ESTIMATING HURRICANE DAMAGE TO ANGELINA AND KISATCHIE NATIONAL FORESTS WITH NDVI FROM LANDSAT 5 AND LANDSAT 8 SATELLITE IMAGERY

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*Introduction*

Background

Forest ecosystems in the United States comprise nearly 1/3 of the total land area and represent 8% of total forests globally (United States Forest Service, 2023). These ecosystems provide numerous ecosystem services that are vital to society such as food, raw materials, water filtration, climate regulation, prevention of soil erosion, cultural enrichment, and other non-material services (Aznar-Sánchez et al., 2018). Forests also play a vital role in providing quality habitat for diverse species, many of which are endangered or threatened (Mori et al., 2017). Forests can also act as a buffer for urban areas to reduce the effect of flooding and wind damage. In Florida, the mangrove forests along the coastlines significantly prevented flood damage from Hurricane Andrew, which could have resulted in billions of dollars more in damage (Sheng and Zou, 2017).

However, disturbances such as fire, wind, timber harvest, and insect damage have resulted in a gradual and continual decline in forests. Many of these stressors have been exacerbated by climate change and have decreased the overall resilience of trees to major, periodic disturbances such as hurricanes (Cohen et al., 2016). Hurricane Katrina in 2005 caused extensive damage to forests near the Gulf of Mexico, with some areas seeing as much as 60% damage to the total forested area. This leaves stands more susceptible to other disturbance forces, which ultimately lead to forest decline (Wang and Xu, 2009).

There has been a growing body of research that suggests climate change will increase the frequency and intensity of hurricanes in the future, especially in the U.S. Gulf region, putting many coastal cities, coastal forests, and inland forests at risk for severe decline (Balaguru et al., 2023). This highlights a need for rapid assessment of hurricane damage to forests. Rapid identification of forest damage can enable landowners to implement management practices that protect their forests from secondary stressors that would lead to tree mortality or exacerbation of damage already inflicted. Hurricane damage is not easily predicted, as wind damage can affect forests differently based on various factors (Kim et al. 2020). Rapid assessment can therefore be used to quickly prioritize areas and landowners that may require government assistance with restoration. Additionally, long-term hurricane damage assessments can be provided to highlight areas that are frequently damaged by hurricanes, which would inform forest managers where they could improve hurricane resilience.

In recent decades, satellite imagery has been utilized extensively to monitor vegetation health. The most commonly used method is the Normalized Difference Vegetation Index (NDVI), which measures the reflectance ratio near infrared and red wavelengths in vegetation. There are many uses for NDVI such as drought monitoring, phenology changes, forest health monitoring, land use changes, and disaster assessments (Pettorelli et al., 2005). There are equally as many platforms from which imagery can be captured and software that can evaluate and calculate NDVI from the imagery. The use of NDVI in hurricane damage assessments is relatively sparse, likely due to the problem of persistent cloud cover after landfall. There have been recent advances in commercial to provide extremely high-resolution Synthetic Aperture Radar (SAR) imagery, which would solve the cloud cover problem (Banazadeh 2020). However, research on the effectiveness of SAR for hurricane damage is rare due to the price barrier of products such as these. Until these products become more widely available, Google Earth Engine (GEE) can be utilized to rapidly evaluate damage where imagery is available and can be an invaluable tool for informing landowners, emergency response, and other stakeholders.

Research Objective

The objective of this project is to evaluate the use of GEE providing rapid damage assessments after hurricane damage to Angelina National Forest in Texas and Kisatchie National Forest in Louisiana caused by Hurricane Rita in 2005 and Hurricane Laura in 2020 respectively. NDVI will be the primary method for which damage is estimated. Preliminary investigation showed that imagery is available for the dates before and after the hurricane and is relatively cloud free, which is critical for completing the NDVI analysis. Results will be compared to any ground surveys that were completed to estimate the damage caused by hurricane and will be used to gauge the accuracy of the GEE analysis. If the analysis proves accurate, this project will show that GEE can be used to rapidly assess damage by natural disasters to forest ecosystems.

*Literature Review*

NDVI Analysis with Google Earth Engine

Google Earth Engine (GEE) is a relatively new cloud-computing open-source tool. Its open-source availability allows for a variety of important uses across many fields (Ghaffarian et al., 2020, Valderrama-Landeros et al., 2021). In GEE, users are easily able to calculate a normalized difference vegetation index (NDVI) for various purposes. There are a variety of image collections from various platforms that users can access, but the Landsat and Sentinel Series are most commonly used for NDVI. For imagery dating prior to 2014, the Landsat series is useful for tracking long-term trends in NDVI (Robinson et al., 2017). The authors utilized a compositing method to stack imagery from multiple sensors due to the availability of imagery over a 30-year span. From this composite they were able to calculate NDVI for their site over a long period of time. In more recent studies, it is more common to see the use of Sentinel series satellites being utilized over Landsat due to the increased resolution from 30m to 10m. This enables higher accuracy for showing NDVI changes (Valderrama-Landeros et al., 2021, Lasaponara et al., 2022). These authors both used GEE and NDVI to monitor long term changes in land use and phenology change in their studies. Both authors utilized Sentinel-2 imagery to perform their analysis, and both utilized random forest classification to capture changes. Random forest classification is a machine learning method for creating model predictions and is important for NDVI classification. Valderrama-Landeros et al. (2021) reported a 79% accuracy for their random forest classification. They also concluded that the timeframe in which NDVI data is collected can drastically affect accuracy, as they reported a 55% accuracy when using non-optimal period data. Lasaponara et al. (2022) introduced a linear regression to their classification, in contrast to only using random forests. This enabled them to obtain a higher accuracy of 86% due to its ability to extract NDVI trends over time.

# Disaster Analysis

Natural disasters are an unfortunate reality of our world, and there are many different reasons and methods employed to study them. Many times, disaster analysis involves utilizing different datasets to better understand how the disaster has impacted or will impact affected infrastructure or the environment. This type of analysis lends well to a GIS based analytical approach, which typically involves a weighted overlay analysis. Akbulak et al. (2018) used this weight overlay analysis in combination with the analytical hierarchy process (AHP) to analyze fire risk. AHP is a process that includes expert opinions to give weights to the various layers in the overlay, which can be important for complex interactions such as fires. This method, coupled with NDVI and other raster layers can greatly improve the accuracy of predicting disaster risk. In contrast to raster and imagery data, disaster analysis can be performed with vector datasets as well. Karaye et al. (2019) utilized a hotspot analysis to determine contamination risk to citizens from hurricanes. They concluded that hurricanes pose a significant long-term risk to citizens and the environment through contamination of water supplies.

Remote sensing can also be a valuable tool in disaster analysis, and there are several different methodologies to performing this kind of analysis. Mukherjee and Singh (2020) utilized an NDVI approach coupled with weighted overlay analysis to detect flood prone areas in Texas. The authors demonstrated that using primarily raster datasets can be beneficial when analyzing natural disasters. Although they did not report the accuracy of their model, they suggest that using higher resolution satellite data than Landsat 8 (30m) will ultimately improve accuracy. Ghaffarian et al. (2020) used a similar approach to calculate land change, however they incorporated NDVI with four other vegetation indices using Landsat 5 and 8 satellites to monitor post-disaster recovery instead of raster layers. The authors reported an overall land classification accuracy of 88%. This shows that high accuracy may be attained using vegetation indices as opposed to weighted overlay analysis with raster datasets. This is consistent with reports seen in Laurin et al (2021), which reported an accuracy of 86% using multi-spectral imagery. The authors also evaluated the use of Synthetic Aperture Radar (SAR) on change detection. They concluded that although SAR has less overall accuracy (68%), it can be used for rapid assessment of disaster damage due to cloud penetration. This is a valuable feature due to the tendency of clouds to stay in affected areas for months after an incident.

Hurricane Forest Damage

Hurricanes affect forests differently depending on many factors (Boucher et al. 1990, Harcombe et al. 2009, Kim et al. 2020). Boucher et al. (1990) demonstrated that although pine forests can withstand hurricane wind damage more than rainforests (25% vs 56% felled trees), survivorship is lower in pine forests. Similar results to pine forest damage were reported by Harcombe et al. (2009), showing between 5 – 31% loss and Staudhammer et al. (2011) showing 36% loss. Harcombe et al. (2009) and Kim et al. (2020) also showed that tree damage can vary within sites and between hurricanes. Harcbome et al (2009) identified 10 resistant, three intermediate, and 14 susceptible species populations. They also found that dominance changes in canopy can be accelerated by hurricanes, resulting in increasing dominance of shade-tolerant species in some sites but not others. Hurricane disturbance typically creates conditions that slow succession and increase diversity. However, frequent disturbance may make successional change unpredictable. This is supported by the findings of Kim et al (2020), which showed that the damage from two consecutive hurricanes affected trees in different ways. Hurricane Rita caused severe damage to shorter, shade tolerant species, while Hurricane Ike just three years later damaged taller, shade intolerant trees.

*Methodology*

Study Area

This project will focus on two National Forests owned by the United States Forest Service (USFS). Kisatchie National Forest was established in 1930 and is the only National Forest in Louisiana. There are several separated Ranger Districts, but this project will look at the Catahoula (south) and Winn Ranger District (north) as viewed on Figure 1. Together, these districts are approximately 285,00 acres. The forest is primarily used for recreation, sustainable timber harvesting, and provides critical habitat for the endangered Red-cockaded Woodpecker (RCW) as well as other ecosystem services that are provided by forests. The Catahoula Ranger District is a mix of piney-woods and hardwoods, while the Winn Ranger District is dominated by Longleaf Pine.

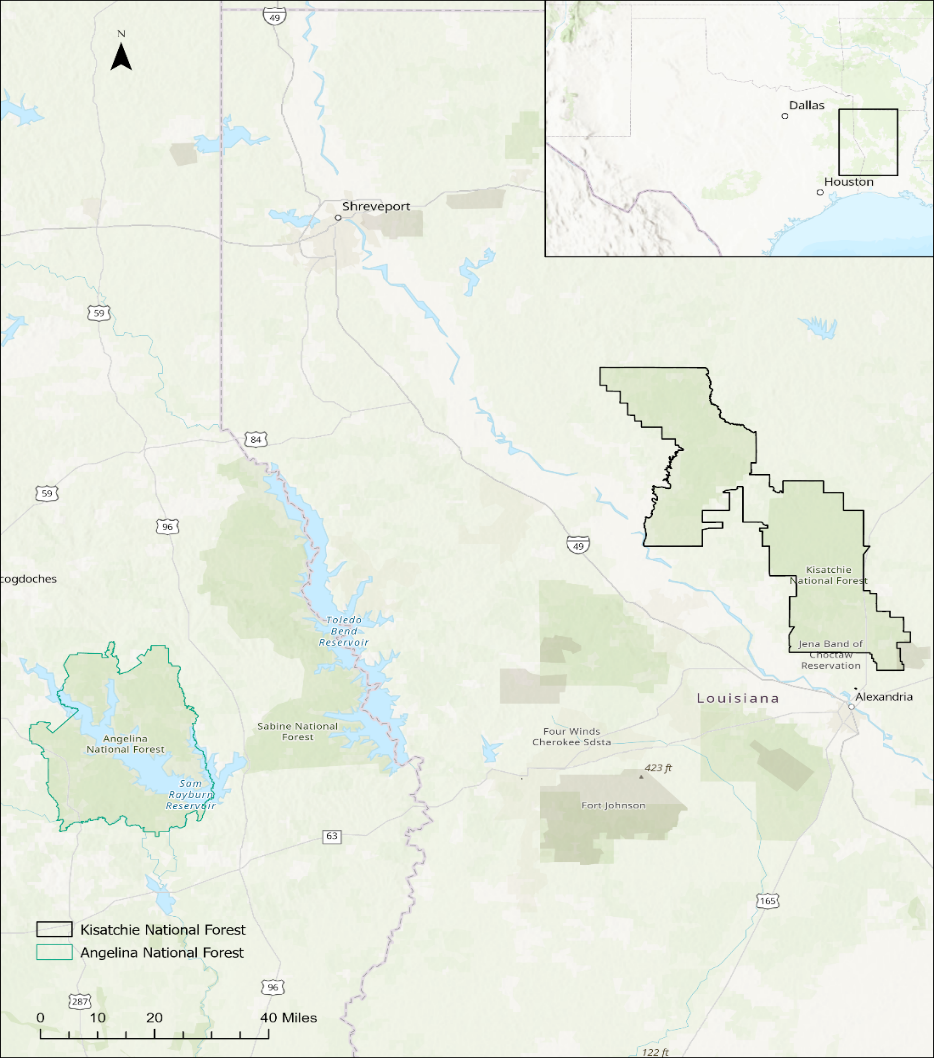
Angelina National Forest is one of four forests in Texas, established in 1935, and encompasses approximately 150,000 acres. The forest is separated into a north and south section by the man-made Sam Rayburn Reservoir, which was formed by the construction of the Sam Rayburn Dam in the 1960’s. The forest is primarily used for recreation, wildlife habitat, timber management, and fire management. The north section is dominated by loblolly and short-leaf pine, while the southern section is dominated by long-leaf pine. **

Figure 1. Study Area depicting Angelina National Forest (left) and Kisatchie National Forest (right).

Data Source

Image acquisition was performed in GEE using JavaScript code to perform cloud-masking and NDVI calculations on Landsat 5 and 8 images. Additionally, Sentinel - 2 imagery was acquired to be used as a ground truth image to be used in the accuracy assessment. Sentinel - 2 imagery is higher-resolution (10-meter) satellite imagery (Table 1). Hurricane Rita occurred in 2005, which required the use of Landsat 5 images because Landsat 8 was not launched until 2013. Landsat 8 imagery was used for Hurricane Laura due to the availability of imagery. Hurricane Rita passed through Angelina National Forest on September 9, 2005 as a Category 1 hurricane. Hurricane Laura passed through Kisatchie National Forest on August 27, 2020, as a Category 2 hurricane.

Table 1. Image Dates and Uses. Use 1 –Baseline vegetation index. Use 2 –NDVI assessment several months after the hurricane passed through. Use 3 –NDVI assessment one year after the hurricane passed through. Use 4- Reference image for the accuracy assessment.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Image Number** | **Image Date** | **Platform** | **Use** | **Bands Used** |
| 1 | 6-14-2005 | Landsat 5 | 1 | Red, NIR |
| 2 | 11-06-2005 | Landsat 5 | 2 | Red, NIR |
| 3 | 7-01-2006 | Landsat 5 | 3 | Red, NIR |
| 4 | 6-06-2020 | Landsat 8 | 1 | Red, NIR |
| 5 | 11-05-2020 | Landsat 8 | 2 | Red, NIR |
| 6 | 06-13-2021 | Landsat 8 | 3 | Red, NIR |
| 7 | 07-25-2020 | Sentinel – 2 | 4 | RGB |

Methodology Overview

Imagery from Landsat 5 and 8 was imported into GEE and cloud-masking functions were performed to reduce cloud cover in the analysis. The timeline for this study was broken into three categories: NDVI calculations before the hurricane to get a baseline vegetation index, NDVI calculations several months after the hurricane, and NDVI calculations one year after the hurricane. An accuracy assessment was performed on the NDVI classifications using 2020 Sentinel-2 imagery and GEE’s confusion matrix function. These classifications comprised of five categories including dense vegetation, intermediate vegetation, sparse vegetation, bare soil, clouds, and water. The study timeline for Hurricane Rita was June 2005 – July 2006, and June 2020 – June 2021 for Hurricane Laura. The NDVI difference was then calculated twice; once between the baseline image and the image several months after the hurricane, and again between the baseline image and the image one year after the hurricane. These timelines were chosen so that immediate and long-term damage could be calculated. Additionally, the image dates were chosen so that the season would be close to same, reducing the chance of NDVI change resulting from phenological changes. The NDVI difference rasters were then clipped to the national forest boundaries and exported as GeoTIFF files to be processed in ArcGIS Pro. The GeoTIFF NDVI difference rasters were then categorized to represent different classes of damage, including no damage, light damage, intermediate damage, and heavy damage depending on their percent change in NDVI. The different classes were transformed into polygons using the Raster to Polygon tool. A new field in the feature class was created to hold the calculated acres, and the acres for each category was calculated. These values were then divided into the total acres of calculable damage to get a percentage of damage. (Figure 2).

A diagram of a company

Description automatically generated

Figure 2. Flowchart visualizing the project methodology.

Cloud Masking

Cloud-masking is a critical pre-processing step in analyzing satellite imagery. Cloud-masking allows for the selection and removal of pixels that have been identified as likely clouds during the satellites image acquisition. An image with too much cloud cover will reduce the amount of land surface that can be assessed for damage, making it unsuitable for analysis. For the Landsat series, these pixels are identified on the Quality Assessment (QA) band, and there are several functions that can be utilized in GEE to remove or reduce these pixels. Cloud-masking is especially important for hurricane damage assessments, as clouds can remain in the affected area for months after the storm. In GEE, images were accessed through Image Collections, which were then filtered based on cloud cover using the QA band. Images were also filtered by date so that NDVI could be calculated before the hurricane and again after the hurricane.

NDVI Calculation

NDVI is calculated using the following formula:

(Near-Infrared Band (NIR) – Red Band / Near-infrared (NIR) + Red Band).

The band composition changes between Landsat 5 and 8, where NIR is band 4 and 5 respectively, and the Red band is 3 and 4 respectively. NDVI was calculated before the hurricane to get a baseline of green vegetation, and then again three months after and one year after the hurricane to detect changes. The difference between the baseline NDVI values and after disturbance NDVI were then calculated to show where NDVI decreased after the hurricane, potentially correlating to immediate or long-term tree damage. The forest boundaries were then imported into GEE, and the final NDVI difference was clipped to the boundary and exported as a GeoTIFF file.

Damage Assessment

GeoTIFF files were imported into ArcGIS Pro, where the differenced NDVI values were categorized into 4 categories based on the range of percent change: No Damage, Light Damage, Moderate Damage, Heavy Damage. Pixel values were then converted into Vector polygons to estimate the total area in acres impacted to the forest. The damage assessment categories were listed as No Damage, Light Damage, Moderate Damage, and Heavy Damage to mirror what is done with on-the-ground forest damage assessments. NDVI is a unitless measurement that ranges from -1 to 1. The difference between two NDVI’s can be viewed as a percent change, and a decrease in percent change would likely indicate a decrease in vegetation health and therefore an indication of hurricane damage (Aghababaei et al., 2021). Since there is no standard classification of change in NDVI values correlating to forest damage in the literature, these classifications were made following the author’s logic. A percent change from -5 to greater than 0 was given a designation of No Damage, -5 to -12% was classified as light damage, -13 to -20% was classified as moderate damage, and values less than -20% were classified as heavy damage (Table 2).

Table 2. Damage Classification. This table shows the damage classification based on the range of percent change in NDVI values.

|  |  |
| --- | --- |
| NDVI Percent Change | Damage Classification |
| > 0 to -5 | No Damage |
| -5 to -12% | Light Damage |
| -13 to -20% | Moderate Damage |
| < -20% | Heavy Damage |

Accuracy Assessment

The accuracy assessment for this project was done following the methods of Aghababaei et al. (2021) using GEE’s Confusion Matrix function, sometimes referred to as an error matrix, which is built upon the Random Forest classifier. To acquire the training data for the classifier, 50 random sample points for each land class were generated on the Sentinel - 2 imagery which were then compared to the baseline NDVI calculated Landsat images using visual inspection. Dalezios et al. (2001) describes land classifications under the following NDVI values: 0.5 to 1 indicates dense vegetation, 0.14 to 0.5 indicates intermediate green vegetation, 0.09 to 0.14 indicates sparse vegetation, 0.025 to 0.09 indicates bare soil, 0.002 to 0.025 indicates clouds, and values less than 0 indicate water. These ranges were used to compare the accuracy of the NDVI classification.

*Results*

NDVI Calculation

Analysis indicates that Angelina National Forest was approximately 84% covered in dense vegetation (NDVI values > 0.5). This number dropped drastically to only 41% in the months after Hurricane Rita. Then one year later, the forest was covered in approximately 75% dense vegetation (Figure 3).

A satellite image of a city

Description automatically generated A map of a city

Description automatically generated

1. (b)

Figure 3. Angelina National Forest Images. These images show Angelina National Forest across the timeline of the project for Hurricane Rita. (a) The first image is raw satellite imagery that was used as a baseline. (b) The second image shows the NDVI of the baseline (c) The third image shows the raw satellite image several months after the hurricane. (d) The fourth image shows the NDVI several months after the hurricane. (e) The fifth image shows the raw satellite image one year after the hurricane. (f) The sixth image shows the NDVI one year after the hurricane.

A satellite image of a city

Description automatically generated A high angle view of a city

Description automatically generated

(c) (d)

**A satellite image of a red land

Description automatically generated A map of a city

Description automatically generated**

(e) (f)

Figure 3 cont.

For Kisatchie National Forest, approximately 88% was covered in dense vegetation (NDVI values > 0.5). This number dropped to approximately 70% in the months after Hurricane Rita. Then one year later, the forest was covered in approximately 72% dense vegetation (Figure 4).

A map of red color

Description automatically generated A map of the state of nevada

Description automatically generated

1. (b)

A satellite image of a red area

Description automatically generated A high angle view of a map

Description automatically generated

(c) (d)

Figure 4. Kisatchie National Forest Images. These images show Kisatchie National Forest across the timeline of the project for Hurricane Laura. (a) The first image is raw satellite imagery that was used as a baseline. (b) The second image shows the NDVI of the baseline (c) The third image shows the raw satellite image several months after the hurricane. (d) The fourth image shows the NDVI several months after the hurricane. (e) The fifth image shows the raw satellite image one year after the hurricane. (f) The sixth image shows the NDVI one year after the hurricane.

A map of red color

Description automatically generated with medium confidence

(e)

High view of a map of the state of nevada

Description automatically generated

(f)

Figure 4 cont.

Damage Assessment

From the NDVI difference damage assessment calculations, Angelina National Forest received no damage on 13.93%, 69.44% light damage, 2.67% moderate damage, and 13.96% heavy damage in the first 3 months after Hurricane Rita in 2005. One year later, the calculations show that the forest sustained no damage on 89.50%, 9.67% light damage, 0.15% moderate damage, and 0.68% heavy damage (Figure 5) (Table 3).

A map of a city

Description automatically generated

(a)

A map of a city

Description automatically generated

(b)

Figure 5. Angelina National Forest Damage Images. (a) shows the damage several months after Hurricane Rita. (b) shows the damage one year after Hurricane Rita.

In 2020, the NDVI calculations show that Kisatchie National Forest received no damage on 35.64%, 63.10% light damage, 0.67% moderate damage, and 0.68% heavy damage after the first 3 months. One year later, the calculations show that the forest sustained no damage on 9.65%, 89.26% light damage, 0.60% moderate damage, and 0.49% heavy damage (Figure 6)(Table 3).

A map of different areas of light and dark areas

Description automatically generatedA map of a city

Description automatically generated

(a) (b)

Figure 6. Kisatchie National Forest Damage Images. (a) shows the damage several months after Hurricane Laura. (b) shows the damage one year after Hurricane Laura.

Table 3. Damage Calculations. This table shows the percentages of the forest that was damaged according to severity.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Angelina Damage (~ three months)** | **Angelina Damage (one year)** | **Kisatchie Damage (~ three months)** | **Kisatchie Damage (one year)** |
| **No Damage** | 13.93% | 89.50% | 35.64% | 9.65% |
| **Light** | 69.44% | 9.67% | 63.10% | 89.26% |
| **Moderate** | 2.67% | 0.15% | 0.67% | 0.60% |
| **Heavy** | 13.96% | 0.68% | 0.59% | 0.49% |

Accuracy Assessment

Confusion matrix results are shown in table 4, which was assessed to be 92% for overall accuracy and 83% for an overall Kappa. In addition, the Producer’s Accuracy (PA) and User’s Accuracy (UA) were also calculated for each land class. The expected accuracy was 85%, with a 5% margin for error. All land classes exceeded this expected accuracy with water having the lowest accuracy at 86% UA and 90% PA, and clouds having the highest at 98% UA and 92 PA. The accuracy assessment was only performed on the 2020 NDVI classification over Kisatchie National Forest and the same accuracy is expected for all other images.

Table 4. Confusion Matrix for the accuracy assessment on the NDVI values.

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | **2020 Sentinel – 2 Image (Reference)** | | | | | | | |
| **2020 Classified NDVI** | **Pixels** | **Dense Vegetation** | **Intermediate Vegetation** | **Sparse Vegetation** | **Bare Soil** | **Clouds** | **Water** | **Row Total** | **User’s Accuracy** |
| **Dense Vegetation** | 47 | 3 | 1 | 0 | 0 | 0 | 51 | 92% |
| **Intermediate Vegetation** | 0 | 45 | 0 | 1 | 1 | 2 | 49 | 92% |
| **Sparse Vegetation** | 0 | 2 | 46 | 0 | 0 | 1 | 49 | 94% |
| **Bare Soil** | 2 | 0 | 1 | 46 | 0 | 2 | 51 | 90% |
| **Clouds** | 0 | 0 | 1 | 1 | 49 | 2 | 53 | 92% |
| **Water** | 1 | 0 | 1 | 2 | 0 | 43 | 47 | 91% |
| **Column Total** | 50 | 50 | 50 | 50 | 50 | 50 | 300 |  |
| **Producer’s Accuracy** | 95% | 90% | 92% | 93% | 98% | 86% |  |  |
|  | Overall Accuracy 92%  Overall Kappa: 83% | | | | | | | | |

Discussion

These results tell an interesting story of hurricane damage to the two national forests. In the 2005 assessment, it was calculated that 13.96% of the forest sustained heavy damage. Additionally, there is a drastic difference in light damage from 2005 to 2006. Heavy damage to trees can be characterized by trees that are uprooted, snapped off, leaning more than 45 degrees, or otherwise likely to die within 12 months. This is inconsistent with the 2006 damage assessment, which shows that there is no heavy damage sustained in the following year. It is unlikely that, if that section of forest was indeed heavily damaged, one year would have been enough time for a tree or surrounding vegetation to re-sprout and be able to register a smaller percent change in NDVI. One explanation for this is that it is possible that the hurricane was just strong enough to wind-blow enough leaves and limbs off to register a drastic difference in NDVI, but not enough to kill the tree. This would explain why one year later, only 9.67% of the forest was lightly damaged, as those leaves and limbs would have had enough time to grow back.

For the Kisatchie National Forest, approximately 0.49% of the forest was shown as heavily damaged and 0.67% moderately, which remained consistent into the following year. The light damage increased from 63% to 89% of the forest after one year. This is almost the opposite from Angelina National Forest, where it appears there wasn’t long-term damage to the forest. A possible explanation for this is that the wind from Hurricane Laura damaged the tree limbs to the point where re-sprouting was not possible after one year. This is consistent with the fact that Hurricane Laura was registered as a Category 2 hurricane when it passed through Kisatchie National Forest, which indicates higher wind speed and therefore more likely to cause damage.

Lessons Learned

Without true on-the-ground field measurements, satellite imagery was used as ground-truthing. This project would be improved with detailed field measurements to compare results for the highest possible accuracy. In the absence of field measurements, drone or aerial imagery could be used in long-term monitoring to evaluate how forests respond to hurricanes over an extended period of time. Cloud cover is also a major issue when analyzing hurricanes damage, so imagery acquired below cloud formation would be most ideal.

*Conclusion*

The goal of this project was to estimate the damage caused by Hurricane Rita to Angelina National Forest and Hurricane Laura to Kisatchie National Forest using NDVI on Landsat satellite imagery. Image acquisition, cloud masking, and NDVI calculations were done in GEE and area calculations were performed in ArcPro. NDVI was classified for six images, three for each National Forest. These comprised the NDVI before the hurricane, several months after the hurricane, and one year after the hurricane. An accuracy assessment was performed on the NDVI classification using Sentinel – 2 satellite imagery. The NDVI difference was then taken between the baseline NDVI and each stage after the hurricane for each forest. The percent change between the NDVI baseline and NDVI’s after the hurricanes were then categorized into damage classes: no damage, light damage, moderate damage, heavy damage. The areas assigned to these categories were then calculated to get an estimate of the damage to each forest.

This project has shown that in some cases, NDVI can overestimate the amount of damage caused to trees in Category 1 hurricanes. In Angelina National Forest, most of the estimated damage was light damage at 69.44% with 13.96% heavy, while one year later the light damage was only 9.67% and less than 1% heavy damage. However, for Category 2 hurricanes, NDVI can be used as a good indicator of how much damage a forest has sustained. In Kisatchie National Forest, approximately 63% of the forest sustained light damage, and one year later it sustained approximately 89% light damage. This project also showed that GEE can be a valuable resource when estimating hurricane damage. Damage assessments should be used with caution however, as Landsat satellite imagery can only produce a spatial resolution of 30 x 30 meters, reducing the accuracy of assessment. As higher resolution satellite and aerial imagery becomes more easily accessible, hurricane damage assessments should also increase in accuracy and reduce the need for field measurements.

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