Remote Sensing of 2016 Fort McMurray Wildfire Incident with NDVI and Burn Severity

Xingchen Yan

\GEOG 465 – Remote Sensing

Term Project

(2594 words)

Report

2.1 Introduction and Objectives

2016 Fort McMurray incident is one of the most devastating wildfire incidents in Canada. The fire started in a forested area because of a below average in snow cover during the winter prior and a dry spring that follows. The fire started May 1, 2016 and was put down officially on August 2, 2017. The fire displaced more than 90,000 people and caused more than 3.77$ billion in damages. The objective of this project is to examine deeper into the Fort McMurray incident with the help of GIS tools and satellite images, acquire more knowledge on wildfires and finally learn potential means to mitigate wildfires and prevent damages.

This map from the provincial government shows the large perimeter of the fire on May 24. (Government of Alberta)

Alberta Agriculture and Forestry. (2017). *A review of the 2016 horse river wildfire: alberta agriculture and forestry preparedness and response* (Ser. Canadian public documents collection). Read - A Review of the 2016 Horse River Wildfire : Alberta Agriculture and Forestry Preparedness and Response: Alberta Agriculture and Forestry - desLibris (concordia.ca).

The Alberta Agriculture and Forestry reviewed extensively the 2016 Fort McMurray incident. In response to the wildfire, they have recommended multitude of plans in an attempt to mitigate future fire disasters. Some of the recommendations are be prepared and ready to respond to wildfires, improve wildfire forecasts, expand and enhance the planning sector by providing daily fire behaviours and predictions and many more.

Struzik, E. (2017). *Firestorm : how wildfire will shape our future*. Imprint. https://doi.org/10.5822/978-1-61091-819-0

Edward Struzik's book Firestorm has a very interesting chapter that depict the start of the 2016 Fort McMurray firestorm incident. "On Sunday May 1 2016, a small group of firefighters was on standby at the Grayling Creek Fire Base, 22 miles (35 kilometers) south of Fort McMurray in northern Alberta." They have expected a fire to occur in the region weeks prior to the incident because Alberta had a mild winter that year with mild snow and a very spring. That day the fire started but when the team of 4 arrived on scene they already knew they could do nothing for this particular fire, it was too big and spread too rapidly, they tried dropping buckets of water from nearby Horse River, but it was hopeless. They expected the fire to reach town soon. Local state emergency was declared around 10pm that day. Local polices and Royal Canadian Mounted Police tried their best in evacuating civilians. The book continues to narrate in detail the events of the wildfire incident.

“By the time the fire was finally brought under control, more than 2,500 homes were destroyed. Twelve thousand cars and trucks were badly damaged. Nearly 1.5 million acres, an area twice the size of Rhode Island, burned. It was the costliest natural disaster in Canadian history. Insurance claims were expected to reach the 3.77 billion.”

Tedim, F., Leone, V., & McGee, T. K. (Eds.). (2020). *Extreme wildfire events and disasters : root causes and new management strategies. Elsevier. https://doi.org/10.1016/B978-0-12-815721-3.01002-X.*

A book on wildfire management strategies was published not too long ago, by Tedim, F et al. This book “highlights new ways to prevent and respond to extreme wildfire events and disasters through sustainable development, thus revealing better management methods and increasing protection of both the natural environment and the vulnerable communities within it.” In one of the chapters of this book called, Extreme wildfires and disasters around the world: lessons to be learned, this chapter focuses on wildfires and disasters on Portugal’s but also make references to Greece, Italy, Australia, USA and Canada’s Fort McMurray incident. For example, one of the lessons that was recommended by the author is to use non-flammable materials for house constructions in fire prone regions which is already the case for majority of houses in Greece and the rest of Mediterranean region. Another counter intuitive lesson is the spontaneous evacuation of settlers is not necessarily a good option, because it could lead to panic and further disaster.

Lewis, S. A., Hudak, A. T., Ottmar, R. D., Robichaud, P. R., Lentile, L. B., Hood, S. M., ... & Morgan, P. (2011). Using hyperspectral imagery to estimate forest floor consumption from wildfire in boreal forests of Alaska, USA. *International Journal of Wildland Fire*, *20*(2), 255-271.

Lewis & Co (2011) used pre- and post-fire forest floor depths and post-fire ground cover assessments to map forest floor consumption after the 2004 wildfire. They have also established correlation between the deepness of forest floor and the severity of the burn. Being able to spatially predict the depth and degree of consumption with hyperspectral data is an important prospect for the future of boreal fire ecology.

This topic is important because similar cases could also happen in Canada because Alaska should be similar to Northern Canadian in this case Alberta, in term of climate and forestation. It is important to access the degree of damage that was caused and expect the same thing to happen in the Northern Canada because natural forest fire are frequently terrorizing forested regions. They should have learned from the prior experience from the United States and have proper counter measure set in place and be prepared.

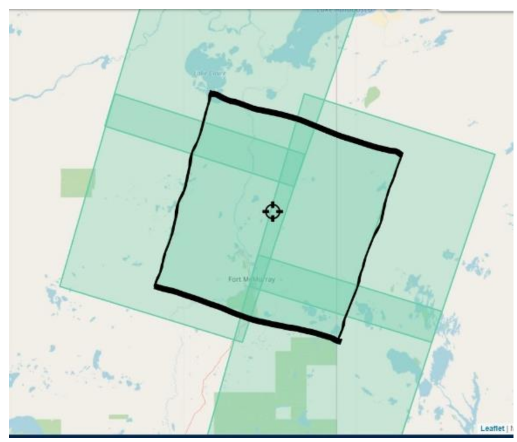
Hammond, D. H., Strand, E. K., Hudak, A. T., & Newingham, B. A. (2019). Boreal forest vegetation and fuel conditions 12 years after the 2004 Taylor Complex fires in Alaska, USA. *Fire Ecology*, *15*(1), 1-19.

Hammond & Co (2019), examined modern climate dynamic of the boreal forest and said that the fire sizes and frequency are increasing. It is thus, important to examine the aftermath of such event. The author researched on the burn degree of the ground, assessed changes in dominant vegetation. They found that species doubled over time, and there is a difference on the species and amount of vegetation that resides depending on the severity of the burnt ground. Moss species decreased over the period while shrubs increased over the same period.

2.2 Methodology.

All satellite images and data are downloaded from USGS Global Visualization Viewer (GloVis). Glovis is a easy to use and access satellite information and data platform the only requirement is to create an account and register to the website. Some of the data are paid only but most Landsat data are free for everyone. The data used for this research are all in the Month of August because that is usually when most vegetation is thriving and giving the most information on their health. After acquiring the data, we imported the data using the LANDSAT tool, and choose Convert to reflectance option for multispectral bands and the cost model for the reflectance correction. Importing also results the hard to use TIF format to be converted to a format that TerrSet uses.

Unfortunately, during the project the 2015 and 2016 data was very fortunate to be at the same location, whereas the data for 2017 was not overlapped. In the scenes to the right, you can see that the highlighted one is the location for the 2015 and 2016 file, whereas 2017 files are the 4 squares around it. To remediate this problem, I toke the 4 squares of the 2017 files and used the MOSAIC tool to combine them and used the WINDOW tool to essentially cut the bigger 2017 scene into the 2015 scene.



True composite and false composite (infrared for vegetation) are a good way to grasp the situation of the area. To create color composites simply use the corresponding bands and display them according to RGB. The natural color true composite are band 432RGB the infrared false composite used to identifying vegetation used in this research are 543RGB. (Figure.5 and 6)

The NDVI spectral indices is a good representation of healthy vegetation we can differentiate the healthy vegetation from the unhealthy or not vegetation. Create vegetation indices NDVI using VEGINDEX tool. The bands used were, Red band 4 and infrared band 5. After that we need to find the threshold for healthy vegetation using HISTO tool. The calculation for threshold is the mean + standard deviation. Threshold for 3 years are listed below. After classification of the area 3 maps were produced of the area of Fort McMurray pre, during and post wildfires. (Figures 1,2,3)

2015 Threshold

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Mean 0.1352159 + SD 0.1264965 = 0.2617124
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2016 Threshold

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Mean 0.1542536 + SD 0.1503402 = 0.3045938
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2017 Threshold

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Mean 0.6513699 + SD 0.1907133 = 0.8420832
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Then reclass numbers below threshold to 0, higher than threshold to 1. For maps of vegetation indices NDVI for that year. Now to make maps of change between years 2015-2017, use image calculator and use the 2015NDVI map – the 2017 NDVI map. For the result of these maps, we get numbers of -1 0 and 1. To classify those numbers I have made a table below. Number 1 means that the conditions of the plants have deteriorated because the plants were healthy thus, they were 1 in 2015, but in 2017 they were 0 unhealthy. Number 0 means that the condition has not changed but it could be because it is healthy and it has not changed or it could also be unhealthy and it has not changed, because in either case 1-1=0 which means in both years they were healthy and gave the number 0 or 0-0 = 0 which means that the condition of the plants was bad during both years thus it has not changed. Finally, -1 could only be possible because the condition of the plants was 0 unhealthy during 2015 and 1 healthy during the year 2017 thus producing -1 and it means that the condition of the plants became healthy. After the operations 1 map of the difference in NDVI between the year 2015 and year 2017 was produced. (Figure 4)

2015 number	2017 number	Final number
1	0	1
1	1	0
0	1	-1
0	0	0

Normalized burn ratio for short NBR is a useful indexing tool to differentiate between the burned and unburned areas of the land as well as distinguish the degree of land burned. The NBR formula is NBR= (NIR-SWIR)/ (NIR+SWIR). In the meta data file and on the Landsat website we can see that the bands that we need for NBR are band 5 NIR and band 7 SWIR.

Thus NBR= (Band5-Band7)/ (Band5+Band7)

To calculate the NBR after importing the files. Use the Image Calculator tool and plug in the NBR equation above.

Here is an example below using Image calculator,

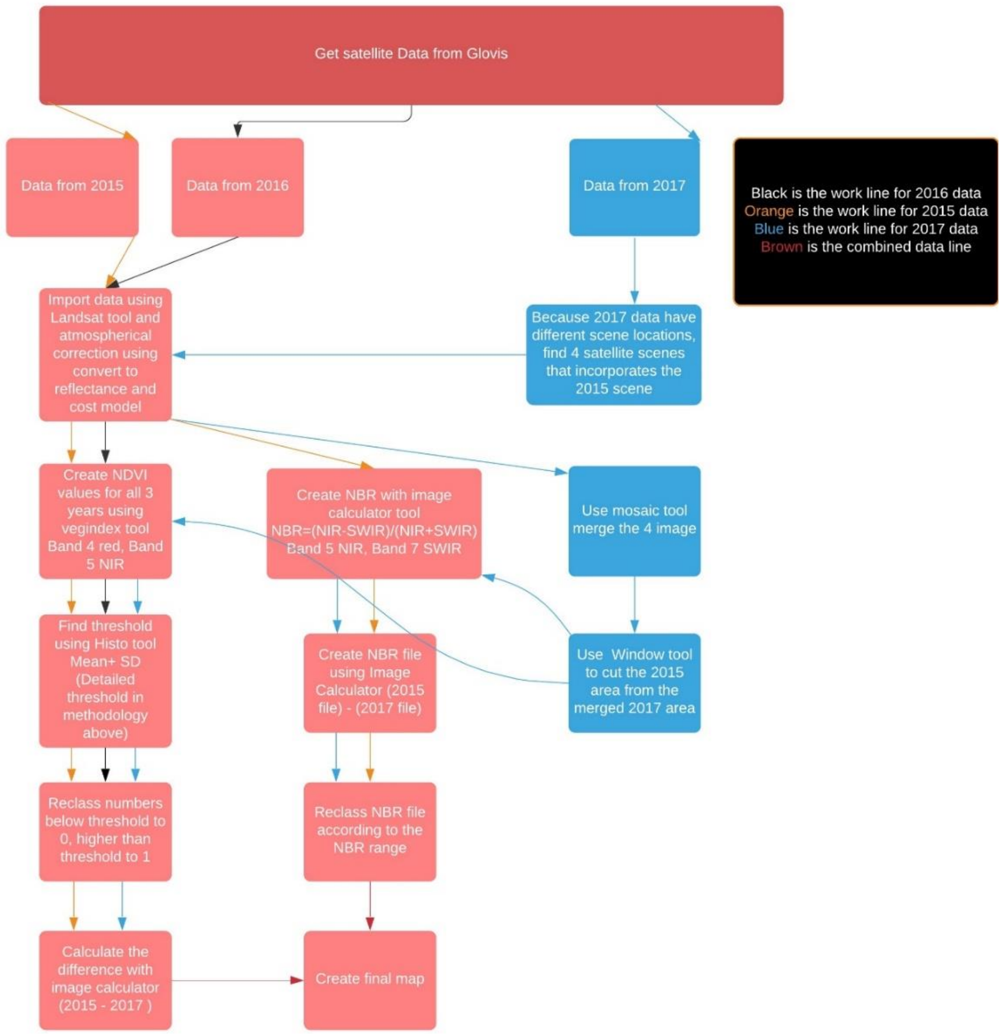
([2015_0830_20170225_01_t1_b5]-[2015_0830_20170225_01_t1_b7])/([2015_0830_20170225_01_t1_b5]+[2015_0830_20170225_01_t1_b7])

After doing this for the year 2015 pre-wildfire and 2017 post-wildfire, use image calculator again to this time 2015 NBR file minus the 2017 NBR file, and reclass the file according to the burn severity level below. (Figure. 7)

Severity Level	dNBR Range (scaled by 10^3)	dNBR Range (not scaled)
Enhanced Regrowth, high (post-fire)	-500 to -251	-0.500 to -0.251
Enhanced Regrowth, low (post-fire)	-250 to -101	-0.250 to -0.101
Unburned	-100 to +99	-0.100 to +0.99
Low Severity	+100 to +269	+0.100 to +0.269
Moderate-low Severity	+270 to +439	+0.270 to +0.439
Miderate-high Severity	+440 to +659	+0.440 to +0.659
High Severity	+660 to +1300	+0.660 to +1.300

During the project, I have noticed that this widely spread picture of NBR Range is actually wrong, the highlighted numbers +99 and +0.99 is incorrect. Because, if we think about the range perspective the unburned bracket which is -0.100 to +0.99, but + 0.99 is even a bigger number than 0.659 which is the moderate-high Severity bracket, which would not make sense. If you were trying to set those numbers as it is in the range, then you would overlap. If we look at the (scaled by 10^3) column another proof that it is wrong is that every number from right column is converted to the left one by moving decimals 3 times to the right. For example, -0.251 the first one becomes -251, but 0.99 should become +990 instead of +99 on the left column. Finally, the last clue is that every row should follow the next one in terms of range, thus the unburned area’s range should be -100 to + 99 for dNBR Range (scaled by 10^3) and -0.100 to + 0.099 for dNBR Range (not scaled).

- **Flow Chart**


Get satellite Data from Glovis
Data from 2015
Data from 2016
Data from 2017
Black is the work line for 2016 data
Orange is the work line for 2015 data
Blue is the work line for 2017 data
Brown is the combined data line
Import data using Landsat tool and atmospherical correction using convert to reflectance and cost model
Because 2017 data have different scene locations, find 4 satellite scenes that incorporates the 2015 scene
Create NDVI values for all 3 years using vegindex tool Band 4 red, Band 5 NIR
Create NBR with image calculator tool NBR=(NIR-SWIR)/(NIR+SWIR) Band 5 NIR, Band 7 SWIR
Use mosaic tool merge the 4 image
Find threshold using Histo tool Mean+ SD (Detailed threshold in methodology above)
Create NBR file using Image Calculator (2015 file) - (2017 file)
Use Window tool to cut the 2015 area from the merged 2017 area
Reclass numbers below threshold to 0, higher than threshold to 1
Reclass NBR file according to the NBR range
Calculate the difference with image calculator (2015 - 2017)
Create final map

2.3 Results / Discussion

With the help of GIS remote sensing, we were able to distinguish the change in the landscape. By comparing the 3 NDVI files of pre, during and post wildfire we can see clearly see the change in the landscape composition from a vegetated area to a mostly barren land. By comparing the change of NDVI with years 2015-2017 we can see that most of the landscape in the scene is deteriorating during the 2-year period, only the patch North-West is seemingly having a great time. The true and false composites also help us see the changes between the landscape we can firstly compare the area mapped with the map provided by the Alberta government and we can see that river which traverse horizontally through the bottom of these satellite images. We can also see green areas turning toward a brownish color plus the addition of clouds that could potentially be what the forest fire was causing. The burn severity map also shows that the majority of severe burns are in the bottom east of the satellite image coincidentally this is also where the urban area is in the Alberta map that was provided by the government, this explains the enormous amount of damage that was caused by the 2016 Fort McMurray incident.

2.4 Conclusions

The purpose of this project is to examine deeper into the Fort McMurray incident with the help of GIS tools and satellite images, acquire more knowledge on wildfires and finally learn potential means to mitigate wildfires and prevent damages. With the help of literatures, books and articles we were able to learn a lot more details from the incident. Some of the books talks about what we have learned and came up with countermeasures to minimalize next wildfires. With the help of GIS remote sensing and satellite imageries, we were able to learn further details of the incident such as the burn degrees of the area by creating a burn severity index. We were also able to assess the vegetation information of the area and come up with hypothesis on the ways of which the fire was spread, where it caused the most damages and the areas that is still thriving in the scene. This project was also a good exercise in the technical perspective, because it requires the uses of actual satellite images and it will help in preparing what we will be encountering after graduation.

Appendix

Figure. 1

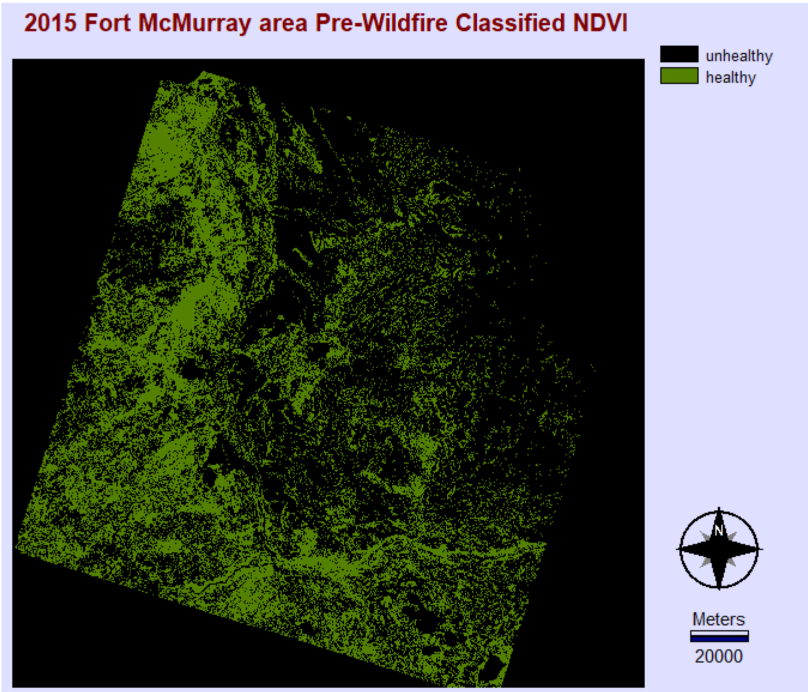


Figure. 2

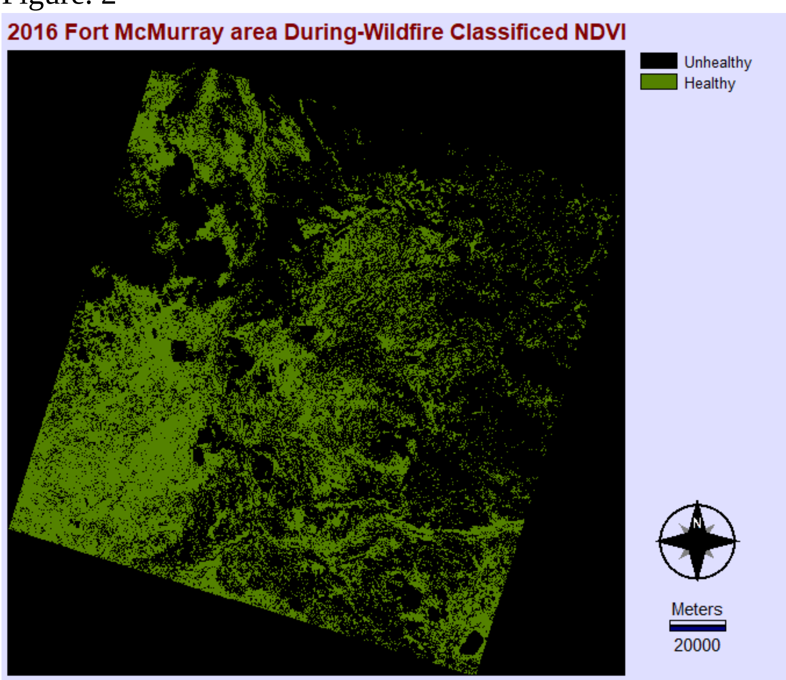


Figure. 3

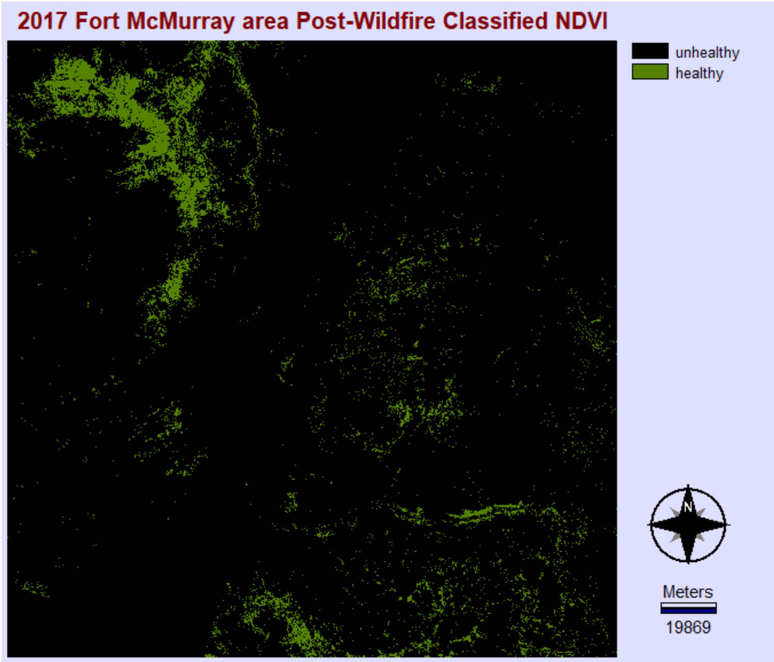


Figure. 4

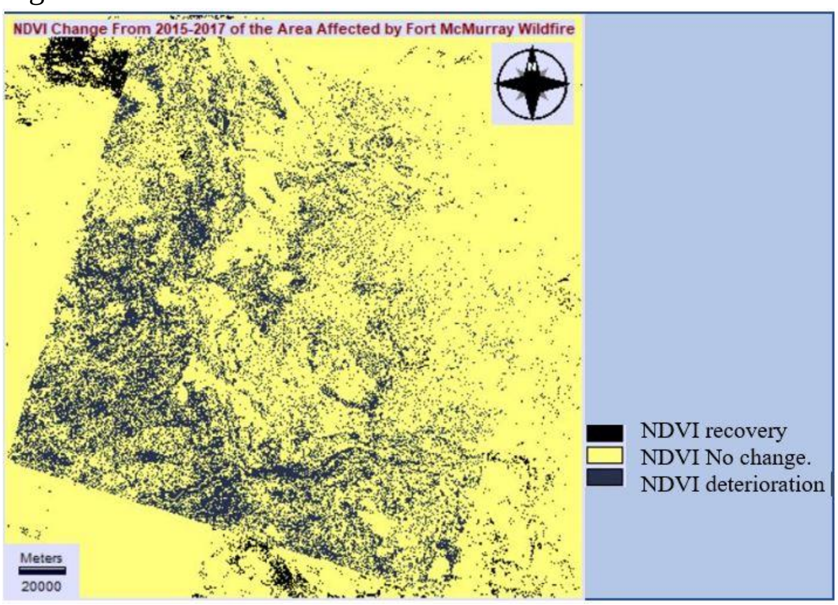
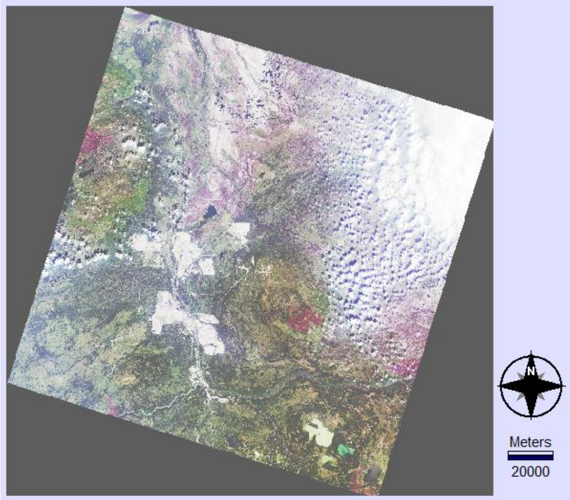


Figure 5

True Composite of the Fort McMurray Pre-Wildfire 2015



False Composite of the Fort McMurray Pre-Wildfire 2015

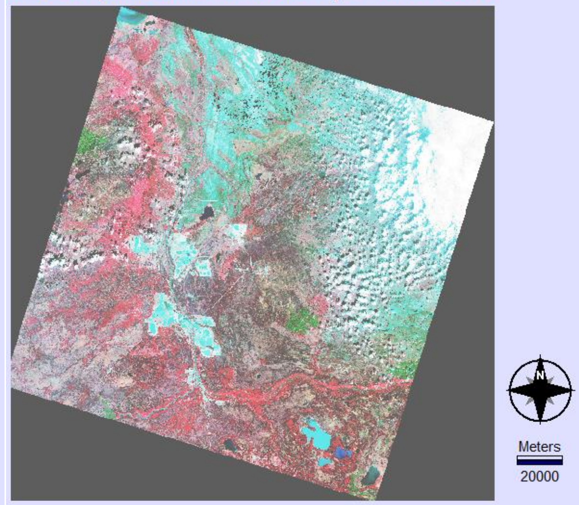
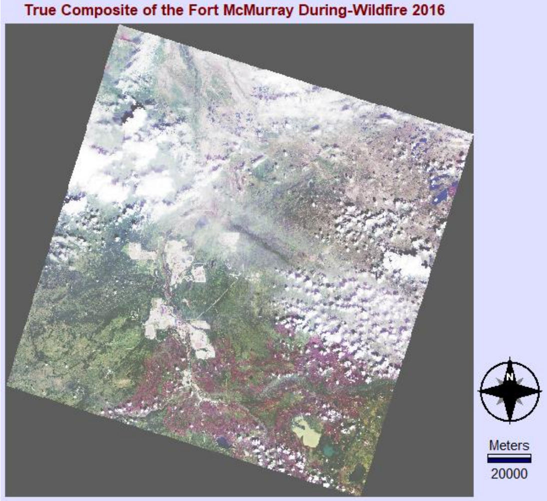


Figure 6

True Composite of the Fort McMurray During-Wildfire 2016



False Composite of the Fort McMurray During-Wildfire 2016

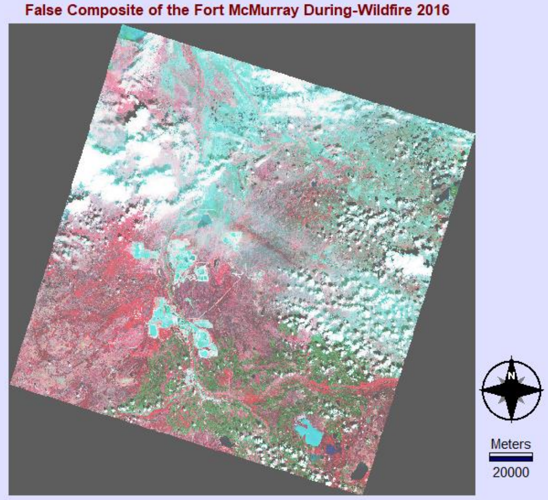
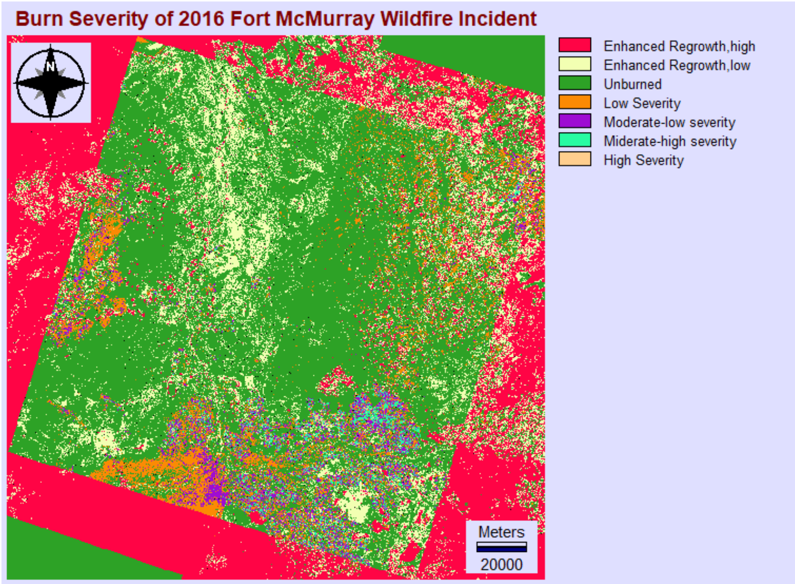


Figure. 7


Burn Severity of 2016 Fort McMurray Wildfire Incident
Enhanced Regrowth,high
Enhanced Regrowth,low
Unburned
Low Severity
Moderate-low severity
Miderate-high severity
High Severity
Meters
20000

2.5 References and Data Sources:

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