Investigating Complex Oak Decline-Diseases: Predisposition Factors with Relevance for Resilient Oak in Designed Landscapes

BALI Webinar Meeting, 21st April 2020

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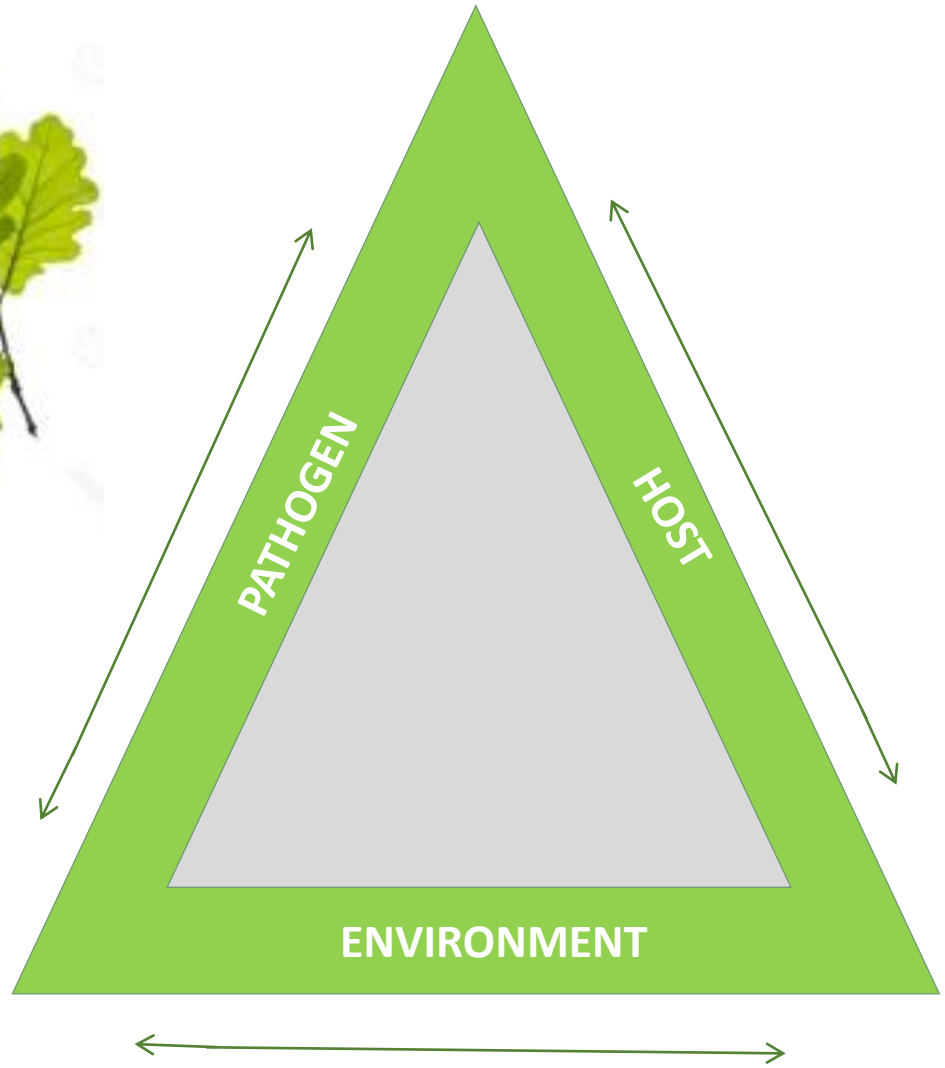
Forest Research
The Research agency of the Forestry Commission



Primary diseases:
One pathogen = One disease model
E.g. Sudden Oak Death – *Phytophthora ramorum*

A disease is defined as: A continuous irritation causing a deviation from normal functioning of the host, often with detrimental effect to the host.

- **Infectious (biotic causes)**
- **Non-infectious (abiotic causes)**
- **Potentially infectious (latent, altered function)**

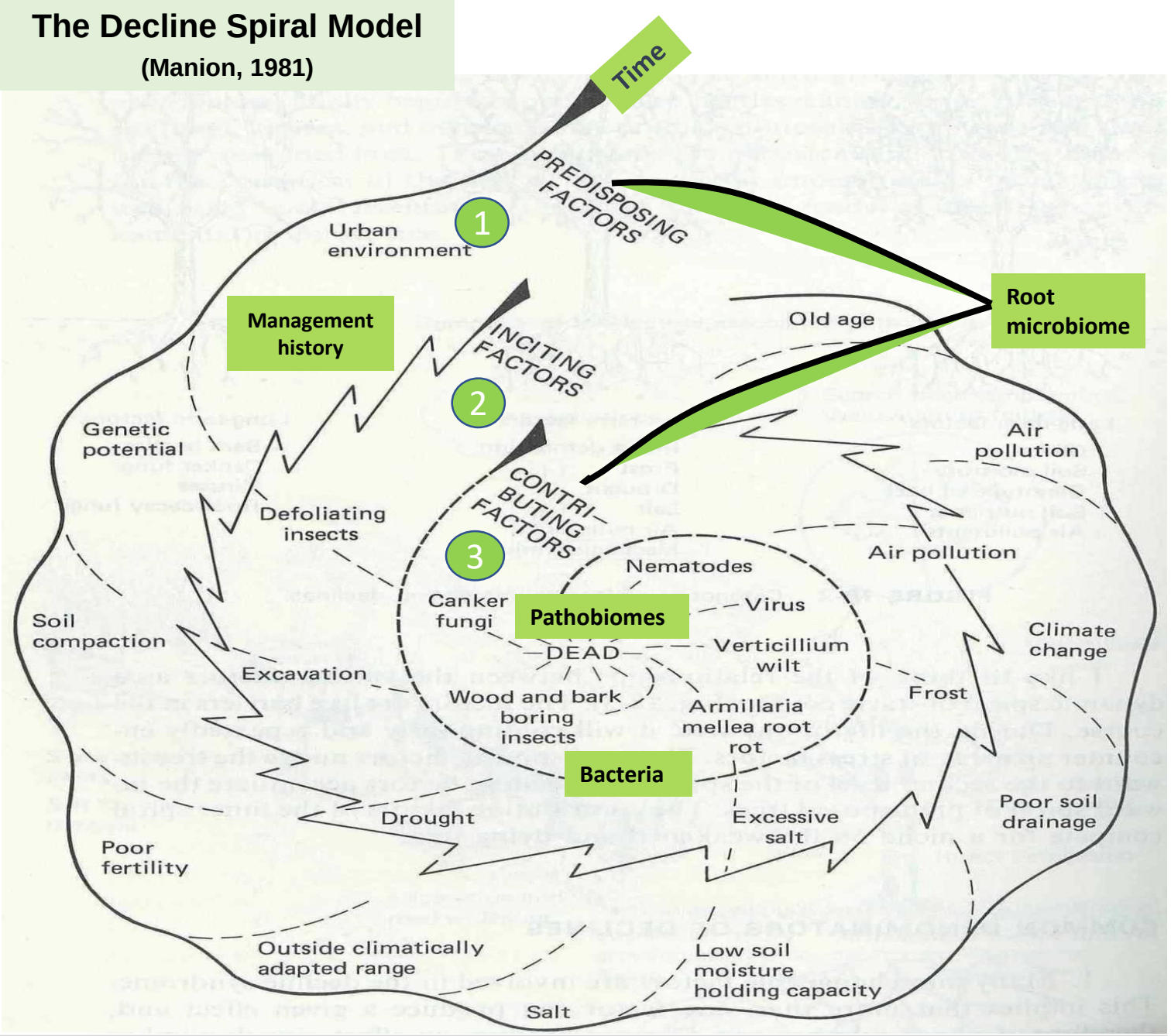
Traditional Model Disease Triangle

3 essential components with dynamic interaction that affects expressed severity

Lacking

- **Temporal aspects of pathosystems**
- **Short on detail**
- **Does not take account of essential inter-microbial interactions that are fundamental to pathobiomes**

The Decline Spiral Model
(Manion, 1981)



Decline: Arises from <u>interactions</u> of <u>interchangeable</u>, <u>specifically ordered</u>, abiotic and biotic factors that produce a general deterioration, often ending in death of trees.

Decline diseases

- **Decline Spiral Model has 3 progressive phases**
  - **Predisposing** (environmental stresses modification of plant resistance making the plant more susceptible)
  - **Inciting** (tipping point, events)
  - **Contributing** (cumulative biotic effects overwhelming of the whole or parts of the host)
- **Time**
- **Dynamic disease system –** linked and impacting each localised factor **–** spirals within spirals
- **Scale**

- Oak Declines complex disease syndromes
- Two forms of oak declines
- Acute Oak Decline – above ground stem weeps
- Chronic Oak Decline – concept developing - root

Acute Oak Decline (AOD) Stem weeps, bacteria, *Agrilus*





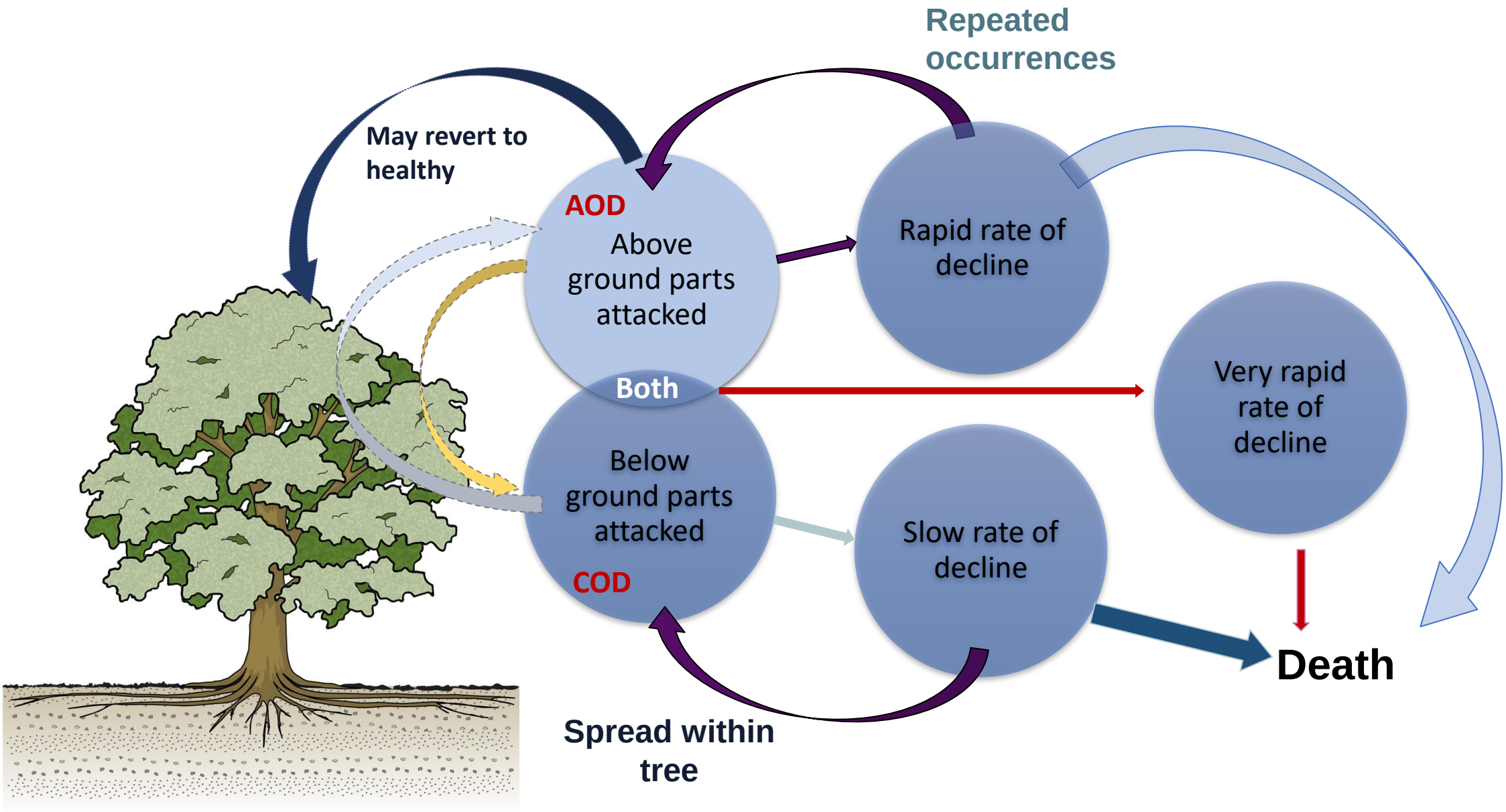

Chronic Oak Decline (COD) driven by poor root health



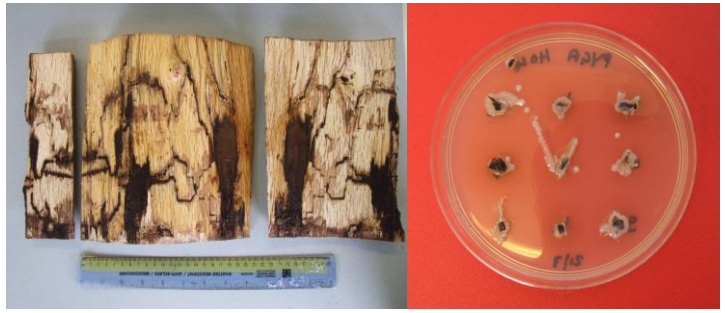


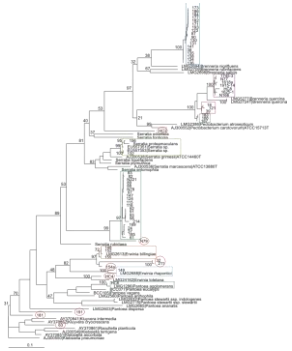


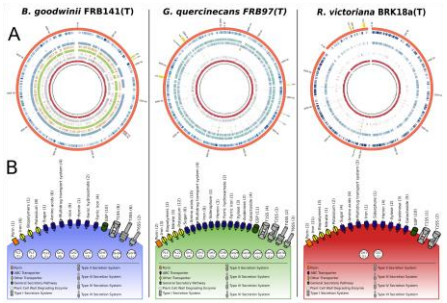
Conceptual relationships between AOD and COD



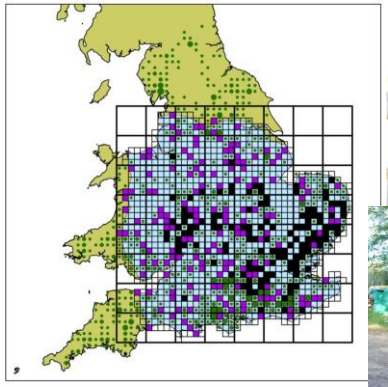
AOD – the past 10 years – research on key causal agents

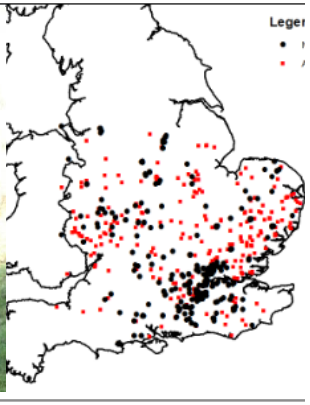


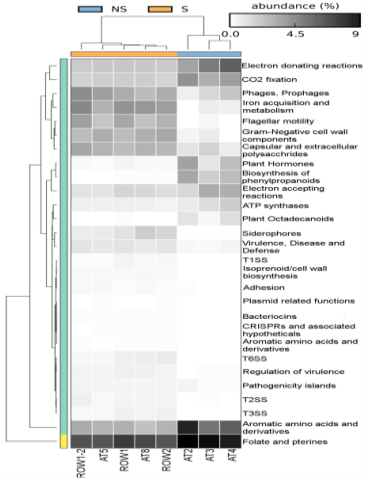


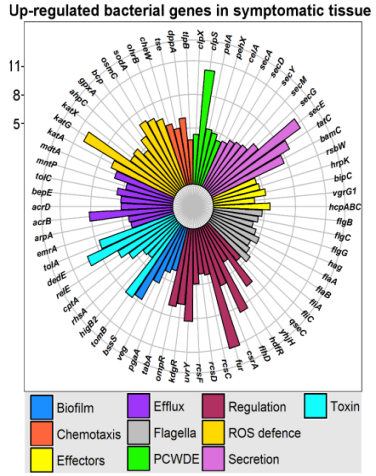


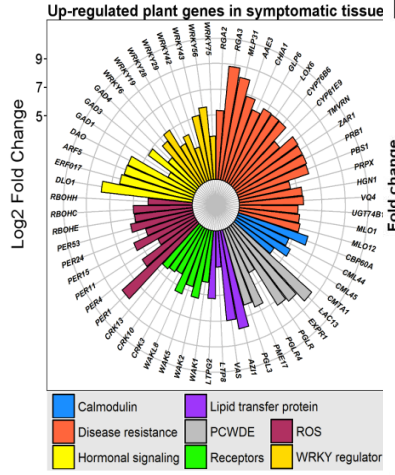
Distribution: survey and risk mapping

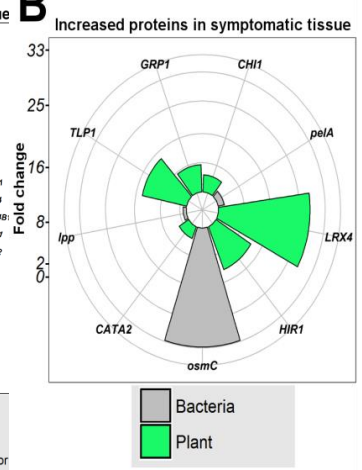












Beetle rearing in captivity and life cycle biology

Interdisciplinary approach

Defining the problem
Causes
Pathology and Entomology

Identity of organisms
Taxonomy

Understanding how the causes take place
Molecular pathology
'Omics'

Host responses
Potential for control
Genetics and metabolomics
Historic host condition
Dendrochronology

Management
Silviculture
Social engagement
Policy

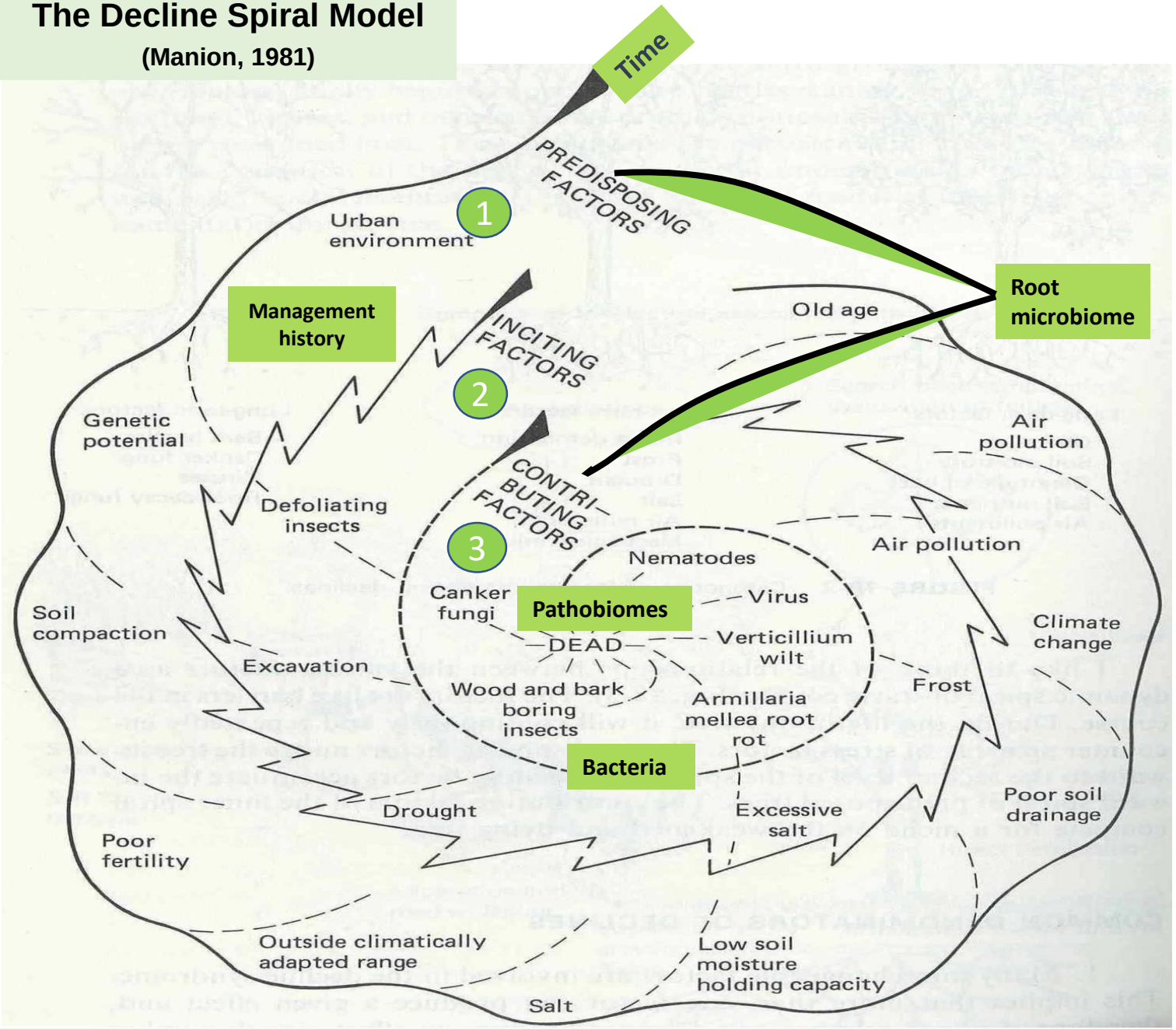
Determining extent and distribution
Spatial epidemiology and modelling

Factors that affect the problem
Environment: soils, pollutants weather
Biogeochemistry

Factors that affect the problem
Human activity: management, land use attitudes

Stakeholder engagement

The Decline Spiral Model
(Manion, 1981)



Decline: Arises from <u>interactions</u> of <u>interchangeable</u>, <u>specifically ordered</u>, abiotic and biotic factors that produce a general deterioration, often ending in death of trees.

Decline diseases

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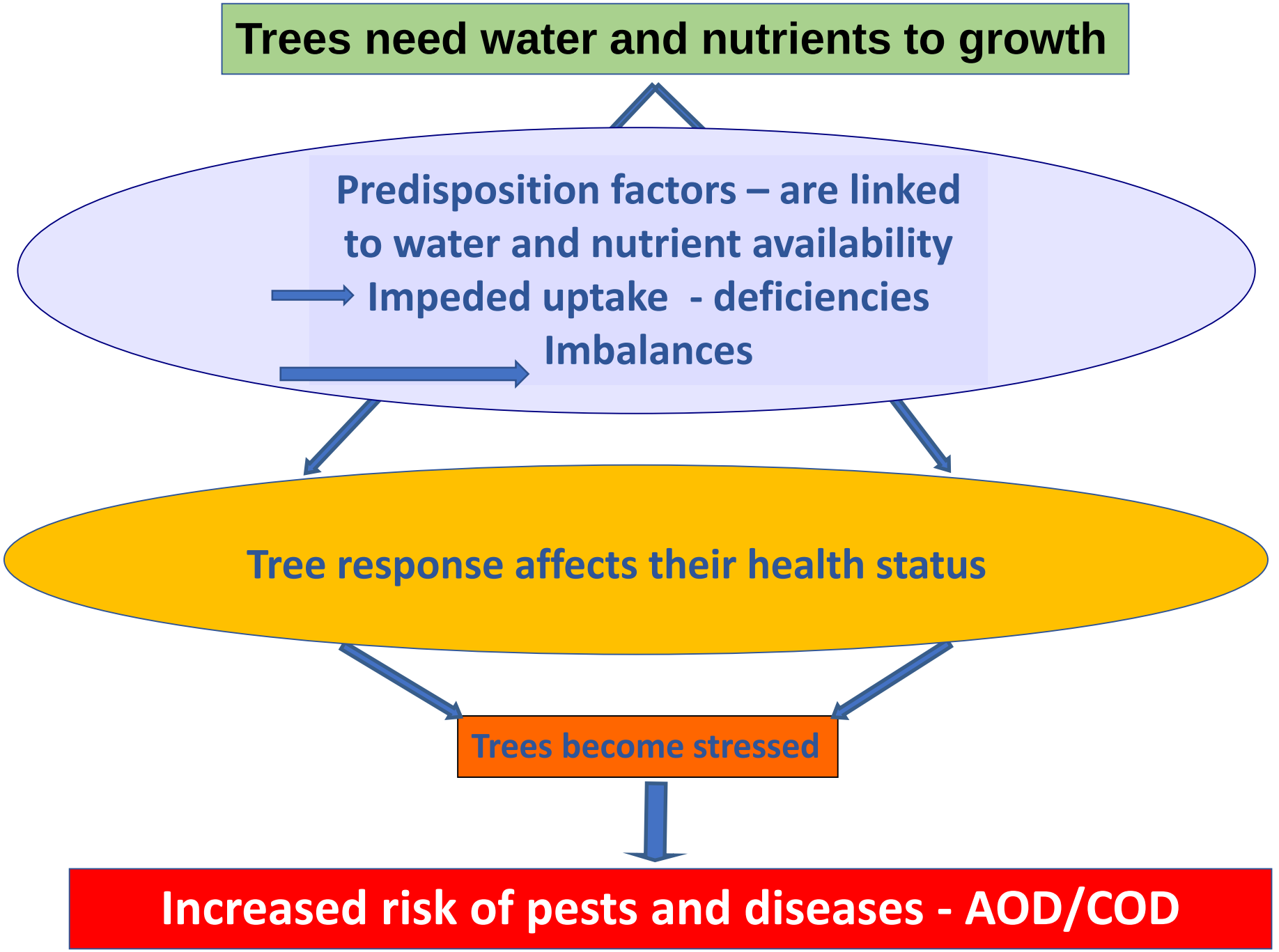
  - **Predisposing** (environmental stresses modification of plant resistance making the plant more susceptible)


Trees need water and nutrients to growth
Predisposition factors – are linked to water and nutrient availability
Impeded uptake - deficiencies
Imbalances
Tree response affects their health status
Trees become stressed
Increased risk of pests and diseases - AOD/COD

Phase 1 of Decline Diseases is Predisposition

WP1: Biogeochemistry

WP2: Rhizosphere metabarcoding, metagenomics, transcriptomics

WP3: Rhizosphere Nitrogen Cycling Microbiology

WP4: Rhizosphere fungi and pathology

Question:

Are there identifiable predisposition drivers in oak declines at UK AOD and COD sites

WP1: Biogeochemistry

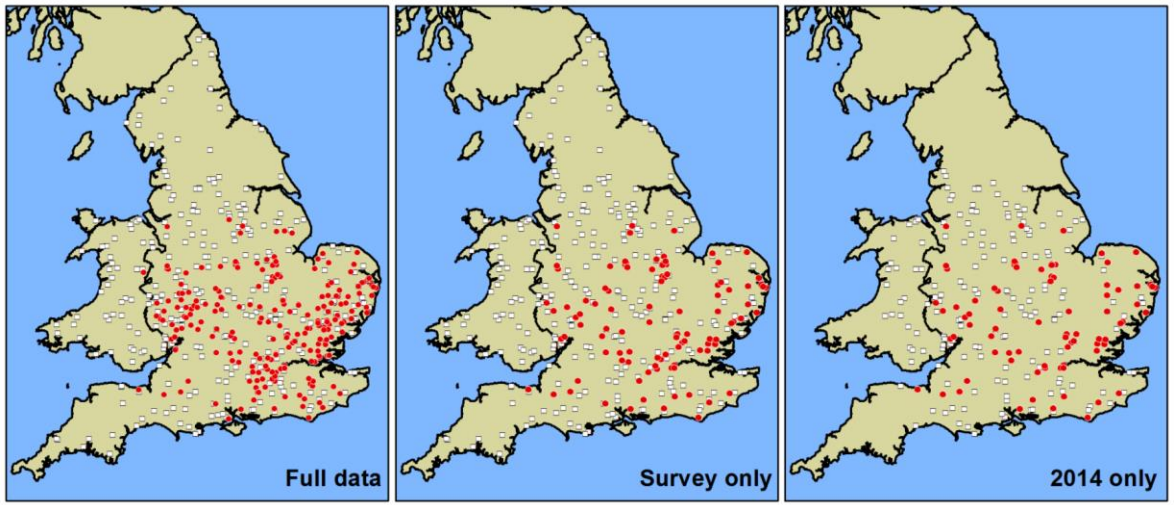
Question:

Are there identifiable predisposition drivers in oak declines at UK AOD and COD sites

Hypotheses:

1. There are identifiable soil pre-disposition drivers associated with AOD and COD
2. Predisposition factors vary at different scales (national, site, tree scales) and tree condition (AOD/COD)
3. Altered and impaired tree nutrient uptake is linked with soil conditions and poor root development
4. Altered and impaired feeder root morphology and chemistry are linked with predisposition factors
5. Linkages occur between soil predisposition factors, tree root and foliage parameters

AOD distribution maps and spatial datasets used



- **GAM – generalised additive mixed models revealed that <u>AOD occurs in</u>:**
- ***Warmer areas***
- ***Low rainfall areas***
- ***Low elevations areas***
- ***High nitrogen deposition***
- ***Low sulphur deposition***
- ***On drought sensitive soils***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Predisposition of forests to biotic disturbance: Predicting the distribution of Acute Oak Decline using environmental factors

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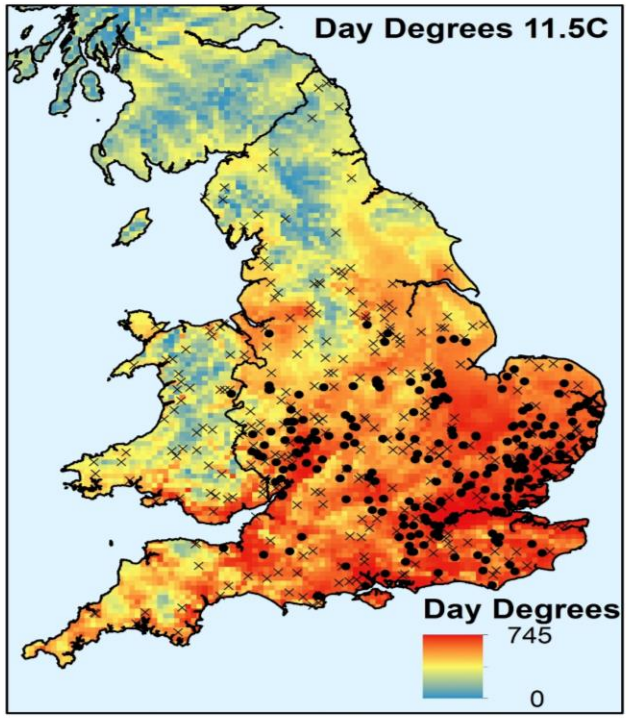
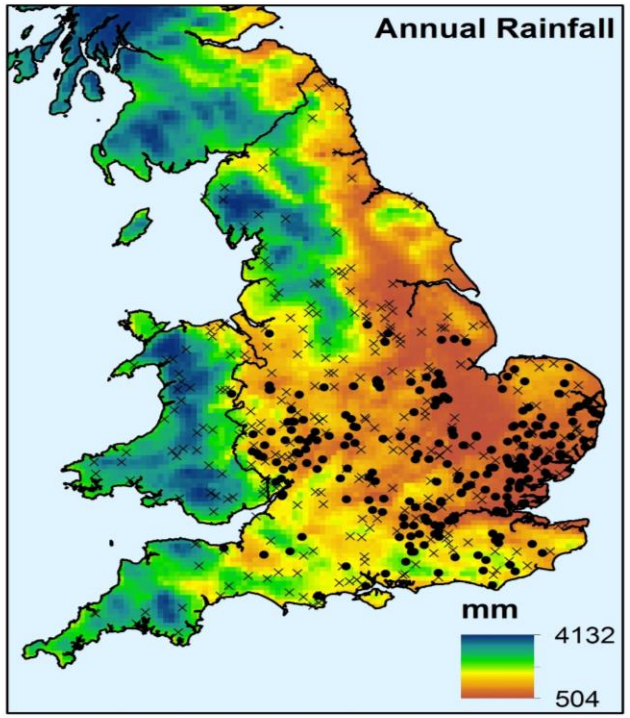
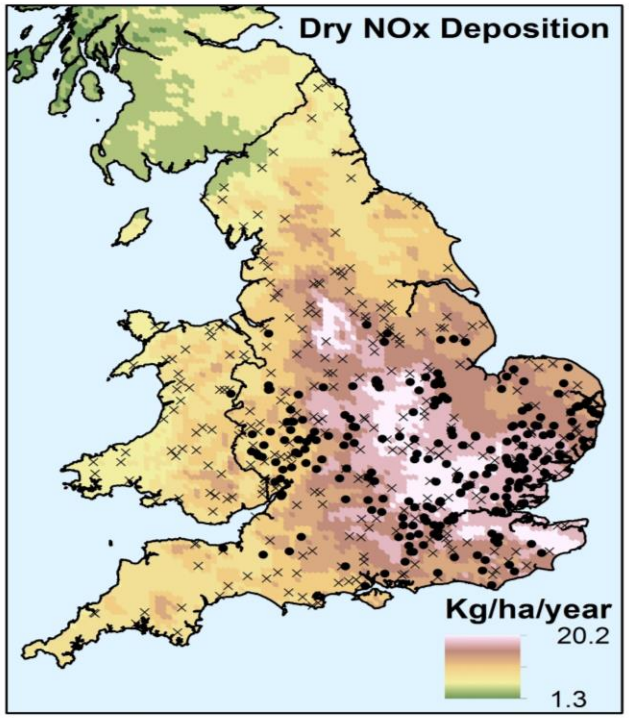
Dataset	Resolution	Source
Climatic parameters	5 km x 5 km grid	UK Met Office Parry and Hollis (2006)
Day degrees above 11.5 °C	5 km x 5 km grid	Average max and min monthly temp (1971-2000) UK Met Office
Atmospheric deposition	5 km x 5 km grid	(CEH, 2006)
National Soil Map 1: 25,000	Polygon shapefile	(Cranfield University, 2004)
NFI woodland map	Polygon shapefile	(FC 2011)
Hydrology of Soil Types (HOST)	Polygon shapefile	(Boorman et. al., 1995)
Ecological Site Classification for forestry (ESC)	Woodland habitat and management map	(Pyatt, Ray and Fletcher, 2001).

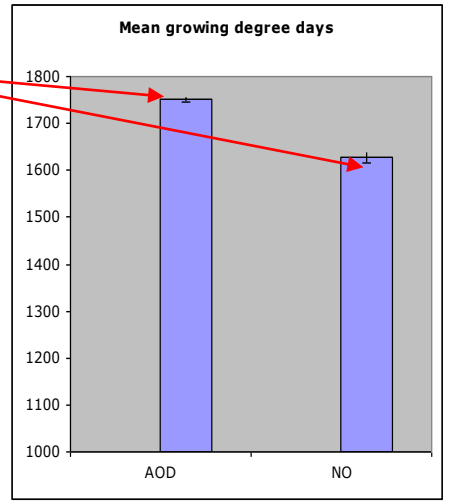
Environment influences distribution



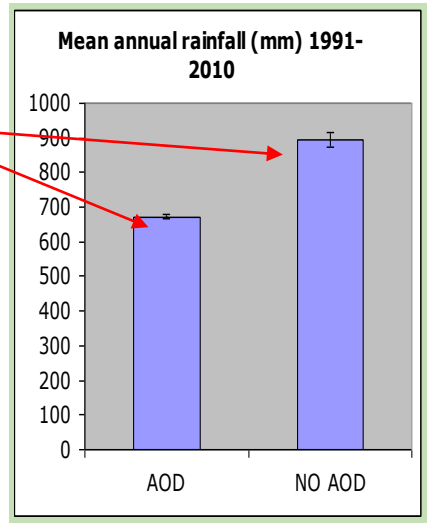




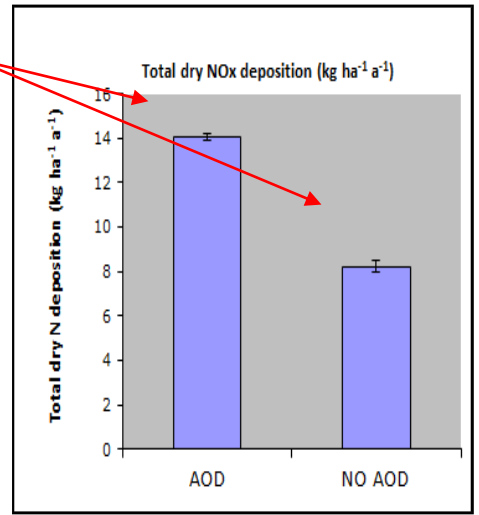
>100 days difference (>11.5 C (sum 1961/90)



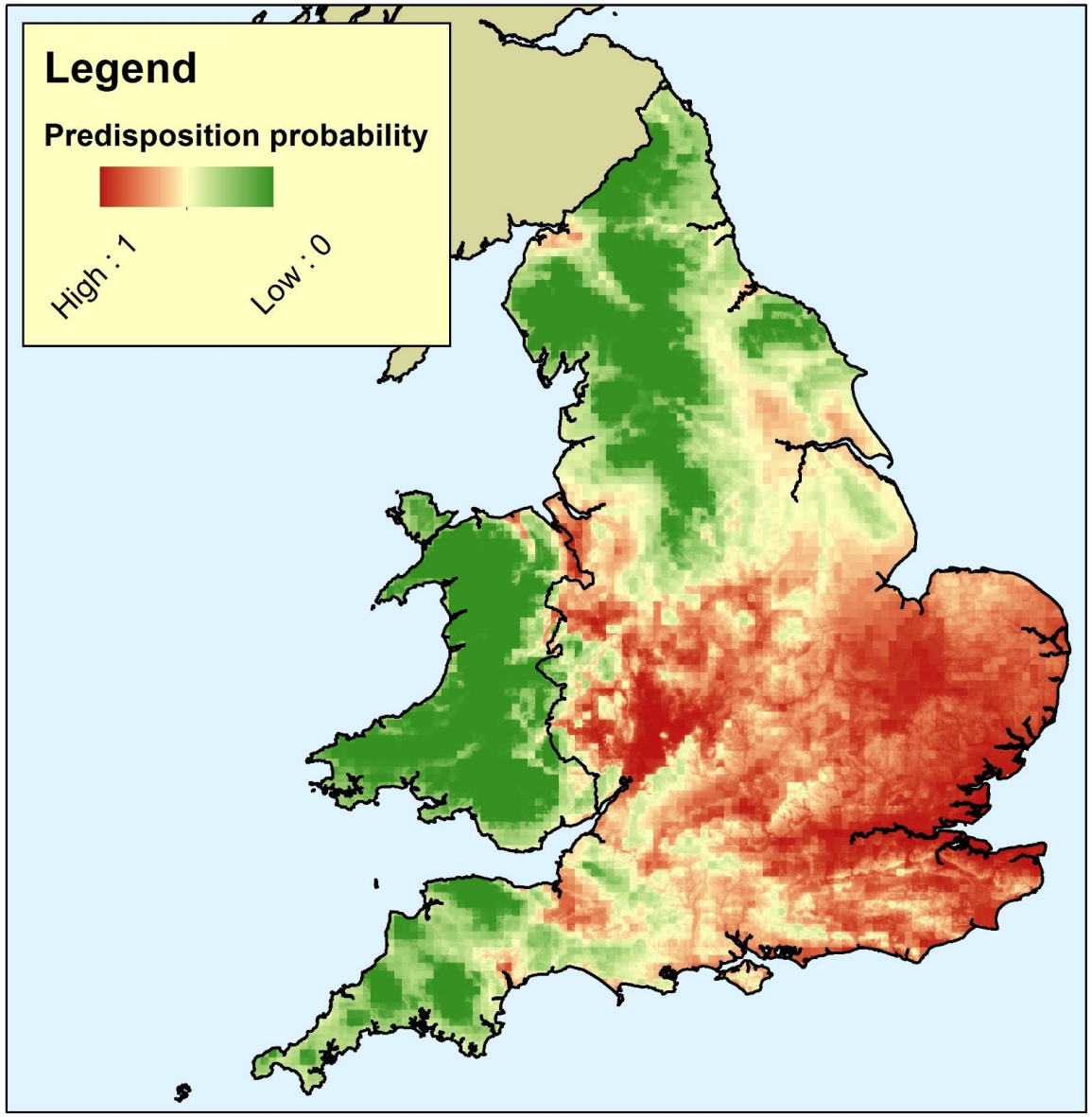
>200mm rainfall difference average annual rainfall (1991-2010)

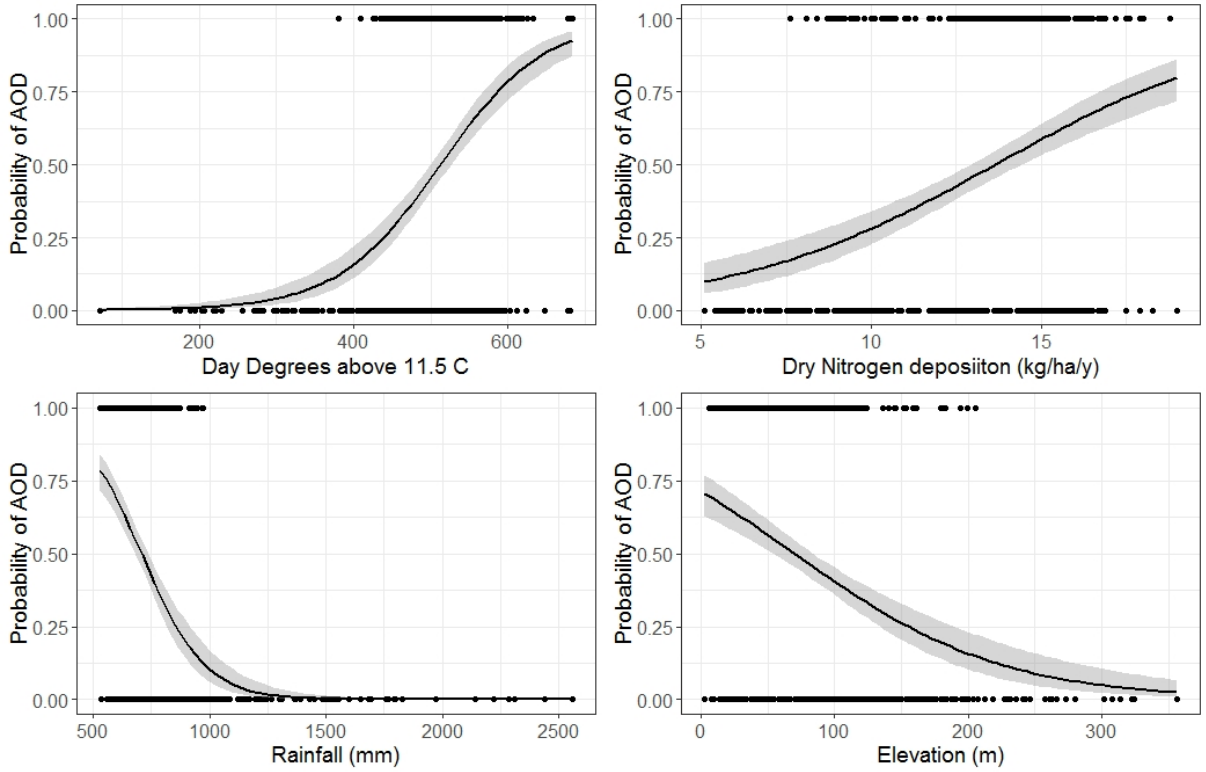


(~7kg/ha/a) difference dry N deposition



Predisposition probability to AOD





Soil as a predisposing factor at site specific scale and the links between soil and trees (roots and foliage)

Ten study sites: 7*AOD and 3*COD

10 healthy and 10 symptomatic paired trees were chosen = 20 trees – used across all work packages

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

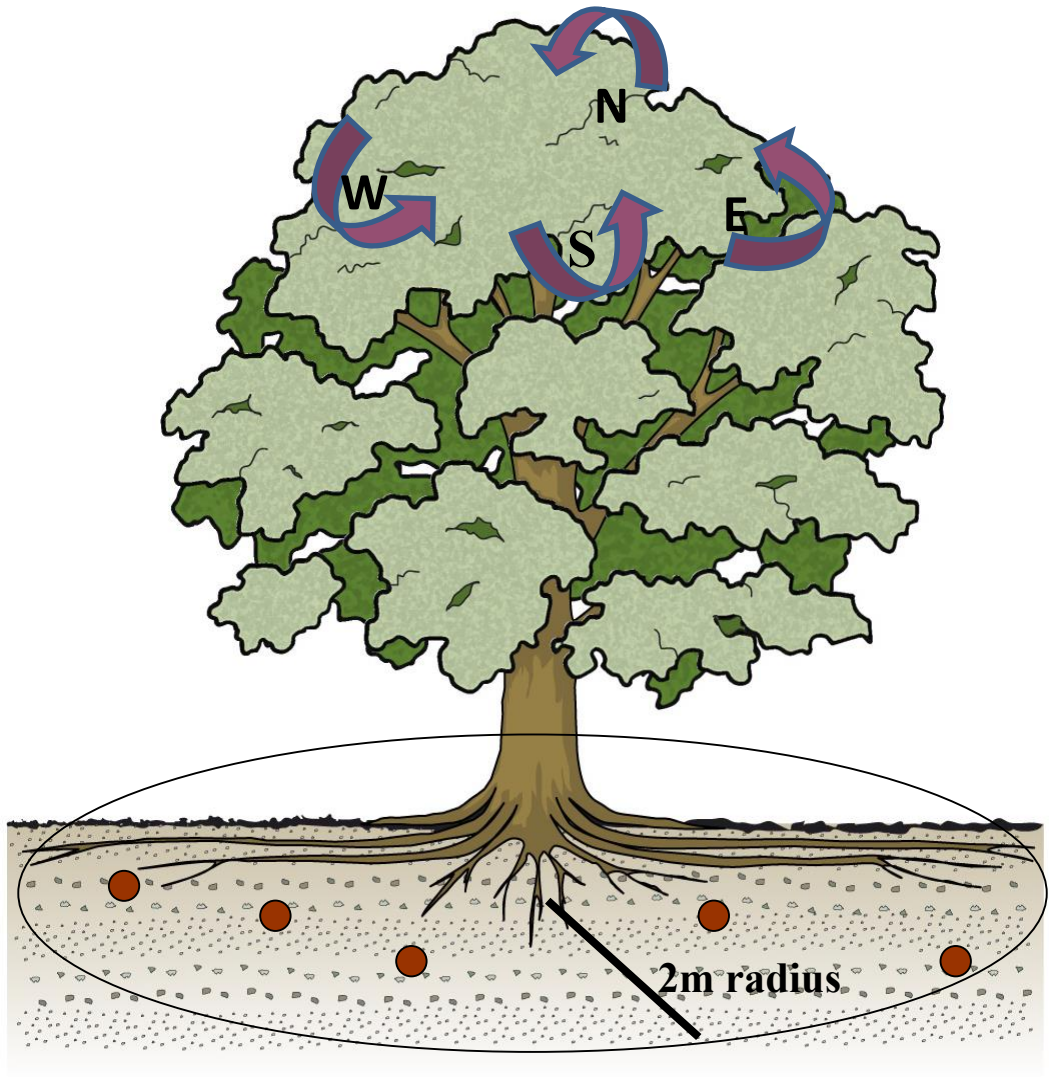
Each root sample split to mineral soil of 0-15-15-30 cm depth

Each soil sample split to humus layer and mineral soil of 0-20, 20-40, 40-80 cm depth

The same 20 trees in each site had foliar sampling and analyses

All chemical analyses carried out in FR's biogeochemical laboratory at Alice Holt

Foliar sampling – 4 cardinal directions



Soil and root sampling – 5 points per tree

Parameters measured

AOD sites = Attingham, Great Monks Wood, Langdale, Winding Wood
COD sites = Bigwood, Chestnuts Wood, Speculation
Tree health condition: AOD, COD, Healthy, Remission

Foliage

Morphology and Chemistry

4 cardinal directions – S, E, N, W

Feeder roots

Morphology and Chemistry

0-15 cm depth Live
0-15 cm depth Dead
15-30 cm depth Live
15-30 cm depth Dead

Soils

Physical properties

Stone content,
clay/silt/sand, bulk density

Chemistry

pH, moisture

Litter layer
Humus layer
0-20 cm depth
20-40 cm depth
40-80 cm depth

Leaf/Root Morphology parameters

- Leaf/Root biomass/necromass
- Leaf/Root surface area
- Root length
- Root diameter
- Number of root tips
- Number of root forks
- Number of root crossings

Foliar/Root/Soil chemistry

- Nitrogen (N)
- Carbon (C)
- Potassium (K)
- Calcium (Ca)
- Phosphorous (P)
- Aluminium (Al)
- Magnesium (Mg)
- Sodium (Na)
- Boron (B)
- Cadmium (Cd)
- Chromium(Cr)
- Copper (Cu)
- Iron (Fe)
- Manganese (Mn)
- Nickle (Ni)
- Zinc (Zn)
- *Ratios*: C:N; N:P; Ca:Al; N:K; N:K; N:Mg;

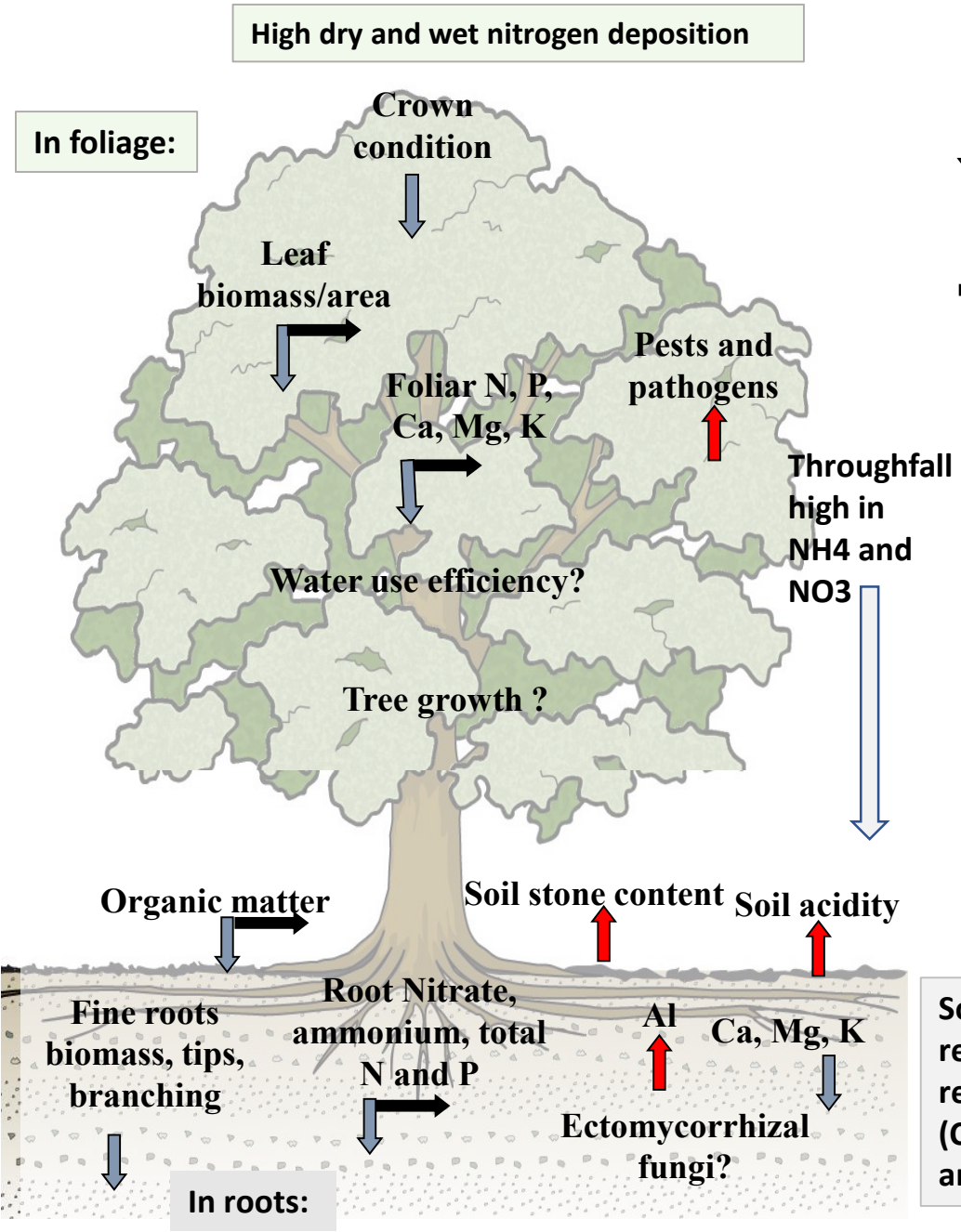
Deposition data of each site

Site	Rainfall (mm)	Growing degree above 11.5C	dry NOX	dry NHX	dry SOx	Base cations
	mm	days	kg/ha/a	kg/ha/a	kg/ha/a	kg/ha/a
Hatchlands	743.61	537	18.1	15.1	6.9	6.2
Langdale	744.15	515	14.2	20	5.2	3.1
Bigwood	636.46	525	17.4	32.5	6.7	4.4
Winding Wood	591.7	534	19.6	17.9	6.7	4.2
Attingham	680.32	468	11.8	30.4	4.9	2.6
Speculation	974.55	434	15.3	17.1	6.9	3.9
Chestnuts	947.76	440	14.8	20.8	6.8	3.9
Sheen	618.45	677	18.2	15	6	5
Great Monks	589.87	588	19.7	17.6	6.8	4.5
Eastnor	702.4	564	13.2	21.6	4.8	2.9

Critical load for N is 12 kg/ha/a

Spatial effects – forests in East Anglia showed measured total N up to 47 kg/ha/a at the edge going down to 20 kg/ha/a inside the woodland

Acidity driven scenario:



↓ = decrease

↑ = increase

→ = no change

Acidity driven Healthy vs AOD trees

Significant differences – in AOD trees:

- Soil acidification
- Al toxicity to roots
- Cation (Ca, Mg, K) depletion
- Higher stone content
- *Lower* root density, biomass, tips, branching
- *Lower* carbon and water holding capacity
- *Lower* specific leaf area but similar biomass
- *Lower* tree uptake of N, P, Ca, Mg and K

Sites exhibiting more of these patterns are:

1. Great Monks wood
2. Attingham park
3. Winding Wood
4. Langdale

All of these are AOD sites!

Soil acidification causes release of Al ions and reduces cations availability (Ca, Mg and K) by exchange and leaching processes → Al toxicity inhibits feeder roots growth causing low capability of trees for nutrient uptake → Reduced nutrient availability in soil and reduced root growth can significantly reduce tree nutrient uptake and tree growth

- At smaller scales we observed soil nutrient and physical characteristics as predisposition drivers.
- Low soil water holding capacity and soil sensitivity to drought are key prevailing factors.
- Other potentially significant soil drivers include higher soil acidity caused in some cases by high levels of ammonium, but lower levels of plant-available nitrogen (impacted by microbial communities), phosphorous and calcium.
- Poor tree feeder root development and altered and impaired tree nutrient uptake are also linked to these soil conditions.
- Inhibition of calcium uptake and changes in carbon and nitrogen cycling in AOD and COD trees compared to healthy trees has also been detected.
- More in depth analyses are required to get clearer indications and identification of other significant interactions.

How does this information help landscapers?

Recommendations

Avoid tree stress!!

- ***Environment, soil type, compaction, season planted***
- ***Tree health, root ball, age of trees, origin, risks of imported problems***

Create optimal conditions for tree growth and maintain it

- ***Organic matter - natural litter (oak leaves), no deep mulching and mulch preparation important – new info***
- ***Water – on planting and throughout first season as req***
- ***Compaction - avoid unnecessary foot-fall traffic, stock, vehicles, maintain manually over time***
- ***Wounding – protect trees - stock damage + other***
- ***Fence trees to trap litter, prevent compaction and wounding***

Mind sets – set new fashions, set new norms, set new expectations

- ***Landscapers can lead and feed public perceptions of beauty***
- ***Challenge to think in tree lifespan, finite space, reshape space dynamic urban forests***

Conclusions

- **Predisposition factors have been identified and further testing will provide empirical evidence that will lead to management options.**
- **Feeder root health is important and all the aspects that suppor it. More research is necessary to understand inter-microbial and microbial – host-dynamics.**
- **Landscapers have a huge role in helping restore environmental balance in a sustainable, life supporting way. Great opportunity**
- **Research is here to help. Together we can make a difference**
- **Say it with design, say it with plants, say it for a better world**

https://youtu.be/3vIfJoNL5Xw **or** https://vimeo.com/405366384 and Woodland Heritage Save our oak film at https://youtu.be/Ajyg9KYBwVA.

For more information contact **Sandra.denman@forestresearch.gov.uk**; **Elena.Vanguelova@forestresearch.gov.uk**; **Sally.Simpson@forestresearch.gov.uk**

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