

## ***I. Project Purpose***

My research and thesis will focus on how NDVI (Normalized Difference Vegetation Index) data can be calculated and used for ~~forest fire~~ management in the boreal (coniferous) forests of Canada and the Northern United States. NDVI is a numerical indicator of the light reflected from vegetation. Specifically, it measures light from the “visible and near-infrared bands of the electromagnetic spectrum.” The equation for  $NDVI = \frac{(Near\ Infrared - Visible)}{(Near\ Infrared + Visible)}$ <sup>1</sup>, with higher NDVI values representing healthy vegetation and unhealthy or dry vegetation producing lower values. These data can be calculated from satellite (LANDSAT) images and used in GIS software to understand their relationship with forest fires. I hypothesize that NDVI data can be used to map out past wildfire areas and help determine vegetation characteristics, such health and fuel load, in Northern British Columbia, Canada.

## ***II. Project Importance***

While this project is specific to British Columbia, it will be possible to apply the results to other regions of the world with boreal forest. In fact, boreal forests cover a majority of Canada, part of Alaska, and most of Russia’s Siberia.<sup>2</sup> An understanding of NDVI patterns in northern forests may be of use to forest managers in those areas, since NDVI is a good indicator of vegetation health. NDVI has the following relationship with vegetation: “Healthy vegetation absorbs most of the visible light that hits it, and reflects a large portion of the near-infrared light.

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<sup>1</sup> NASA Earth Observatory, “Measuring Vegetation”, NASA, 2016.

<sup>2</sup> Justin Gills and Henry Fountain, “Global Warming Cited as Wildfires Increase in Fragile Boreal Forest,” The New York Times, 2016.

Unhealthy or sparse vegetation reflects more visible light and less near-infrared light.”<sup>3</sup> Thus, healthy vegetation has higher NDVI values, and unhealthy or dry vegetation has lower NDVI values.

I will study the effects of forest fires on overall boreal forest health by correlating these NDVI values with forest fire occurrence. In recent years, boreal forest regions have suffered from an above-average number of devastating forest fires. For example, 70 million acres burned in Russia in 2012, and 768 fires in Alaska burned more than 5 million acres in 2015.<sup>4</sup> Many scientists have linked this increase in fire occurrence to rising global and regional temperatures. They fear that more forest fires akin to the 2016 Fort McMurray fire in Alberta will occur. According to David Suzuki, a Canadian academic and scientist, “Climate change is threatening the health of forests around the world.”<sup>5</sup> While others have done NDVI/forest fire studies,<sup>6</sup> none of them were performed in North American boreal forests, so my study will provide valuable information not yet available in this field.

### ***III. Project Overview***

Since January 2016 I have been doing research with Dr. Jensen in the Geography Department. Our initial purpose was to find if there is a difference in NDVI reflectance measurements of forests due to wildfires in northern British Columbia, Canada. Dr. Jensen I

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<sup>3</sup> NASA, “Measuring Vegetation”

<sup>4</sup> Gills and Fountain, “Global Warming”

<sup>5</sup> David Suzuki, “Forest impacts,” David Suzuki Foundation, 2016.

<sup>6</sup> Elena Kukavskaya et al., “Effects of Repeated Fires in the Forest Ecosystems of the Zabaikalye Region, Southern Siberia,” AGU, 2014.

S. Bajocco, L. Rosati, and C. Ricotta, *Knowing fire incidence through fuel phenology: A remotely sensed approach*, Ecological Modelling, 2010.

believed that areas in which fires had occurred would have significantly lower NDVI values than unburned forest.

### **Related Research**

Preliminary scholarly research from primary and secondary sources has reinforced my original hypothesis. One study done in Sardinia pointed to the importance of NDVI as it pertains to forest fires, saying “Areas with higher NDVI values... are usually associated to higher proportions of large fires.”<sup>7</sup> This suggests that dense forests with high NDVI, such as those in the boreal region of Canada, would be prone to large forest fires. The authors of another study, this one performed in two locations in the western U.S., corroborate these results. “Burn severity increased with vegetation greenness, measured as NDVI, in both study areas.”<sup>8</sup> It seems that NDVI values are highly correlated with forest fires and also influence the size and severity of those fires.

It only follows that after a forest fire, measurements of NDVI in the area will be lower because burned forest reflects less infrared light than healthy vegetation. This idea is supported by the results of a study done in southern Siberia, which found that “sites that exhibited a normal recovery trajectory showed a sharp reduction in NDVI... values in the year of fire event and gradual recovery of these values to pre-fire levels after approximately five years.”<sup>9</sup> On a related note, it would make sense for the odds of a large fire happening again in the same area to be

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<sup>7</sup> Bajocco, Rosati, and Ricotta, *Knowing fire incidence*, 64.

<sup>8</sup> Sean A. Park et al., *Previous Fires Moderate Burn Severity of Subsequent Wildland Fires in Two Large Western US Wilderness Areas*, *Ecosystems*, 2013, 38.

<sup>9</sup> Kukavskaya et al., “Effects of Repeated Fires”

greatly reduced, since there would be little fuel left to burn. “Burn severity is significantly lower in areas that have recently burned compared to areas that have not.”<sup>10</sup>

### **Initial Findings/Methods**

Since none of these studies were performed in North American boreal forests, additional studies are needed to determine if NDVI and boreal forests have the same kind of relationship. Under the guidance of Dr. Jensen, I began to examine this by comparing the NDVI of unburned forest areas with the NDVI of the areas in which wildfires occurred, using data from the last 26 years (1990 – 2015). To do so, I had to locate a dataset that would show the date and location of each BC fire that occurred within the time period. Using the British Columbia GIS Data Catalogue, I was able to find a shapefile (a spatial data layer) that contained all of the historical fire perimeters in BC.

Realizing that it would take a long time to analyze the whole of British Columbia, we decided to focus on a specific area. We chose the Watson Lake area, which straddles the border between British Columbia and Yukon Territory and has had a consistent history of wildfires.

In ArcMap, I selected all of the polygons (fire perimeters) that were within each five year-set and exported them, making five new shapefiles. These shapefiles represented the areas affected by wildfires during each of the five-year periods. To study the effects of these wildfires, we decided to use satellite imagery from the end of each five-year period (i.e. for 2010-2015, we used imagery from 2015). To make sure that the results from the five-year periods could be objectively compared, we looked for images that were acquired during the summer months: July, August, and September. In northern British Columbia during these months, the skies are usually

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<sup>10</sup> Park et al., *Previous Fires Moderate*, 29.

clear and the vegetation is growing and green. We used USGS Earth Explorer<sup>11</sup> to find the imagery that we needed.

Although the images already in ArcMap offered a visual idea of the Watson Lake area before and after wildfires over the last 25 years, I needed to find and analyze the NDVI values of the area. To do so, I used 7-Zip to unzip the tar.gz files (which separates the file into individual bands) from each of the five previously chosen LANDSAT scenes/images. I then loaded the LANDSAT files into the geospatial software ENVI and selected the Near Infrared and Red reflective bands, which are relevant to NDVI. To import the files successfully, I also rearranged the bands in ascending order in the “Reorder Files Window”. Thus, my data stack for each of the five images appeared in the Available Bands Window. Since the equation for NDVI uses the percentages of reflected light captured by LANDSAT images, I was able to find the results I needed through an ENVI calculation process. I added the files created from this process to my existing ArcMap project in the form of shapefiles saved as Geotiffs.

Using the shapefiles I had created earlier (fire perimeters for each five-year period), I selected the features within the Watson Lake Area and made five new shapefiles. Next, I randomly generated 30 points within each of the polygons in the forest fire perimeter shapefiles. Since 30 points from each fire perimeter would give us an accurate depiction of the NDVI values, I used the random points to extract NDVI data from the shapefiles. In order to have NDVI numbers from unburned land with which to compare the NDVI data from the burned areas, I manually drew ten polygons outside of the fire perimeter shapefiles and created 30 random points within each. I then extracted the NDVI data from these control points.

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<sup>11</sup> USGS, “Earth Explorer”

At this point, I was ready to conduct statistical analysis to compare the NDVI data of the burned forest with that of the unburned forest. I exported the attribute tables of NDVI values from the two 2015 shapefiles (wildfire and control) as csv files. With this dataset, I used SPSS to perform a set of statistical tests: Comparison of Means Test, Mann-Whitney U Test, One Sample T-Test, Independent Samples T-Test, Paired Samples T-Test, and Wilcoxon Signed Ranks Test. The most important of these was the Independent Samples T-Test, since it compares whether two groups have significantly different average values.

I repeated the steps above for three of the other four datasets (The 2005 image was too cloudy to get good NDVI numbers), but only ran three SPSS tests on them. In addition to the Independent Samples T-Test, I did a descriptive statistics test and a non-parametric Mann-Whitney U Test. These two extra tests were to provide me with additional useful information. The results of the T-Tests clearly showed a significant difference between the means of the forest fire area NDVI values and the means of the unburned area NDVI values. For all four of the datasets, the mean NDVI values of burned areas were significantly lower than those of the unburned areas. Professor Jensen and I came to the conclusion to reject our null hypothesis and state that forest fire occurrence is indeed correlated with NDVI values in Canada's boreal forests.

### **Additional Study Areas**

While I have obtained some promising preliminary results, I will pursue my hypothesis further. I aim to provide substantive evidence that fires impact NDVI measurements in boreal forest regions by continuing my study of the Watson Lake area of British Columbia. Since my initial investigation of the Watson Lake area only included one LANDSAT scene (approximately 114 mi by 106 mi), I will choose two other scenes surrounding the original to study as well. This

secondary study will analyze the NDVI values of these additional areas by following the steps outlined above.

I will also conduct more in-depth library research about boreal forests and how NDVI relates to forest fires, forest health, and fuel load. If the results of the study and research show a significant correlation between forest fires and NDVI values, they will serve to validate my hypothesis initial findings. I will integrate these supplementary findings into the work I have already done in order to develop a complete thesis. With the knowledge presented in my thesis, boreal forest managers will be able to calculate and use NDVI values to understand the fire history and overall health of the forests they oversee.

#### *IV. Thesis Committee*

I have chosen Dr. Ryan Jensen, a full professor and Department Chair of the Department of Geography to be my faculty advisor. I decided to work with Dr. Jensen because of his expertise in the areas of biogeography and geospatial analysis, both of which are very pertinent to my thesis project. Further, he has worked with various graduate students. I have been working with Professor Jensen since January 2016 as a research assistant. Our collaborative work, as mentioned above, will serve as the preliminary basis for the rest of my research.

As for my faculty reader, I selected Dr. Clark Monson, an assistant teaching professor in the Department of Geography. Since he teaches physical geography and climate geography courses, he has the necessary background knowledge to understand and evaluate my project.

The Geography Department Honors Coordinator is Dr. Sam Otterstrom, who is well qualified to supervise the project due to his extensive experience in both the Geography Department and the Honors Program. He has been a professor for the department since 1997. He

has also been the thesis adviser for four honors students in addition to serving as honors coordinator for various other geography students.

*V. Project Timeline*

- ✓ February 21      Finish library research and secondary study
- ✓ March 20        First draft of thesis to advisor
- April 14          Revised draft to advisor and reader
- ✓ May 12          Submit final version of thesis to Honors Program office and upload pdf  
*Thesis Defense?*



## References

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