Analyzing Vegetative Risk for Utility Infrastructure

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Introduction

The electrical power industry is incredibly important to our daily lives. Maintaining the safety, reliability, and efficiency of electrical power systems, particularly transmission lines, is critical to ensuring that homes, businesses, and essential services receive uninterrupted power[1]. One key aspect of this is vegetation management, which involves monitoring and managing trees and other vegetation near powerlines to prevent outages. These regions of vegetation management are called right-of-ways (ROWs)[1]. The clearance levels necessary for each ROW are dependent on the voltage of the power lines and the length of the management cycle[1]. Many stretches of power lines may go years without being monitored due to limited resources, remote locations, or infrequent vegetation management schedules[5,6]. This can lead to vegetation encroachment, where trees or branches grow dangerously close to the power lines, increasing the risk of outages or even wildfires[1]. Regular monitoring and maintenance are essential to ensure that vegetation is kept at safe distances, reducing the likelihood of such incidents and ensuring the reliability and safety of the electrical grid. Unfortunately, consistent monitoring can be time consuming and costly for power companies[5]. By leveraging advanced technologies such as GIS and LiDAR, the industry can more effectively assess and mitigate potential risks, ensuring a stable and secure energy supply for all.

Objective

The goal of this project is to use LiDAR imagery and GIS technologies to calculate risk based on the distance of trees to transmission lines. This project aims to benefit utility companies by demonstrating the ability to use advanced GIS technology to perform mass risk calculations and create tailed GIS webapps. This will in turn prioritize maintenance and vegetation management efforts in the regions with highest risk, allowing for optimal use of company resources. Furthermore, damage to power infrastructure is costly to repair[5]. Understanding the risks of vegetation damage would allow utility companies to better prevent damage and service interruptions, saving them money. The general public will also benefit from GIS-integrated vegetation management as there would be fewer power outages, leading to increased satisfaction and trust in utility providers. The focus of the project is on two transmission lines that go through Centre County, Pennsylvania.

Data and Methodology

This analysis was performed in Python and ArcGIS Pro with use of multiple Python libraries. U.S. transmission line data for Centre County, PA was extracted from Esri's U.S. Federal Datasets using Python[4]. There are two transmission lines that go through Centre County; the easternmost transmission line carries 230kV of electricity, and the westernmost line carries 115kV[4]. The 230kV line has a length of 53,128 meters and the 115kV line a length of 25337 meters[4]. A 40m buffer from the Python GeoPandas library was applied to select the appropriate area for use in canopy height modeling (CHM). Shapely library was also used to prepare data for CHM generation. Code from OpenTopography and the USGS was used to extract 1m resolution USGS 3DEP LiDAR Point Cloud data from 2019 and generate digital elevation models[2,3]. Inverse distance weighted interpolation was used to generate raster datasets from the Point Cloud data[2,3].

The derived data was then used to generate digital terrain models (DTMs) and digital surface models (DSMs)[3]. CHMs were created by subtracting the DTMs from the respective DSMs. The resulting CHMs are 2m in resolution. USGS Class 7 and 18 (low and high noise) were removed from the DTMs and DSMs[3]. The CHMs were corrected to ignore power lines and transmission towers by rasterizing a 20m buffer around the transmission lines vector and using a conditional statement in ArcGIS Pro Spatial Analyst Con to set the values around transmission lines to 0. This reduces errors introduced by the height of transmission lines/towers in the CHMs.

Risk maps were created by using a distance raster created from ArcPy's Euclidean Distance (showing distance from a 15m buffer around the lines) and CHMs to assess which trees are capable of falling over and damaging transmission lines. The "high risk" or red zones were characterized by having trees greater than their distance from the transmission line buffer as well as at least 2m tall. While the transmission lines are much higher than that, there is still the possibility of smaller trees falling and damaging the transmission poles and resulting in outages. The "medium risk" or green zones were characterized by being greater than 2m less than their distance from the transmission line buffer as well as at least 2m tall. This means they have the potential to grow taller and possibly damage the towers or lines.

Cluster analyses were conducted for both risk maps using ArcPy's Density Based Clustering. Only the high risk zones were used for this analysis. The rasterized risk maps were converted to points using the Raster to Point Conversion in ArcGIS Pro and the high risk points were selected for DBSCAN analysis. After testing different clustering variables, minimum features were set to 70 and search distance 50 meters. This allowed for proper separation of the clusters and filtering of noise.

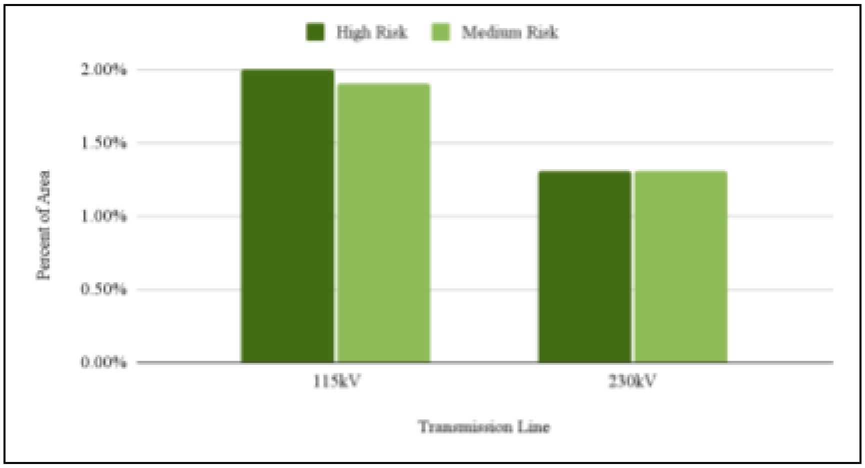


Figure 1, Percentage of high and medium risk areas across two transmission lines.

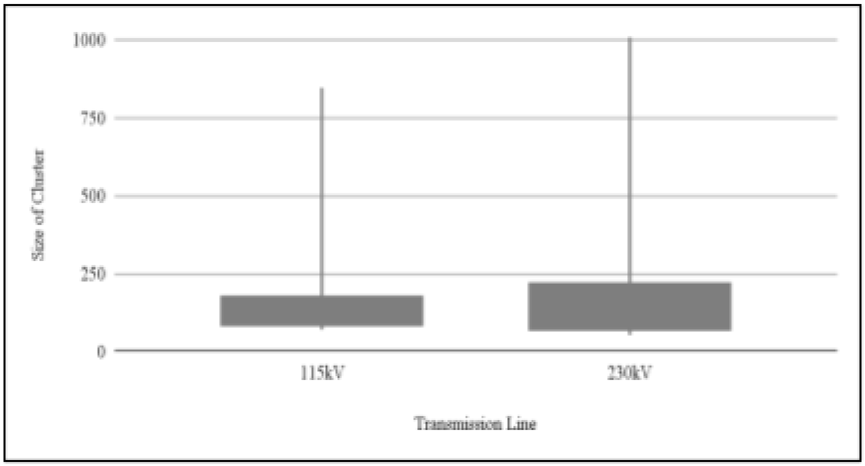
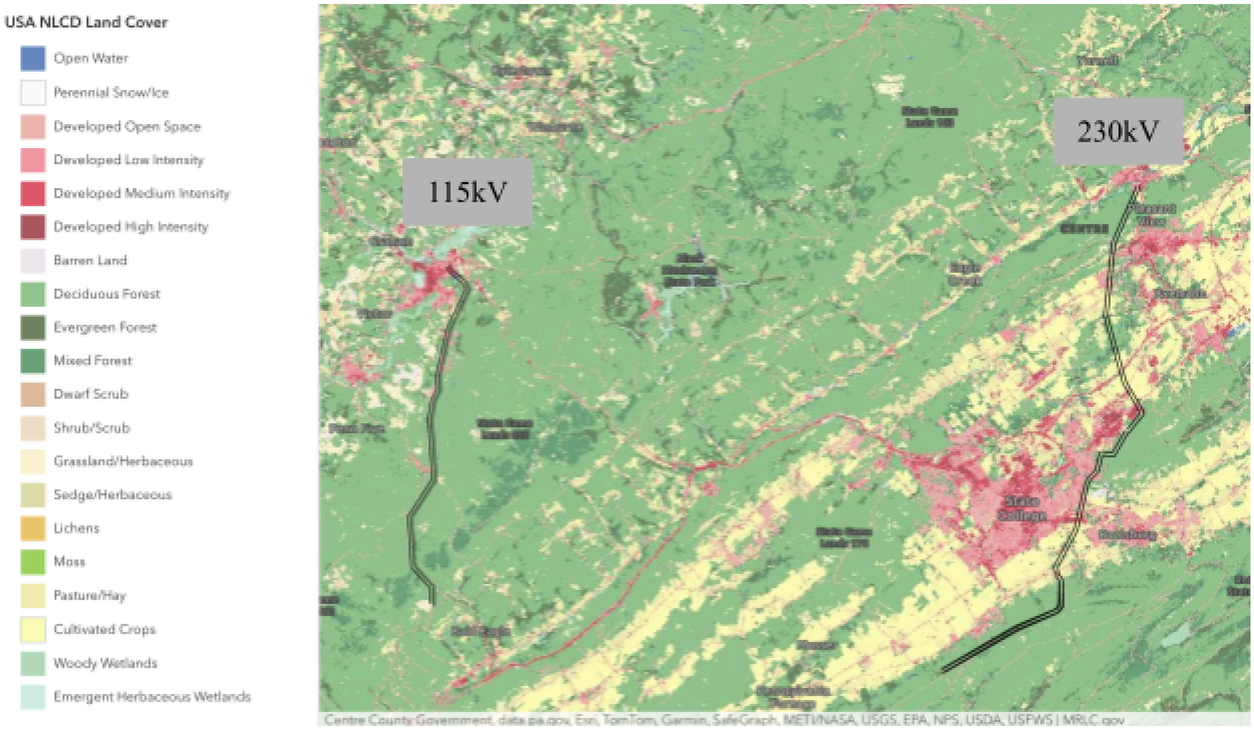


Figure 2, Spread of cluster size for two transmission lines.

Results

The threshold analysis for risk resulted in 1.3% of the area at high risk for 230kV. For the 115kV line, 2.0% of the area was determined to be at high risk. The areas of medium risk were similar, with 1.3% of medium risk across the total 230kV transmission line region and 1.9% medium risk across the 115kV transmission line region.

These values are displayed in Figure 1. The DBSCAN clustering analysis on the 115kV transmission line returned 36 clusters and the 230kV line returned 58 clusters. When normalizing the number of clusters with power line distance, the 115kV line has a value of 0.00142 and the 230kV line has a value of 0.00109. The spread of cluster size can be seen in Figure 2.



Centre County Government, data.pa.gov, Esri, TomTom, Garmin, SafeGraph, METI/NASA, USGS, EPA, NPS, USDA, USFWS | MRLC.gov

Figure 3, Land cover is varied across each of the transmission lines ROWs [7]*. Transmission lines in figure are denoted by double black lines. NLCD land cover key included.*

Conclusions

The results of this project highlight the critical role of GIS and LiDAR technologies in enhancing vegetation management strategies for utility companies. The calculated risk zones and clustering results suggest that a small but significant portion of the vegetation surrounding transmission lines in Centre County poses a threat to power infrastructure, with higher risks identified near the 115kV line. The larger area of high-risk zones within the 115kV ROW could be a result of less frequent maintenance compared to the 230kV line, as it operates at a lower voltage. Normalizing the number of clusters by the transmission line distance provided an objective measure of risk density, with the 115kV line exhibiting a higher cluster density (0.00142) compared to the 230kV line (0.00109). Despite this, the cluster density values between the two transmission lines are very similar. This may indicate that the 230kV line experiences a higher variability of risk along its path compared to the 115kV line. The surrounding land cover may explain this phenomenon; the 230kV transmission line crosses a more diverse area of land cover, as seen in Figure 3[7]. Furthermore, increased diversity often leads to greater variation in risk levels because different land cover types can significantly impact risk factors. For example, hay fields or other crops pose little to no risk to transmission lines, but dense forests may pose higher risks. Figure 4 demonstrates this concept; the regions where the 230kV transmission line crosses through developed areas and cropland have fewer high risk clusters associated with them. A higher number of larger clusters are present in the deciduous forest. Additionally, the land along the 115kV transmission line is more forested than the land the 230kV line runs through. This could explain why the 115kV line experiences higher risk from vegetation.

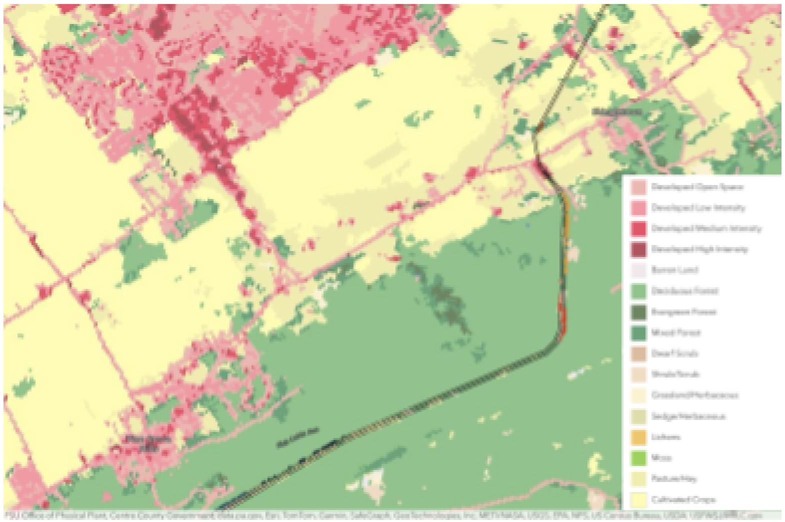


Figure 4, 230kV transmission line clustering analysis and 2019 NLCD Land Cover map in one part of Centre County, PA[7].

Overall, this GIS-based analysis of vegetative risk has revealed significant insights into the spatial variability of risk across Centre County, PA. The analysis highlights how GIS can effectively capture and analyze spatial variations in risk by integrating different data sources and employing advanced spatial analysis techniques. The ability to detect and map risk areas without physically being present provides a unique opportunity to cut back on the high costs associated with vegetation management across utility corridors[5]. By leveraging remote sensing and GIS technologies, utility companies can better anticipate and address risk factors, leading to more robust and reliable service.

References

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Transmission Line Prep Code:
https://colab.research.google.com/drive/17tzLFuoaOJl5964hh9Y2vobXEvZD2m69?usp=drive_link

Risk Analysis Code:
https://drive.google.com/file/d/1hLY1eaO8KDLy89VM35ub0pgUlIDDfSLB/view?usp=drive_link

Experience Builder

Transmission Line Vegetative Risk Assessment (arcgis.com)