Predicting & Preventing Future Forest Fires.

FINAL REPORT

By Marim Abdel Kader
Supervised by: Dr. Damian Maddalena
Course Code: GGR463H5 – Geographic Information Analysis and Processing
Date: April 7th 2022

INTRODUCTION:

Our environment is changing drastically because of dangerous atmospheric deviation caused by human activity which is impacting climate change at a severe rate. Dry areas and droughts are turning out to be more normal, as are heat waves, as global warming increases. They can be obliterating to environments and neighborhood networks, causing human and creature removal as well as huge setbacks on the ecology of our environment. Assuming an answer can be found to comprehend the reasons for these fierce outbreaks of wildfires, there could be a possibility to foresee where future flames could happen in light of observed patterns classification. This can be achieved based on the data that was analyzed from past rapidly spreading fires. Computer models are used to predict the rate of which a current wildfire would burn and forecast which types of land are more susceptible to wildfire in the upcoming years (Andrews et al., 2007). In 2006, a program called “Fire Spread Probabilities” (FSPro) was developed by Mark Finney intended to understand the reason behind the outbreak of several fires that had occurred in Florida, California, and Arizona (Andrews et al., 2007). Through monitoring the past fire behavior and analyzing its path, growth, and rate of speed, FSPro was consulted on more than 70 fire outbreaks later on in America (Andrews et al., 2007). FSPro calculates the probability of land that might be prone to a fire being started in it (Andrews et al., 2007).

Similarly, Australia experienced one of the worst wildfires in modern history in 2020(Tran et al., 2020). Three billion animals were harmed and affected by this fire that started late July, and more than 46 million acres of land were burned (Tran et al., 2020). A study was conducted on the retrospective analysis of south-eastern Australia in order to examine the extent of these wildfires and determine if there are any spatial patterns of the high severity burns that can help us predict future forest fires (Tran et al., 2020). Results confirmed that wildfires in Australia have become more severe over the past 50 years as vegetation grew weaker and tense canopy of trees was apparent (Tran et al., 2020).

From both of these study cases, an implementation of a similar idea can be applied to British Columbia. As British Columbia is a province that has witnessed an outbreak of 1,500 fires in 2021 alone (Kulkarni, 2021). The questions that are aimed to be answered from this project include: What caused the initial outbreak of past wildfires? And what should one be looking for in the type of land and soil in order to know that a future fire might happen here as well. Data analysis and advanced technology can be utilized to decide the primary driver as to why wildfires happen at such a speedy rate. As well as anticipate where they are probably going to occur again. British Columbia is going to be the center of focus throughout this project due to the increasing surge of forest fires that have occurred there in the past couple of years. The aim is to research past wildfires that occurred in British Columbia and analyze satellite imagery, in order to come to reasonable conclusions that can help predict future forest fires based on past wildfires patterns.

BACKGROUND:

In 2021, British Columbia was under a state of emergency as wildfires continued to grow forcing hundreds of people to leave their homes and thousands more were left facing the destruction of their houses. April is considered the official wildfire season in British Columbia as temperatures start rising drastically during the month (Baker, 2015). The beginning of these wildfires occurred on June 26th, with the McCall Creek wildfire that burned four kilometers in Peachland (Kulkarni, 2021). It was the first recorded destruction of property due to fire in 2021 (Kulkarni, 2021). On June 28th, the Sparks Lake Fire was discovered shortly after (Landry, 2021). Two days later, the village of Lytton burned within minutes and the first order of evacuation is implemented (Landry, 2021). It would be 2 week later, when the start of another wildfire will begin on July 13th, which was the White Rock Lake Fire (Kulkarni, 2021). The cause for the two late fires was classified as undetermined by the official website of the government of British Columbia. It was found that the first fire of Sparks Lake that reached about 89,000 hectares was caused by human activity which was later determined as a burnt vehicle (Landry, 2021).

The area of study that will be discussed throughout this report, is going to be centered around those three primaries rapidly increasing fires that took place in the summer of 2021. This is because of many factors, for example, their vicinity of land in neighboring locales, their dates in which these flames happened were extremely close in date and time as well as the huge measure of hectares that were impacted by the fires. Because of the rising measure of land that was singed, it expected there would be more accessible open data that would assist throughout this project in analyzing and comparing the severity of the fires.

METHODS:

The study site for this project was focused on Sparks Lake, which is situated nearby to Moutray Lake, and west of Cayuse, the village of Lytton and White Rock Lake village. All of which lie within the surrounding parameters of the city of Kamloops.

Project Coordinate Reference System: NAD83/ BC Albers EPSG:3005

Extent	Location
Kamloops, a city in south-central British Columbia. Area of study: Nearby areas that are north and west of Kamloops, located in the Thompson-Nicola Regional District	British Columbia, Canada

Characteristics: Kamloops is described as a city that as dry and drought areas as well as semi-desert climate due to its significantly reduced amounts of rainfall throughout the year.

Methods Used:

1. Researching and reading more about past wildfires in British Columbia.
2. Conducing Normalized Difference Vegetation Index on land from past case studies.
3. Conducting Normalized Difference Moisture Index on land from past case studies.

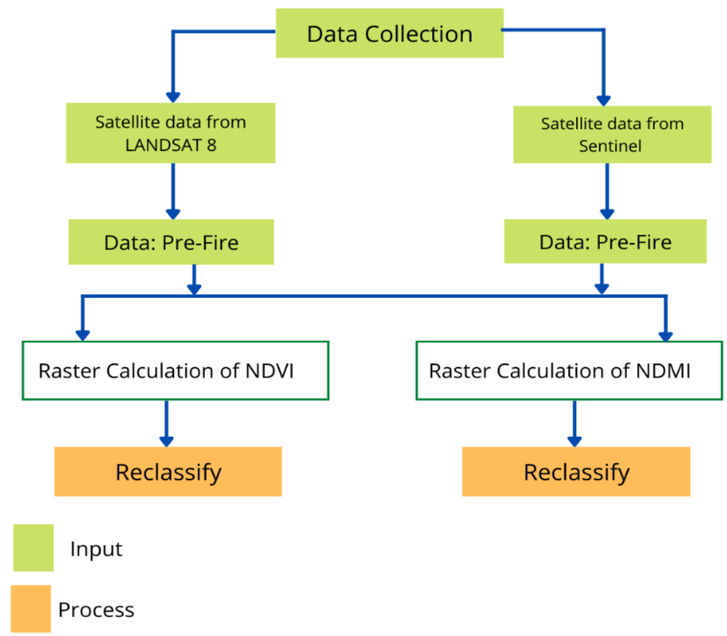


Figure 1: Flowchart Diagram

Researching the most suitable study areas was conducted through the University of Toronto Libraries Website by searching “British Columbia AND Wildfires” in order to find peer-reviewed articles that were done on past wildfires. Following that step, remote sensing imagery was downloaded from Earth Explorer USGS in order to be analyzed further.

The data that was collected from Earth Explorer through two different types of satellite imagery. Landsat 8 Collection 2 Level was used for the NDVI raster calculations. Following the standard formula of NDVI: (NIR - R) / (NIR + R) which is represented by (Band 5 – Band 4) / (Band 5 + Band 4) as Band 4 is Near Infrared and Band 5 is red wavelength. For the NDMI raster calculation, the Sentinel imagery, bands 8 and 11 were used, respectively as date from LANDSAT 8 on my study region was not available. The formula that was used in calculating NDMI is: Sentinel-2 NDMI = (Band 8 – Band 11) / (Band 8 + Band 11).
For the end results, websites such as Landsat Look, Copernicus Open Access Hub, Sentinel Hub were searched and filtered in order to find suitable data from the dates February 1st, 2022, until May 30th, 2022.

Discussion:

For all three study regions, NDVI maps were created and analyzed. This was done First, for the Sparks Lake Fire region, Landsat 8 Satellite imagery was gathered from dates that were pre-fire, and during the fire in order to compare the difference of vegetation. The fire of Sparks Lake occurred on June 28, thus satellite imagery was collected on May 31st, June 10th, and June 17th. Best results on the vegetation of the land were demonstrated on June 17th. The results produced of this pre-fire image show that most of the land experiences feeble and undesirable vegetation which is addressed by the yellow color on the legend. Sound vegetation is represented by the extremely dark green tone on the legend. This makes sense in understanding why the fire spread rapidly once it began occurring as low vegetation shows it has water moisture in it. Water moisture is considered a fuel moisture which is an important factor that determines the ignition probability rate fire behavior (Masinda, 2020).

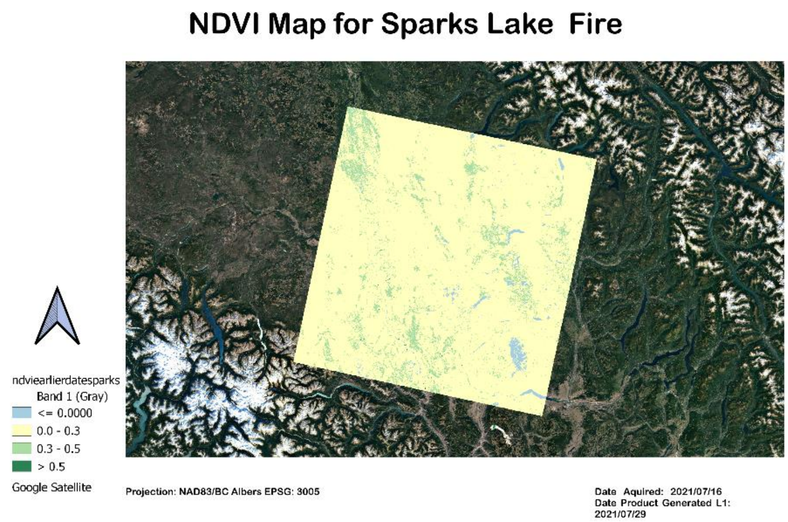


Figure 2: NDVI Values for Sparks Lake Fire

For the Lytton Creek Fire, data was harder to find on the specific area of Lytton that I wanted to highlight and compare in my initial analysis. The Lytton Creek Fire started on June 30th and this image was taken mid-date of the spread of the fire. Represented by through the range 0.0 – 0.3 is the immense spread of weak vegetation in the area. This could be a result of the already spreading fire or pre-fire weak vegetation that already existed. Represented in the light green color from the rate of 0.3- 0.5 is also unhealthy vegetation. This gave me an indication of the type of vegetation that already existed in this area, which is classified as weak and dry vegetation. Similar to the results of the Sparks Lake NDVI map. Lastly, data analysis was done on the White Rock Lake fire region, which started on July 13th. The data that was analyzed was prior to this date which included July 1st and June 15th. Weak vegetation was also found in the surrounding area of which the fire started. Another NDVI calculation map done on the date August 26, was able to showcase the spread of the weak vegetation across the surrounding area. This is most likely due to the fast spread of the fire that burned more than 83,342 hectares of land.

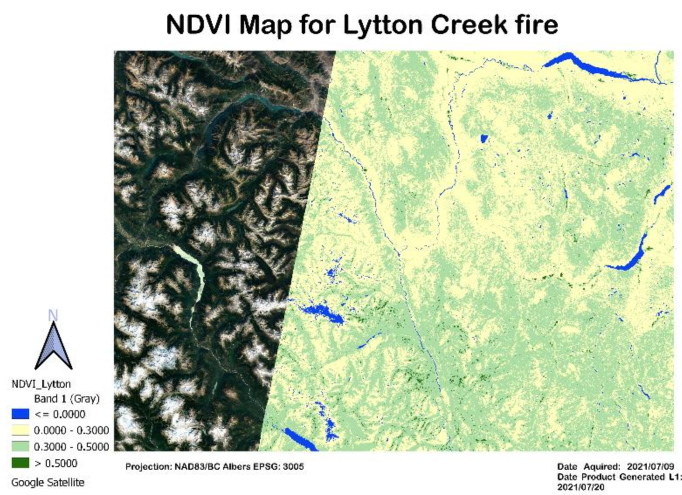


Figure 3: NDVI Values for Lytton Creek Fire

For the Spark’s Lake fire, there was not much satellite imagery that was available in order to conduct NDMI calculations. In figure 4, a satellite imagery was analyzed one day after the fire had started. After changing the symbology and transparency of the map, analyzes was more clearly on the state of moisture that exists within the vegetation.

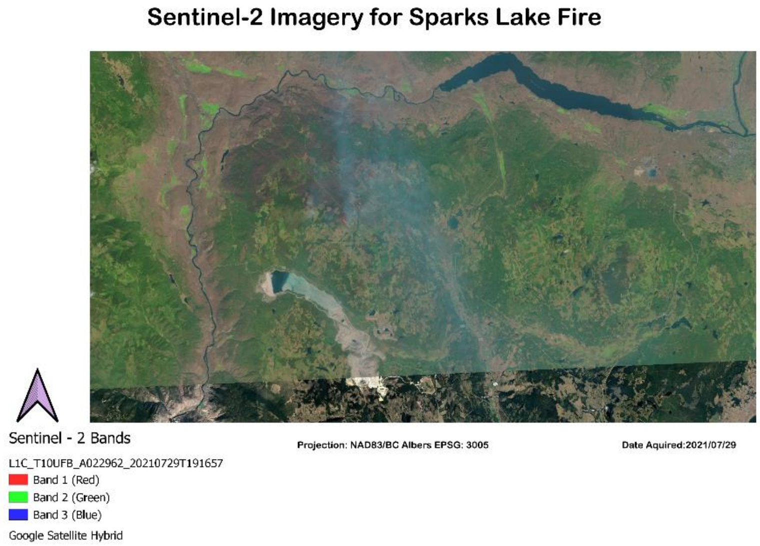


Figure 4: Satellite Imagery for Sparks Lake Fire

NDMI results for the Lytton Area were conducted on the date of which the fire broke out (Figure 5). Most of the area is classified by the dark purple color which represents the NDMI values that are less than -0.6. The negative values indicate that the vegetation in this area is associated with high water stress levels.
As for the White Rock Area, the data that was analyzed was collected pre-fire as well, in order to understand the vegetation health and water moisture that existed within this vegetation.
The overall low values that are presented indicate that the land goes has the same phenological state. Areas where NDMI values are in a range that lies between -0.15 and less than -0.37 vegetation is moderately associated with problems in health and increased water stress.
Once the raster calculations of NDVI and NDMI were conducted, the next step included comparing the results to determine a suitable observable pattern from the data represented. It was then determined that the pattern classification scheme based on these past wildfires resulted in the following.

When NDMI values are in the range of < 0.3, this indicates that this region suffers from high fuel moisture stress within its vegetation. This means that it could be a drought or dry are. Which results in it having low to absent presence of canopy cover and classifies this region as a mid-high-risk area that can ignite a future fire.

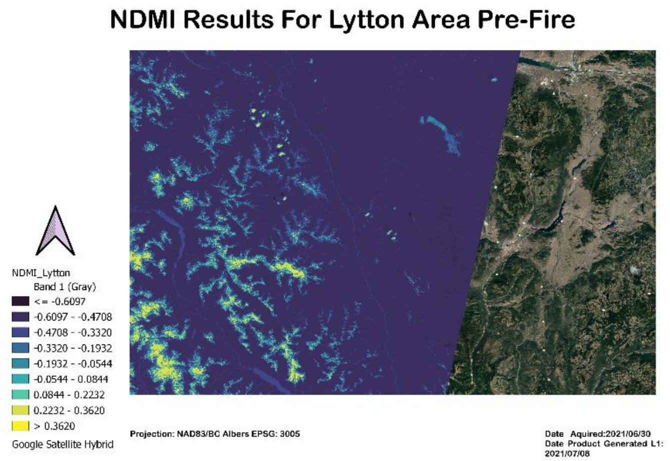


Figure 5:NDMI Results for Lytton Area Pre-Fire

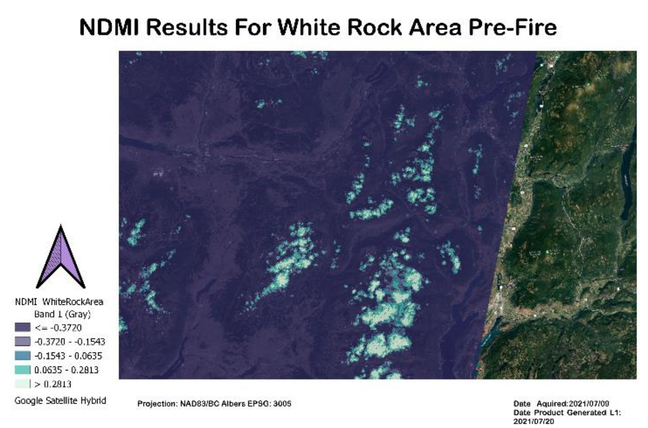


Figure 6: NDMI Results for White Rock Area Pre-Fire

When NDVI values are also less than 0.3, similar results can be found. The vegetation of the land is most likely moisture stressed and unhealthy vegetation. As well as low presence of canopy cover. Thus, if NDVI and NDMI calculations are done on another area, then these presented values and ranges would indicate that this land can be prone to igniting a fire in the future.

Shortcomings and final conclusions:

For a further identification to strengthen the overall aim of this project, a study area done on land that lies North of Kamloops was selected in order to perform further NDVI and NDMI calculations. In order to produce a final map that represents the land in terms of ability to ignite a fire from the ranges High Risk Area – Medium Risk Area – Low Risk Area. However, data acquired from the dates February 1st, 2022, until May 30th, 2022, were not suitable as they had too much cloud coverage. Atmospheric correction was done but it did not strengthen the quality of satellite imagery that was analyzed on the selected study area. The satellite imagery collected from Landsat 8 did indicate growth in the vegetation that was burnt last year during the wildfires. The outskirts of the area that this study was done, had better healthy vegetation than the central region. Which can indicate that any future fire that might occur will have a harder time spreading in the surrounding regions of Kamloops. Satellite imagery included in the appendix is documented as evidence of this problem. Further steps that can be done to improve the findings of this project can include collecting satellite imagery in the upcoming months of June, July, and August when they are available. Once collected, calculation of NDVI and NDMI can be conducted and then compared with the initial findings of this report in order to predict which region have signs of weak vegetation and water stressed areas that can eventually lead to the outbreak of a fire.

A research paper done on fires in Nepal's forest demonstrated a similar idea to this project but with different processing tools. Remote sensing and GIS applications were used in order to produce risk models conducted on two major land areas in Nepal, which were the Terai Arc Land and Chitwan Annapurna Land (Parajuli et al., 2019). However, this study used MODIS to indicate the vegetation types that existed within the land as well the land surface temperature (Parajuli et al., 2019). Slope elevation was also conducted on the two major study areas in order to reclassify the area from high to low fire risk index (Parajuli et al., 2019). As fires tend to burn the slope at a faster rate and more intensely than flat land (Parajuli et al., 2019). These were all considered independent variables that can help in the assessment of forest fires in the selected areas. The analysis done by MODIS was influenced by different variables and conduct from a longer time period that ranged from 2001 until 2018 (Parajuli et al., 2019). Final results were able to conclude that about 65.4% of the total study area in Terai Arc Land, is considered a high-risk fire zone, while only 21.54% of the land in Chitwan Annapurna is prone to fire (Parajuli et al., 2019).

The aim of this project was to be able to determine classification patterns that occurred in past wildfires in a specific area of study done in British Columbia. As well as understand the results that were found from the collected data in order to help predict future forest fires. Indices such as Normalized Difference Vegetation Index and Normalized Difference Moisture Index helped increase the understanding of important variables that helped past wildfires to spread at a fast rate. Further research regarding the usage of other geoprocessing tools and satellite imageries can provide more valuable information on the characteristics that should be considered in order to help predict and prevent future forest from occurring. This will ultimately result in developing better risk assessment plans when it comes to forest fires and prevent the outbreak of larger wildfires in the future.

References:

Andrews, P., Finney, M., & Fischetti, M. (2007). Predicting Wildfires. Scientific American, 297(2), 46-55. https://doi.org/10.1038/scientificamerican0807-46

Baker, W. L. (2015). Are high-severity fires burning at much higher rates recently than historically in dry-forest landscapes of the western USA? https://doi:10.1371/journal.pone.0136147

Bowman, D. M. J. S., Balch, J. K., Artaxo, P., Bond, W. J., Carlson, J. M., Cochrane, M. A., et al. (2009). Fire in the earth system. *Science* 324, 481–484. https://doi /10.1126/science.1163886

Kulkarni, A. (2021). A look back at the 2021 B.C. wildfire season | CBC News.

Masinda, M., Sun, L., Wang, G., & Hu, T. (2020). Moisture content thresholds for ignition and rate of fire spread for various dead fuels in northeast forest ecosystems of China. Journal Of Forestry

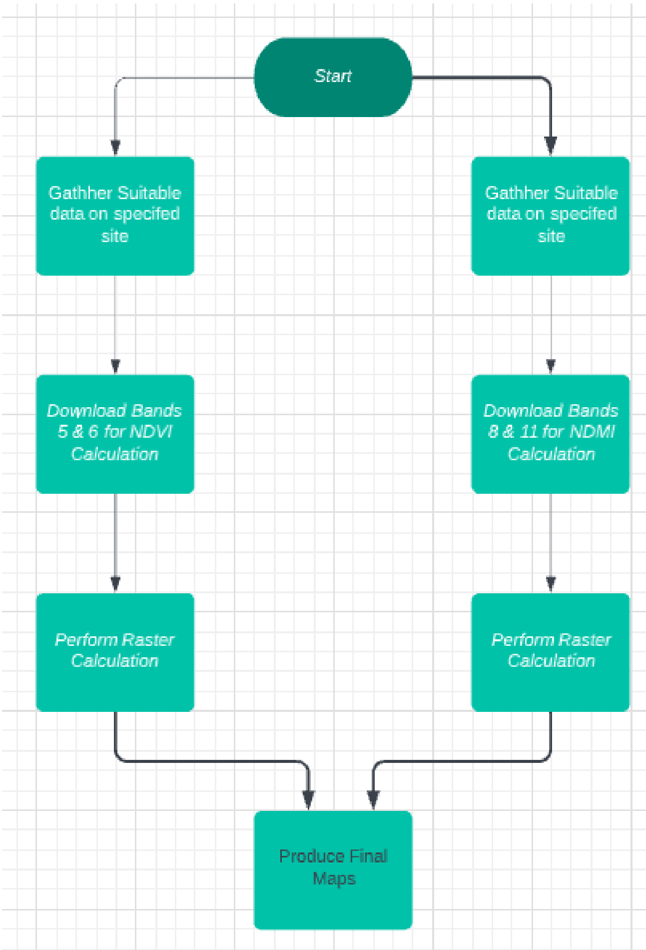
Parajuli, A., Gautam, A., Sharma, S., Bhujel, K., Sharma, G., & Thapa, P. et al. (2019). Forest fire risk mapping using GIS and remote sensing in two major landscapes of Nepal. *Geomatics, Natural Hazards And Risk*, *11*(1), 2569-2586. https://doi.org/10.1080/19475705.2020.1853251

Research, 32(3), 1147-1155. https://doi.org/10.1007/s11676-020-01162-2

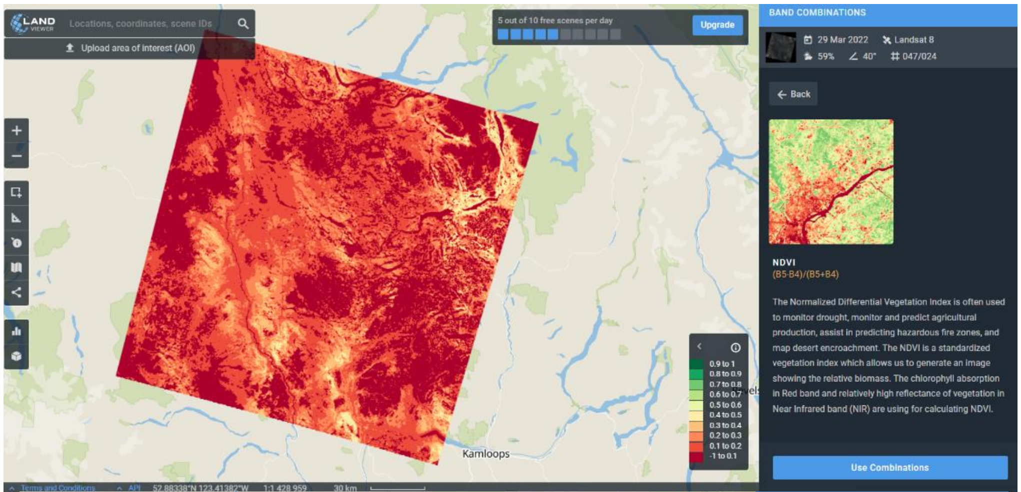
Tran, B., Tanase, M., Bennett, L., & Aponte, C. (2020). High-severity wildfires in temperate Australian forests have increased in extent and aggregation in recent decades. PLOS ONE, 15(11), e0242484. https://doi.org/10.1371/journal.pone.0242484

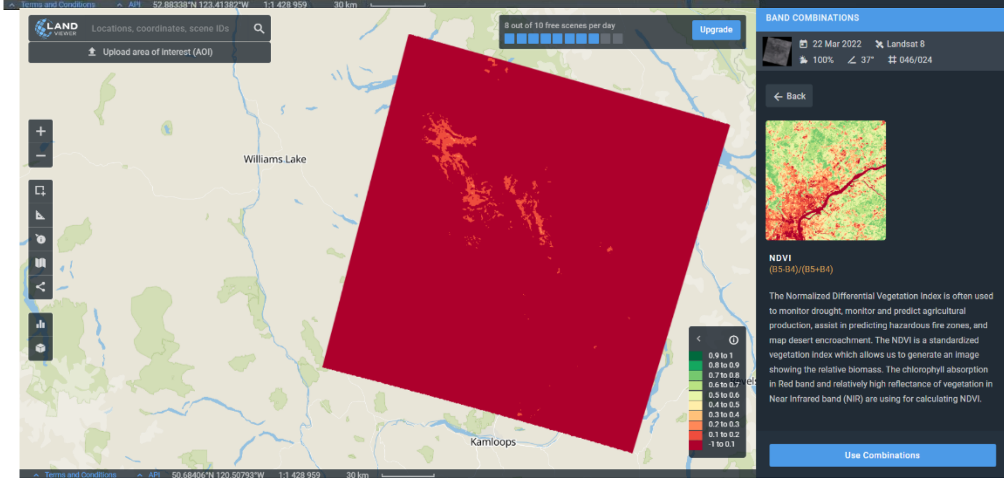
APPENDIX:

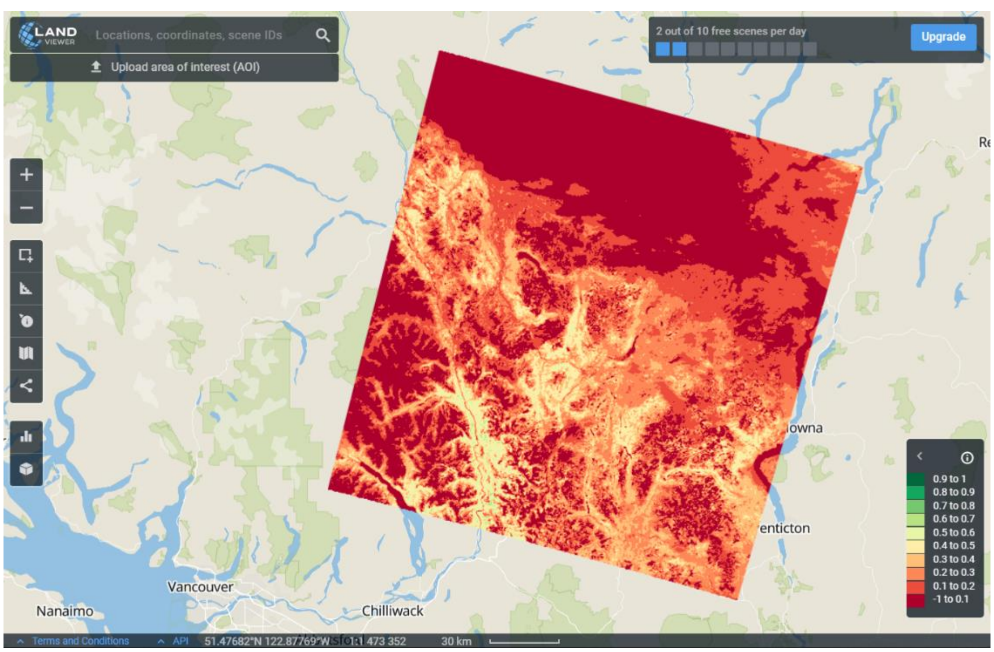
Workflow Documentation:



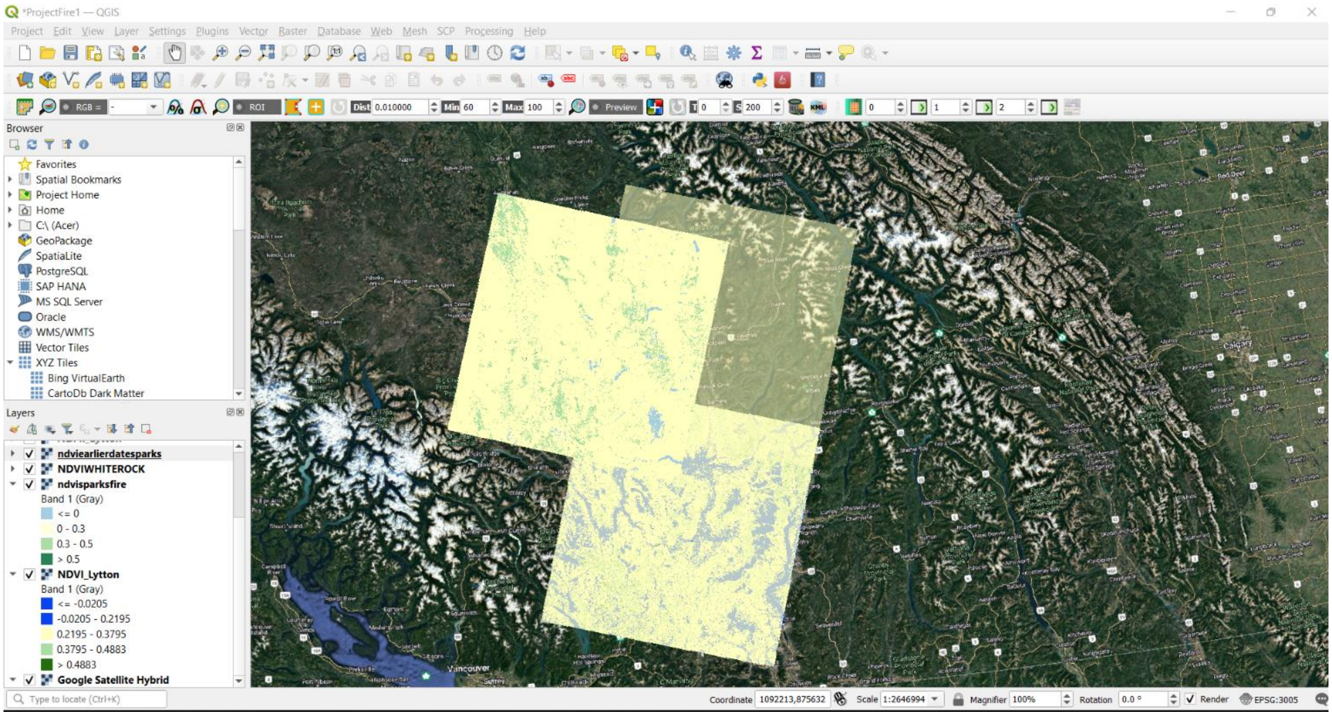
Evidence of research done on land that is North and West of Kamloops Region:

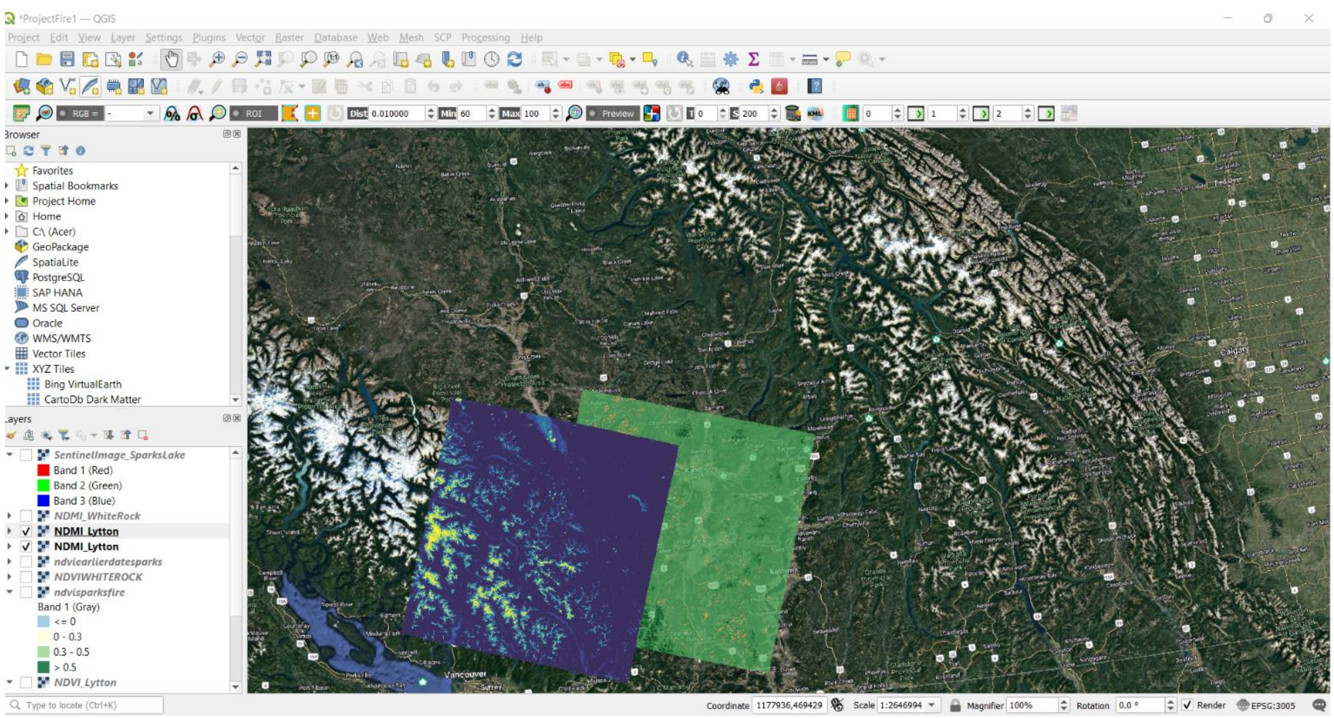




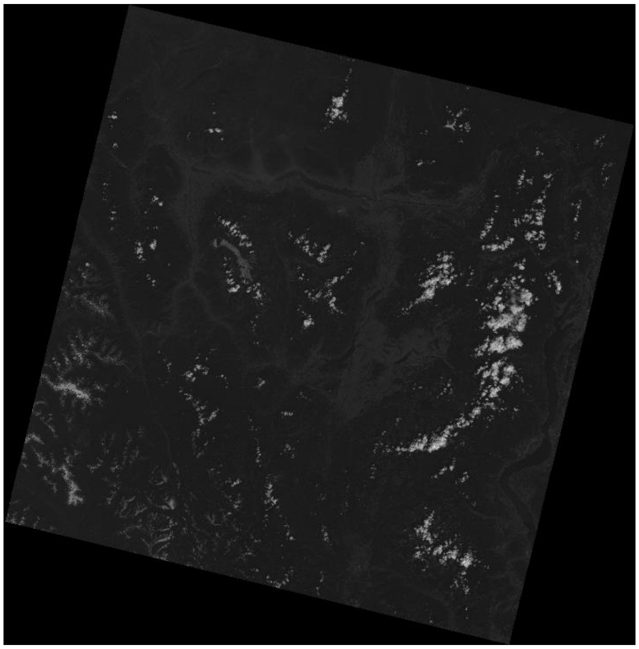


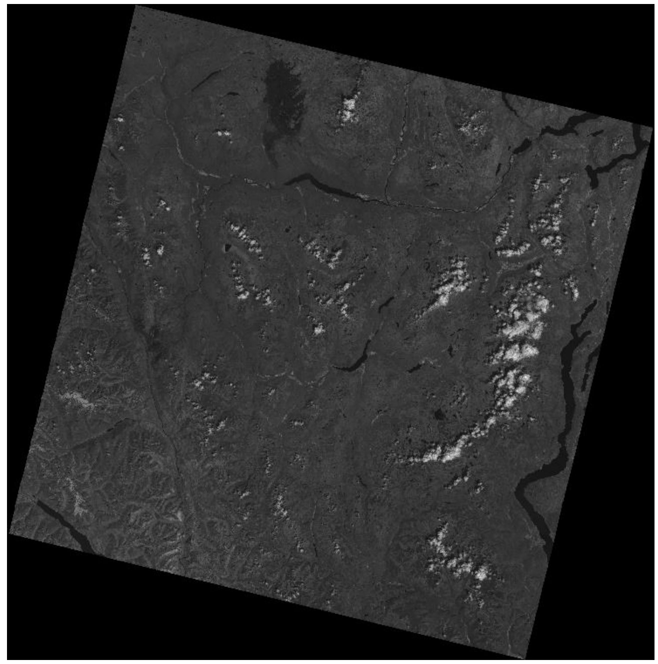
Evidence of Open-Source Data and QGIS App used:





Bands 4 and 5 from Landsat 8 before being used for NDVI calculation on the Lytton Creek Area.





Evidence of Metadata:

File Name	Description	Type	Projection	Extent	Source
NDVI_SparksLake	NDVI raster calculation for Sparks Lake Fire	Remote Sensing Data (Data Type: Float32)	EPSG:32610 - WGS 84 / UTM zone 10N	Kamloops	Earth Explorer USGS Gov
SentinelImage_SparksLake	Satellite imagery of band1, band 2 and band 3	Remote Sensing Data	EPSG:32610 - WGS 84 / UTM zone 10N	Kamloops	Earth Explorer USGS Gov
NDVI_Lytton	NDVI raster calculation for Lytton	Remote Sensing Data (Data Type: Float32)	EPSG:32610 - WGS 84 / UTM zone 10N	Kamloops	Earth Explorer USGS Gov
NDMI_Lytton	NDMI raster calculation for Lytton	Remote Sensing Data (Data Type: Float32)	EPSG:32610 - WGS 84 / UTM zone 10N	Kamloops	Earth Explorer USGS Gov
NDVI_WhiteRockLake	NDVI raster calculation for White Rock Lake	Remote Sensing Data (Data Type: Float32)	EPSG:32610 - WGS 84 / UTM zone 10N	Kamloops	Earth Explorer USGS Gov
NDMI_WhiteRockLake	NDMI raster calculation for White Rock Lake	Remote Sensing Data (Data Type: Float32)	EPSG:32610 - WGS 84 / UTM zone 10N	Kamloops	Earth Explorer USGS Gov