Tree Risk Evaluation Environment for Failure and Limb Loss (TREEFALL): Predicting tree failure within proximity of infrastructure on an individual tree scale.

Gullick D.*[1], Blackburn A.†[1], Whyatt D.‡[1], Vopenka P.§[3] and Abbatt J.¶[2]

[1]Lancaster Environment Center, Lancaster University
[2]RSK ADAS Ltd, Preston
[3]Faculty of Forestry and Wood Sciences, Czech University of Life Sciences, Prague, Czech Republic

January 13, 2017

Summary

Many key infrastructure providers consider proximity based forestry management a key part of maintenance. In many cases tree failures have a direct negative effect both on the infrastructure's continued functionality, and also financially due to increased compensation claims. Direct tree assessment to preemptively diagnose and remove 'risky' trees by a qualified arborist is expensive, subjective and impractical for the continued monitoring of millions of trees within proximity to critical infrastructures. Therefore, we introduce TREEFALL as a non-subjective, quantifiable, and repeatable model that works on a per-tree basis to support relevant decision makers. It builds on a set of well tested and referenced models and its large scale functionality is demonstrated with a focus on power lines as a key infrastructure, however it is generalisable to others. The case study shows how TREEFALL can be used to support key decision makers by suggesting priorities for human surveyors, and 'weak' points in the infrastructure.

KEYWORDS: Tree failure, Wind-throw, Spatial Model Framework, Integrated assessment, Infrastructure, Decision support.

*d.gullick@lancaster.ac.uk
†alan.blackburn@lancaster.ac.uk
‡d.whyatt@lancaster.ac.uk
§vopenka@gmail.com
¶jon.abbatt@adas.co.uk

1 Introduction and Background

Tree failure is an area of particular interest to the research community - with wind storms being one of the primary causes of destruction in forests (Gardiner et al., 2010) . For example, 2009's storm Klaus resulted in the loss of 43 million meters^3 of timber (Colin, Meredieu, Labbé, Belouard, & Batifol, 2010). Indeed, with the changing climate even stronger wind storms are expected (Della-Marta & Pinto, 2009). For many forestry applications, the proper estimation and prevention of tree failure results in reduced timber loss in such events. As a direct result of this need, a number of models exist within the community to perform such calculations on tree stands; HWIND (H. Peltola, Kellomäki, Väisänen, & Ikonen, 1999), GALES (Gardiner, Peltola, & Kellomäki, 2000), FOREOLE (Ancelin, Courbaud, & Fourcaud, 2004), and are similar in the way they each work (H. M. Peltola, 2006). However, the losses experienced in the case of tree failure is not limited to just the monetary value of the timber; the area surrounding the tree will experience localised effects of tree loss such as water-logging, ground destabilisation, reduced weather protection and many more. In addition to the environmental impacts, trees within proximity to critical infrastructure (such as power lines, rail, or road) also pose a potential risk of damage to, or blocking of the infrastructure. This financially damages the providers in multiple ways: it requires the removal of the tree(s), the repair of any damage caused, and the costs incurred from increased compensation claims.
As the size of these infrastructure grows over time, it is becoming apparent that traditional approaches alone, such as employing experienced arborists, are costly, and impractical for the continued assessment and monitoring of such large numbers of trees. As a result, such infrastructure providers are looking towards technology and modelling to help concentrate their efforts in key areas. This problem is unique in the way that infrastructure is the focus, rather than trees. Interestingly, this means using a stand of trees as the unit of analysis is no longer suitable: many trees within the stand (especially in the middle) are physically too far away from infrastructure to cause damage, whereas trees near the edge of the stand are more likely to be within proximity to critical infrastructure. With this uneven distribution of risk throughout the stand, a more apt unit of assessment would be a single tree, the lack of such has been argued as a weakness of existing models (Gardiner et al., 2008). This project, Tree Risk Evaluation Environment for Failure and Limb Loss (TREEFALL) aims to address both of these issues within one tool - it acts as a repeatable, non-subjective model for assessing the risk of failing trees to critical infrastructure, on a *per-tree* basis. What this model does not do is aim to replace the skills and experience of trained arborists - it instead calculates a value of risk based upon a number existing peer-reviewed models as a way to aid decision makers prioritise the use of human assessors.

2 The model

The TREEFALL model data flow is shown in Figure 1. It collects three categories of data as inputs; firstly, data pertaining to wind calculations (shown top left) which consist of long term wind averages available from Met Office Integrated Data Archive System (MIDAS), observed and predicted weather data collected from approximately 170 Met stations across the UK, a Digital Terrain Map (DTM) of the UK at 50m resolution, and a Landcover map for the same area; secondly, data pertaining to tree calculations (shown top right) which consist of tree locations, heights and crown areas described within the National Tree Map (NTM) dataset provided by our project partner, BlueSky; and finally a dataset describing the spatial characteristics of the infrastructure in question - which can be lines, points or polygon features.

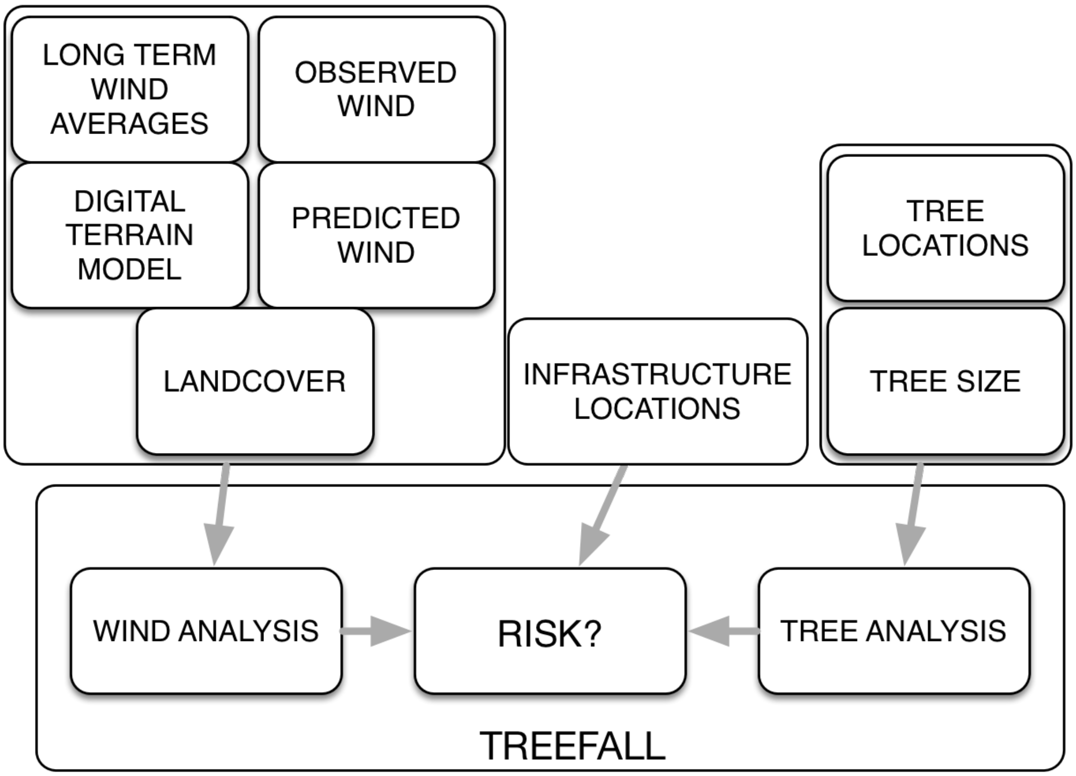

Figure 1: A diagram showing the flow of information in treefall.

The data from these is then grouped and processed by type. The wind and land data is used to build high resolution wind model of the UK (down to 10m) which takes into account wind characteristics caused by surface roughness. The data pertaining to trees is used to construct a map of trees - and to evaluate the protection from wind effects that trees may offer by sheilding them from the weather. These two datasets are then used to calculate risk by asking; 'what is the predicted wind at the tree top?' and 'what speed of wind do the academic models predict failure, given the trees properties, and the sheilding offered to it by other trees?'. A 'risky' tree is identified when the actual wind is greater than the critical wind speed estimated to cause tree failure - and the level of risk is proportional to the difference between the two values. Similarly, that tree is only risky if it can physically hit or block infrastructure when falling. TREEFALL performs a novel 3D collision detection algorithm to calculate the ratio of possible failures that collide with infrastructure. This value, ranging between 0 and 1 is then multiplied by the aforementioned risk factor as a combined value for the indication of both risk to windthrow failure, and risk to infrastructure.

3 Real World Usage

TREEFALL focuses on a small number key factors to predict wind throw failure in trees. As such it should not be seen as a tool to predict exactly *when* a tree will fail, but more as a tool that quantifies such risk, targeted at those making forestry based decisions. As such, the whole model is available as a web interface, and designed to be as user friendly as possible. This interface allows the exploration of all discussed datasets (trees, wind, land and infrastructure network). From here a user can load either historical or predicted weather events, or even simulate a hypothetical weather scenario. Once processed, the web interface colours trees using a 'traffic light' colour code: red for risky, and near infrastructure, orange for risky, but cannot hit infrastructure, and green for no risk. Similarly, the 'in-danger' sections of infrastructure are coloured red to indicate risk. These can be seen in Figure 2. It should be noted that whilst the traffic light colours are used in the following figures, additional colour schemes suitable for those with colour-blindness are available within the interface options.

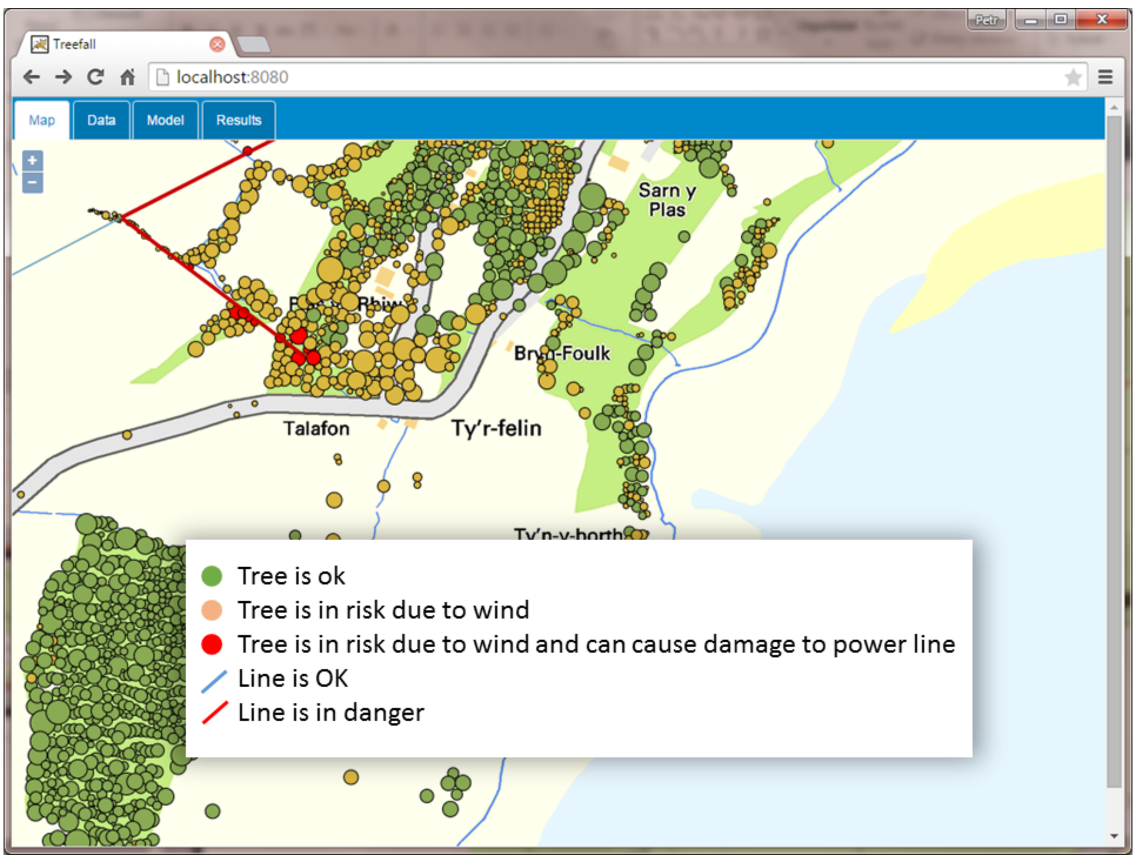

Figure 2: A screenshot of TREEFALL showing web interface, and 'traffic light' risk colouring. Here, powerlines at risk can been seen in red, with those trees posing risk also coloured red.

Whilst useful to gain an overall understanding of the location of 'risky' trees, this model is arguably most helpful when used with scenarios, and then analysed in conjunction with a number of network characteristics. This is possible as the tool allows the export of the predictions in a number of common data formats. For example, Figure 3 shows risky trees from a southerly 20m/s wind classified by quantiles. This might be used to identify high density areas of risky trees to prioritise further tree surveys in person.

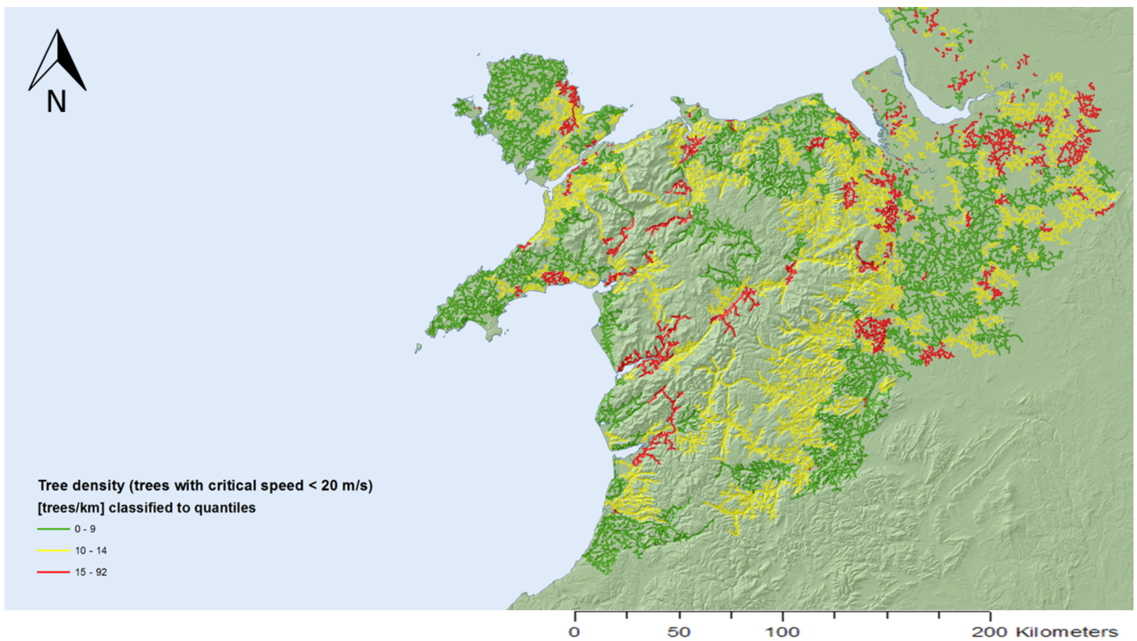

Figure 3: The Lynn Peninsula, network coloured by density of nearby risky trees.

Similarly, there exist a number of other metrics which can be investigated - e.g prioritising those areas of the network that are more important. Whilst TREEFALL's immediate use is fairly self-evident as demonstrated above, the continuation of this work investigates and discusses more complex uses of this risk assessment with focus on critical infrastructures in two example areas - one in north Wales, of roughly 8000 km^2 and and estimated 1.8 million trees[1], and another in southern England of approximately 1,600 km^2, and just over 3 million trees estimated[2].

4 Acknowledgements

We would like to thank NERC for funding this research, and extend our gratitude to our industrial partners.

[1] This dataset only includes trees within 50m of infrastructure, hence the low number of estimated trees.
[2] This dataset has full tree coverage.

5 Biography

David Gullick is a senior research associate working at Lancaster University, UK.

Alan Blackburn is an associate director of the Lancaster Environment Centre, Lancaster University, UK.

Duncan Whyatt is a senior lecturer in GIS at Lancaster University.

Petr Vopenka is a PhD student at the Czech University of Life Sciences, Czech Republic.

Jon Abbatt is the Associate Director and Head of the ADAS Environment group.

References

Ancelin, P., Courbaud, B., & Fourcaud, T. (2004). Development of an individual tree-based mechanical model to predict wind damage within forest stands. *Forest ecology and management*, *203*(1), 101-121.

Colin, A., Meredieu, C., Labbé, T., Belouard, T., & Batifol, S. (2010). Étude rétrospective et mise à jour de la ressource en pin maritime du massif des landes de gascogne après la tempête klaus du 24 janvier 2009.

Della-Marta, P. M., & Pinto, J. G. (2009). Statistical uncertainty of changes in winter storms over the north atlantic and europe in an ensemble of transient climate simulations. *Geophysical Research Letters*, *36*(14).

Gardiner, B., Blennow, K., Carnus, J.-M., Fleischer, P., Ingemarson, F., Landmann, G., ... others (2010). Destructive storms in european forests: past and forthcoming impacts. *Destructive storms in European forests: past and forthcoming impacts*.

Gardiner, B., Byrne, K., Hale, S., Kamimura, K., Mitchell, S. J., Peltola, H., & Ruel, J.-C. (2008). A review of mechanistic modelling of wind damage risk to forests. *Forestry: An International Journal of Forest Research*, *81*(3), 447. doi: 10.1093/forestry/cpn022

Gardiner, B., Peltola, H., & Kellomäki, S. (2000). Comparison of two models for predicting the critical wind speeds required to damage coniferous trees. *Ecological modelling*, *129*(1), 1-23.

Peltola, H., Kellomäki, S., Väisänen, H., & Ikonen, V.-P. (1999). A mechanistic model for assessing the risk of wind and snow damage to single trees and stands of scots pine, norway spruce, and birch. *Canadian Journal of Forest Research*, *29*(6), 647-661.

Peltola, H. M. (2006). Mechanical stability of trees under static loads. *American Journal of Botany*, *93*(10), 1501–1511.