**NASA DEVELOP National Program**

**Spring 2016 Project Proposal**

**NASA Marshall Space Flight Center**

**Alabama Ecological Forecasting**

Assessing Southern Pine Beetle Epidemics in the Bankhead Forest of Alabama Using NASA Earth Observations

**Project Overview**

***Objective:*** The objectives of this project are to identify areas of the Bankhead Forest that have been infested with the Southern Pine Beetle (SPB), *Dendroctonus frontalis,* by creating a historical coverage map using NDVI, NMDI, and precipitation. Then, using climate data records, a future outbreak map will be derived to better evaluate where researchers should implement preventative management practices.

***Community Concern:*** The Southern Pine Bark Beetle is an opportunistic species that typically attacks stressed pine trees that have been weakened by drought, storm damage, or fire. Outbreaks of the beetles typically have a six to twelve year interval and spread radially from the epicenter of attack. It is estimated that nearly 60,000 pine trees are lost to SPB every year. The costs associated with infestation management and the loss of pines is estimated around $800,000 per year. In the past few years, the time interval between outbreaks has decreased while the intensity and distribution has increased due to climatic impacts and the availability of preferred pine hosts.

***National Application Area Addressed:*** Ecological Forecasting

***Study Location:*** Bankhead National Forest, Alabama

***Study Period:*** October of 2000 to December 2030

***Advisors:*** Dr. Jeffrey Luvall (NASA at NSSTC), Dr. Robert Griffin (University of Alabama in Huntsville)

***Source of Project Idea:*** This idea came from a participant’s application who reapplied for the fall 2015 term. This participant, who is interested in ecology, became aware of the major environmental and economic impact the Southern Pine Beetle has on the region. As research had been done for the bark beetle in lodgepole pines for the west, this participant thought that a similar methodology could be applied to the southeast U.S. to help land management suppress the spread of the Southern Pine Beetle. After reaching out to the project’s end-users, they have shown interest in this project and have given support to conduct this project.

**Partner Overview**

***Partner Organizations:***

United States Forest Service (USFS) (End-User, POC: Dave Casey, District Ranger, Dr. John Nowak, USDA Forest Service SPB Coordinator, and Dr. Chris Asaro, Forest Health Monitoring Coordinator)

***End-User Current Decision Making Process:***

Currently, the partners use expensive manned aerial surveys from the Forest Health Protection (FHP) Aviation Program for every county, which are conducted during the summer months to capture when the beetles are most active. With the aerial data, field surveys must also be used since the species of beetle must be positively identified before conservation efforts can be implemented. For each species of beetle, specific management control and recommendations are needed as the beetles attack different pine trees at varying health and stress levels. During the winter months, suppression techniques include the removal of infested trees by salvage, piling and burning, or chemical control.

***NASA Earth Observations Capacity:***

United States Forest Service (USFS) – USFS currently uses NASA Earth observations. This project will expand their capacity of NASA Earth observations, such as GPM, by creating methodologies and products that will help with mitigation efforts at a local scale.

***Communication Plan & Transition Approach:***

An initial outreach to project partners has been conducted. Further communication will continue at the start of the term with the team lead emailing the partners to schedule telecons with the team to do introductions and a review of the project for any necessary changes. During this meeting, it will be established as to how frequent he partners would like to be updated on the project. In approximately the fifth week of the term, the team lead will contact the partners to discuss the hand-off mechanism of the end-products. The hand-off of the end-products will take place during the last week of the term complete with any necessary tutorials.

***End-User Benefit:***

The use of NASA Earth observations will reduce the amount of flight time needed to conduct aerial surveys over a larger study area, as well as focus field surveys for those locations. Satellite data would also provide end-users a cost-effective assessment as to where suppression efforts should be made. The benefits of the end products to the project partners would be to reduce costs and time associated with Southern Pine Beetle suppression in the region. Expensive aerial and ground surveys limit the coverage that could be obtained during an outbreak, especially as the timing between outbreaks has decreased while the intensity and dispersal has increased in the last few years. The end products will increase the temporal and spatial coverage of the infected area which in turn could focus and expedite suppression efforts (e.g. tree removal or chemical control) and, thus, reduce research, economic, and environmental costs for the end-users.

Currently, there is not an active pine beetle outbreak, but due to the recent wildfires at Bankhead National Park, an outbreak in the near future could be predicted. By assessing the historical pine beetle infestations at the Bankhead National Park, a better understanding of what makes the beetles thrive will be achieved. From this, a future prediction map can be created and will aid in mitigation efforts at the park. In addition, expanding the end user’s capacity with the NASA Earth observations will potentially cut down the use of aerial surveys which will save money and man power.

**Earth Observations Overview**

***Earth Observations:***

|  |  |  |
| --- | --- | --- |
| **Platform** | **Sensor** | **Geophysical Parameter** |
| **EO-1** | Hyperion | Identification of Tree Species |
| **Aqua** | MODIS, AMSR-E | NDVI & NMDI, Soil Moisture |
| **Terra** | MODIS, ASTER L1B | NDVI & NMDI, Identification of Tree Species, Elevation  |
| **Landsat 5, 7, 8** | TM, ETM+, OLI | Land Cover Classifications Tasseled Cap Brightness |
| **TRMM/GPM** | TMI, DPR | Precipitation, Drought, Flood information |

***NASA Earth Observations Use:***

EO-1 Hyperion data is hyperspectral imagery with 242 bands at 30m spatial resolution. Using this dataset will allow for tree species data to be derived by offering more band combinations to enhance species detection.

Aqua and Terra MODIS offers the spatial and temporal resolution needed to derive the Normalized Difference Vegetation Index (NDVI) and Normalized Multiband Drought Index (NMDI) values for the study area. This data will provide information about the health of the trees and when drought is present for the region. These factors are important in assessing the stress of the pine trees and the correlated likelihood of beetle infection. Aqua AMSR-E would provide information on soil moisture for the area and would be utilized for the NMDI. Terra ASTER Level 1B would be used to supplement EO-1 Hyperion data gaps as it is multispectral imagery with bands at 15-30m resolution. ASTER DEM will provide elevation information that will be used in calculating topographic variables such as slope or aspect.

Landsat 5 TM, Landsat 7 ETM+, and Landsat 8 OLI will provide the temporal and spatial resolution necessary for the project. The data will be used to create land cover classifications over the study area. Due to the spectral characteristics of the tree canopy, which changes to a bright reddish-brown hue when infected with the SPB, infestations can be detected. The pine trees also die in a directional pattern, starting from the epicenter of the outbreak and progressing outward. A Tasseled Cap Brightness could be used to better assess changes on the landscape.

TRMM and GPM data offers precipitation coverage and would be used to identify contributing weather factors such as drought and strong rainfall events that may have preceded an outbreak.

***Ancillary Datasets:***

Google Earth historical land cover; FORWARN Forest NDVI Change; USGS National Land Cover Database (NLCD); Alabama State Forest boundary maps; NOAA Climate Data Record; Southern Research Station Southern Pine Beetle in situ data

***Models:***

USGS Software for Assisted Habitat Modeling (SAHM) (POC: Amanda West, Fort Collins Mentor)

Princeton University Maximum Entropy Distribution Model (MaxEnt) (POC: Daryl Ann Winstead, NASA Marshall Space Flight Center Assistant Center Lead)

**Decision Support Tool & End-Product Overview**

|  |  |  |
| --- | --- | --- |
| **Proposed End Products** | **Decision to be Impacted** | **Current Partner Tool/Method** |
| Historical Pine Beetle Coverage Map | Determine infected areas and how they have changed to help prioritize suppression  | Aerial imagery and field surveys |
| Pine Beetle Prediction Map | Determine where the efforts should be made for future conservation | None |

*Historical Pine Beetle Coverage Map –* This map will be derived from the NDVI, NMDI, tree identification, and land cover classifications by assessing the health, the color, and stress of the trees. Precipitation data from TRMM and GPM will be used to identify weather factors such as strong precipitation events that may have preceded outbreaks. This will be compared to the AMSR-E soil moisture and ASTER DEM to further determine which variables play an important role in the health of the trees.

*Pine Beetle Prediction Map –* Using the results from the Historical Pine Beetle Kill Map, these will be combined with climate data records in the Fuzzy Logic or Maxent model to analyze areas that are most likely to experience a pine beetle outbreak.

**Project Timeline & Previous Related Work**

***Project Timeline:*** 1 Term: 2016 Spring

***Previous Related DEVELOP Work:***

Fall 2008 (Stennis Space Center) - Big Creek Lake Ecological Health: Forest Health, Vegetation Stress, Drought, and Detection of Pine Beetle Infestations

Summer 2013 (Marshall Space Flight Center) - Great Smoky Mountains: Utilizing NASA Earth Observations to Monitor Loss of Hemlock Forest and Advance Mitigation Practices Against the Invasive Hemlock Woolly Adelgid

Spring 2014 (University of Georgia) - Smoky Mountains Ecological Forecasting: Utilizing NASA Earth Observations to Monitor Long Term Hemlock Decline Caused by Invasive Hemlock Woolly Adelgid in Great Smoky Mountains National Park

Fall 2014 (Stennis Space Center) - U.S. Disasters and Ecological Forecasting: Assessing the Potential to Use VIIRS 375m Data for Detecting Forest Disturbances

Fall 2015 (Marshall Space Flight Center) - North Mexico Ecological Forecasting: Using NASA Earth Observations to Monitor and Manage Ocelot Habitat Loss in North Mexico

**Project Needs/Requests**

***Participants Requested:*** 3-4

***Software & Scripting:***

ArcGIS - Raster manipulation/analysis, image enhancement & map creation of Landsat TM, ETM+, OLI, EO-1 Hyperion, Aqua and Terra datasets

ENVI Classic/5.0 - Raster manipulation/analysis of EO-1 Hyperion

Dnppy model - Landsat data pre-processing to TOA

R - Regressional analysis, execution of Maxent, and land cover delineation

**Notes & References:**

***Notes:*** SPB has been spreading throughout the Southeastern United States since 1960; in particular from Pennsylvania and New Jersey to Texas. The peak of the beetle’s activity is during the summer months from June to October. October was selected for this project as it would be the furthest extent of SPB for that year before the onset of winter conditions.

Preliminary search for EO-1 Hyperion data has shown that some does in fact exist for the study area between the years of 2001-2014, though the data is sparse. However, the availability of Terra ASTER Level 1B data for the entire study period is abundant and can supplement for lack of Hyperion data.

***References:***

Belanger RP, Hedden RL, Lorio Jr. PL. 1993. Management strategies to reduce losses from the southern pine beetle. Southern Journal of Applied Forestry 17: 150-154.

Price TS, Doggett C, Pye JL, Holmes TP, eds. 1992. A history of southern pine beetle outbreaks in the southeastern United States. Sponsored by the Southern Forest Insect Work Conference. The Georgia Forestry Commission, Macon, GA. 65 pp.

Alabama State Forests: <http://www.fs.usda.gov/detail/alabama/about-forest/districts/?cid=fsbdev3_002553>

USGS EO-1 Hyperion Spectral Coverage: <http://eo1.usgs.gov/sensors/hyperioncoverage>

Multi-Resolution Land Characteristics Consortium (MRLC): <http://www.mrlc.gov/finddata.php>

NOAA National Centers for Environmental Information: <https://gis.ncdc.noaa.gov/map/viewer/#app=cdo>

Alabama Forestry Commision: <http://www.forestry.state.al.us/SPBAdvisory.aspx>

Terra ASTER Handbook: <https://asterweb.jpl.nasa.gov/content/03_data/04_Documents/aster_user_guide_v2.pdf>

Southern Pine Beetle Data: http://www.srs.fs.usda.gov/econ/data/spb