Forest Research

# *Predisposition factors to Oak decline*

## *Links between soil biochemistry with Oak nutrient and health status*

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**Forest Research, UK**

# Acute Oak Decline (AOD) and Chronic Oak Decline

Chronic Oak decline – poor crown development – *Almillaria* – since the 1900

Acute Oak decline syndrome – profuse bleeding extending up to the canopy of the tree since the 1980-1990s

Dried fluid crusted in bark splits

*Agrilus Biguttatus* beetle exit holes associated with stem bleeding

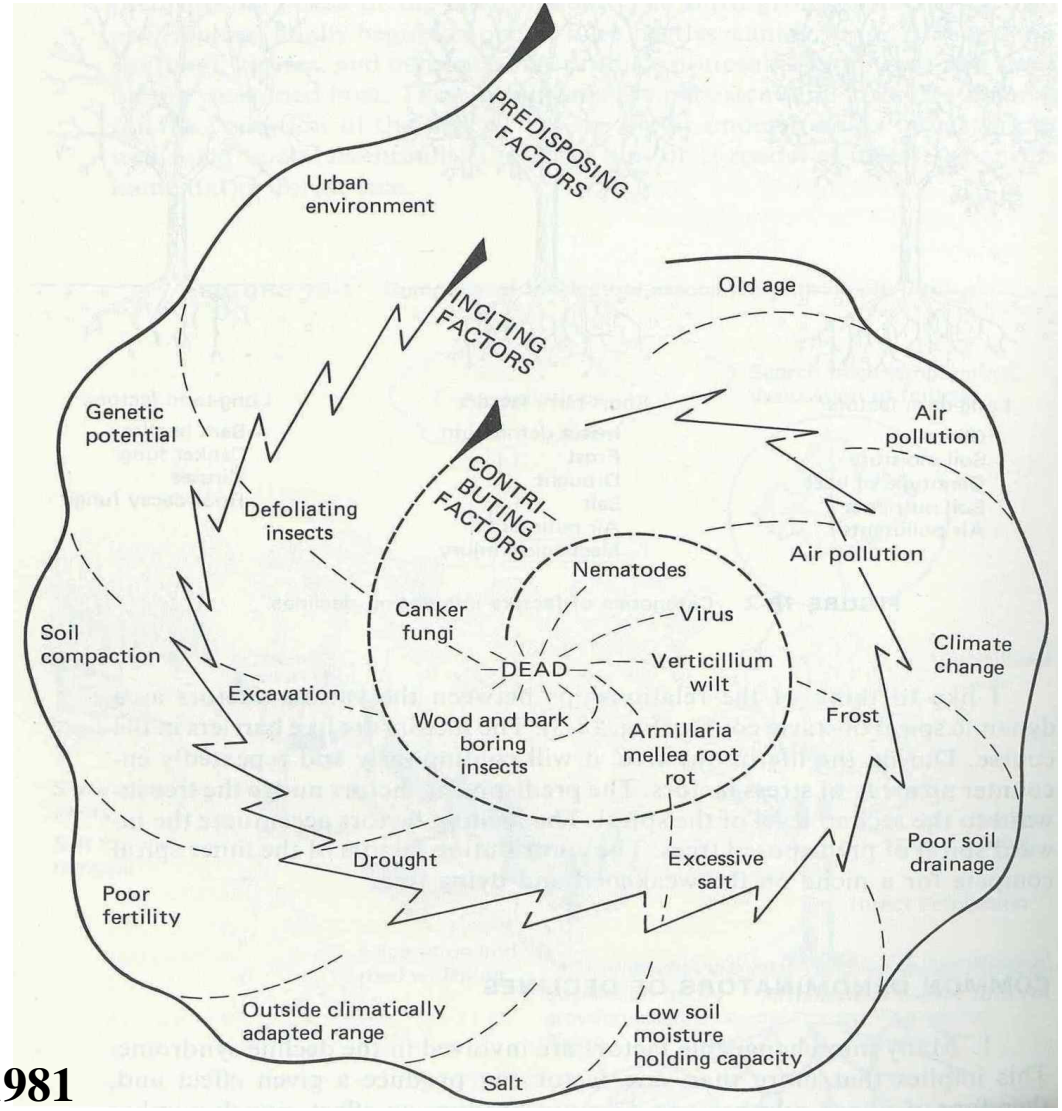
**Oaks – the iconic trees of Britain**

**Pedunculate oak (*Quercus robur*)**

**Sessile oak (*Quercus petraea)***

# Manion Decline Spiral

- **Causes of Decline diseases are multifaceted and multi-staged, developing over various time periods.**
- **Predisposition is fundamental to the onset of Decline, but lacking qualitative and quantitative evidence.**
- **The linkages between Decline factors and host effects are poorly understood**

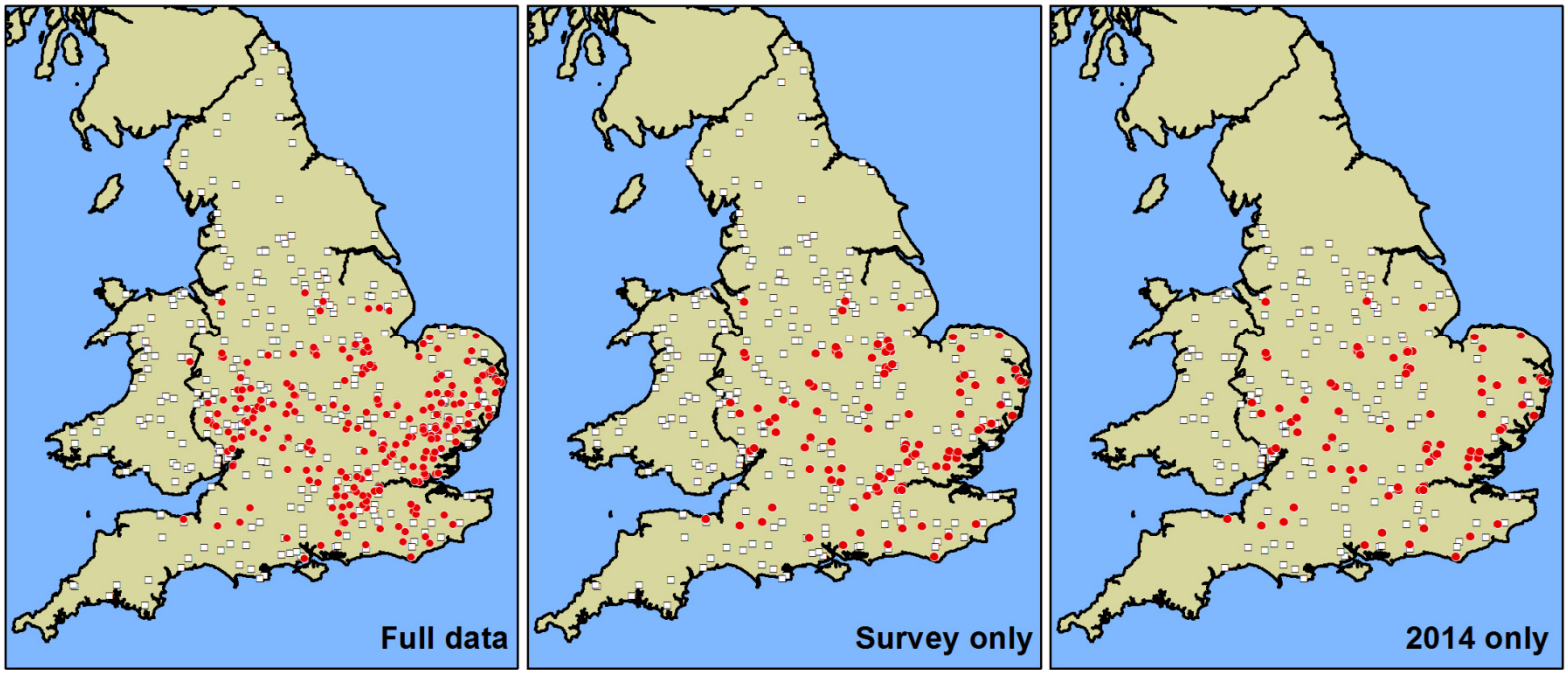



**Decline syndromes -Manion, 1981**

# Acute Oak Decline (AOD) survey sites

- Locations of woodlands used in this study from systematic and citizens surveys.
- AOD positive locations are shown as dark red dots and negative locations are shown as small white squares.
- Datasets used in the spatial modelling.

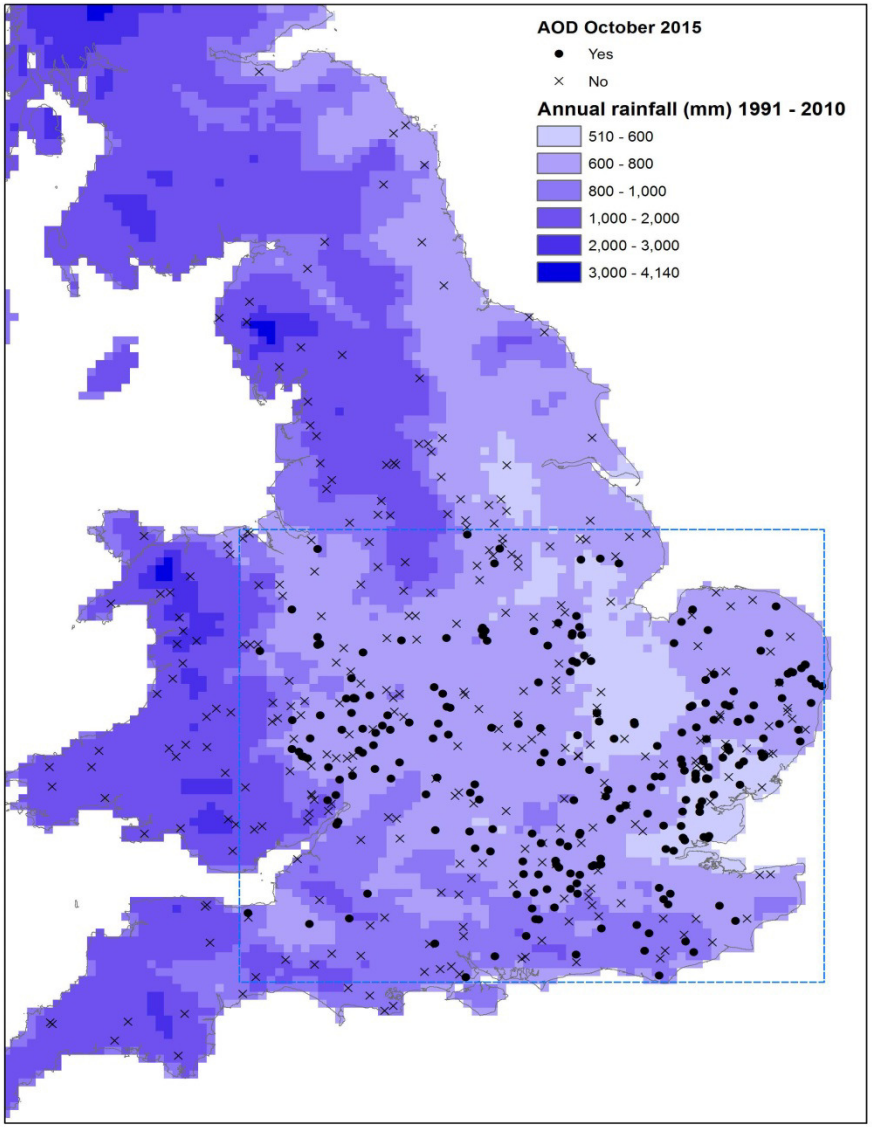
**Full data** n=544;
**Survey only** includes only sightings from survey selected hectads (n=371);
**2014 only** includes only data from the second focused survey (n=253).



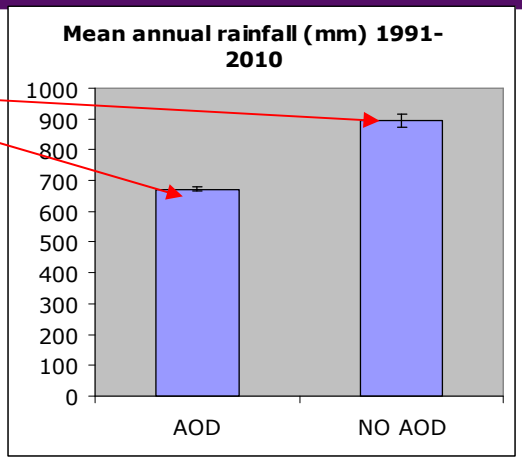
# Spatial datasets used in the study

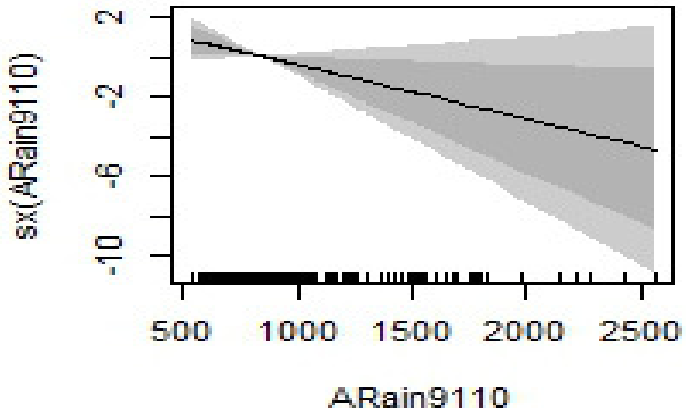
| Dataset | Resolution | Parameters/Description | Source |
|---|---|---|---|
| **Climatic parameters** | 5 km x 5 km grid | mean air temperature, rainfall, sunshine duration, wind speed, growing season length, growing season degree days. | UK Met Office Parry and Hollis (2006) |
| **Day degrees above 11.5 °C** | 5 km x 5 km grid | Calculated in CLIMEX. 11.5 °C corresponds to estimates of the development thresholds for *A. biguttatus* (Reed et al., 2017), using average monthly temperatures (1971-2000). | UK Met Office |
| **Atmospheric deposition** | 5 km x 5 km grid | wet $SO_4$ (non marine sources), dry $SO_2/SO_4$ (non marine sources), wet $NH_4$, wet $NO_3$ dry $NO_2/NO_3$,/$HNO_3$, dry $NH_3/NH_4$, total N, Ca+Mg+K (non marine sources) deposition | (CEH, 2006) |
| **National Soil Map 1: 25,000** | Polygon shapefile | The soils of England and Wales are classified according to the English and Welsh Soil Classification system (Avery, 1980). | (Cranfield University, 2004) |
| **National Forest Inventory woodland map** | Polygon shapefile | The 2013 woodland area map was used to calculate the area of woodland in each National Soil Map sub-type. | (Forestry Commission 2011) |
| **Hydrology of Soil Types (HOST)** | Polygon shapefile | Using the HOST class soils were reclassed as: well drained, seasonally water logged or permanently wet. | (Boorman et. al., 1995) |
| **FC Grand Database** | Woodland habitat and management map | Forestry Commission spatial data of woodland habitat and management supported through grants | (Pyatt, Ray and Fletcher, 2001). |

# Rainfall



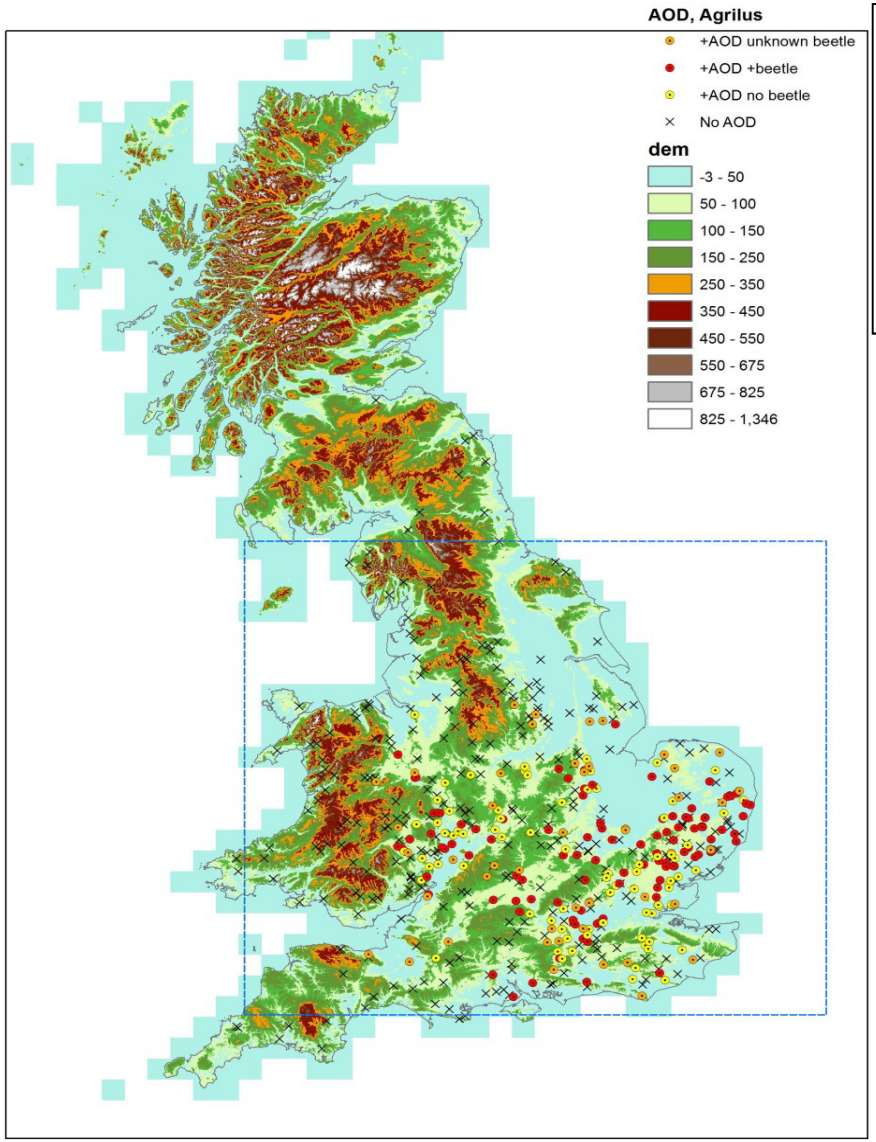

**>200mm rainfall difference in average annual rainfall (1991-2010)**



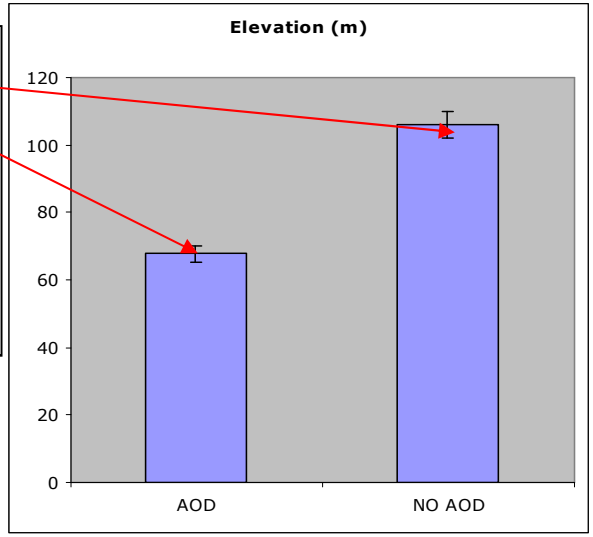



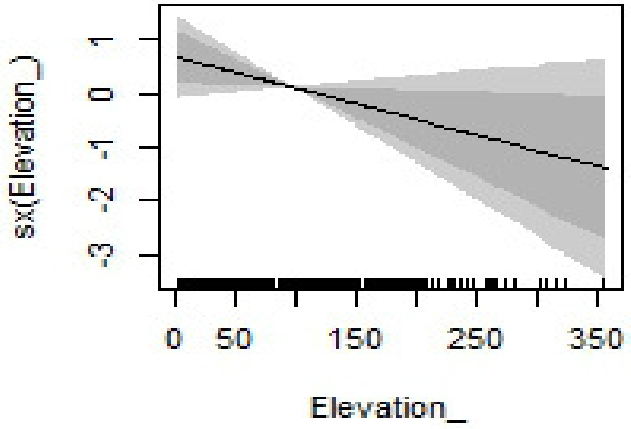

-GAM model with logistic regression,
**-positive = AOD, negative = not,**
-with confidence intervals for the estimate 80% and 95%

# Elevation

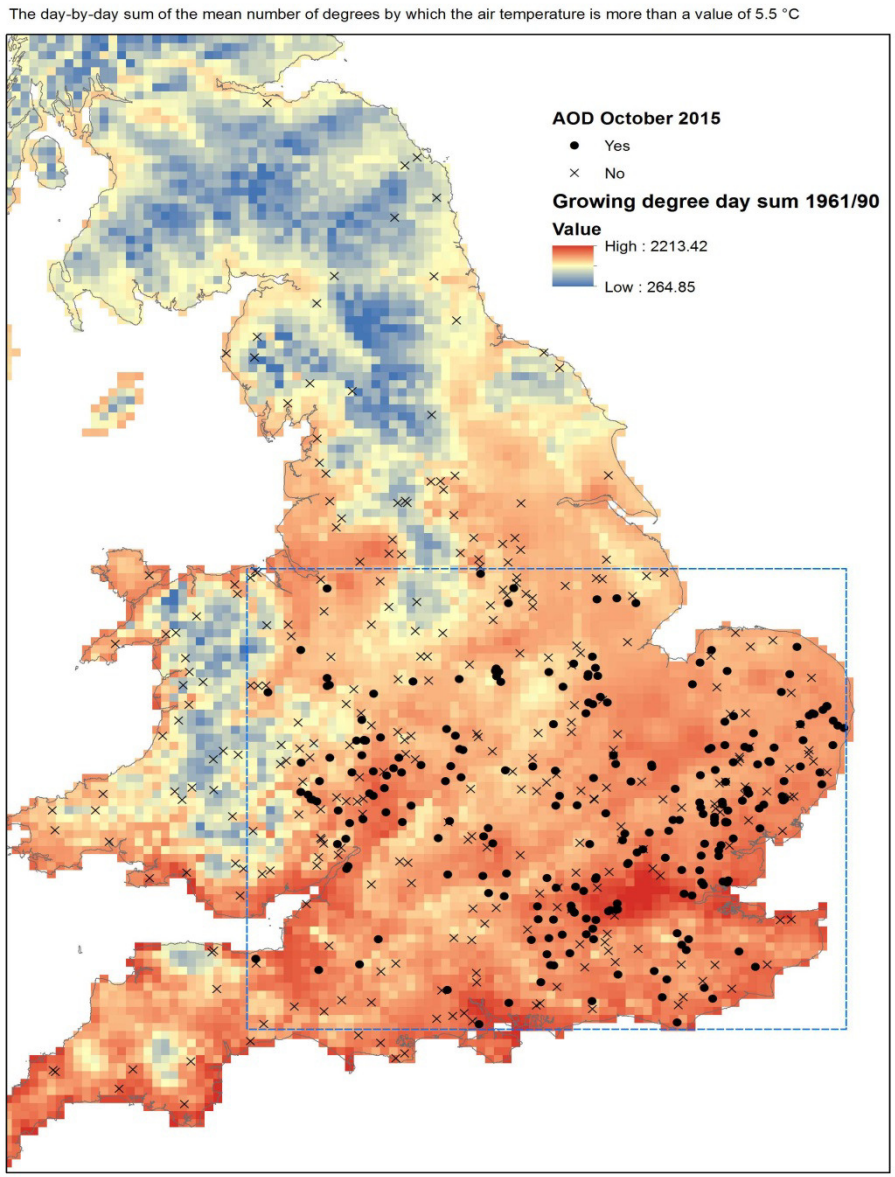



**> 30 m difference in elevation between AOD and NO AOD plots**



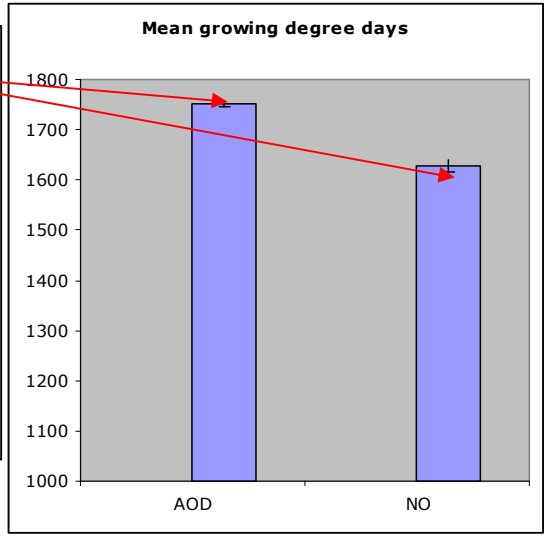



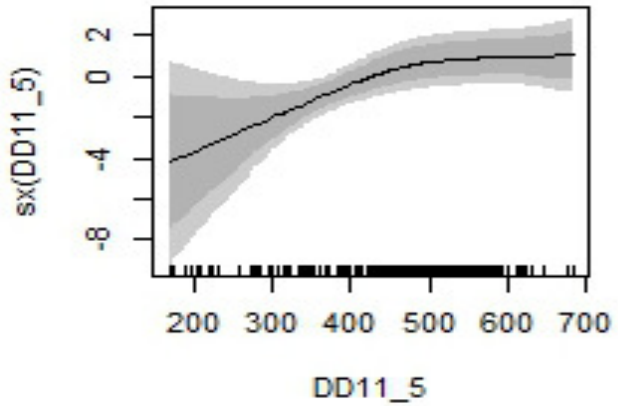

-GAM model with logistic regression,
-**positive = AOD, negative = not,**
-with confidence intervals for the estimate 80% and 95%




**>100 days difference**

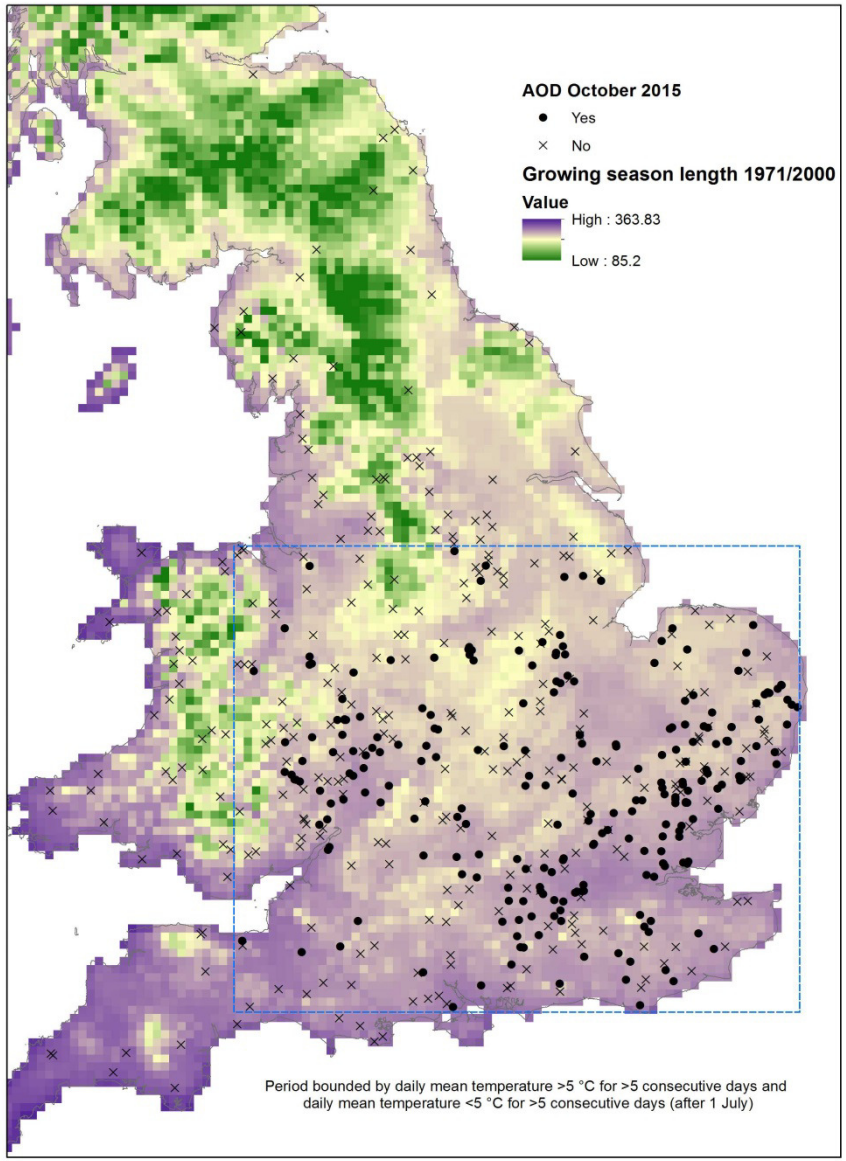
**Temperature effect (mean growing degree days >11.5 C (sum 1961/90)**



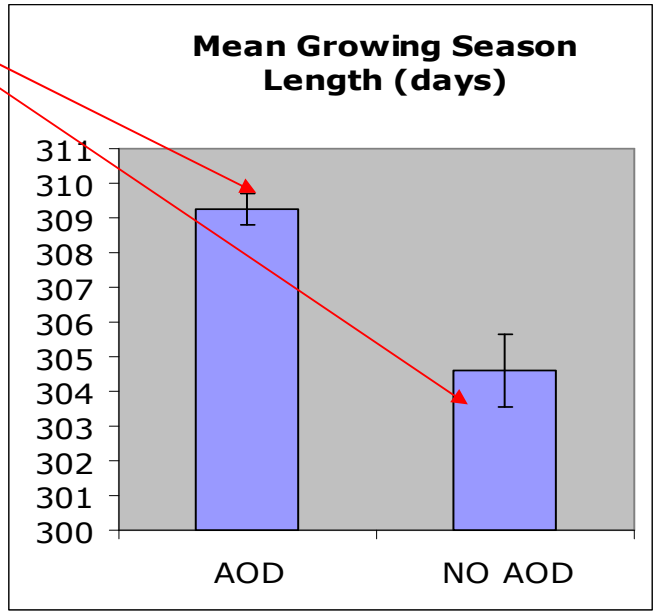




-GAM model with logistic regression,
-positive = AOD, negative = not,
-with confidence intervals for the estimate 80% and 95%

# Growing Season



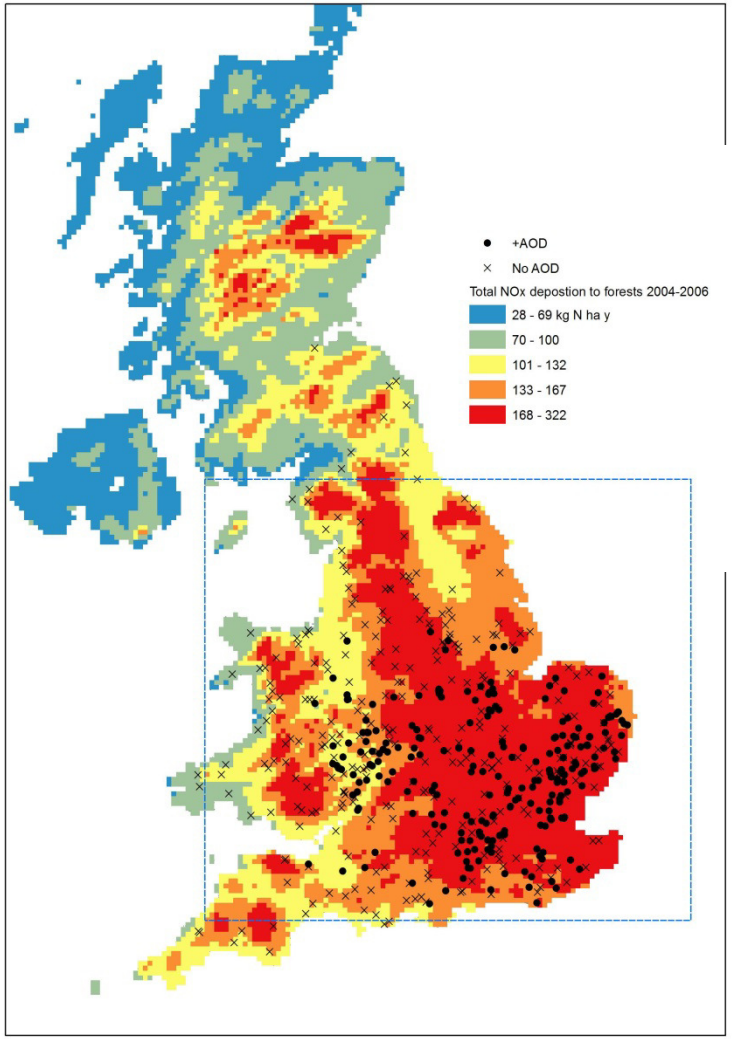

**About 5 days difference (1971-2000) in mean growing season length between AOD and NO AOD plots**



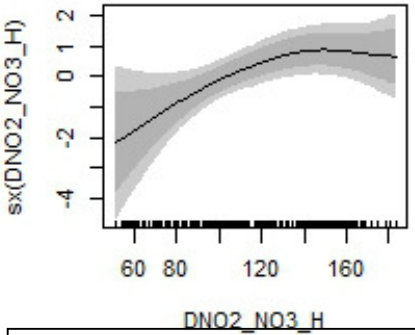

**Links with Temperature effect and likely links with beetles distribution temperature threshold**

**No significant spatial trends found for Growing season length (1971-2000)**

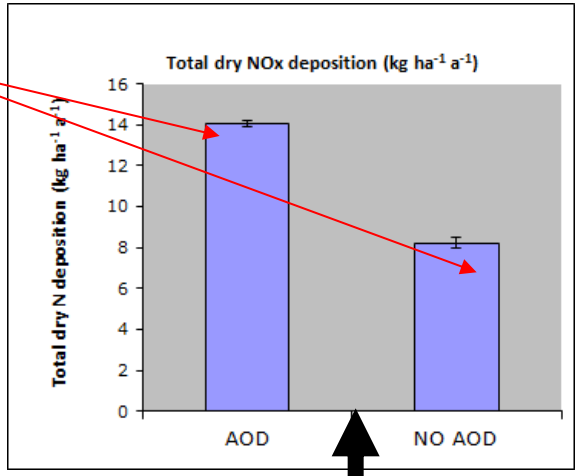
# Nitrogen deposition



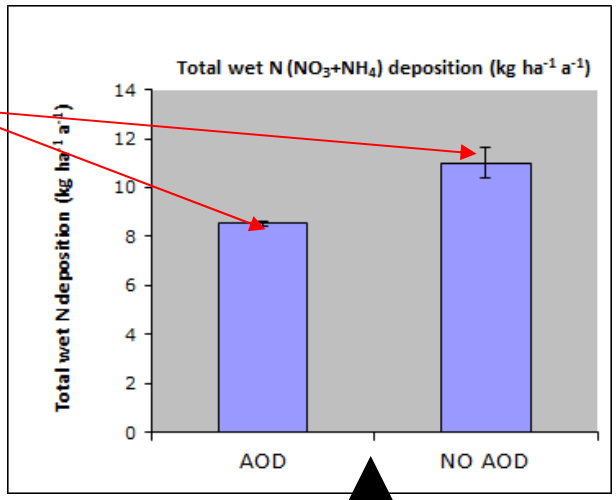

**significant higher (~7kg/ha/a) dry input of $NO_2$, $NO_3$ and H to AOD than NO AOD plots**




**significant lower (~3kg/ha/a) wet input of $NO_3$ and $NH_4$ to AOD than NO AOD plots**

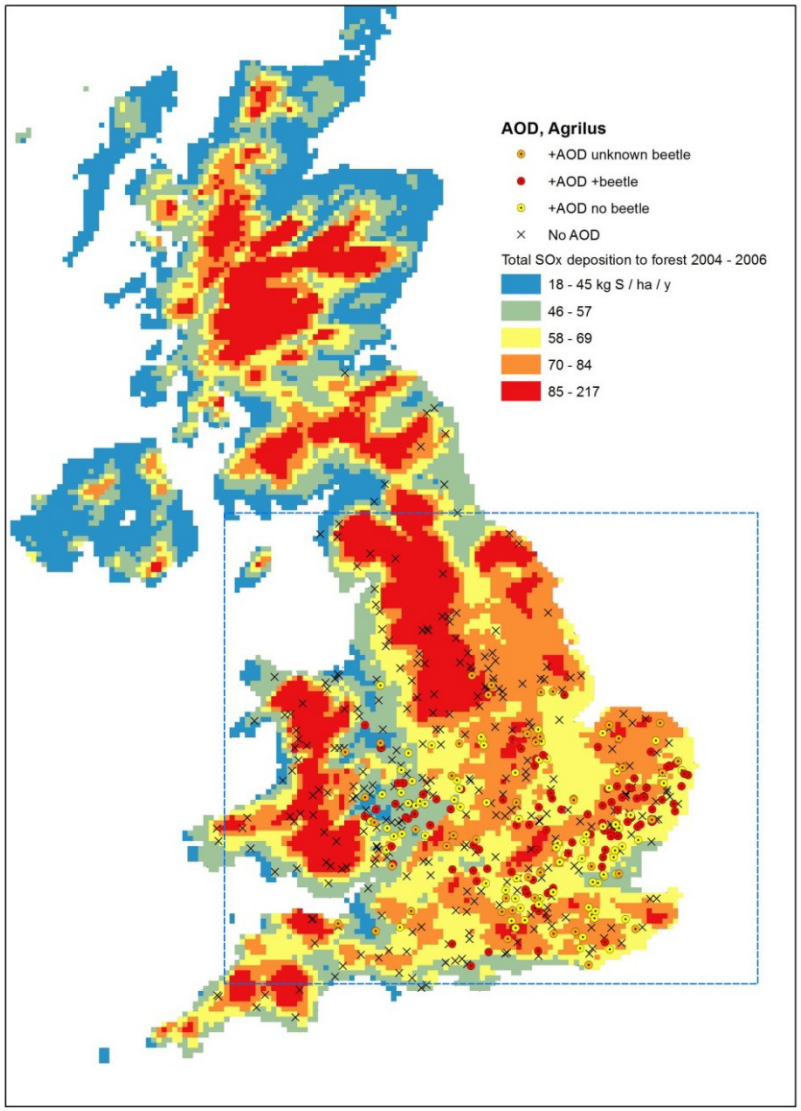



**Effect on tree canopy**

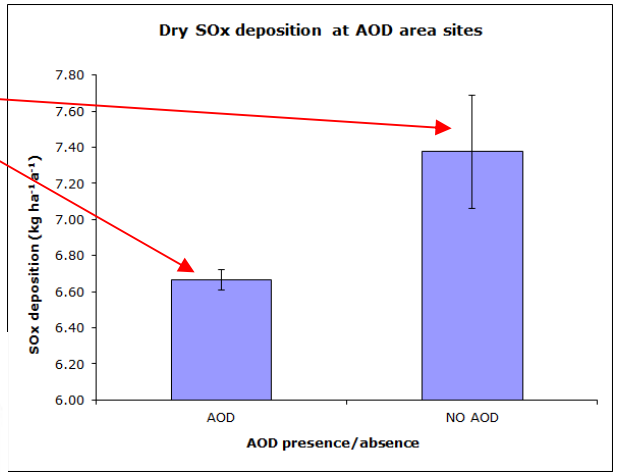


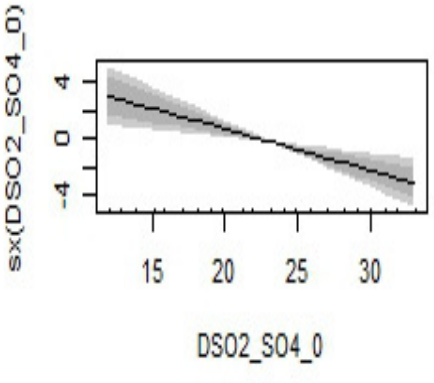

**Effect on tree roots and N uptake**

# Sulphur deposition

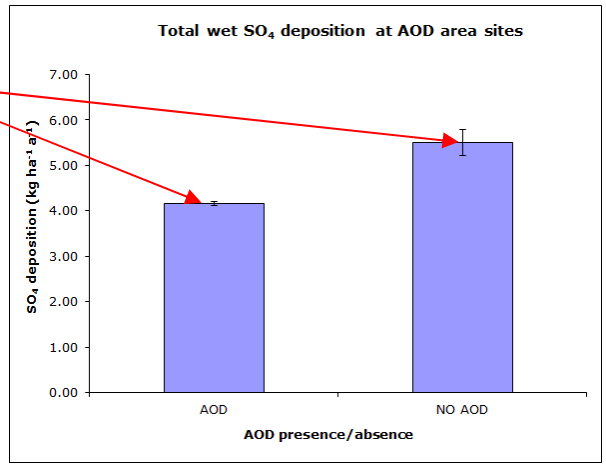


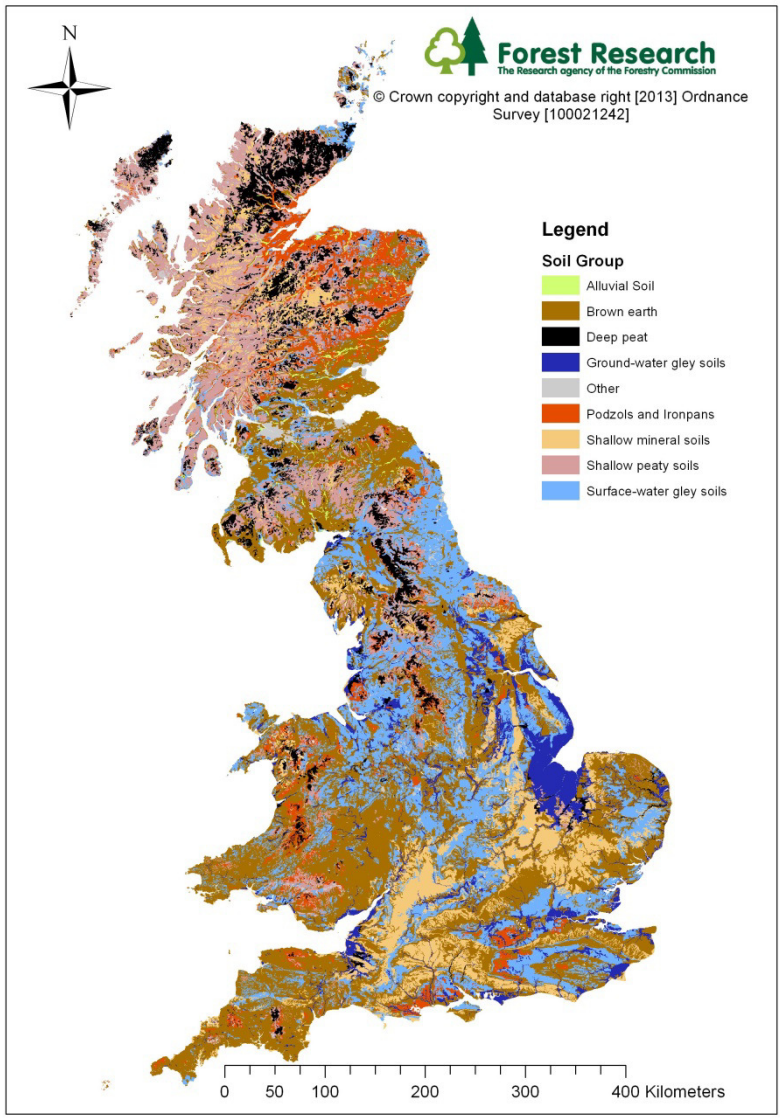

**Significantly lower input of dry $SO_2$ and $SO_4$ to AOD than NO AOD plots**




**Significantly lower input of total wet $SO_4$ deposition at AOD sites**

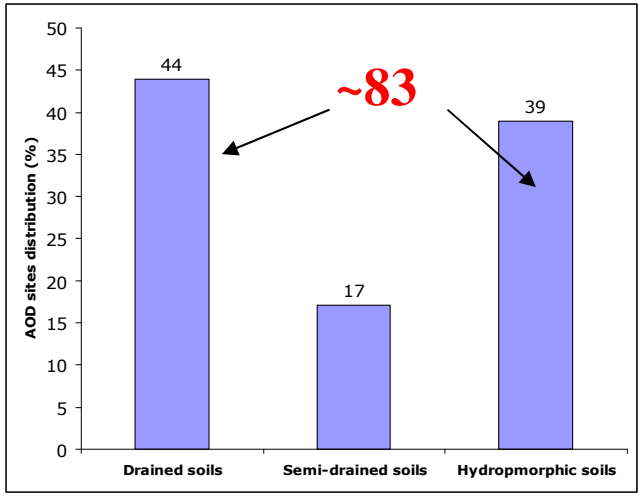


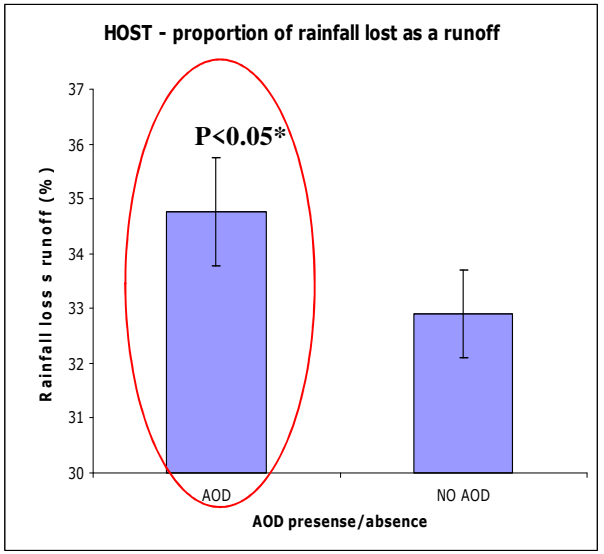



**~83% sites on drained and seasonally waterlogged soils, both drought sensitive soils**

**Significant difference between AOD and non AOD sites only found on seasonally waterlogged clay soil**

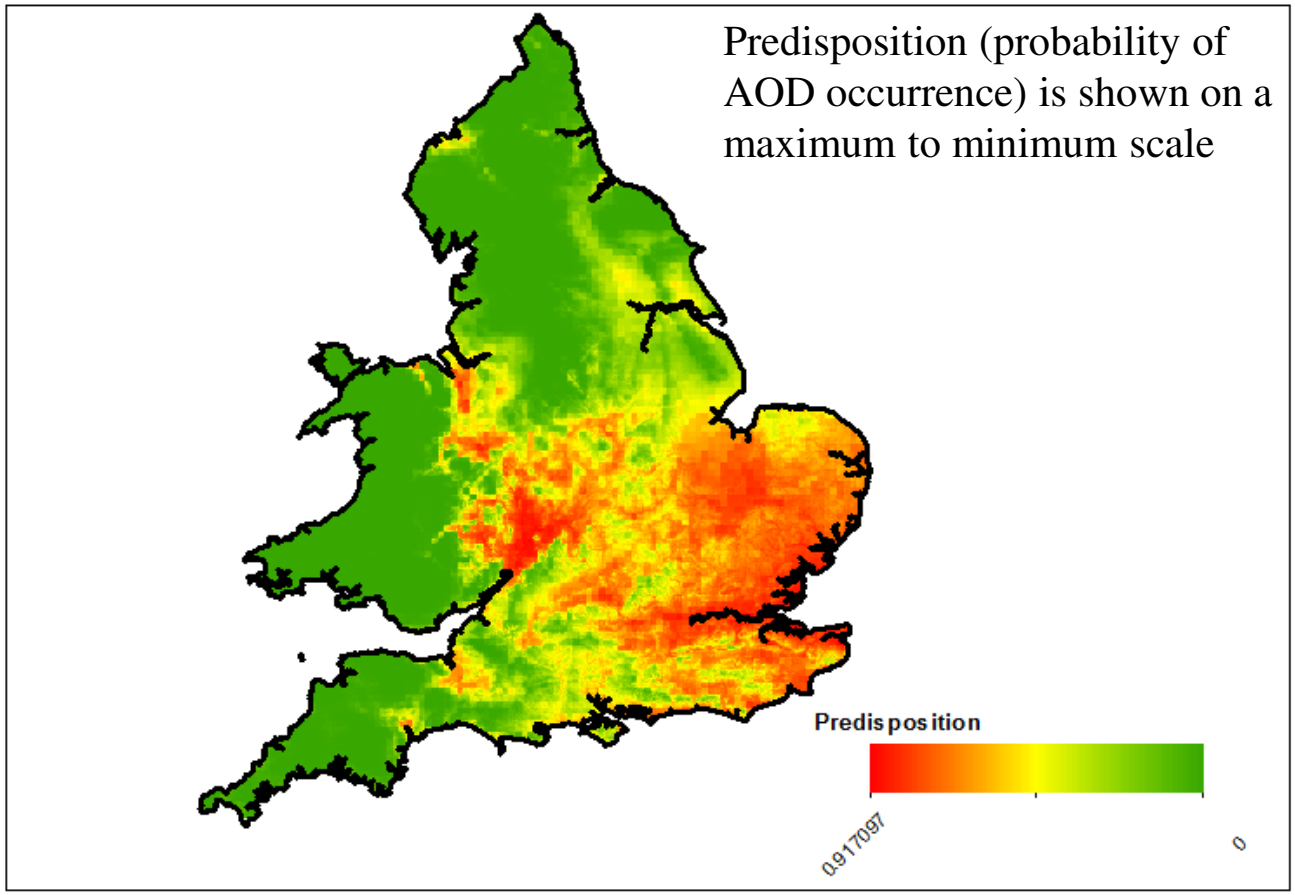
**AOD site with higher proportion of rainfall lost as a runoff, suggesting the soils are drought sensitive But no spatial relationship found**



# Final spatial model for AOD risk

Final model predictions generated using the full AOD dataset at 1 km square scale




**Useful tools (spatial and statistical modelling) for development of future predictive spatial mapping and modeling on tree susceptibility to any other tree pests/diseases -** *Brown et al., 2017, FEM, 407, 145-154*

# Tree Health monitoring sites

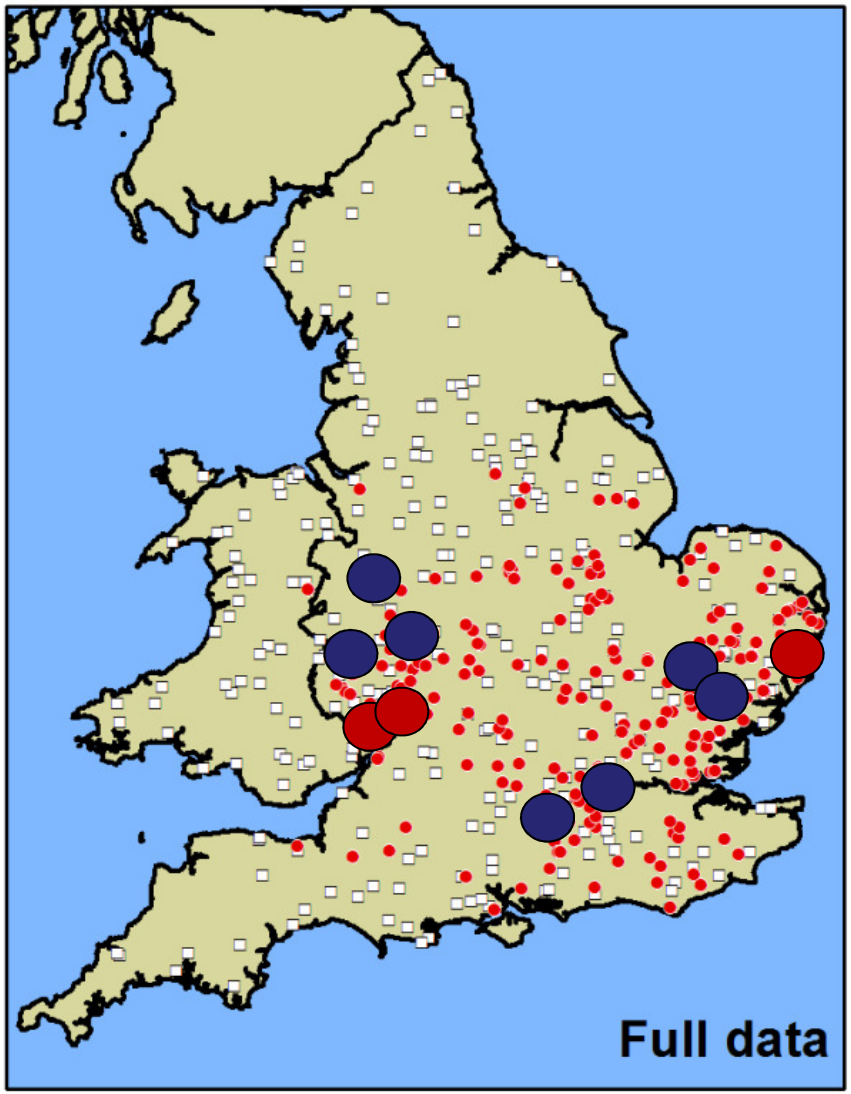
**Cronic Oak decline sites**

**Acute Oak decline sites**

## Monitoring

Tree crown condition, decline symptoms, beetle exit holes, bark lesions, swaps for bacteria.

Remission of trees observed, e.g. callusing bark lesion, improved crown condition



# Site/tree scale study

## 10 monitoring sites in England
(6 Acute Oak Decline and 3 Chronic Oak Decline)

1) In each site 10 healthy and 10 AOD or COD per 3 decline stages trees have been chosen = 20 trees

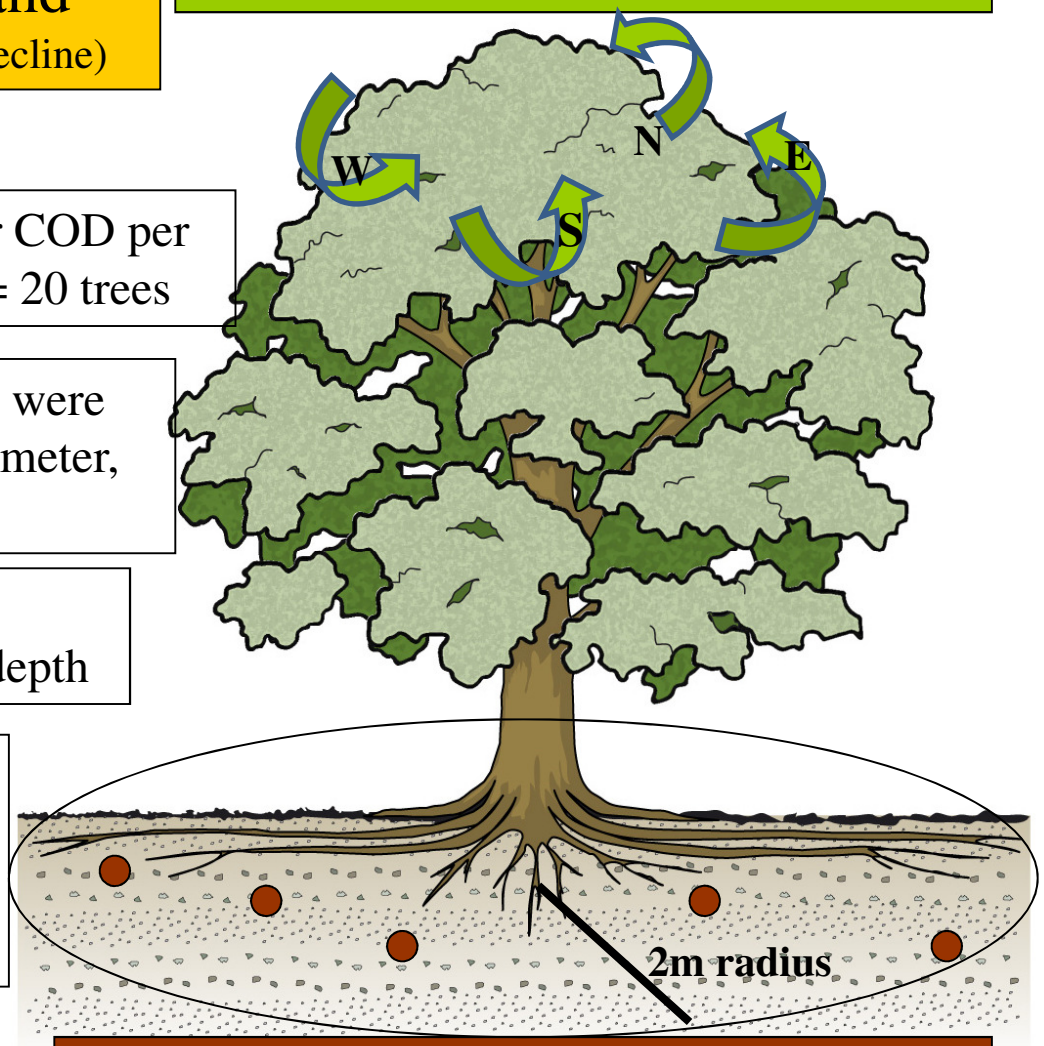
2) For each tree, 5 soils and root samples were taken with soil cylindrical core (8 cm diameter, 15 cm depth)

3) Each soil/root sample is split to Litter, Humus and mineral soil 0-15-15-30 cm depth

4) From the same 20 trees (10 AOD and 10 healthy) foliar sampled from the 4 cardinal direction (August/September) before leave fall.

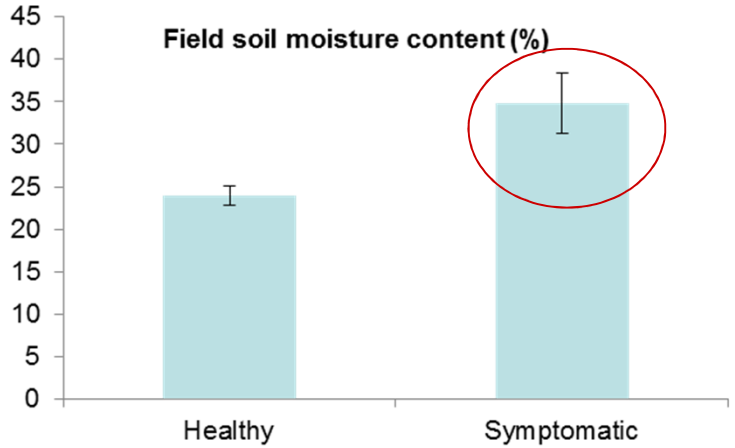
5) Chemical/physical and biological analysis

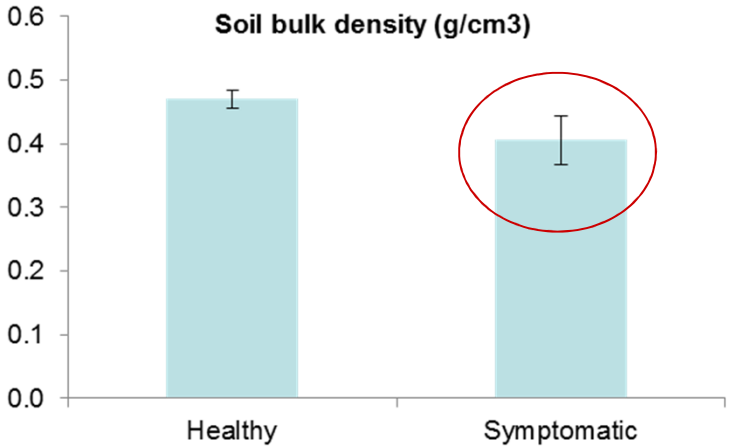
***Foliar sampling – 4 cardinal direction***

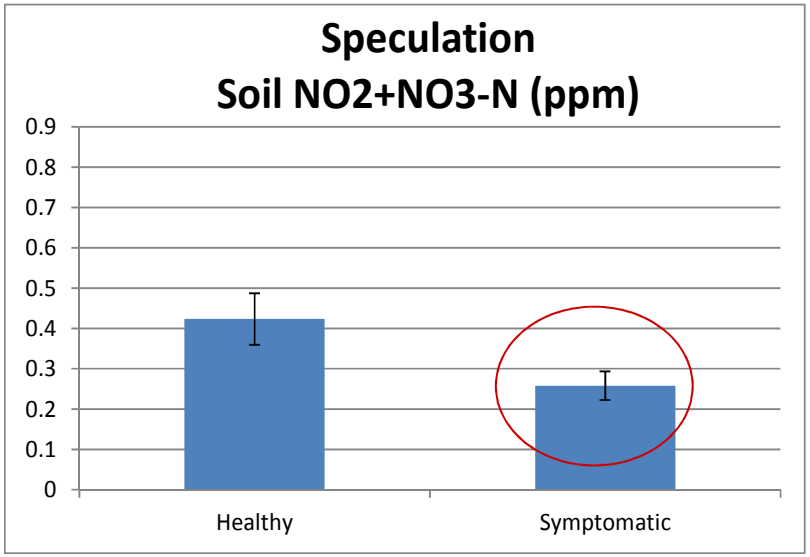


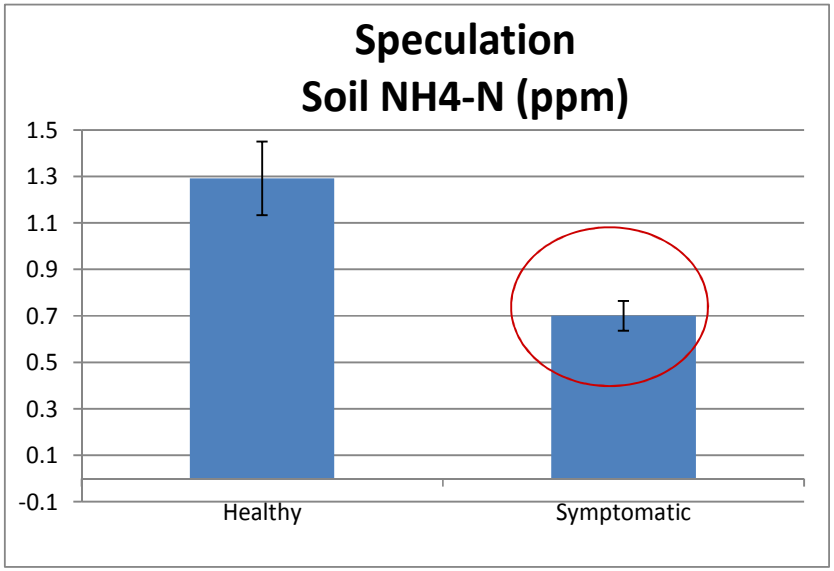

***Soil and root sampling – 5 points per tree***

# Results from COD site on clay soils



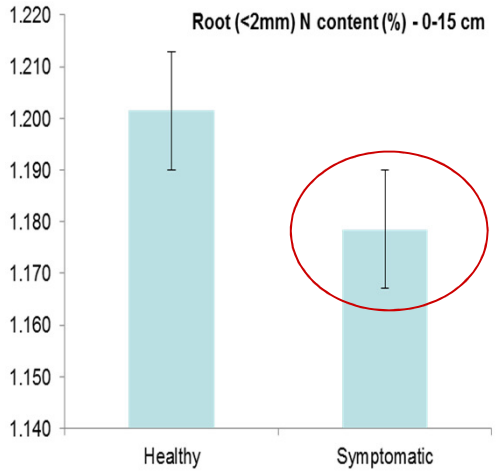



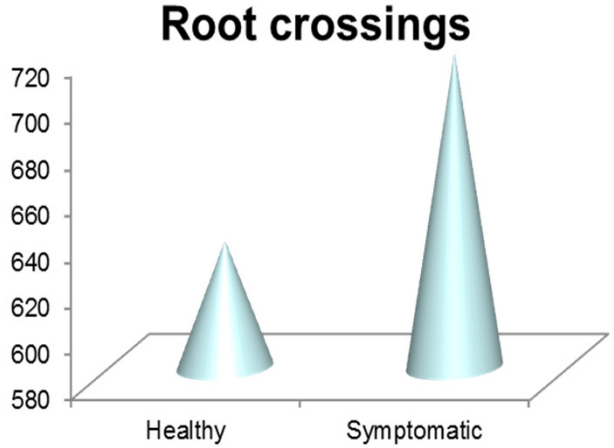



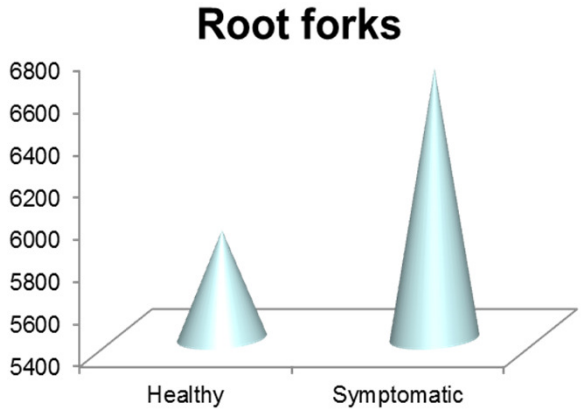



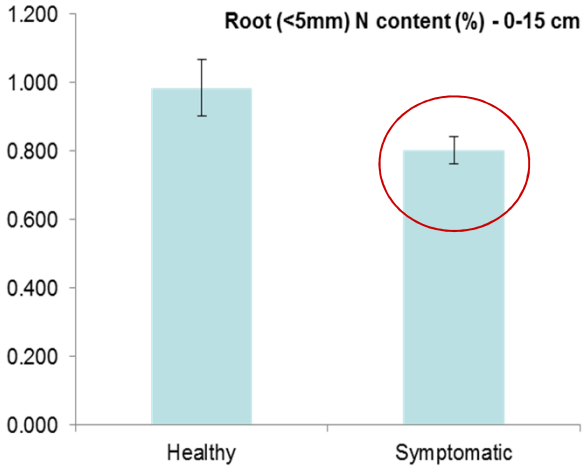
# Results so far at COD sites

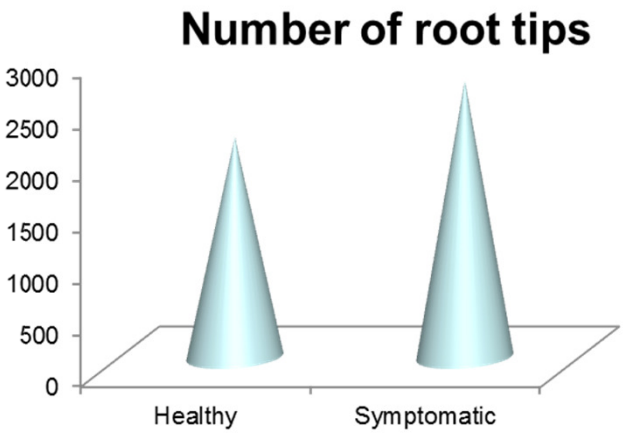
**No difference in fine root biomass at Chronic Oak declined compared to healthy trees**
**But significant difference in root N content and morphological traits**

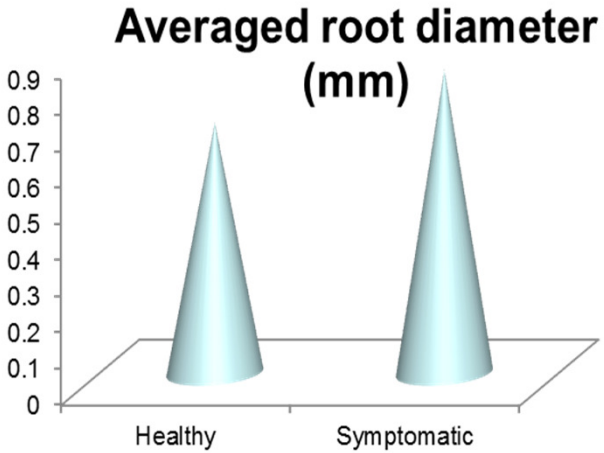


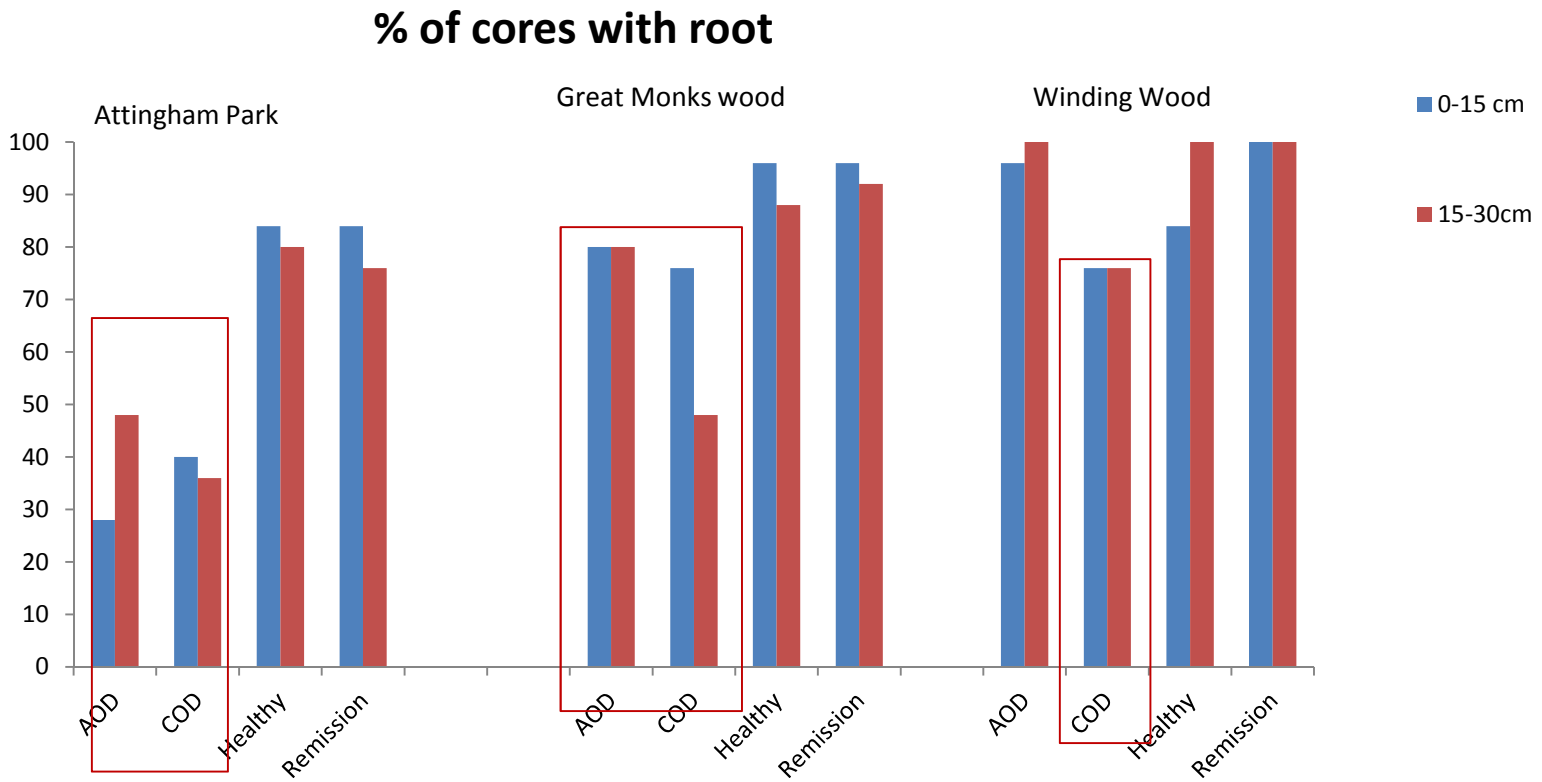



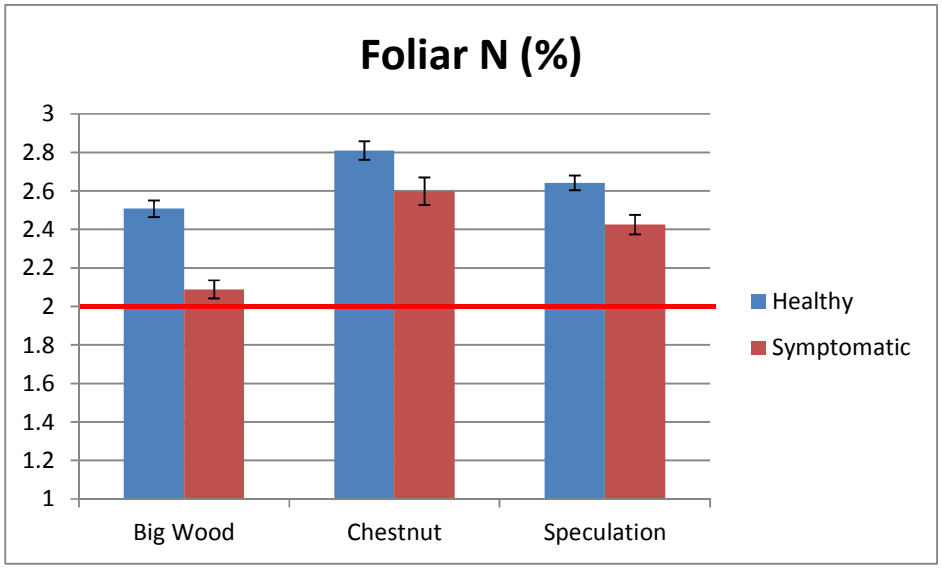



# Percentage of root in cores of 3 AOD/COD sites

**Significantly less fine roots at Acute and Chronic Oak declined compared to healthy trees at sites where bot COD and AOD present**

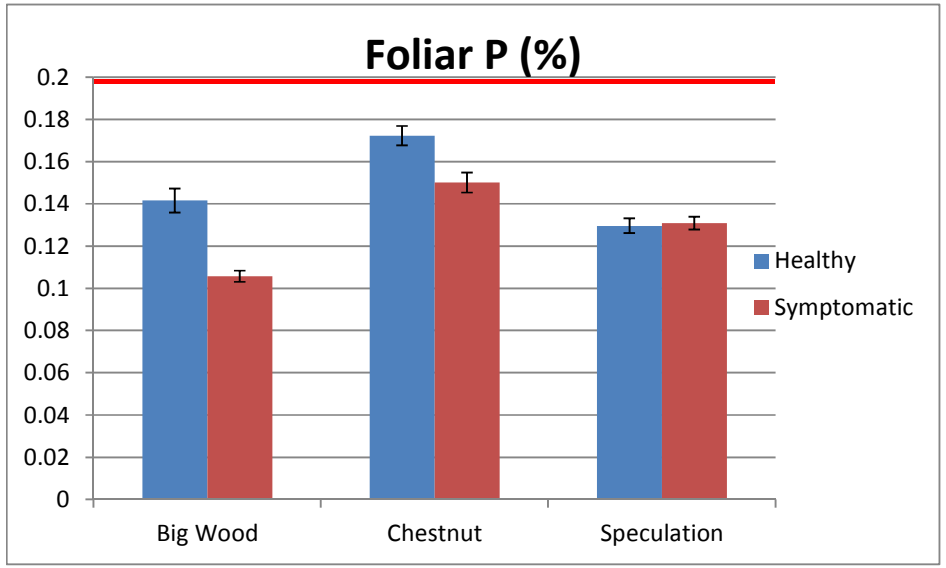


# Foliar nutrients content at 3 COD sites

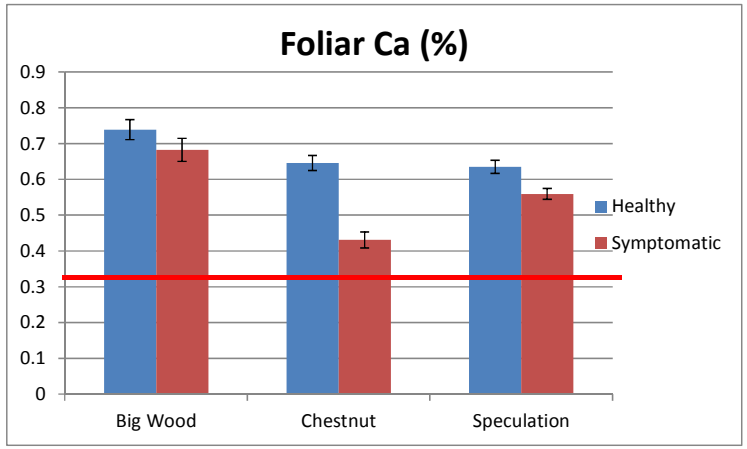



Foliar N concentration significantly lower in symptomatic trees than healthy trees in all three sites but only in Big Wood site levels are nearly critical in symptomatic trees

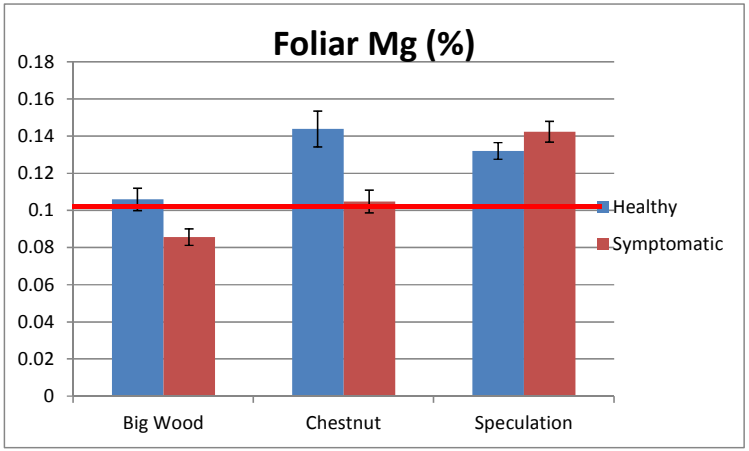
Foliar P concentration significantly lower in symptomatic trees than healthy trees in Big Wood and Chestnut but not at Speculation, but all under critical P levels



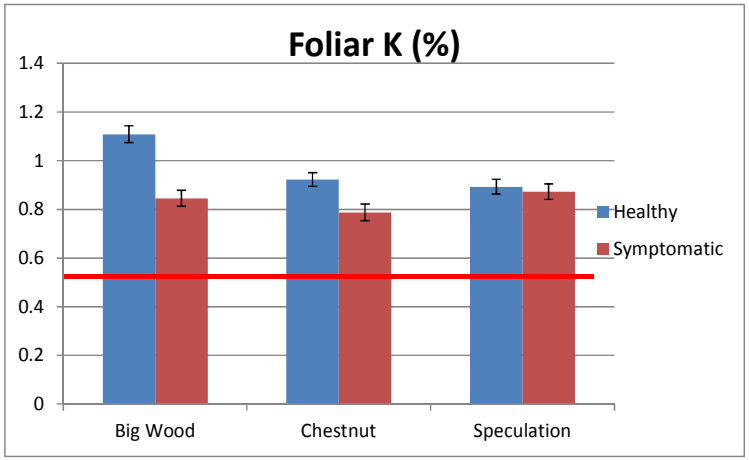
# Foliar nutrients content at 3 COD sites




Foliar Ca concentration significantly lower in symptomatic trees than healthy trees in all three sites




Foliar Mg concentration significantly lower and under critical levels in symptomatic trees than healthy trees in Big Wood and Chestnut but not at Speculation




Foliar K concentration significantly lower in symptomatic trees than healthy trees
in Big Wood and Chestnut but not at Speculation

# Linking the rhizosphere microbiome and acute oak decline – Diogo Pinho

## Sites – Oak - AOD parklands

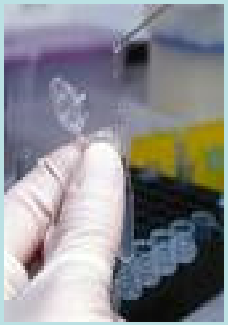
Eastnor

Richmond

Hatchlands

## Methods

Rhizosphere soil sampling
Healhy and AOD trees



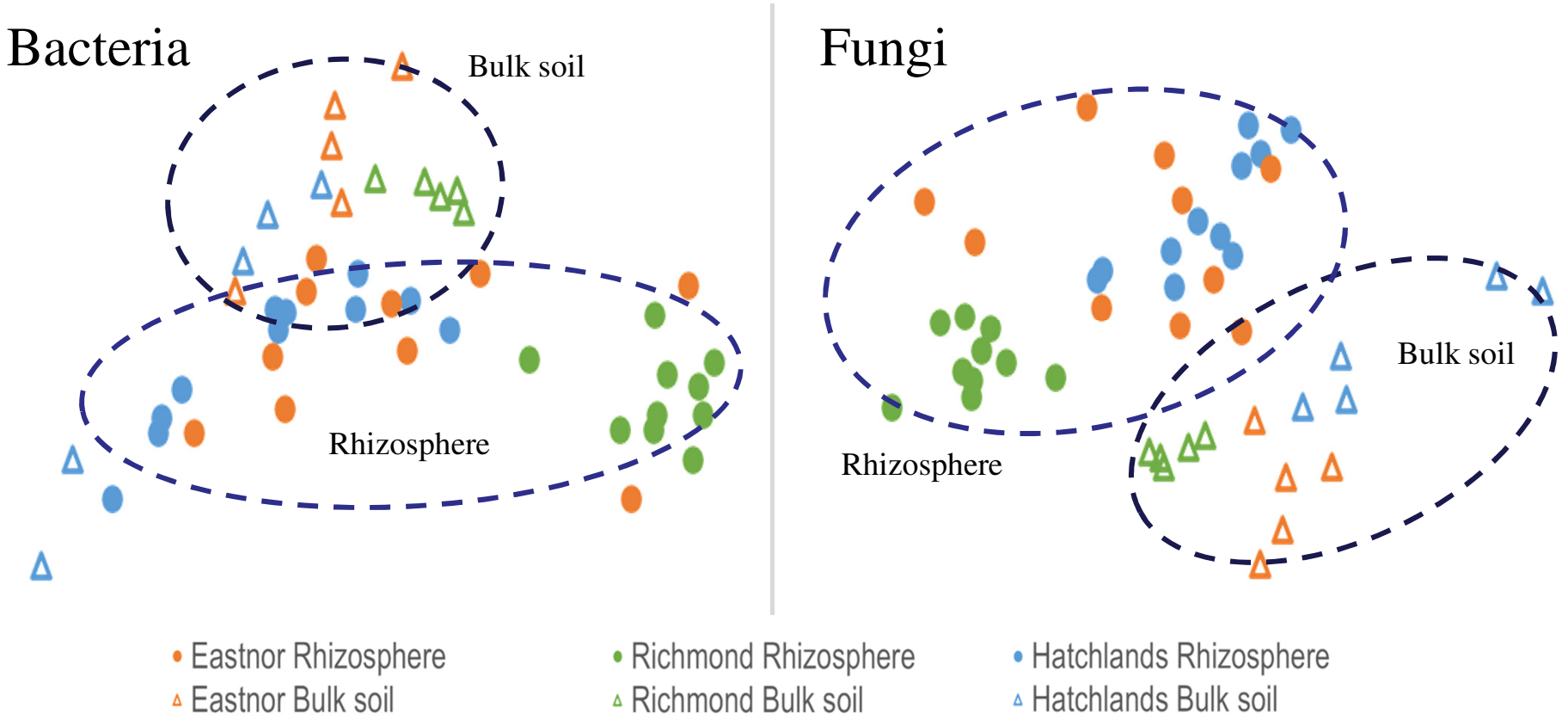
DNA Extraction and PCR
16S rDNA (bacteria)
ITS2 (fungi)

High-throughput sequencing
MiSeq Illumina 2x300bp

Data processing
QIIME

Statistical analysis
R and PRIMER

# Results



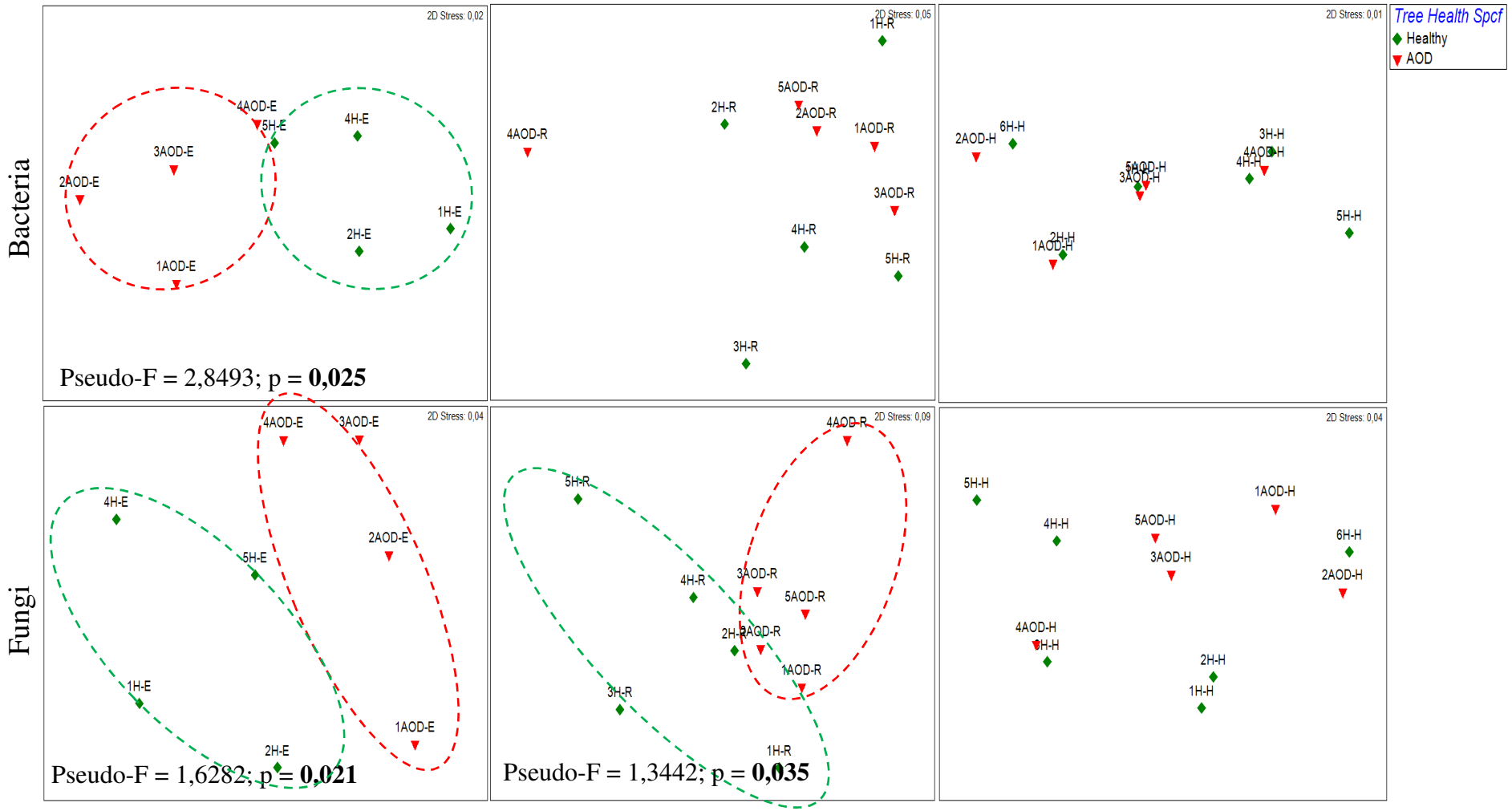

*PERMANOVA:* Soil type p<0,0001; Site p<0,001; SoxSi p<0,01
*BEST Analysis:* Soil pH; Soil TOC

*PERMANOVA:* Soil type p<0,0001; Site p<0,0001; SoxSi p<0,0001
*BEST Analysis:* Root nitrogen; Root P/K; Soil moisture; Soil pH

**Soil and root chemical parameters are the main drivers of microbial composition.**

Bacterial and fungal communities are significantly impacted by forest location and soil type

# Results




Preliminary results suggest a link between belowground microbial composition and tree health

# Conclusions so far

- **Elevation, Rainfall and Temperature are significant predisposition factors for Oak health (pests and diseases).**
- **Dry and Wet nitrogen and sulphur and base cations deposition are also significant predisposition factors for Oak health (pests and diseases).**
- **Soil type/nutrient /moisture status are important factors at spatial scale but even more significant in relation to tree health status at stand/tree level due to small scale variability.**
- **Preliminary results suggest a link between belowground microbial composition and tree health.**
- **Soil and root chemical parameters are the main drivers of microbial composition.**
- **Pleminary results suggest strong links between belowground traits and tree health, but proof of cause and effect is required.**

Forest Research

# Thank you!