Understanding the past, present and future of vegetation risks on a bushfire prone electricity network with geospatial analysis

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Abstract

Endeavour Energy and NM Group have worked together to understand the dynamics of vegetation on this large, dispersed electricity distribution network. The innovative project used spatial analysis and sophisticated model building to combine multi-temporal LiDAR data with a dozen other sources including historical meteorology, vegetation work patterns and actual observations of tree fall. Cloud processing enabled the massive processing of these datasets and the creation of localised models which described where vegetation was situated, how fast it was growing towards lines and the potential hazards posed by individual trees based on a predictive index. The results enabled the improved targeting of ongoing inspection, trimming and tree removal works and ultimately help minimise cost and better manage network risks.

Introduction/Rationale

Fire history in Australia

The history of fire in Australia exceeds 40,000 years. The aboriginal people were our first Fire Ecologists, routinely harnessing continual low intensity, small fires to encourage new growth, attract game for hunting and clear dense vegetation difficult to traverse. This practice resulted in a diverse mosaic of vegetation and fuel ages across the landscape making larger scale, non-intentional, intense bushfires rare. Since the European settlement of Australia in 1788 the shift in focus to fire prevention has resulted in lower diversity, higher fuel load forests and grasslands which are much more at risk of catastrophic fires. The impacts of post European settlement has compounded pockets of refugia, landlocking communities placing them at significant risk from the consequences of a catastrophic fire event. Today, on average 84 homes are lost to bush fires each year (McAneney 2005) and a 2007 study by the CSIRO found evidence that climate change will lead to increases in very high and extreme fire danger rating days and earlier onset of the fire season.

Fire risk in NSW

In New South Wales specifically, studies have projected that the probability of extreme fire risk will increase by around 25% by 2050, and this is under the better case relatively low emissions scenarios (Pitman et al., 2005). This is a troubling concept for NSW electricity utilities, especially when DNSPs have begun to face class action lawsuits following devastating fires involving their network infrastructure (2009 Victoria Black Saturday Fires and 2013 NSW Springwood/Mt Victoria Fires). Endeavour Energy are one such NSW utility facing this challenge to manage changing land use practices, increasing environmental pressures and the momentum of litigation. Endeavour has around 12,000km of overhead powerlines running through high bushfire risk areas and manages this threat alongside powering some of the fastest growing regional economies in Australia, keeping the communities they serve safe.

Internal drivers at Endeavour

In addition to these external drivers, Endeavour Energy have also undergone a change in ownership which has resulted in a push towards contract renovation. This involves moving away from large area maintenance contracts and moving more towards risk-based unit rate contract development and a preventative vegetation management program, requiring sophisticated multidimensional business intelligence. Though Endeavour undertake yearly LiDAR inspections of the high bushfire risk portions of their network to identify vegetation growing too close to or overhanging the line, they see the value in using multitemporal data to begin to track trends and, at a higher level, better understand the distribution of vegetation risk around the network.

A collaborative project

To address these enduring challenges, Endeavour chose to undertake a project alongside NM Group, an electrical network technology service company. NM Group had recently finished an innovative two year research project modelling vegetation and the associated risks around electricity networks, with Durham University in the UK. The company was also looking to collaborate with a forward-looking business such as Endeavour Energy to bring these academically proven techniques in a real-world setting. The ethos behind this research and the subsequent commercialisation activity was to try and give a holistic multi-year picture of vegetation threats to an electrical network. The idea was to move beyond a single snapshot of the network, derived from a lidar survey which only tells you what the status is right now – just identifying defects. NM Group wanted to be able to say how will that status change going forward and what can be done proactively manage future issues – under a cost efficient, justifiable, risk-based approach.

Defining the project

The project was jointly devised encompassing the pre-summer bushfire inspection (PSBI) areas of the network and using the available LiDAR data and vegetation management records alongside third-party soil, weather and vegetation information. Endeavor Energy would hope to achieve:

- A physical delineation and quantification of the utility forest surrounding the network.
- An understanding of the varying rate of growth of vegetation towards conductors across the network.
- An understanding of the trees that have the potential to impact the line when fallen and which of these are most likely to fall based on known hazard tree locations, senescence and historic tree fall patterns.
- Ensuring results are integrated with the Endeavour Energy standard risk matrices of likelihood and consequence.

These objectives, when realised, would provide the network operator with a means to perform risk versus investment scenario planning, optimise inspection cycle lengths, target hazard tree removals and ask questions of their network they hadn’t envisioned before having the data available to do so.

Methods

Desktop preparation

NM Group had a significant exercise to undertake in order to collate and process the numerous data sets from multiple sources, which had been collected over 2-3 years. As the LiDAR data had been provided by different vendors, NM Group began with standardising the multi-temporal LiDAR data to a common classification schema and ensuring relative alignment between datasets. This enabled each object within the point cloud to be assigned the same classification ‘code’ year on year, allowing these datasets to be further processed through the same software. Furthermore, ensuring alignment between datasets ensured that any differences did not influence the growth rate calculations. There was also an exercise to understand exactly how much of the network had been captured each year. It seemed that the scope for the PBSI areas may have changed year on year as the network and risk profiles changed, and so understanding where it was and was not possible to track trends due to data availability was a vital step.

Field work

Outside of the office, NM Group conducted an extensive field campaign which involved visiting 43 individual sites around the network. Covering a representative sample of the forest types within the PSBI areas, a field team collected allometric measurements and observations from over 400 trees. This provided a rich field dataset from which models could be developed from the LiDAR data to extrapolate these measurements to the remaining trees not included in the field survey.

Assessing patterns of tree fall

Both in the field and using a desk-based inspection of the LiDAR data, NM Group pinpointed the location of tens of thousands of fallen trees and recorded tree allometric measurements where the trees still lay in situ. Using the principle that by analysing and understanding patterns of past tree fall we can begin to look at areas at higher risk of tree fall in the future, this provided one half of the dataset NM Group used during a machine learning process to identify vegetation, soil, terrain and weather scenarios most likely to contain tree fall hazards. The other half of this dataset came from identifying standing trees in the LiDAR data. Due to the volume of data and tight project timescales, data processing was undertaken using NM Group proprietary software operating on AWS. This string of processes amalgamated the Endeavour Energy GIS spans dataset to generate operational bays, assign measures of distance to vegetation and potential fall hazards each year whilst matching, where possible, field records of cutting locations to these bays. This process also facilitated the delineation of the LiDAR point cloud into individual canopy objects, providing a representation of the utility forest, and the generation of forest structure and terrain raster layers, utilising the weather information from the Australian BOM for modelling vegetation wind exposure (see figure 1). This information was joined to both canopy objects and bays and allowed a detailed understanding of conditions at the tree level and also generalised to a bay.

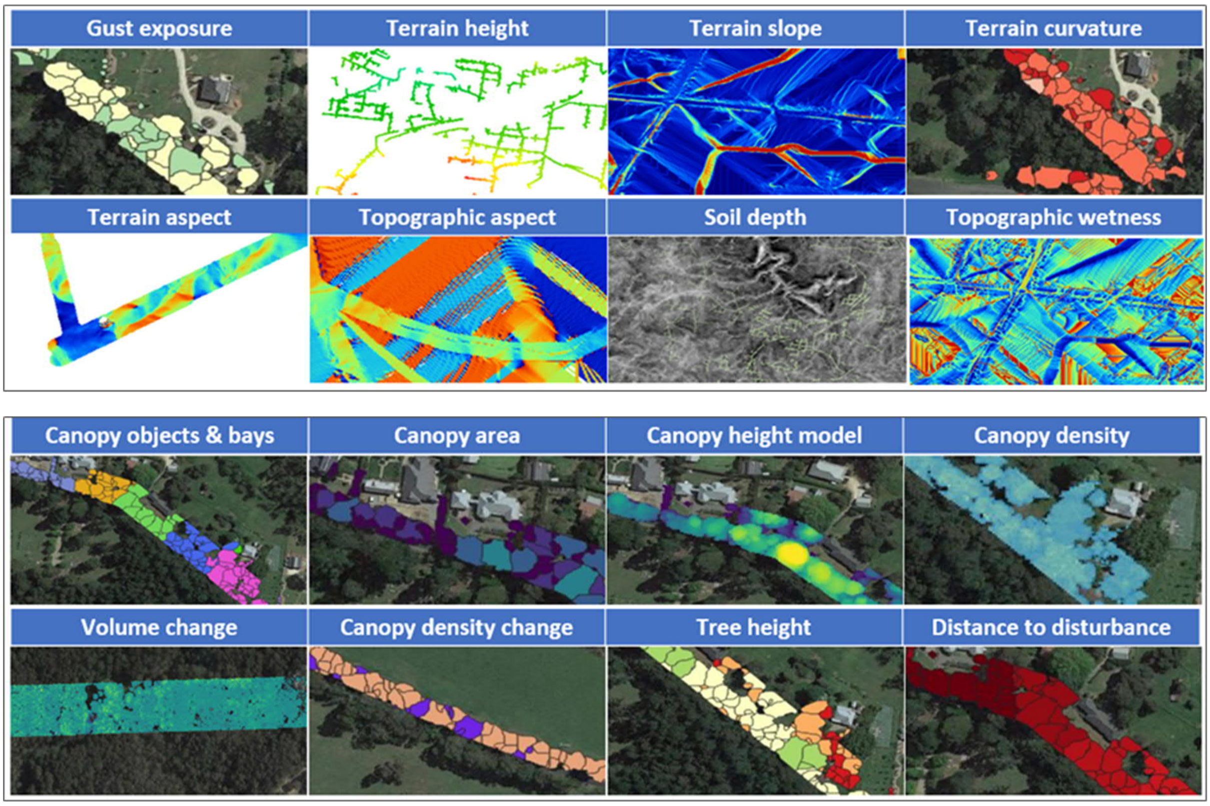

Figure 1: An example of some of the input layers generated for the analysis model

Generating growth estimates

By having cutting activities and multiple years of measurements between wires and vegetation linked to a bay, along with the exact dates of LiDAR survey, NM Group could begin to develop an understanding of the rate of vegetation growth towards the wires. One of the main difficulties of this process was the discrepancy between the precision of the LiDAR data and the spatial precision and detail included with the cutting records. Often it was unclear which spans the cutting records were referencing, what management practice took place and when this took place within a three-month timespan. In addition there may have been untracked changes to the vegetation, perhaps not carried out by a utility arborist. This inevitably will lead to inaccuracies in the modelled growth rates, but it is hoped that with easier conflation of more detailed field records and with further years of LiDAR data this process and the associated results can only improve. For this project, the team identified the general distribution of growth rates and highlighted those which did not appear logical. For example, a negative growth rate where no vegetation management has been tracked, or an impossibly large growth rate where vegetation may have been added – and normalised these results.

Project output

This entire process produced a rich GIS database, flexible enough to be queried in a multitude of different ways. It also produced detailed reports on growth and fall-in risk. A key part of the project was iterative field work during processing, where early results were obtained to enable the team to improve the processing methodology and results presentation. This also ensured that at each step the results matched up with the real world conditions.

Results

Statistical findings

Tree count estimates and fall risk estimates stood up to general scrutiny when results were verified in the field. This was done jointly by NM Group and Endeavour Energy as well as independently. Ad-hoc checks looked at clearance, vegetated status, overstrike and hazard tree pattern matches both in the field and in the LiDAR data and showed good general agreement. Through holding back 25% of the fallen and standing tree locations within each depot from the process of building the tree fall pattern modelling, the technical team could use this data to test the accuracy of model by assigning fallen trees the highest fall rating. NM Group analysis showed that the prediction ability of the customised models constructed for each depot was on average 85%. Considering the many diverse factors affecting tree fall which may not be incorporated into our modelling this was a particularly good result. The reproducibility of a high accuracy rate for each depot reinforced the idea that this was an effective methodology, and the analysis of future tree fall will only further clarify this, as well as improve future modelling.

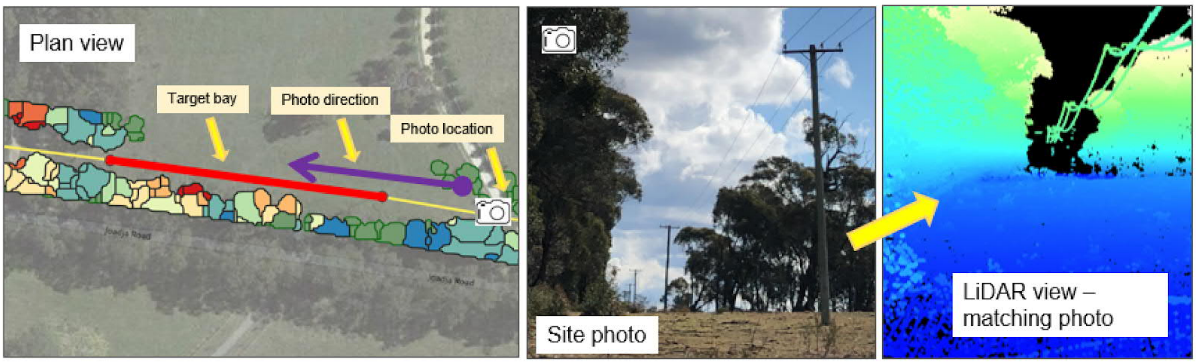

Figure 2: Ad-hoc checks looked at clearance, vegetated status, overstrike and hazard tree pattern matches – showing good general agreement.

Reporting

The reports and GIS database generated from the project were able to provide guidance to Endeavour Energy on rates of growth in the entire scoping area. This provided a very granular breakdown on historical patterns of growth rate span and what this meant across the next five years. The reports were also able to provide guidance on individual trees in terms of the relationship of that tree to the nearby span – including its ability to fall into line, the size of the overstrike in the ranked likelihood of the tree to fall.

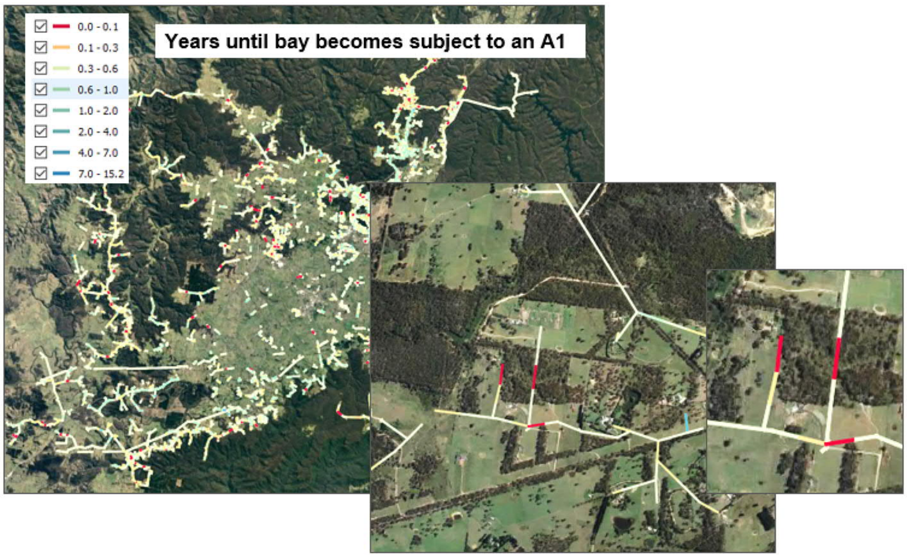

Figure 3: An example of outputs pertaining to the rate of growth of trees within individual spans

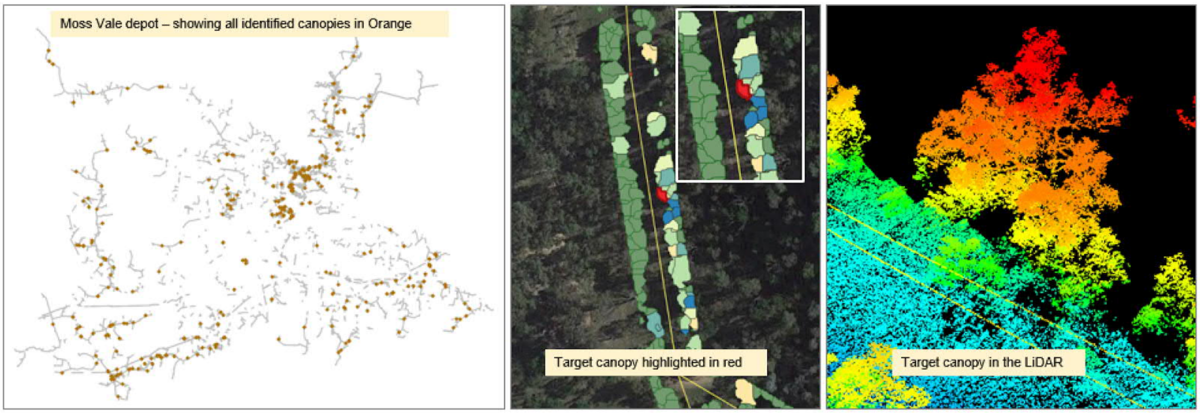

Figure 4: An example of a depot wide assessment of potential hazard trees showing a highly ranked as a tree in red, both in the GIS format and the lidar.

Despite difficulties with conflating multiple datasets from different stakeholders, when comparing these estimates to full network scoping undertaken by Endeavour Energy's utility arborist contractor undertaken as part of general vegetation management activities, there was robust correlation (see figure 5). The amount of noise around the distribution is to be expected and may be due to a combination of difficulties such as matching scoping information to bays or vegetation management since most recent LiDAR survey.

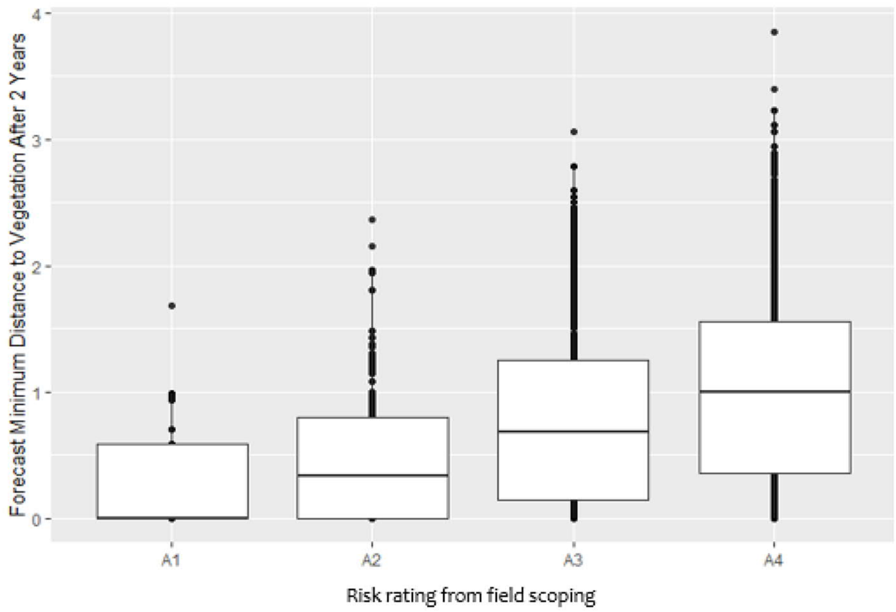

Figure 5: A statistical assessment across the entire depot comparing field scoping results with a prediction made from two-year-old data. The

Conclusions

This project has let us demonstrate that existing datasets, from lidar through to tree trimming records, can be used to design a risk-based vegetation management program. It is anticipated that the reporting outputs will enable Endeavour energy to make meaningful savings in operational expenditure while simultaneously reducing vegetation exposure. For example, the risk ranking of potential hazard trees enables better targeting of scarce specialist resources to conduct follow-up inspections as well as the identification of trees which may have otherwise been overlooked. The projection of span growth rates should enable the design of approved vegetation trimming cycles, which can help avoid over and under servicing adjacent vegetation.

Next steps

Now we are confident in the outputs and their accuracy, we will aim to further extend the technical capabilities of the approach. This will look to further increase the accuracy and also integrate the results to existing systems and processes. Technically we will continue to explore refinements such as the directional fall hazard trees linking predictions to near-term climate data and the introduction of species information.

Lessons

There have been a number of useful lessons learned during the study. The first is a very collaborative approach needs to be taken in the design and implementation of a data driven vegetation management program. There are many unique challenges associated with the changing of a major practice as well as many nuances of interpretation on areas such as risk assessment, reporting and language. The second lesson is that the approach benefits from consistent, quality input data and accurate asset descriptions. This particularly relates to the GIS outputs and asset system exports. The team has also determined that the existence of an attributed 3D network model will significantly add to accuracy and efficient process integration.

Moving forward, the wider project team will continue to expound the rollout of the technology to the non-bushfire parts of the network and improve the way in which the data can be ingested, integrated and shared.

References

Pitman et al. 2005
http://faculty.fortlewis.edu/korb_j/global%20fire/climate%20change%20australia.pdf

CSIRO (2007). "Bushfire Weather in Southeast Australia Recent Trends and Projected Climate Change Impacts"