resolution Imaging Spectrometer), on the other hand, has a twice- daily temporal resolution and covers large areas in each scene, but has a coarser spatial resolution (250-1000m). In order to overcome this, the relative strengths of the two satellite sensors were combined so that the temporal advantages of MODIS could be applied to Landsat data, and the spatial advantages of Landsat could be applied to MODIS data.

MODIS and Landsat 8 OLI (Operational Land Imager) data products were used to calculate vegetation indices such as NDVI and EVI and to produce land cover classifications based on vegetation types. These products were used to calculate fuel type and fuel load maps. Fusion techniques were then used to create Landsat-scale versions of these products based on corresponding MODIS data.

MODIS-scale products were also generated to cover the entire state that are capable of representing more current conditions than the Landsat-based models which take years to produce. This provided Texas with the ability to create fuel maps based on near real-time data. The project produced a model with the ability to input MODIS data and output a fuel load map based on the conditions recorded on any particular day.

**Study Area:**

The project team analyzed the entire state of Texas which consists of 43 counties and spans over 12.1 million acres. The terrain is consistently dry with deserts in the far west. Grasslands cover the panhandle in mid-Texas, with forestry and shrubland farther east. Mid-Texas transitions between cross timbers and prairies. East Texas is mostly forested, consisting mainly of pine forests, also known as Piney Woods, but there are some oak-hickory stands and various other tree types throughout (author, date).



**Study Period:**

Our NASA DEVELOP team perform studies between 2009 and 2015 and a case study period based between 2010 and 2011. The current study period includes 2009, which was a relatively normal year with average temperatures and rainfall. In 2010, weather conditions consisted of a higher summer rainfall than the average. In 2011, Texas experienced shockingly low amounts of rainfall and very low humidity.

**Application Areas:**

The NASA Applied Sciences application areas addressed by this project were Disasters, Ecological Forecasting, Agriculture, and Water Resources.

**Project Partners:**

The Texas Forest Service is tasked with estimating and evaluating potential fire risk in order to manage and allocate resources for the prevention and containment of possible wildfires across the varied and dynamic Texas landscape. Texas Fire Service currently uses data derived from the LANDFIRE Program to predict and monitor wildfires in efforts to save lives, infrastructure, and natural resources. This program provides comprehensive and detailed maps that take a long time to produce and do not have the capability of representing current conditions. By combining data from Landsat and MODIS, this project created fuel maps that were produced based on the most current data available. The Texas Forest Service will utilize these products in order to better understand and evaluate wildfire risks throughout the state.

# III. Methodology

**Data Acquisition:**

Landsat 8 OLI atmospherically-corrected data were downloaded from the USGS Earth Explorer website. Landsat data was downloaded for both the warm season and the cold season and path-rows were chosen to represent different terrain and vegetation types (Table 1). MODIS data from 2009-2015 were obtained from the NASA’s Reverb Echo website. MOD09Q1 (Surface reflectance), MOD13Q1 (vegetation indices), and MOD15A2 (leaf area index) were downloaded for the entire time period.

|  |  |  |
| --- | --- | --- |
| Path | Row | Dates |
| 25 | 39 | 2013-08-17; 2015-01-27 |
| 28 | 39 | 2013-07-25; 2014-01-29 |
| 29 | 37 | 2014-01-20; 2014-06-27 |
| 29 | 38 | 2014-06-29; 2015-02-08 |

Table 1: Landsat data acquisition

**Data Processing:**

**Preprocessing:**

To combine the data from Landsat and MODIS satellites, the MODIS data was preprocessed using the MODIS Reprojection Tool (MRT) downloaded from NASA’s Land Processes Distributed Active Archive Center (LP DAAC). This tool enabled the team to convert the MODIS data into a format that could be combined with the Landsat data.

**Fuel Type Maps:**

In order to create the fuel type maps, several localized fuel maps were created.

The areas each represented different terrain and vegetation types. Path 25 row 39 is the Piney Woods region of Texas which contains both coniferous and deciduous vegetation. Path 28 row 39 contains the Texas Hill Country as well as the southern extent of the Cross Timbers. This area represents the transition from forests in the east and prairie to the west. Path 29 rows 38 and 39 represent the grasslands of the Great Plains. The northern image contains more of the grassland region, while the southern image contains more of the brushy vegetation.

In order to create fuel type maps, a classifier was trained on several Landsat 8 images to include the fuel type classes. The fuel type classes were based upon the Rothermel fire spread model classes and then reduced down into broader class. The main class types that were used were conifer forest, mixed forest, grasslands, shrubland, cropland and other. The layer stack included Landsat 8 bands 2-5 (blue-infrared), and a Normalized Differential Vegetation Index (NDVI).

**Landsat to MODIS:** Using MODIS data to create large-scale, moderate-resolution maps based on Landsat classifications

To produce the statewide maps, the Landsat classification raster was converted to polygons in QGIS, an open source GIS software, and those polygons were used as training data for classification of the MODIS stack. This allowed for quick generation of MODIS-derived maps that cover a large region that represent the current conditions of potential wildfire fuels.

**MODIS to Landsat:** Using MODIS data to create small-scale, higher-resolution maps based on Landsat classifications

The Spatial and Temporal Adaptive Reflectance Fusion Model (STAR FM) was used to fuse the Landsat and the MODIS images together. This tool uses 30m resolution Landsat data and combines it with 250m MODIS data (bands 1 and 2) from the same day to produce a predicted Landsat-resolution image based on the input of MODIS data from another day. This allowed the team to create 30m fuel maps based on the variation of MODIS data, which eliminated the need to wait for the next high quality, cloud-free Landsat data to be available.

**Fuel Load Maps:**

To produce the fuel load maps, the MODIS input included the peak NDVI from the previous growing season or the current growing season, depending on which had the higher value. The biomass was then computed by using the NDVI-to-biomass formula. The biomass was then entered into the final fuel load formula which converted the biomass into quantified fuel load.

# IV. Results & Discussion

Insert images, graphs, maps, charts, etc. here. Choose the most important results to highlight here. No word cap, but two to six pages is a good range.

Things to discuss:

* Analysis of Results: What can you tell from your graphs, images, etc? What does this mean for your project?
* Errors & Uncertainty: What factors could you not account for, what things didn’t work out like you expected they would, etc.
* Future Work: If this project was to be selected for another term, what would be the focus? What other areas would be of interest?
  + Phenology study – project continuation
    - Data fusion creates a platform for phase two of the project to be done on multiple temporal and spatial scales.

# V. Conclusions

Final conclusions. Word count: 200-600 (~a page).

# VI. Acknowledgments

Insert here. Keep to a concise paragraph or bullets of names. End with the following sentence.

This material is based upon work supported by NASA through contract NNL11AA00B and cooperative agreement NNX14AB60A.

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Smith, Aaron. "Texas Wildfire, Drought Damages Exceeds $5 Billion." *CNNMoney*. Cable News Network, 8 Sept. 2011. Web. 24 June 2015.

"Texas Almanac - The Source for All Things Texan since 1857." *Forest Resources*. Web. 24 June 2015. <http://texasalmanac.com/topics/environment/forest-resources>.

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# IV. Appendices

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