On the factor of safety of urban trees

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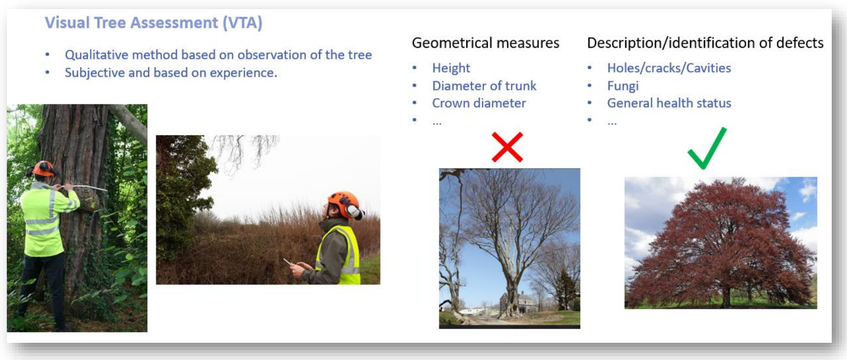
Industry Challenge

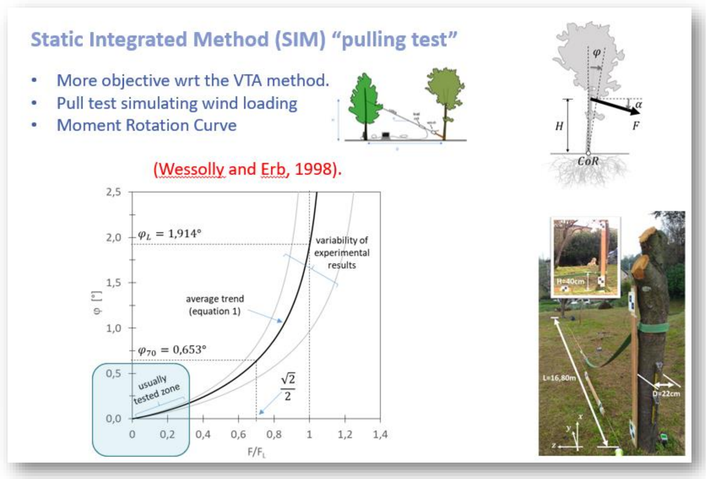
Since the Scottish & UK Governments' manufacturing strategies provide for the implementation and development of infrastructures, in order for local industry to be globally competitive, it is necessary that goods can transit more efficiently.
This did not happen for few weeks after storm Arwen hit the UK. Storm Arwen claimed at least three fatalities and widespread power outages. The damage was compounded by the unusually strong winds coming from the north, a direction the trees were not accustomed to.

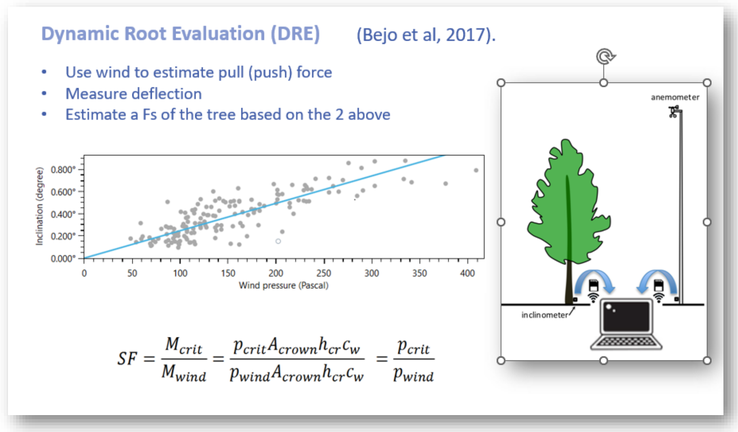
- 80,000 homes and businesses without electricity in for weeks,
- Many people relying on local establishments for food and other services.
- Large sections of overhead lines needing to be rebuilt.
- Cost for insurers in the UK was of the order of hundreds of millions of pounds
- Around eight million trees in Scotland damaged. (A striking example is the Tentsmuir forest, see figure 1)

Figure 1. Tentsmiur Forest on April 2022. Thousands of trees uprooted, tons of wood lost, an enormous damage both for landscape and forest business

How strong are trees around me? 3 ways to know:







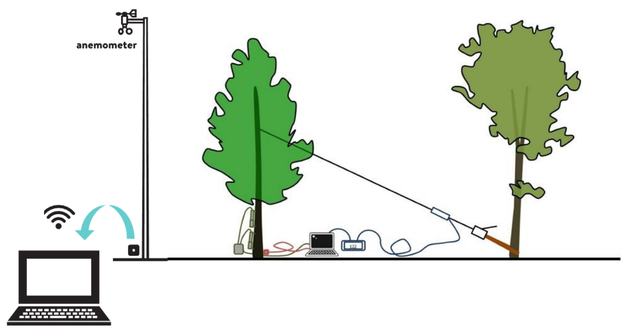
At present, the most accepted method for evaluating the safety and stability of tree roots is the SIM. By applying a bending load on the trunk via a cable attached to the tree.

Proposed Research

By considering a **tree as if it was a civil engineering structure**, mechanical calculations using geotechnical engineering principles will be used to asses the stability of a tree. It is shown that the typical subjective visual inspection approaches are not suitable to quantify tree safety and that more mechanistic approaches are more suitable. A novel, cheap, efficient and mechanical based approach, is shown to provide reliable factors of safety which are comparable to the time consuming pull-test used in arboriculturally practice.

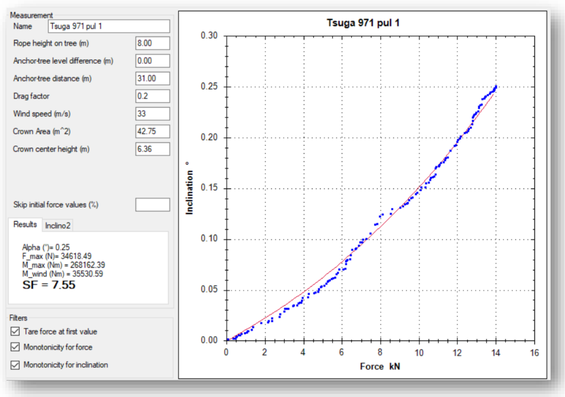
How is this done?

Instrument a set of large trunk tree in very diverse environments
- Preform static pull tests on Dynaroot monitored trees to validate procedure
- Analyse Dynaroot data and perform statistical analysis in order to explore further the existing correlation functions.
- Develop analytical approach that combines geotechnical engineering modelling of soil tree mechanical interaction and machine learning (ML) algorithms to predict tree deflection and tree safety factor using Dynaroot data.

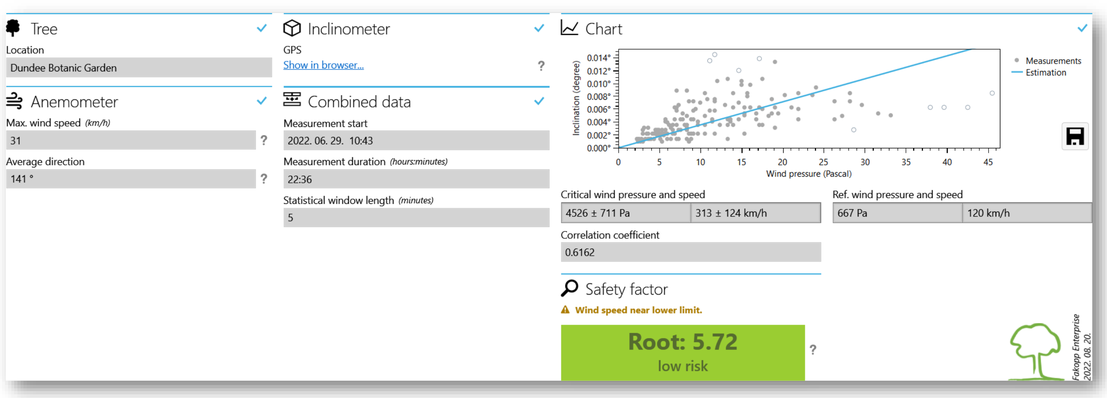


Results

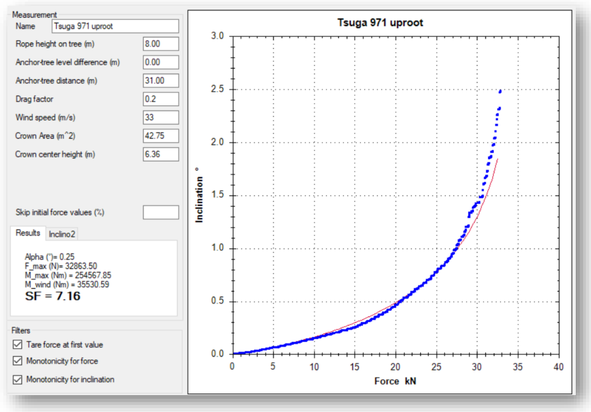
SIM evaluation Fs=7.6



DRE evaluation Fs=5.7



True Fs=7.2



Desired Outcomes / Impacts

It is shown how the factor of safety of a tree can be calculated if treated as a civil engineering structure. Results show that the SIM is suitable to determine the Fs of a tree. The DRE, a novel, cheap and efficient approach not requiring heavy nor hazardous equipment but just wind loading (few hours of wind data required) is shown to provide reliable factors of safety.
- Implementation and use of the DRE by councils, would allow for the creation of hazards maps for trees. This information would be key for making decisions related to tree felling or public space closure before forecasted strong winds.

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