Scenario DOCTORAL TRAINING PARTNERSHIP

NERC SCIENCE OF THE ENVIRONMENT

Understanding Acute Oak Decline using X-ray micro-tomography and leaf reflectance: linking reduced tree water transport capacity to changes in xylem and leaf cellular structure.

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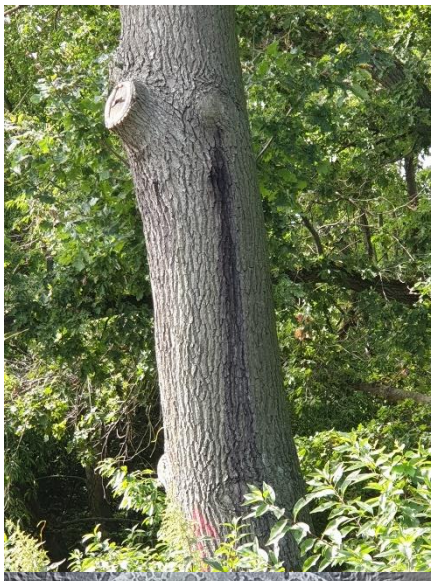

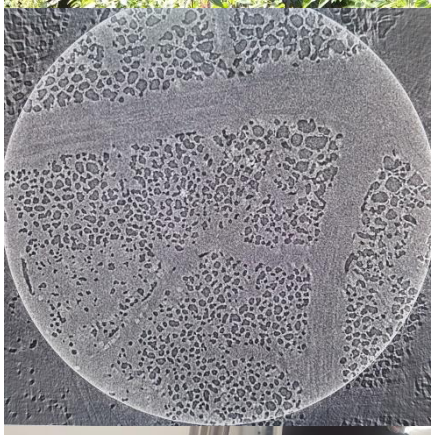

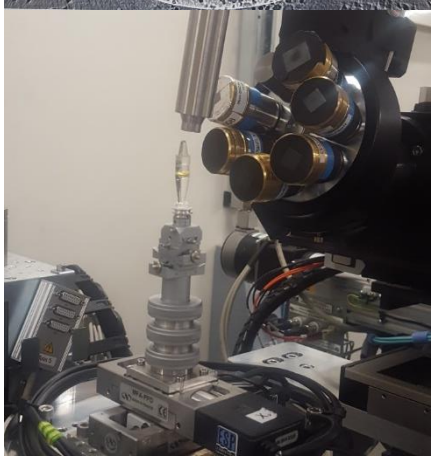

Ecologically important tree species in the UK are facing increased threats from invasive pests and pathogens, spurred on by climate change and globalization. Emerging and aggressive tree diseases, such as Acute Oak Decline, Horse-Chestnut Bleeding Canker and Ash Dieback, have gained considerable public, governmental and scientific attention in recent years.
Acute Oak Decline (AOD) was first recorded in the UK in the early 1900's. Outbreaks of the disease have gone through several historic and distinct episodes with the current, ongoing spread having started around 2002. The disease, however, is poorly understood and described as multi-causal, probably involving both biotic and abiotic drivers. AOD appears to occur in trees over 50 years old and relates to a sudden manifestation within a 5-10 year period that causes high mortality within populations (Denman & Weber 2010). Trees with AOD show symptoms like reduced foliage and black bleeding lesions on trunks, which are colonised by a bacterial consortium (Denman et al 2014). The lesions are thought to be the result from blockages in the water transporting vascular system (xylem) leading to water stress in the canopy and ultimately tree death. In preliminary field work we have been able to identify differences in canopy leaf near-infrared reflectance between trees with and without lesions (https://ieeexplore.ieee.org/abstract/document/8518049). The data also suggests that this difference may be driven by changes in leaf intercellular structure (described as the 'N' parameter in the widely used PROSPECT leaf reflectance model (Jacquemoud & Baret 1990)), which we suspect are due to a lack of water in the leaves caused by the tracheae blockages.

X-ray micro-tomography of leaves can reveal their internal structure, similar to histology but for a full 3-dimensional volume, instead of a single slice. X-ray micro-tomography of xylem can reveal the connectivity of tracheal elements (i.e. water transport). Analyzing the three-dimensional structure of additional parts of the tree (branches, xylem and roots) might allow pinpointing where, if any, structural changes occur that have an impact on the tree's water transport capacity. This knowledge would enable us to better understand AOD than solely based on its symptoms. Using a synchrotron light source like Diamond Light Source enables investigations into a

statistically significant numbers of samples in a matter of hours or days. In addition, the synchrotron enables phase contrast imaging which is much more sensitive to small changes in density and ideally posed to investigate soft matter samples with a very good signal-to-noise ratio.

The project will investigate the cellular structure of leaves and xylem tissue from trunk and branches to establish whether trees affected by AOD show a change in leaf and xylem cell structure that can be linked to a change in the tree's water transport capacity:

1. Analysis of X-ray tomography data of leaves to quantify leaf intracellular structure and attribute the observed difference in leaf near-infrared reflectance to changes in intracellular structure. An initial experiment at the Diamond light source has produced scan data for leaves samples from 8 pairs of symptomatic and asymptomatic trees. After tomographic reconstruction, these will be analysed to determine, among others, mean leaf density, leaf density profile, mean number of intracellular and cellular layers, to find correlations with the leaf reflectance parameter N.
2. Analysis of X-ray micro-tomography data of trunk and branch xylem tissue and of leaves to attribute the changes in leaf intracellular structure to water stress caused by blockages of trachea cells. A new set of trunk, branch and leaf samples will be collected from trees showing a gradient of AOD symptoms (from mild to severe) and prepared for X-ray micro-tomography at the Diamond Light Source. After scanning and tomographic reconstruction, these samples will be analysed to determine and link intracellular and cellular changes of the xylem and leaf samples.
3. Through field based tree water transport observations, establish a link between AOD, a reduction in tree water transport capacity, and cellular changes.

Training opportunities:

The student will be trained in laboratory skills required to develop optimal ways of preparing the leaf and xylem tissue samples for X-ray micro-tomography scanning. The student will also receive specialist training to use the X-ray micro-tomography beam at the Diamond Light Source in Harwell, to analyse the subsequent 3-dimensional tomography imagery and to use the leaf reflectance model PROSPECT.

There will be training in effective experimentation design, with a view on sound statistical principles together with efficient data collection and management. The planning and delivery of field work will enhance skills in project management. The student will have access to some of the generic skills training activities at CEH and Reading, such as statistical methods, big data modelling and analysis tools in R, conference presentation and writing skills, and fieldwork first aid.

Applying for access to beam time at the Diamond Light Source will provide hands on training in proposal writing. Spending time at Diamond Light Source will give the student valuable insight into other X-ray techniques, which will be a valuable asset for the student's later career, as it will enable him/her to look at solutions for problems from a different perspective.

The supervisor team has excellent contacts into Forest Research ,providing opportunities to learn applied aspects of knowledge transfer (to inform forestry practitioners and policy makers of evidence-based research into AOD).

Student profile:

This project would be suitable for students with a degree in ecology or biology with a strong and passionate enthusiasm for scientific research, involving field, lab and computer based work. They must have good interpersonal skills for working within an interdisciplinary team environment. They must also be able to work responsibly on their own initiative in the field. Ideally, the candidate will have strong numerical literacy and have an aptitude for programming (in R). Desirable attributes would be skills in forest/tree science, general botany, plant physiology or image analysis. We would also hope the candidate has good writing and oral presentation skills.

Funding particulars: CASE sponsorship from an industrial partner.

References: Hendry et al. (2005) Information Note FCIN 73* Forestry Commission, Edinburgh**;** Denman & Webber, (2010) *Plant Pathology* 57, 368; Denman et al. (2014) *Forestry* 87, 535-51; Jacquemoud & Baret (1990) Remote Sens. Environ. 34(2), 75-91.