August 27-31, 2023
FLORENCE - ITALY
16th International Conference on Wind Engineering
ICWE 16

Use of NDVI from satellite imagery to assess tornado tracks in crops

F. Jessa [1], C.S. Miller [2], G.A. Kopp [3]

[1] *Northern Tornadoes Project, Western University, London, Canada, fjessa3@uwo.ca*
[2] *Northern Tornadoes Project, Western University, London, Canada, connell.miller@uwo.ca*
[3] *Northern Tornadoes Project, Western University, London, Canada, gakopp@uwo.ca*

SUMMARY:
There are numerous tornadoes that occur each year in Canada. However, many of them occur in Canada's croplands, making it impossible for them to be classified under the current Enhanced Fujita (EF) scale as it has no Damage Indicator for crops. Not knowing the true number or intensity of these tornadoes results in inaccurate tornadic risk assessments for certain areas of Canada. Therefore, the objective of this project is to better understand Canada's tornado climatology by assessing the viability of using remote sensing satellite imagery in the visible and near-infrared spectrum to examine characteristics of tornadic events. This project examined all the tornadoes that occurred across Canada between 2017 –2021 using satellite imagery collected from the Northern Tornadoes Project. This satellite imagery was analyzed in ArcGIS Pro to empirically define the damage in low-lying vegetated areas from the percent change in plant health via the usage of a Normalized Difference Vegetation Index (NDVI). Preliminary results show that this method provides many insights into the characteristics of tornadoes.

Keywords: tornadoes, crops, NDVI

1. INTRODUCTION

Tornadoes often occur in less populated areas (such as the Prairies and Northern regions of Canada), which results in many of them going undetected, and therefore unreported (Cheng et al., 2013). In addition to undetected tornadoes, there are also cases of tornadoes that are detected but are unable to be properly classified. The current method to rate the intensity of a tornado in Canada relies on the Enhanced Fujita Scale (TTU, 2006). The Canadian version of the EF-scale is a rating system that includes 31 observable damage indicators to aid in classifying a tornado (Sills et al., 2014). Depending on the amount of damage, an associated estimated wind speed and corresponding EF-scale rating can be determined for the tornado event (TTU, 2006). Currently, these damage indicators are mainly reliant on trees and structures such as commercial buildings, homes, and farm structures to be present in the affected areas. However, there are many tornadoes that occur in locations that do not have trees or structures in the area, as illustrated in Figure 1. For instance, this often occurs in the Prairies, where the area mostly consists of low-lying crops and vegetation. In these cases, a proper classification of the tornado is not possible and a default EF-scale rating of zero (EF0-Default) is given. This leads to many tornadoes being underestimated and, thus, we cannot accurately assess Canada's tornado climatology. This is particularly concerning because the majority of Canada's agricultural land tends to be in warmer, more tornado prone regions of Canada (Finnigan, 2018).

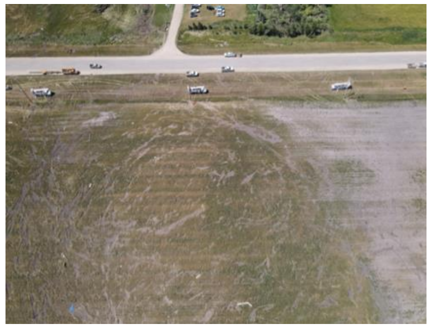

Figure 1: Drone image captured by the Northern Tornadoes Project showing major ground scour caused by the EF3 tornado in Scarth, Manitoba on August 7, 2020.

The goal of this research project is to investigate the usefulness of vegetation indices from 4-band satellite imagery to detect and assess tornado damage to crops and low-lying vegetation. Past studies have looked at individual tornado events using satellite imagery for damage identification; however, the availability of this large dataset from the Northern Tornadoes Project (NTP) spanning multiple events, over multiple years, in multiple and varied geographic areas has the potential to go further and systematically identify unique features that vegetation indices can provide. For example, looking at the effect different land cover has on identifying damage using satellite imagery. Another objective is to look at the different types of crops that were damaged and be able to identify any properties that certain crops possess when damaged from tornadoes. Ultimately, the main goal of the project is to use the information learned from satellite imagery to determine a relationship between the damage in crops and low-lying vegetation and the EF-scale rating of a tornado.

2. LITERATURE REVIEW

2.1. Normalized Difference Vegetation Index (NDVI)

A vegetation index is a value that is able to recognize the presence of a plant and its state of health (Earth Observing System [EOS], 2019). It is measured from the reflectance across different spectral bands using sensors where the reflectance values from two or more bands are used in a mathematical combination (EOS, 2019). The Normalized Difference Vegetation Index (NDVI) is the most commonly used vegetation index. It is a measure of plant health based on how the plant reflects light at the near infrared (NI) and red frequencies (R) using Equation (1).

$$NDVI = \frac{NI-R}{NI+R} \tag{1}$$

This index works well for vegetation because chlorophyll, which is a health indicator for vegetation, reflects near-infrared light and absorbs visible light. Therefore, if there is less chlorophyll, more near-infrared light is absorbed, and more visible light is reflected (compared to the healthier plant). NDVI values fall between -1 to 1, where negative values are created from areas such as clouds and water, values close to 0 are created from bare soil, and positive values are created from areas with plants, trees, or other vegetation. A healthy plant will have a value close to 1 while unhealthy plants will be closer to 0.

3. METHODOLOGY

NTP collects satellite imagery that captures 4 spectral bands, the visible spectrum in the red, green and blue (RGB) bands and the near infrared (NI) band at a nominal resolution of 3 m. Each image is then automatically corrected to reduce spatial inconsistency across time and location. The satellite images that are chosen for analysis for each event are clear images (smokeless, hazeless, and cloudless). These images are then combined to create a mosaic which forms a larger image to cover the entire damage path. The NDVI value is calculated using the pre-tornado imagery, as well as using the post-tornado imagery. These values are then used to measure the percent change in NDVI between the before and after mosaics using Equation (2). Since the goal of this study is to measure multiple types of vegetation in different regions of Canada, the percent change equation is used to better account for the varying starting conditions across the tornadic events.

$$NDVI_{\%CHANGE} = \frac{NDVI_{AFTER} - NDVI_{BEFORE}}{NDVI_{BEFORE}} \tag{2}$$

Once the equation is applied a new image is generated that contains NDVI percent change values. After this, the center of the tornado damage track is drawn with a buffer, half the size of the maximum path width, to capture the entire damage path. Since the maximum tornado path width does not occur along the entire length of the damage track, the buffer can capture homes, lakes, rivers, roads, and fields. These features do not contain plants and in the case of the fields, the after date of a captured image may be a while after the tornado where the farmer may have harvested the crops. These features can cause changes to the NDVI value that are unrelated to the tornado damage and are removed from the data set. A spatial average is then taken, where the values within a certain distance of the point of interest are averaged which results in a new value for that point. The size of the spatial averaging area is based on the box method, which is a method for classifying the intensity of the tornado based on the amount of treefall in an area that is defined as half the size of the maximum path width of the tornado (Sills et al., 2020). However, crop damage widths rarely cover the entire tornado path width at any point along the damage track. Therefore, the maximum crop damage width for each event was determined and the smallest distance was chosen then divided by half to use as a baseline area for spatial averaging. The peak point is then found and double checked to ensure that it is from an area that contains crops or low-lying vegetation. The other damage indicators in the area are used to classify the tornado event and this will be used to create a correlation between the estimated wind speed and EF-scale rating and the peak crop damage value.

4. RESULTS

In total, 90 events from across Canada were analyzed, Figure 3 shows an example of the analysis from the EF4 Alonsa, MB tornado on August 3, 2018.

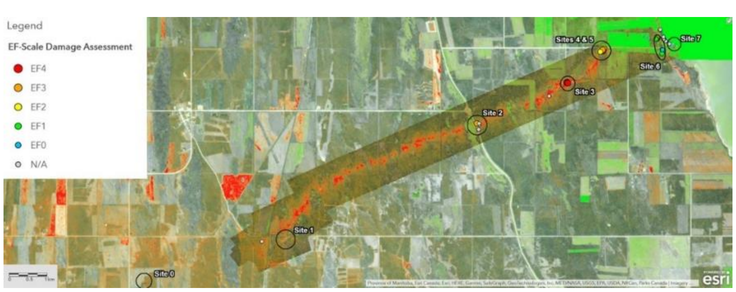

Figure 3: Overview of the Alonsa, MB tornado from August 3, 2018, showing NDVI analysis along with corresponding EF-scale assessment.

Across the 90 events analyzed; a weak trend was observed that higher values of damage are observed at higher intensity rated tornado events. This shows that NDVI analysis has the potential to provide a lot of insight into the properties of tornadoes, but many factors need to be taken into account. For example, how the peak values of damage change over time. This will identify how time between the event and the collection of clear satellite imagery affects the peak values and a correction based on these events can be applied to the other events to determine a more reliable peak value of damage. The effect of specific landcover on NDVI and damage identification will also need to be determined by firstly identifying the landcover over the areas where tornadoes have occurred. Then, a comparison between the NDVI values can be made and potentially explained due to the overlying landcover. Finally, the final objective with this large dataset is to look at the different types of crops that were damaged and be able to identify any properties that certain crops possess when damaged from tornadoes. To study this, an NDVI analysis over time can identify the type of crop from its growing season properties or based on crop maps developed by external sources. Once the type of damaged crop is known, a more recent NDVI analysis will be able to determine which stage of the growing process the crops were at and thus help in assigning a EF-scale rating/windspeed.

5. CONCLUSION

The method used and explained in this research project is a straightforward way to identify characteristic of tornadic events via damage of vegetation using remote sensing technologies. The process involves gathering the before and after satellite imagery, performing the NDVI percent change equation to produce a new image, drawing the centerline and a buffer, applying the spatial averaging tool to the extracted image and then the peak value of crop damage can be identified. Other critical factors such as landcover and time between imagery were also noted.

REFERENCES

Burow, D., Herrero, H., and Ellis, K., 2020. Damage analysis of three long-track tornadoes using high-resolution satellite imagery. Atmosphere. 11, 613.

Cheng, V., Arhonditsis, G., Sills, D., Auld, H., Shephard, M., Gough, W., and Klaassen, J., 2013. Probability of tornado occurrence across Canada. Journal of Climate. 26, 9415-9428.

Earth Observing System. 2019. NDVI FAQ: All You Need To Know About Index. Available from https://eos.com/blog/ndvi-faq-all-you-need-to-know-about-ndvi/. [accessed 16 January 2022].

Finnigan, P., 2018. Toward a resilient Canadian Agriculture and Agri-Food system: Adapting to Climate Change. House of Commons, Ottawa, Canada.

Sills, D., Kopp, G., Elliott, L., Jaffe, A., Sutherland, E., Miller, C., Kunkel, J., Hong, E., Stevenson, S., and Wang, W., 2020. The northern tornadoes project – uncovering Canada's true tornado climatology. Bulletin of the American Meteorological Society, 101, 2113-2132.

Sills, D., McCarthy, P., and Kopp, G., 2014. Implementation and application of the EF-scale in Canada. 27th AMS Conference on Severe Local Storms. Madison, WI, American Meteorological Society, Paper 16B.6.

Sills, D., Cheng, V., McCarthy, P., Rousseau, B., Waller, J., Elliott, L., Klaassen, J., and Auld, H., 2012. Using tornado, lightning and population data to identify tornado prone areas in Canada. 26th AMS Conference on Severe Local Storms, Nashville, TN, American Meteorological Society, Paper P59.

TTU - WiSE, 2006. A recommendation for an Enhanced Fujita Scale (EF-Scale). Lubbock, TX: Wind Science and Engineering Center, Texas Tech University, 95.

Yuan, M., Dickens-Micozzi, M., and Magsig, M., 2002. Analysis of tornado damage tracks from the 3 May tornado outbreak using multispectral satellite imagery. Journal of Weather and Forecasting. 17, 382-398.