Unravelling interactions in disease complexes and syndromes: the case of Acute Oak Decline

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ROTHAMSTED RESEARCH

Forest Research

Defining a complex disease

- Pests and pathogens do not act in isolation.
- Environmental conditions (e.g. drought) may predispose host plants.
- Most common in forestry, due to host resilience and longevity.
- Within these system agents may act sequentially and are likely to have a cumulative affect.
- Multidisciplinary approach is key to explore these systems.
- ***Focus of this talk will be the survey and monitoring element.***

Outline

- AOD background
- Intensive monitoring
- National survey
- Interpreting survey data

Stem symptoms and signs

Acute Oak Decline (AOD) is a distinct syndrome that falls within the wider context of oak decline. *A fast deterioration in health has been reported.*

1) Stem "bleeds"

- Dark liquid runs from cracks between bark plates.
- Necrotic tissue below bark
- Observed historically across Europe but no causal agent was identified.

2) Agrilus biguttatus

- Larval development may take 1-2 years.
- Adults present briefly in a single summer.
- Exit holes first sign of presence
- Secondary pest (affecting declined trees)?

Taxonomy and Phylogeny

Forest Research

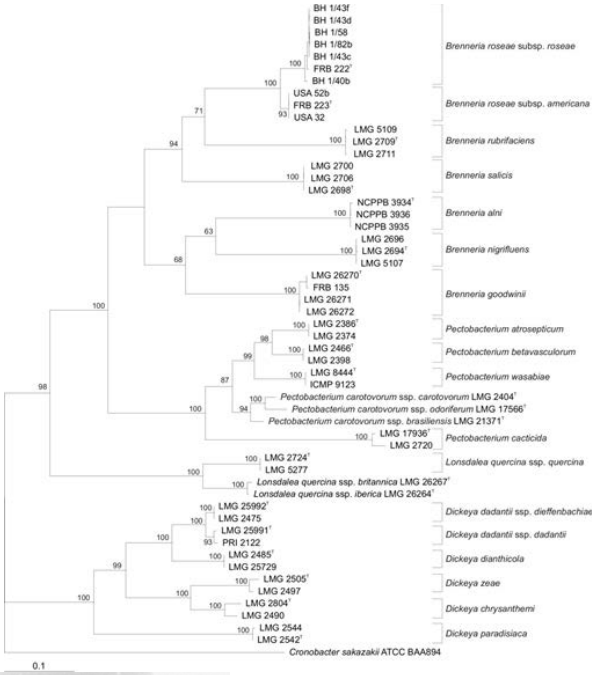
ROTHAMSTED RESEARCH

Created two novel Genera:

Twelve novel species:

Brenneria goodwinii

Gibbsiella quercinecans

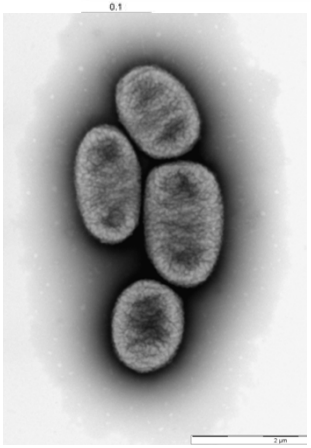


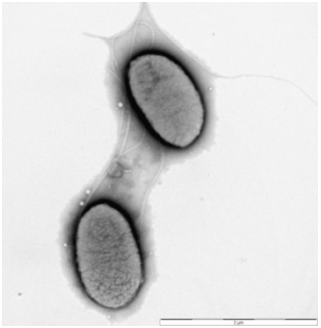
Pathogenicity is a complex problem:

Log and tree inoculations (beetle and bacteria)

Genetic tools to be infectious

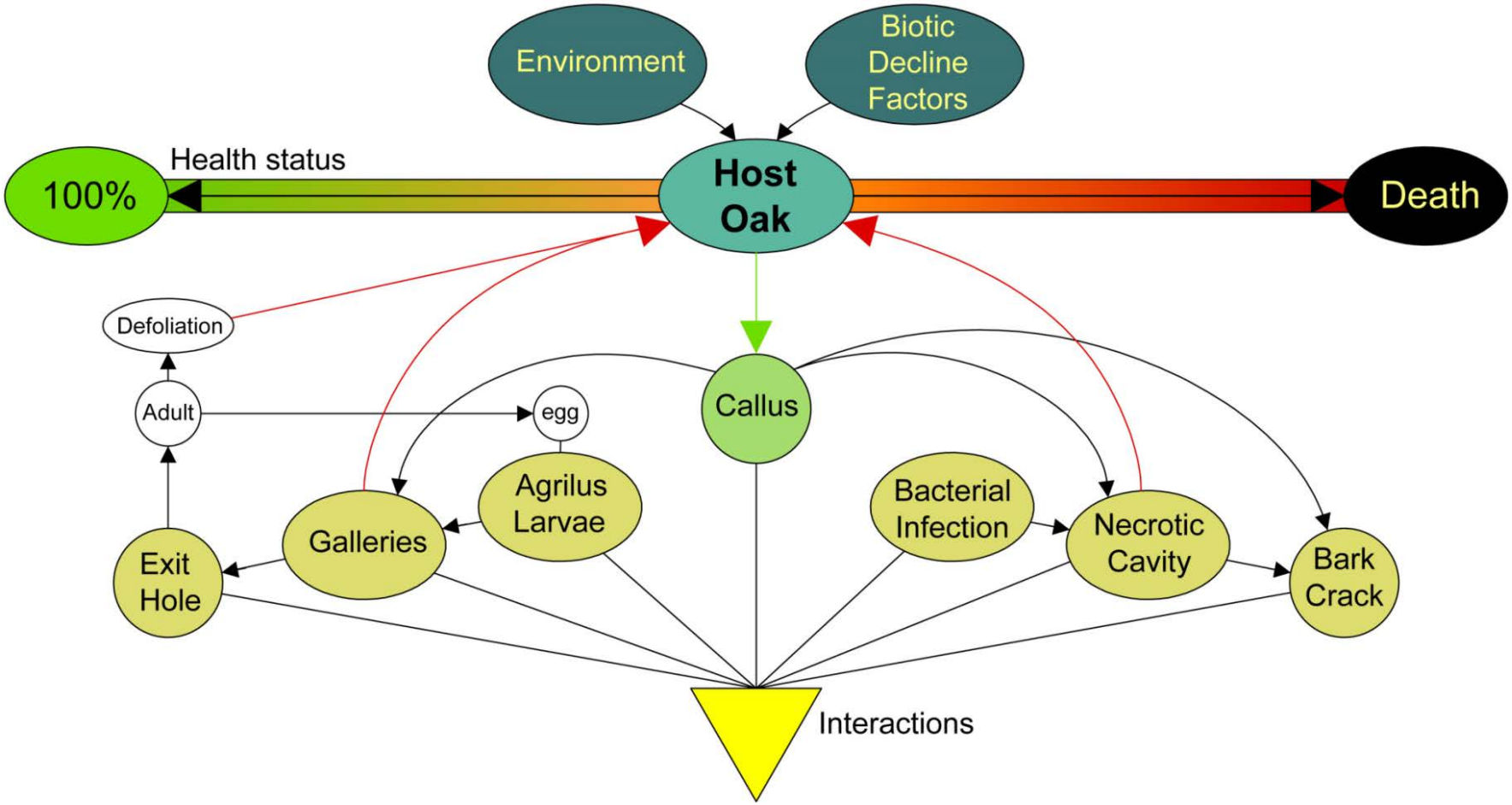
Predisposition of the host





BBSRC bioscience for the future

AOD system


Environment
Biotic Decline Factors
Health status
100%
Host Oak
Death
Defoliation
Adult
egg
Callus
Agrilus Larvae
Galleries
Exit Hole
Bacterial Infection
Necrotic Cavity
Bark Crack
Interactions

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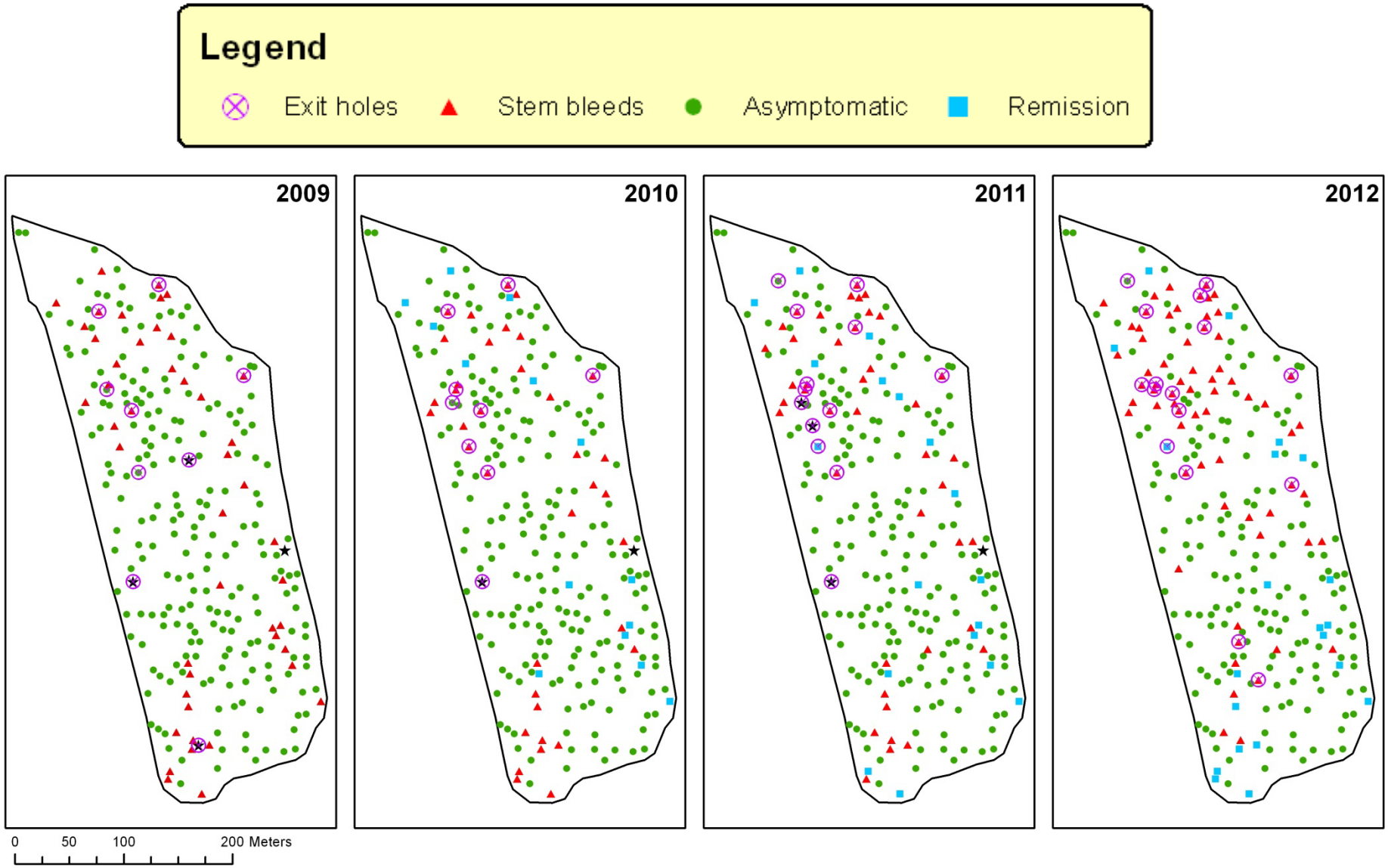
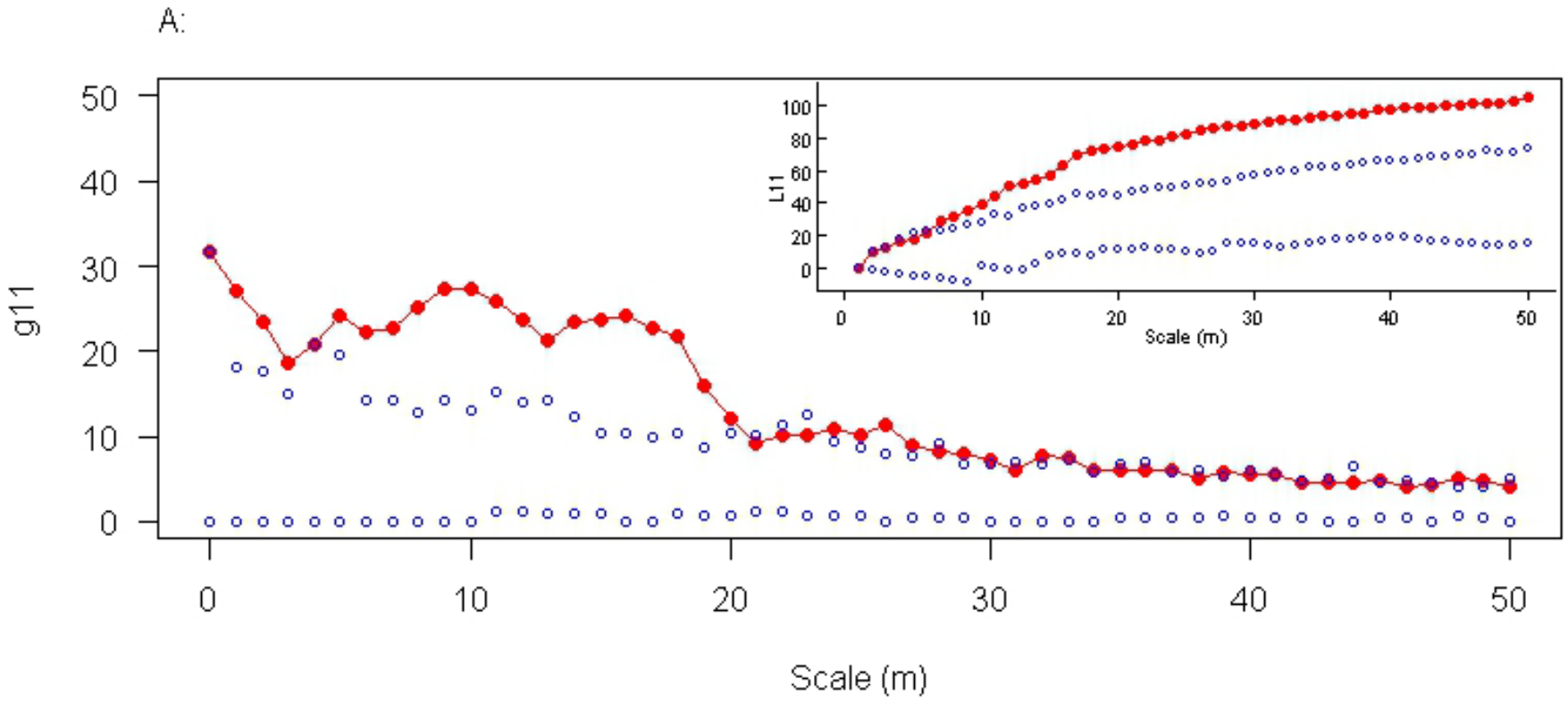
- **Intensive monitoring**
- National survey
- Interpreting survey data



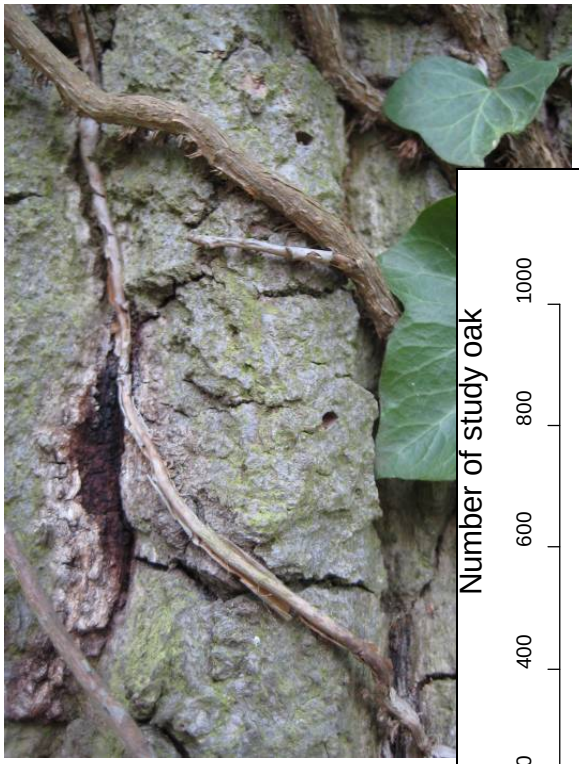
n (all oak) = 260

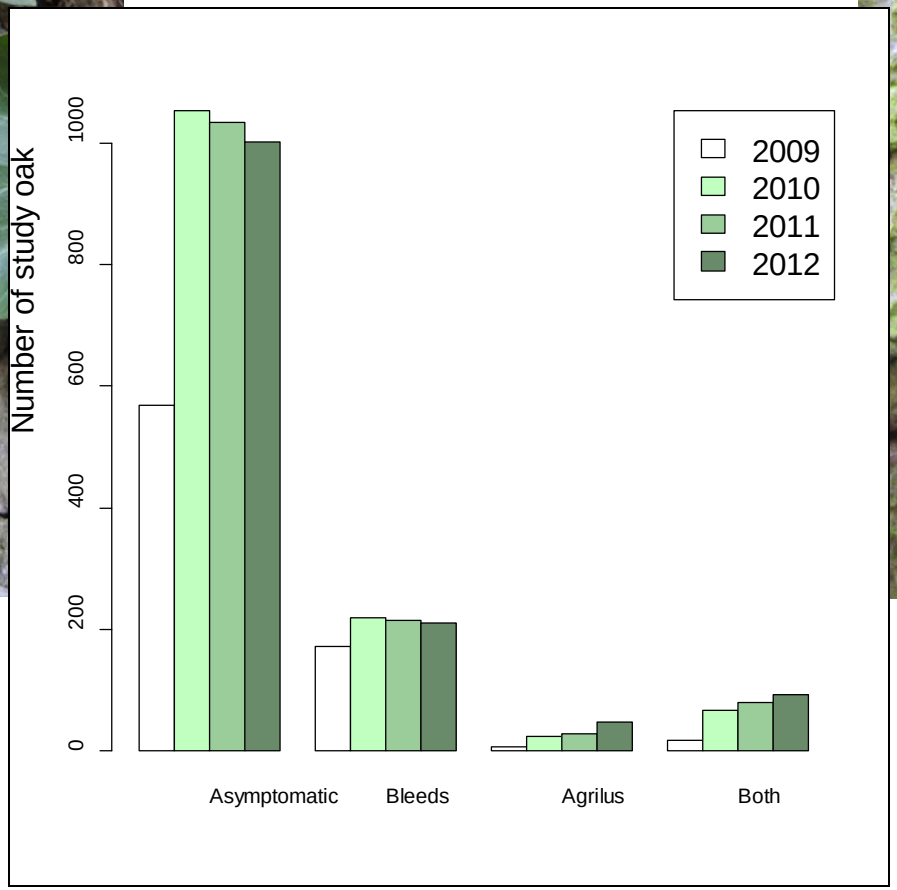
Affected trees are in clusters



- Main graph shows distance specific clustering (O-ring)
- Cumulative pattern (L-function) shown top right

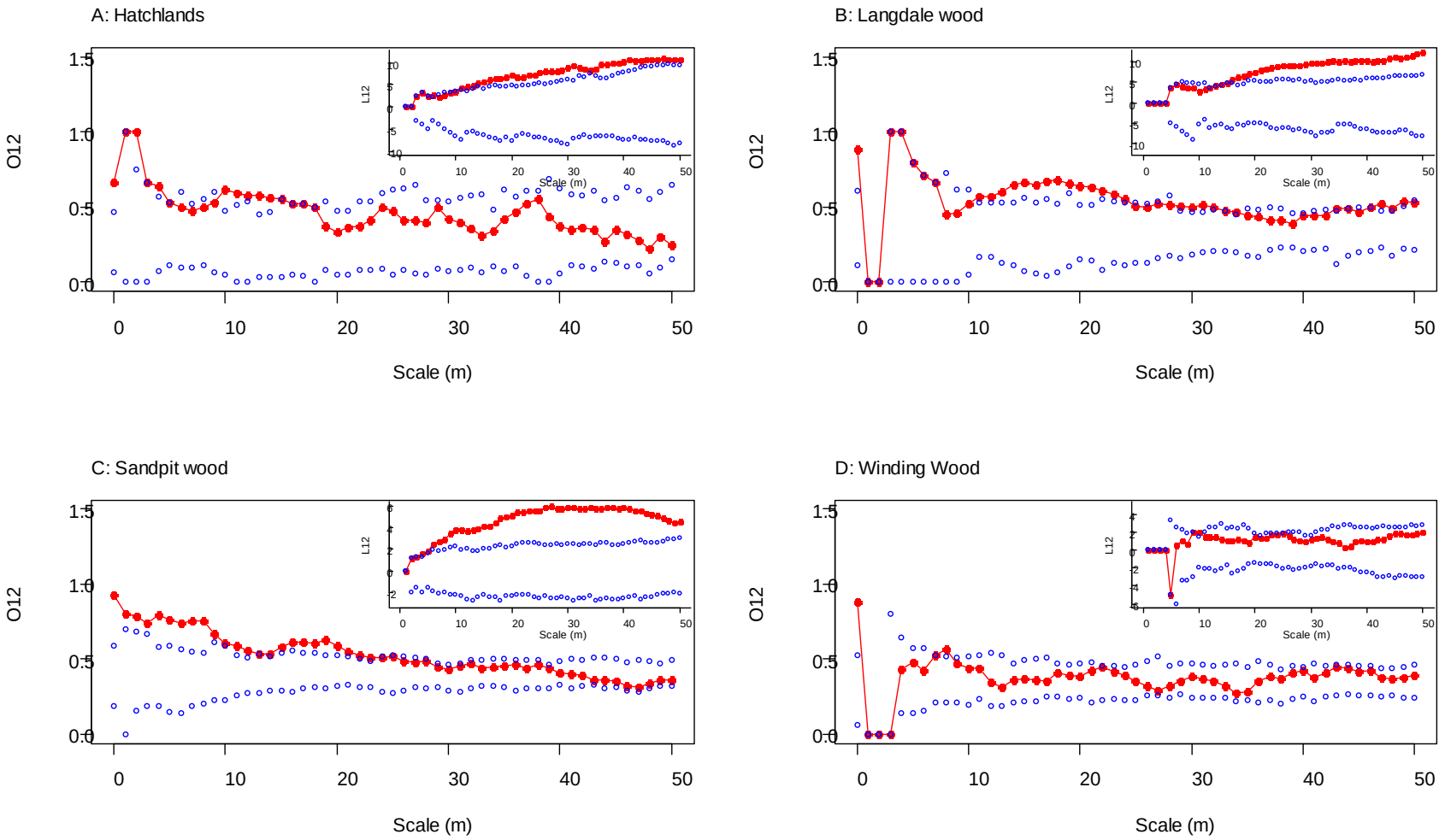
Co-occurrence of stem bleeds and *Agrilus*





Year	X^2	p
2009	28.27	$p < 0.001$
2010	157.29	$p < 0.001$
2011	183.10	$p < 0.001$
2012	166.42	$p < 0.001$

Bleeds around exit holes



Trees with stem bleeds are found around those with exit holes

What comes first?

66.67% of trees that develop exit holes already had stem bleeds

A further **14.1%** of trees develop both in the same year

So is the beetle a opportunist?

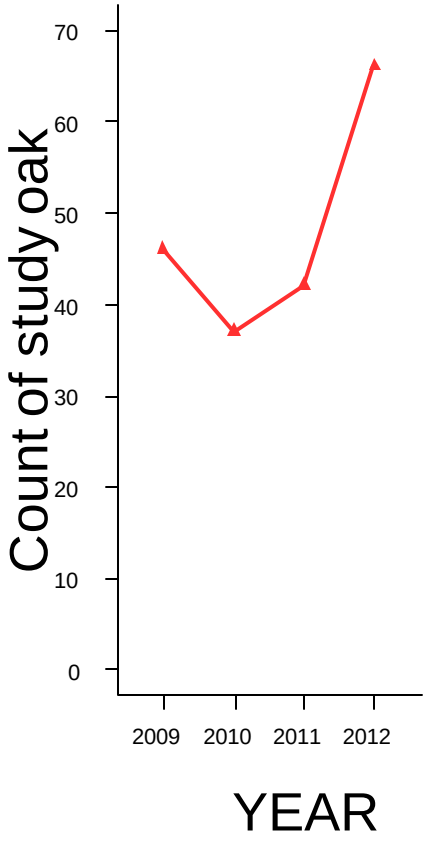
Maybe not…

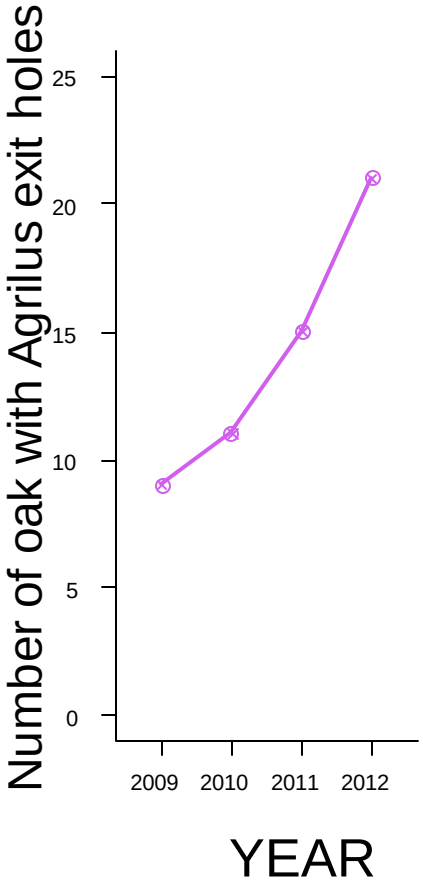
galleries were observed in almost all trees with bleeds:

36/38 = 94.7 %

the remaining two trees were sampled before methods were standardised

General trends over time





Patterns varies between sites, **but...**

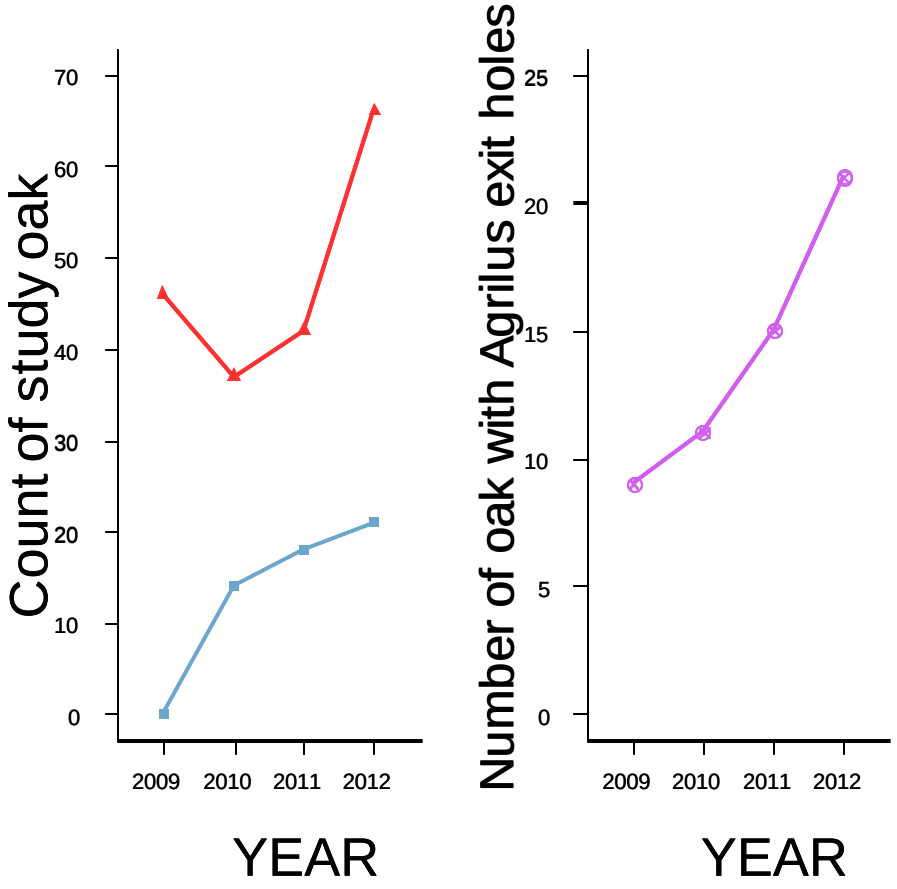
All sites had newly symptomatic oak.

All sites had trees that entered remission (active stem bleeds stopped).

Indicates an important role for host health and defences.

n (all oak): Top left = 260,

General trends over time



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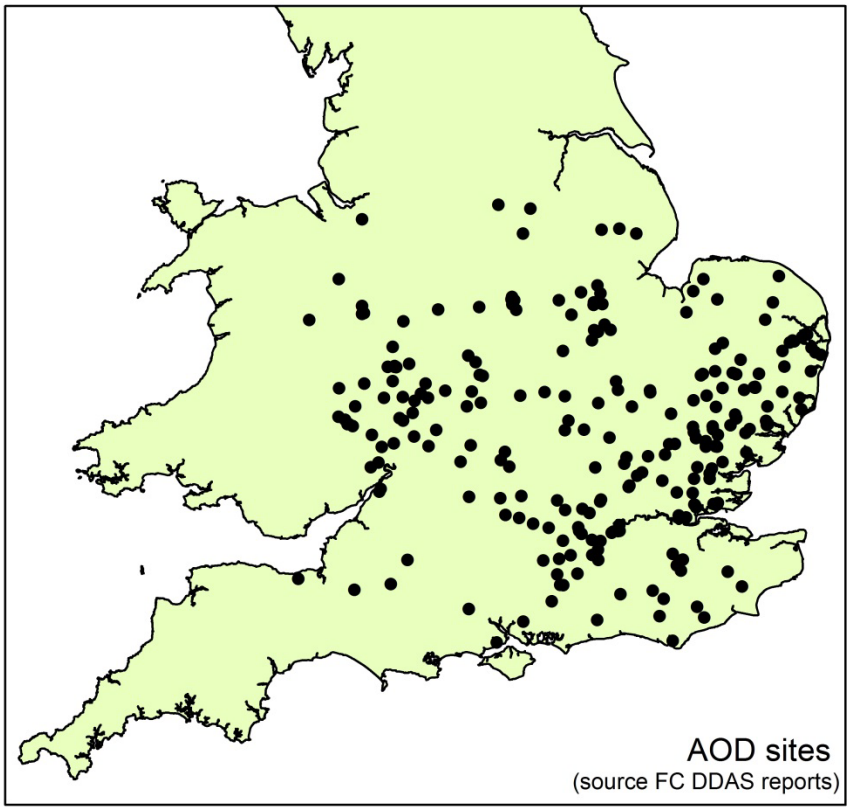
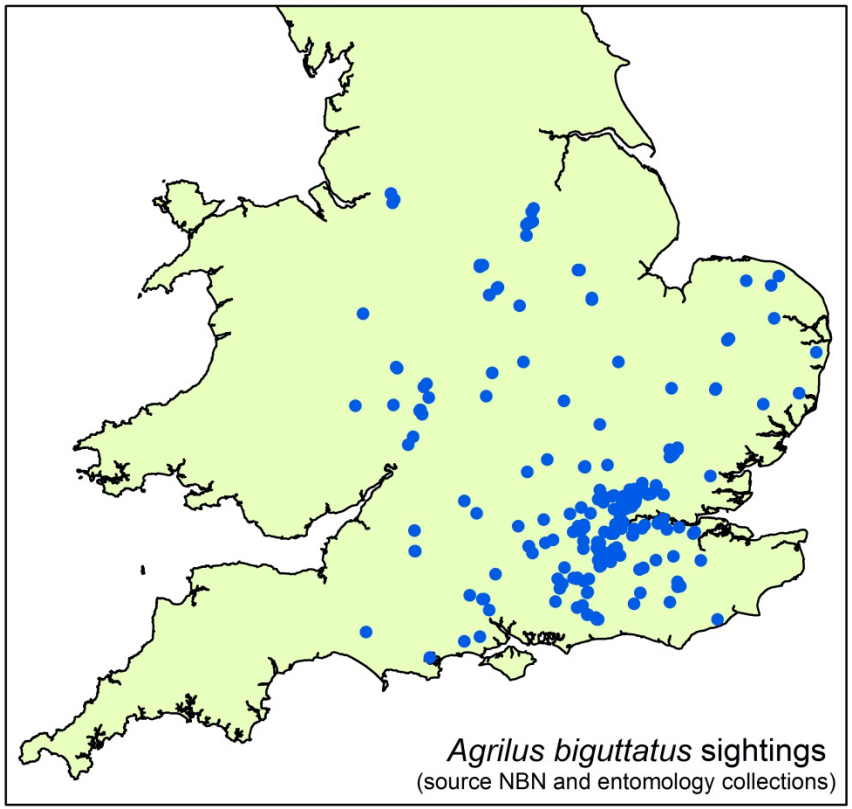
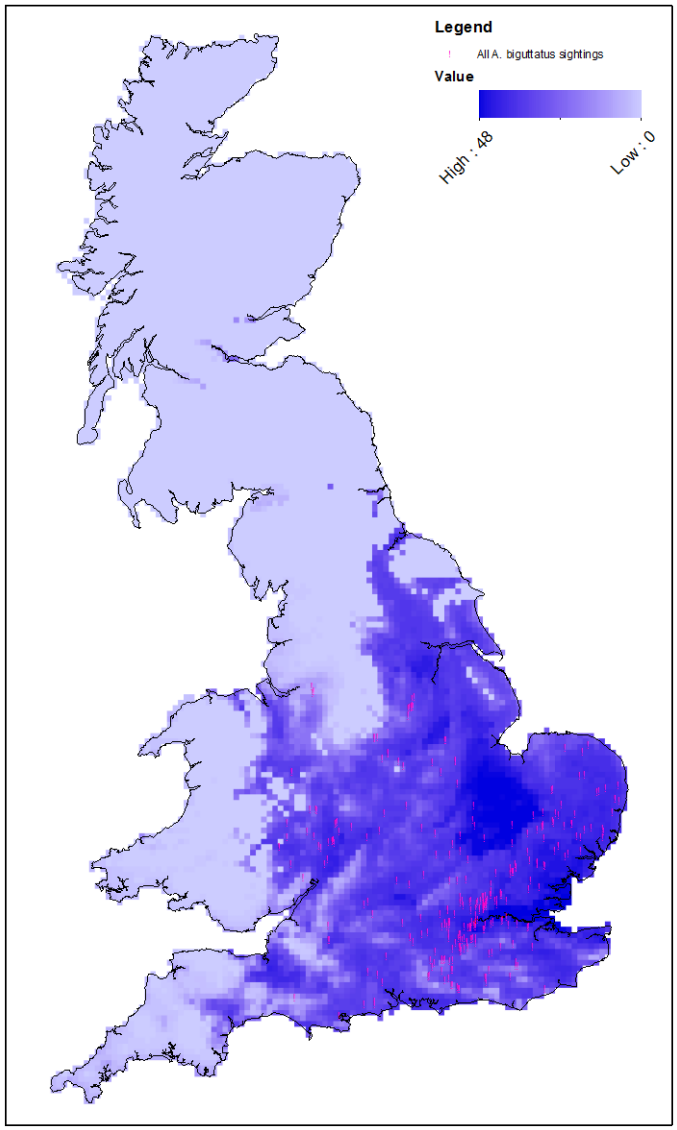
National distribution





Climex



- Uses provisional distribution data.
- No systematic data collection.
- No negative records.

- Gives a potential distribution
- Mainly predicted by temperature.
- More suited in dry areas.

- **But can we trust this?**

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THE wildlife TRUSTS

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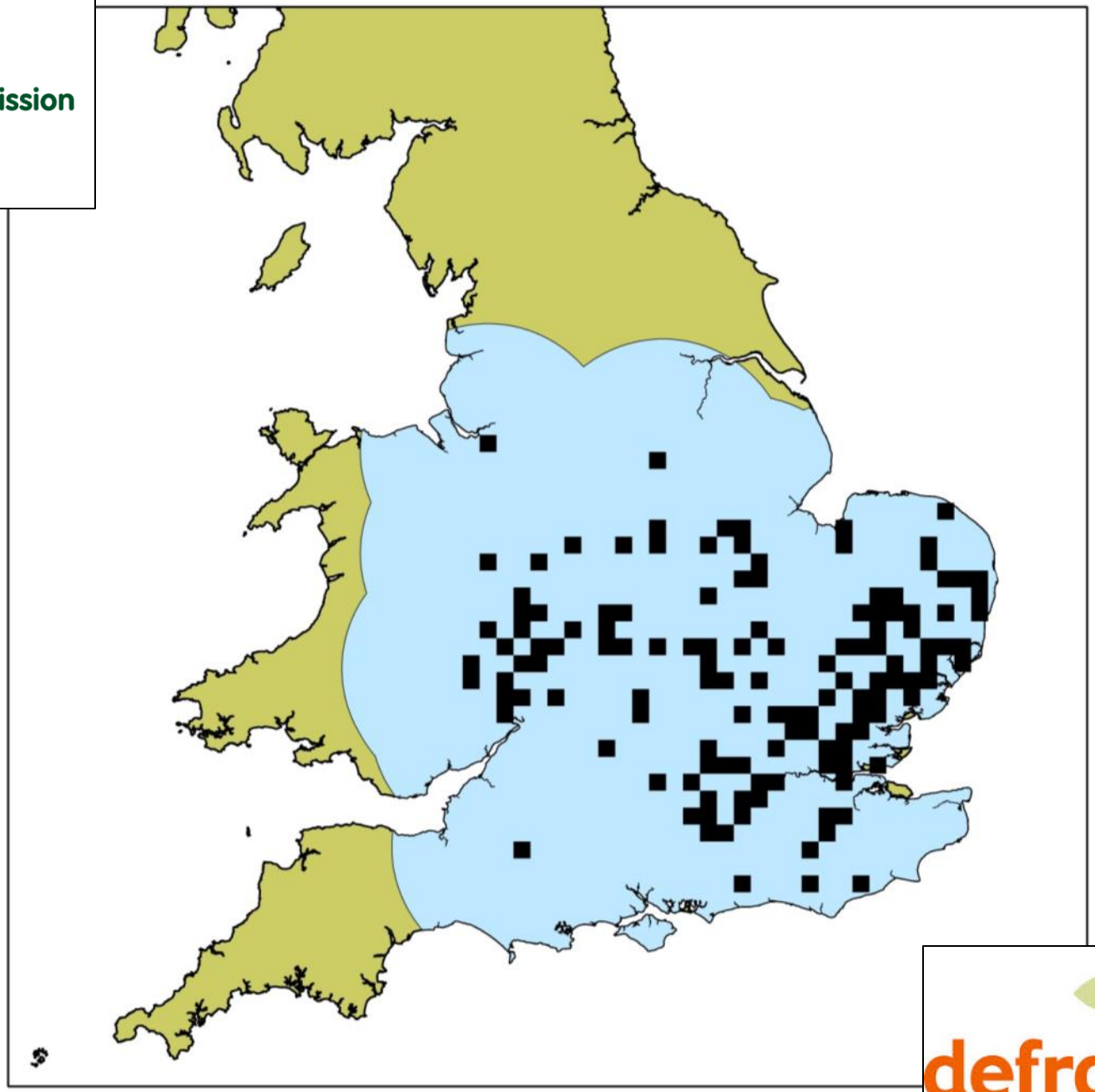

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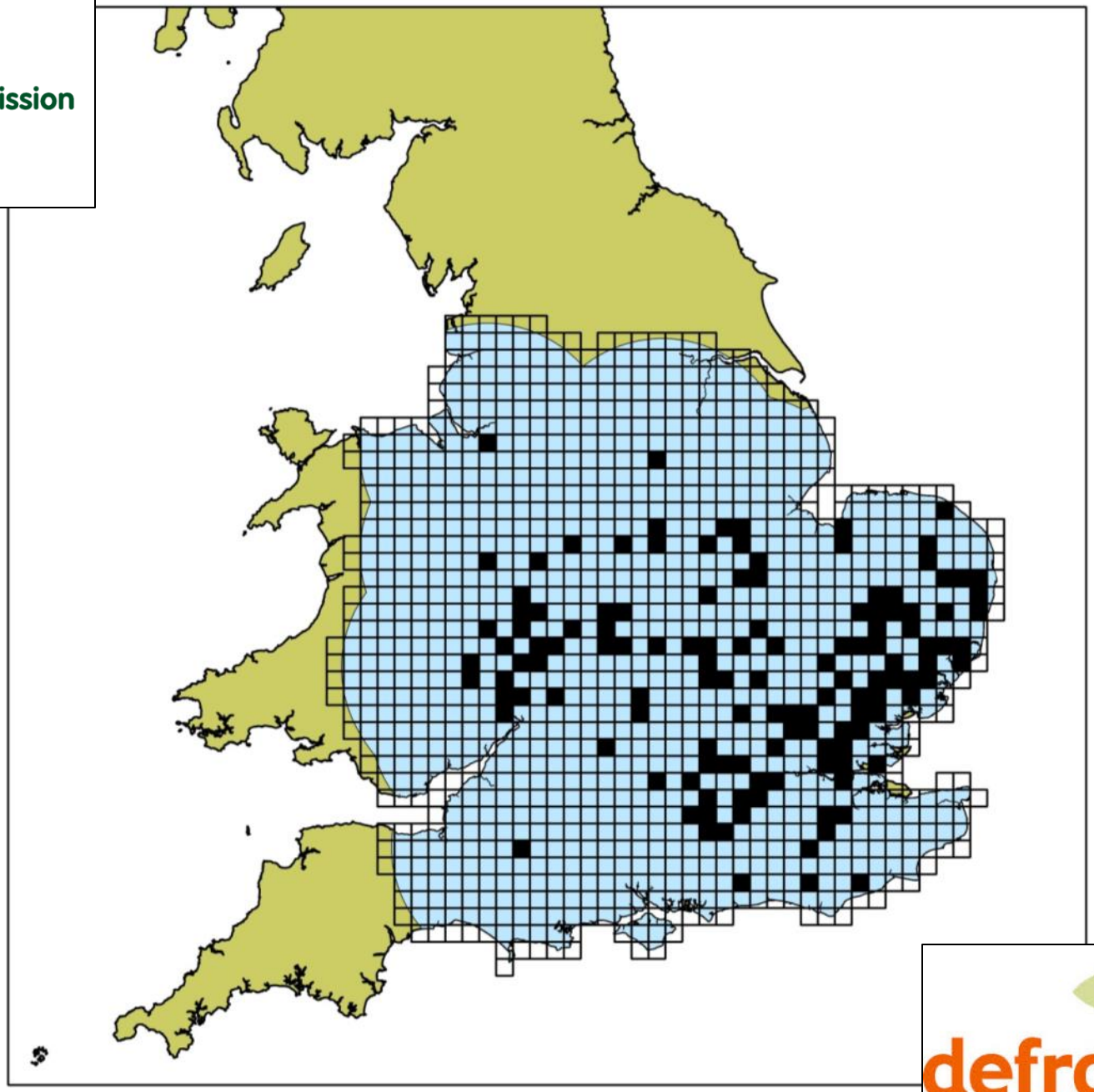

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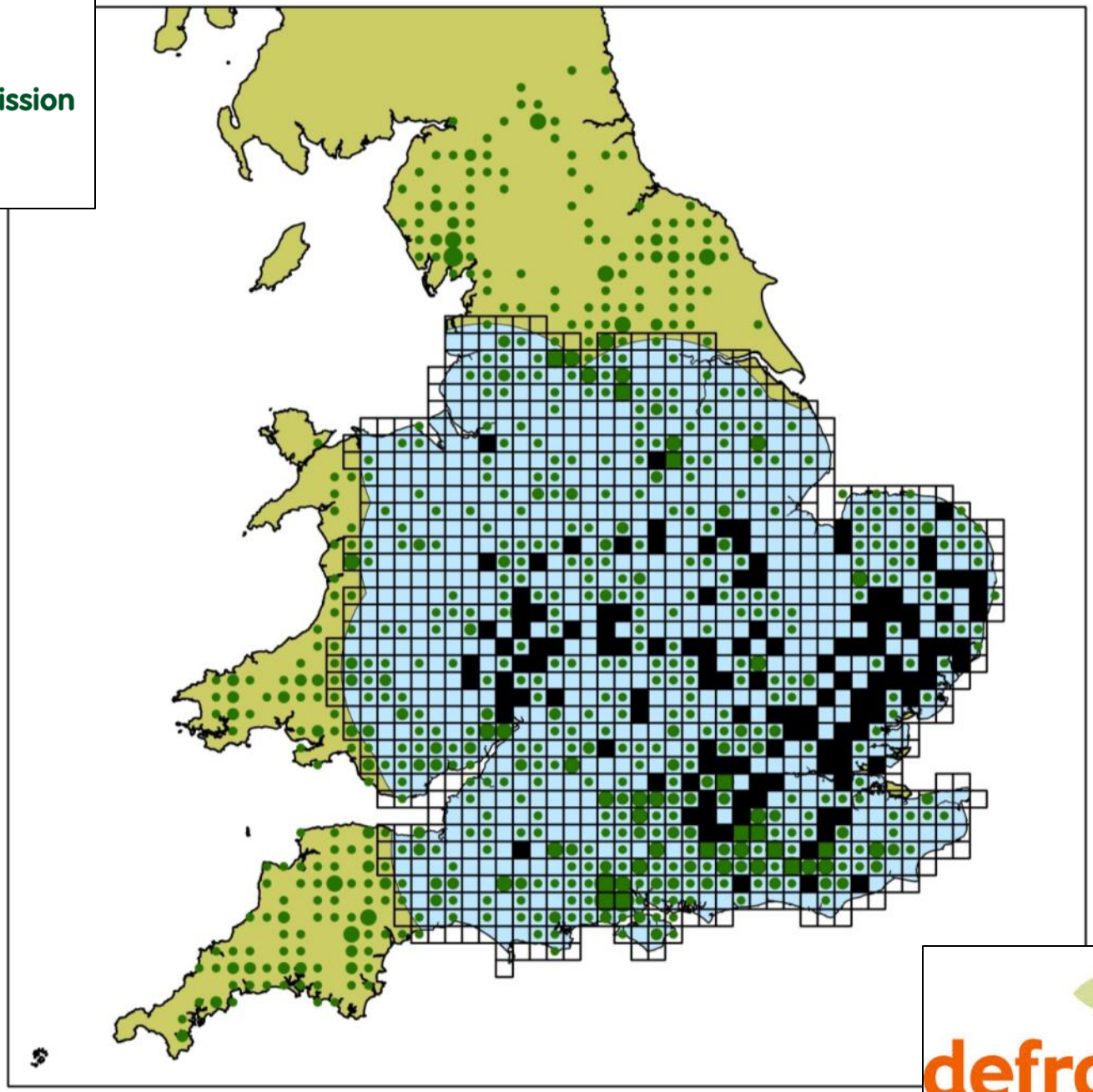

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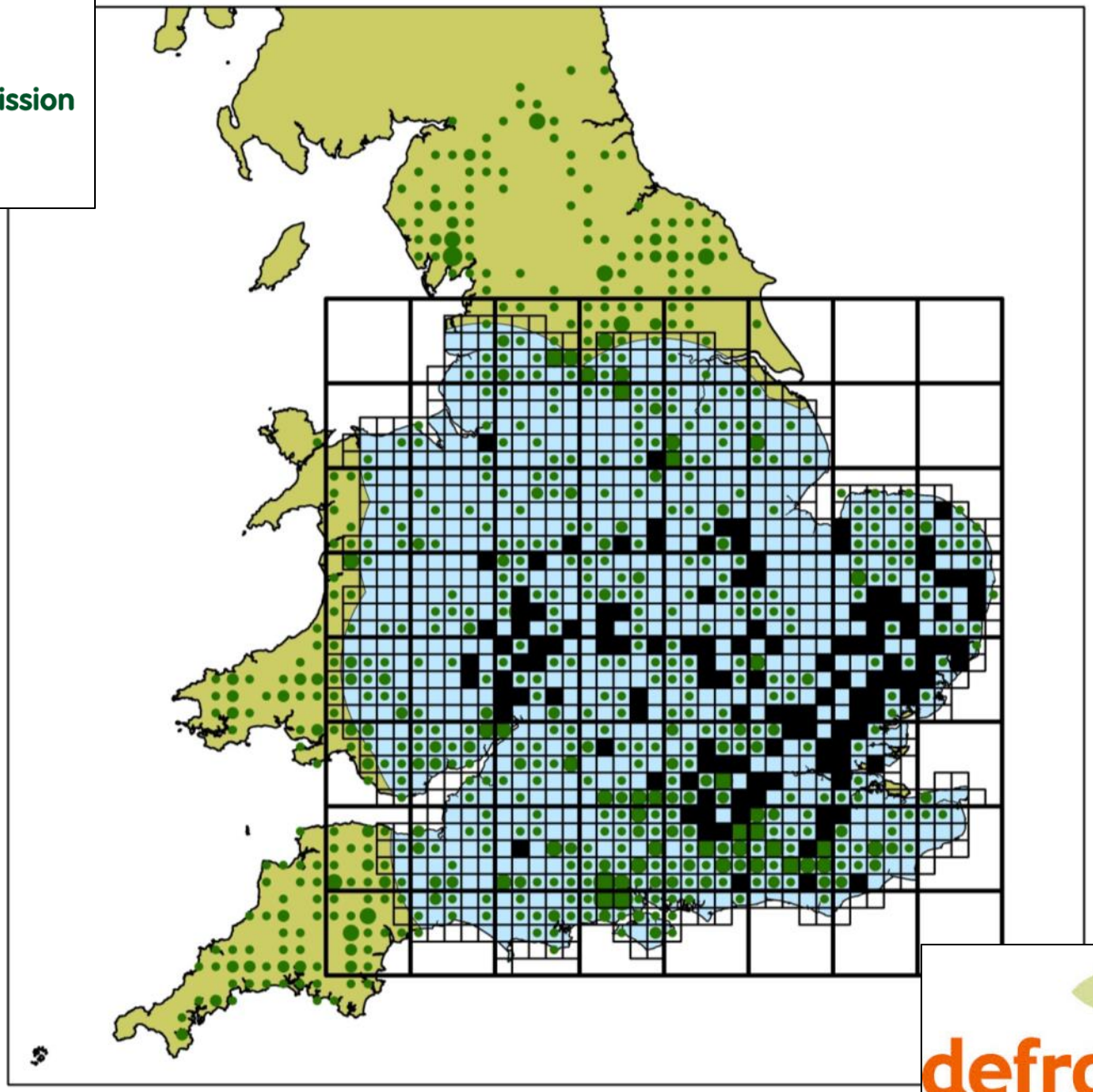

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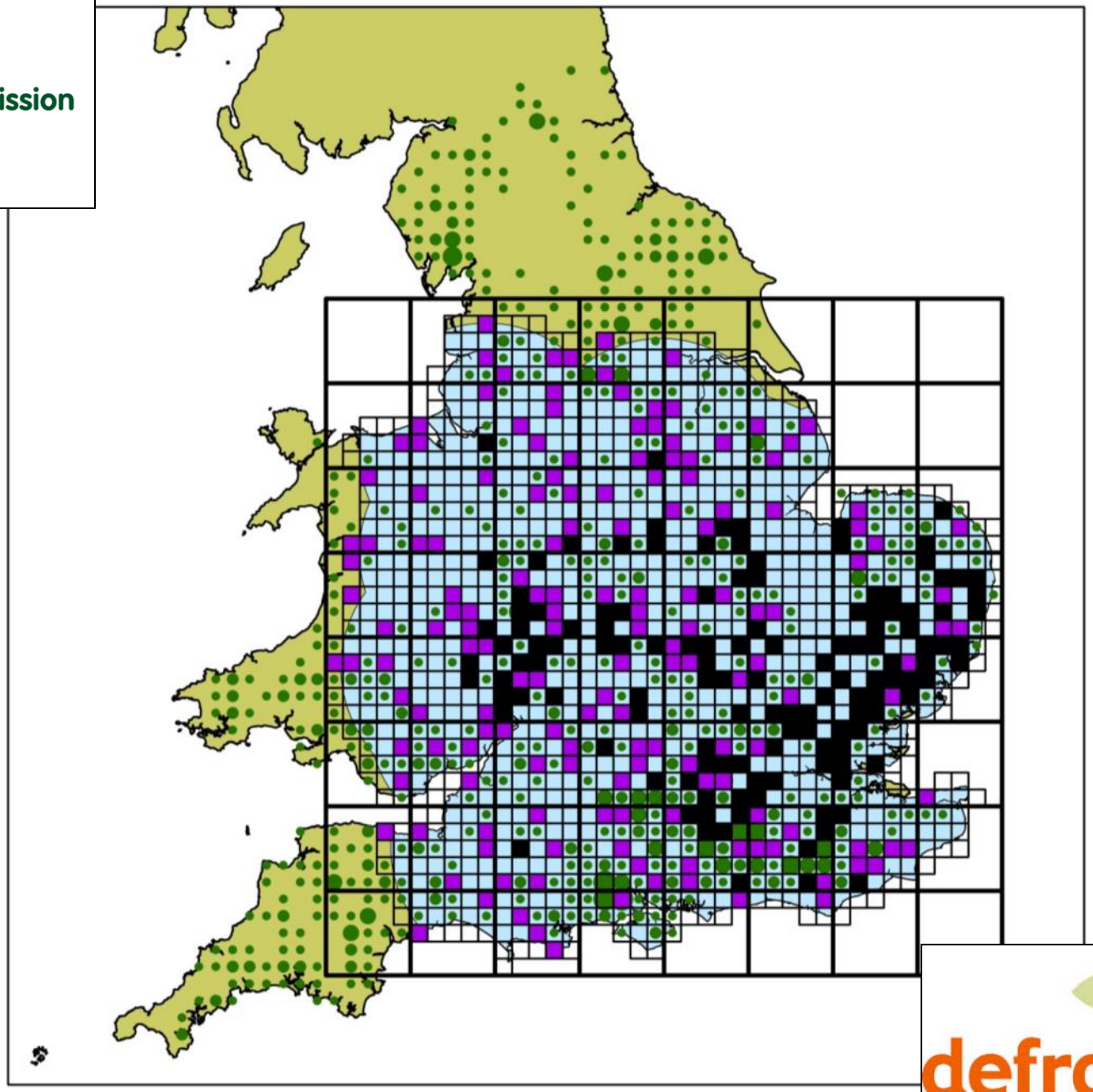

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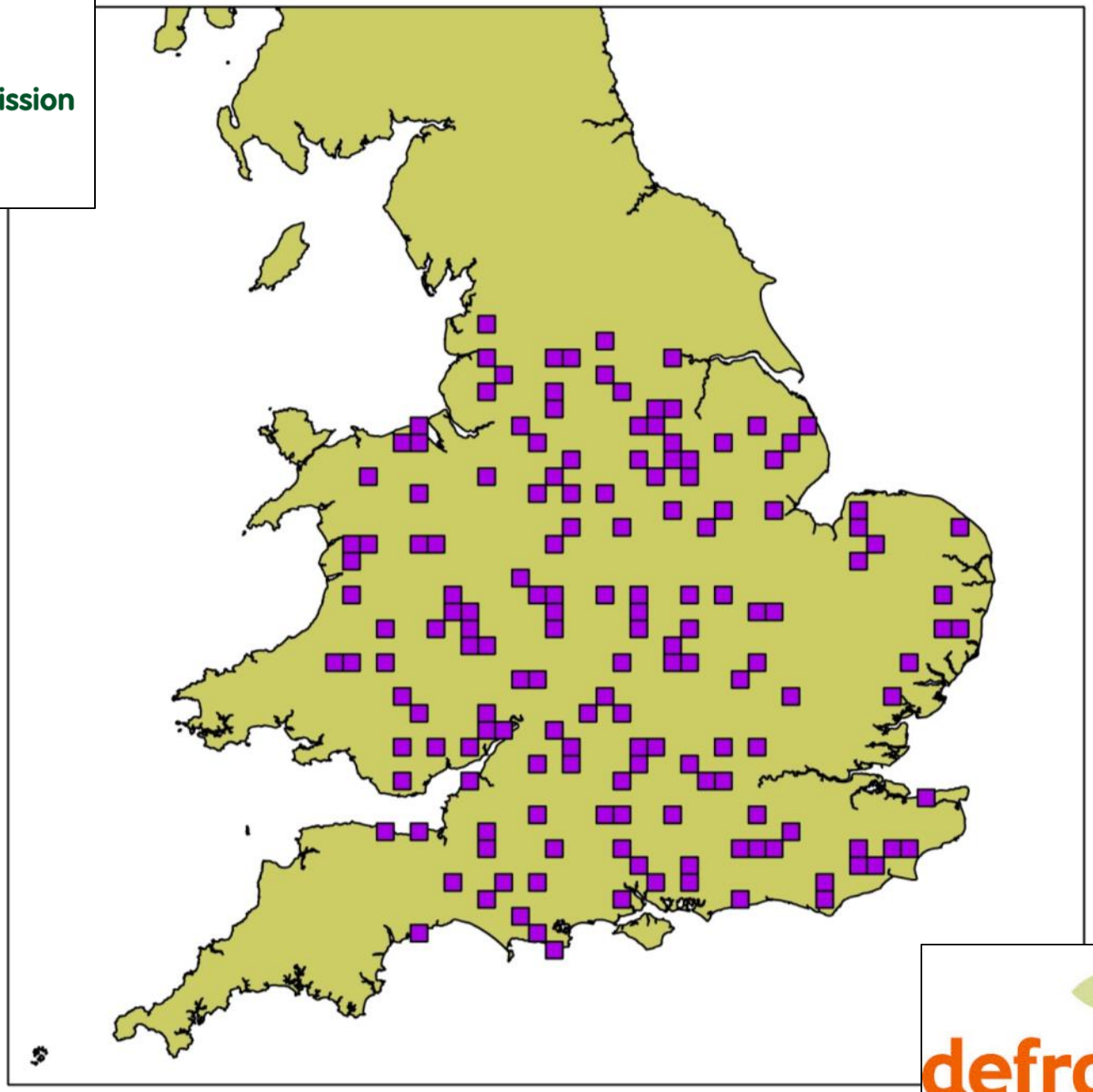

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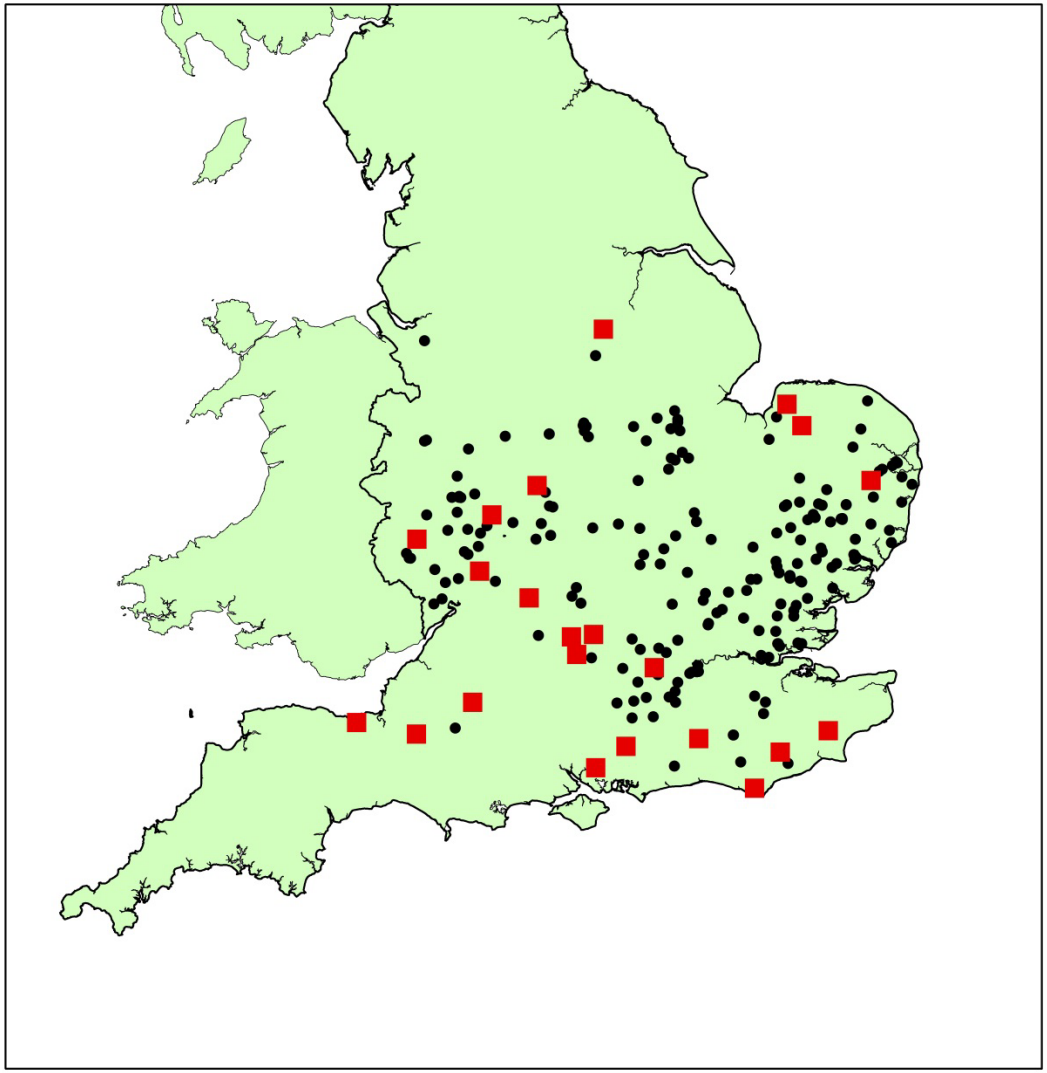
2014 Survey results

- 196 hectads selected
- 38 contained AOD positives already, so not surveyed
    - ❖ *Approximately 20% of selected area*

- First detection of AOD in 22 squares

- In total (22+ 38) 60 out of 196 squares contain AOD symptomatic trees
    - ❖ *Approximately 30% of selected area*

2014 Survey results



New discoveries are shown in **red**.

Earlier AOD reports are shown as **black** dots.

Outline

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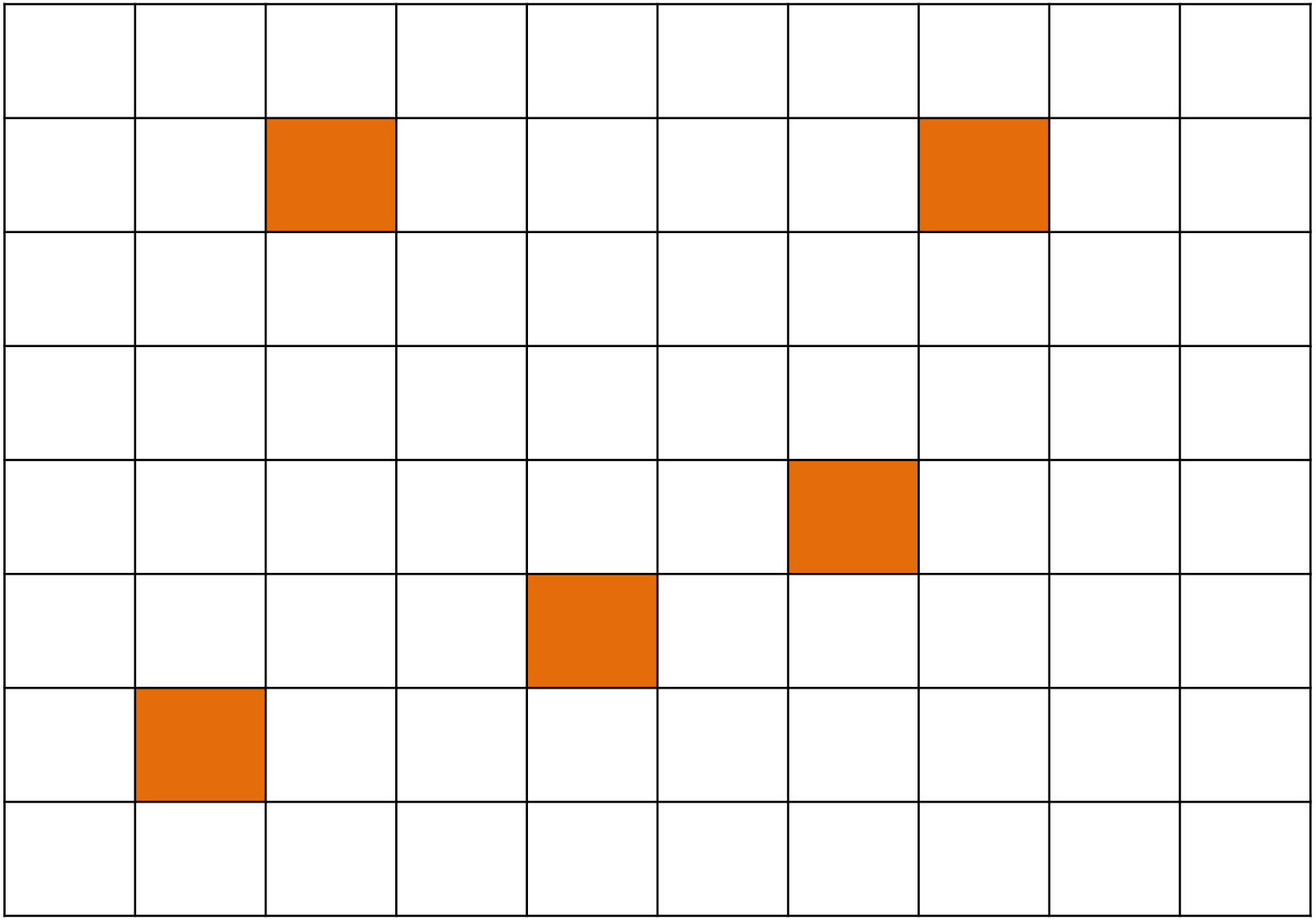
Surveys are conducted in some squares, but what happens in between?



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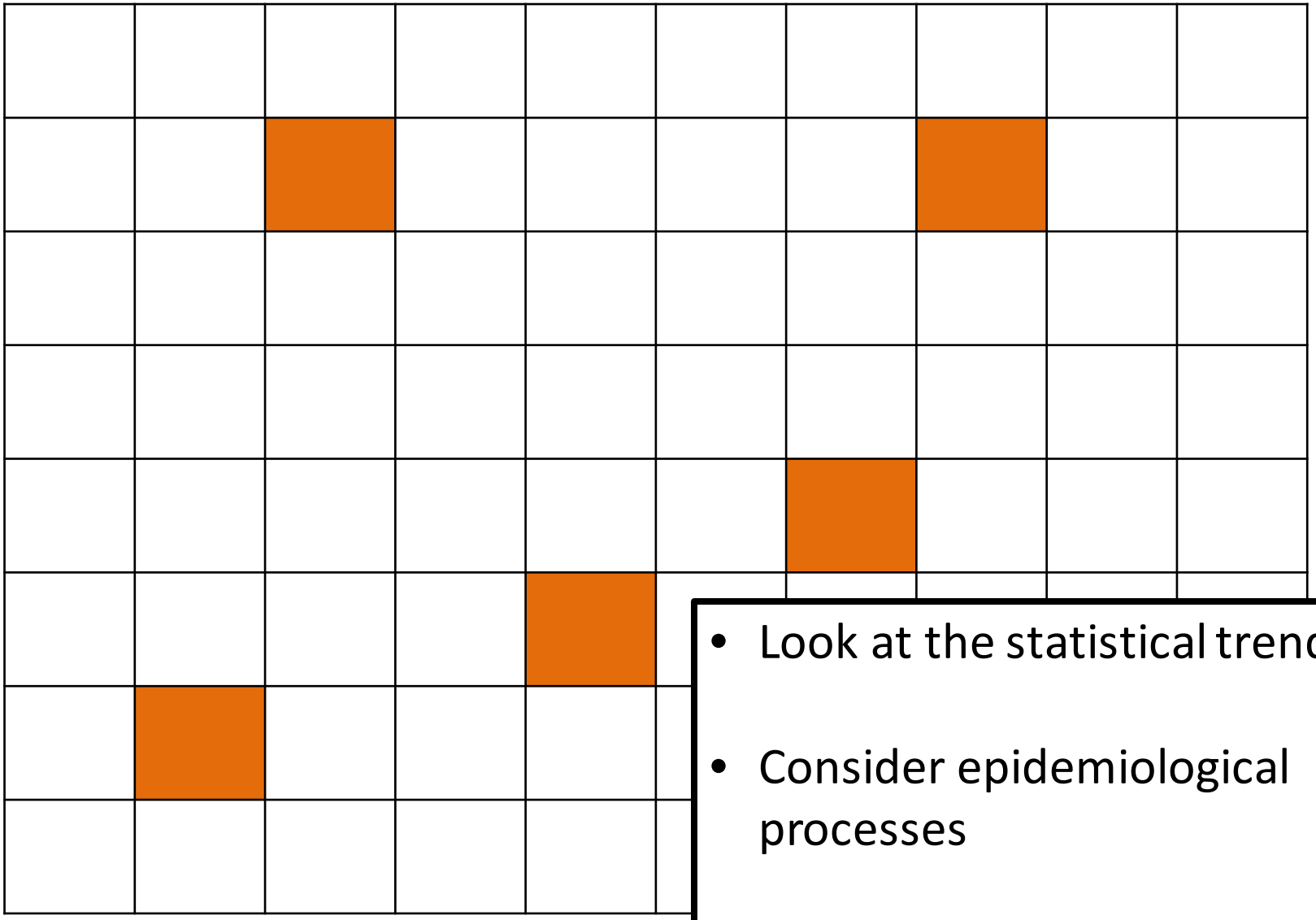
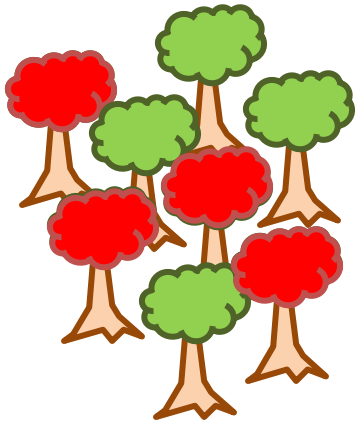


- Look at the statistical trend
- Consider epidemiological processes

Principles used to calculate disease incidence:

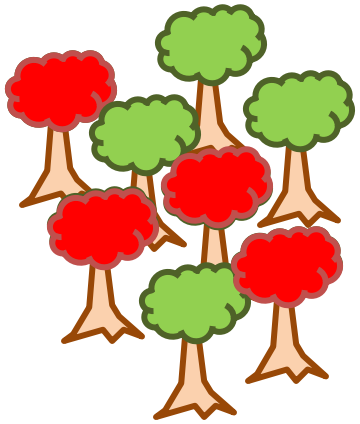


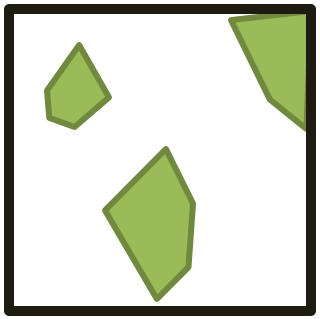
Disease Incidence (cell 1)

=

Disease Incidence (cell 2)

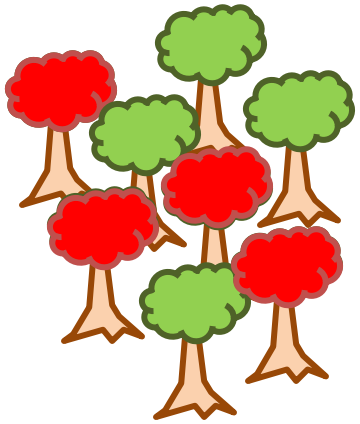
Principles used to calculate disease incidence:

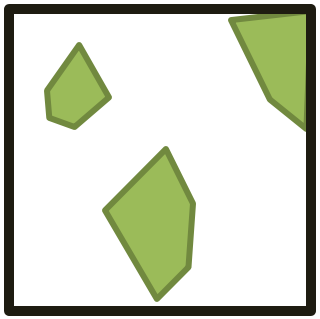


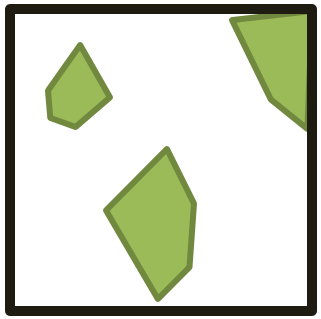


Disease Incidence (cell 1) X Host Area (cell 1) = Disease Incidence (cell 2)

Principles used to calculate disease incidence:







Disease Incidence (cell 1) X Host Area (cell 1) X Host Area (cell 2) = Disease Incidence (cell 2)

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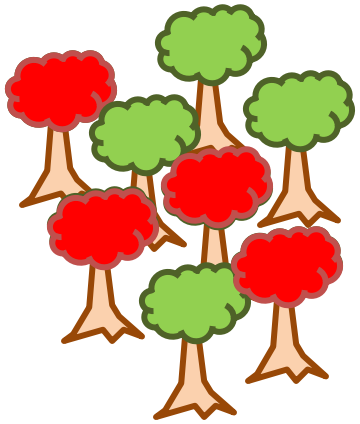
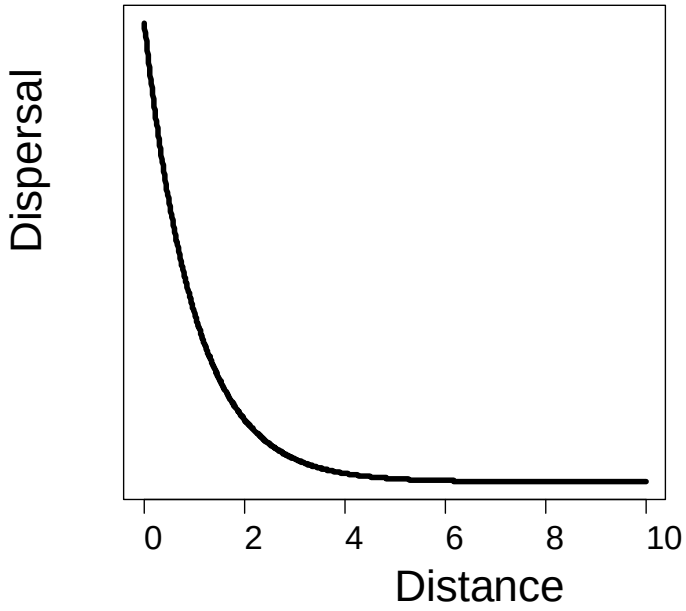
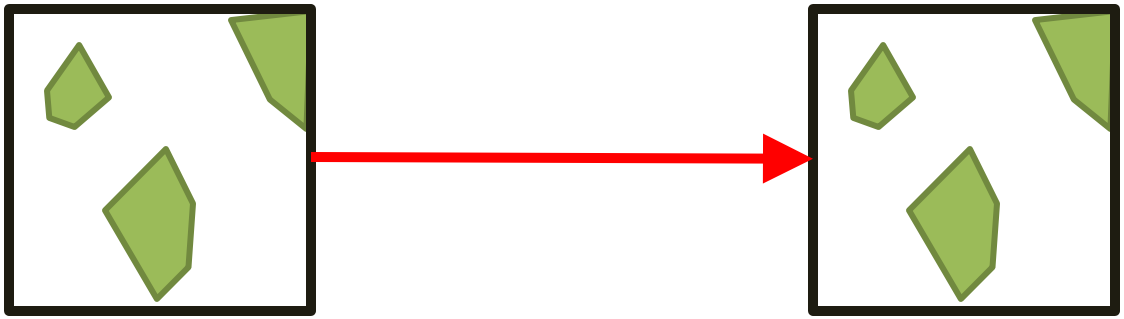
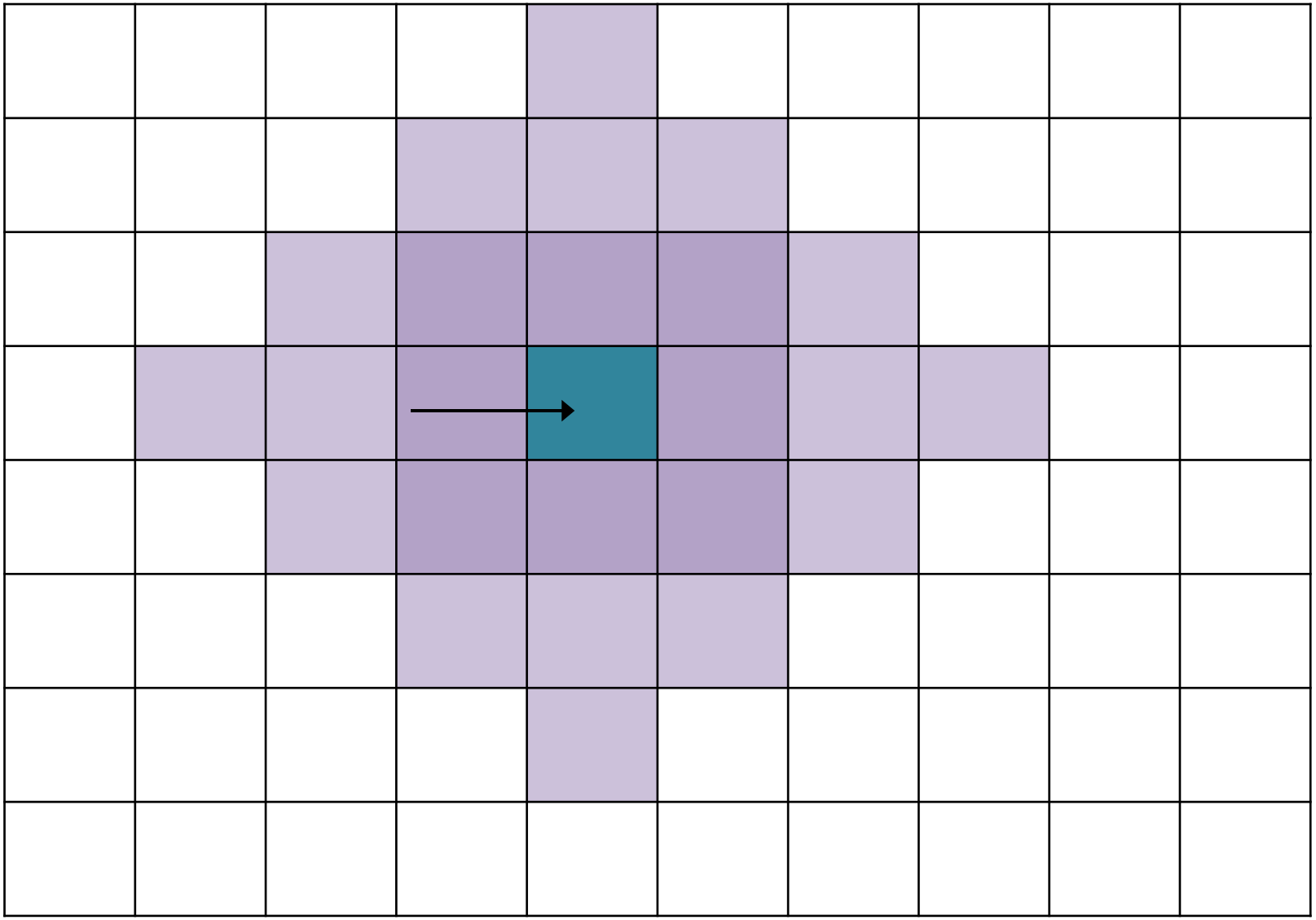






Disease Incidence (cell 1) X Host Area (cell 1) X Distance (cell 1 to cell 2) X Host Area (cell 2) = Disease Incidence (cell 2)

Probability of disease is calculated from all neighbours



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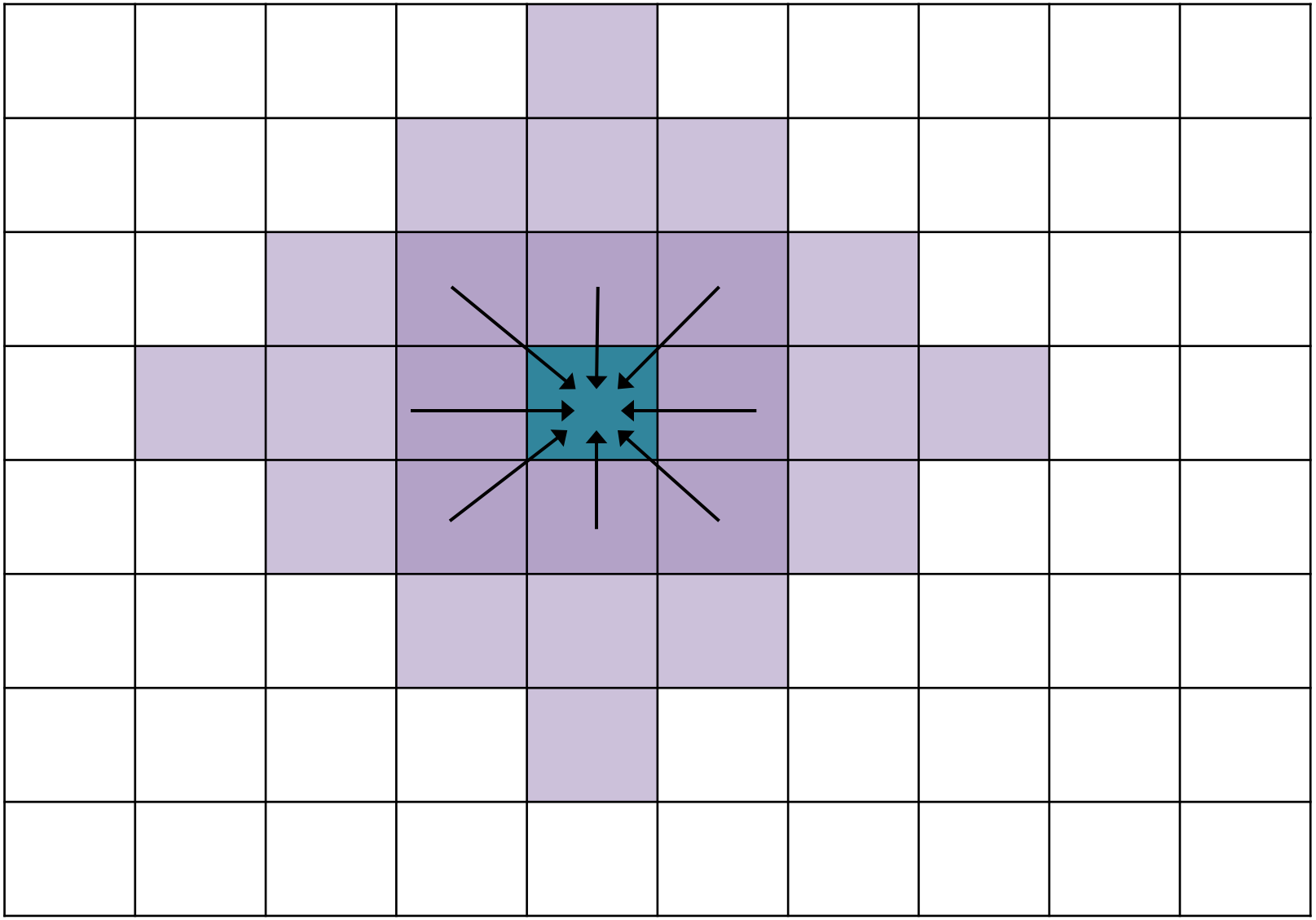

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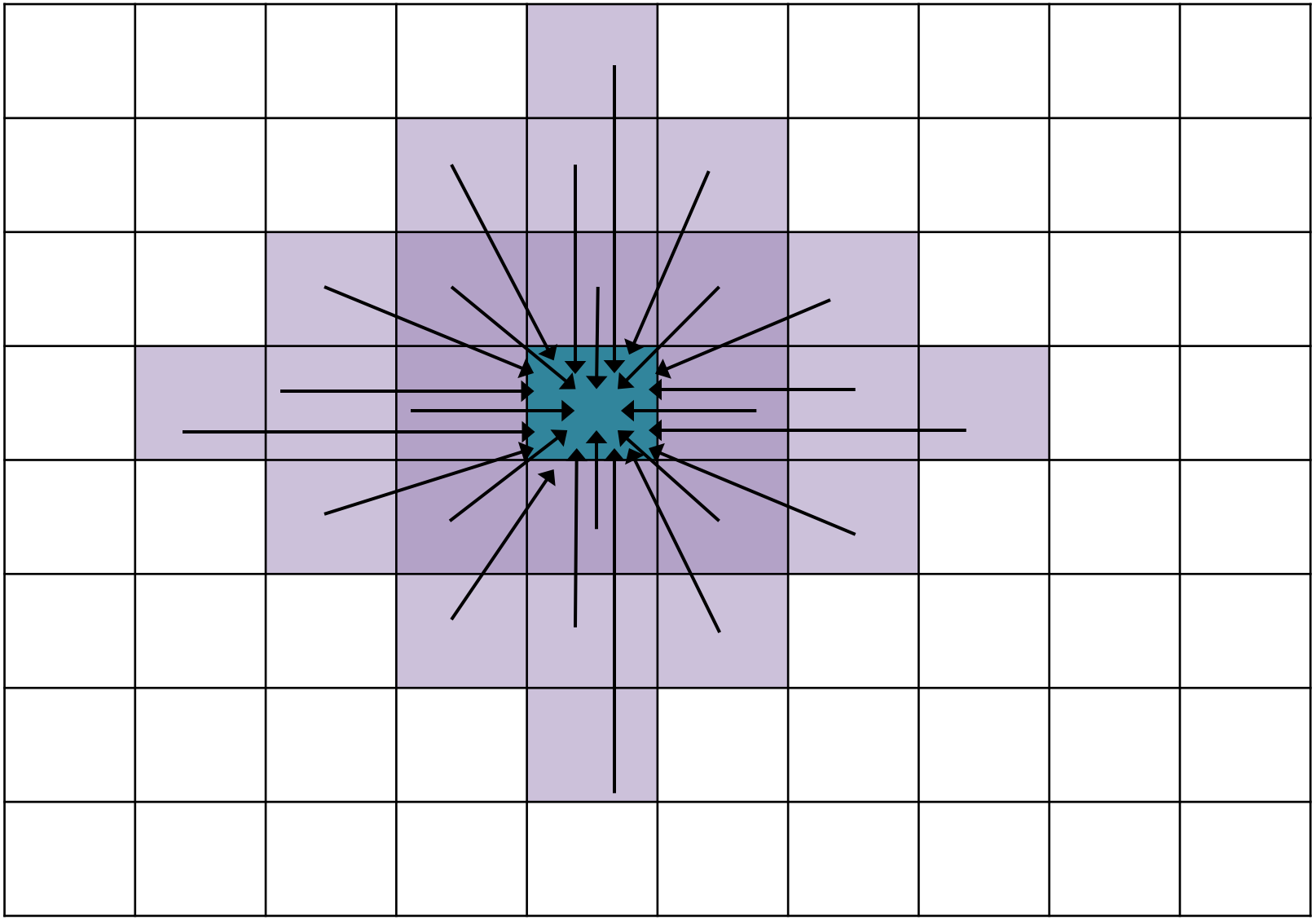
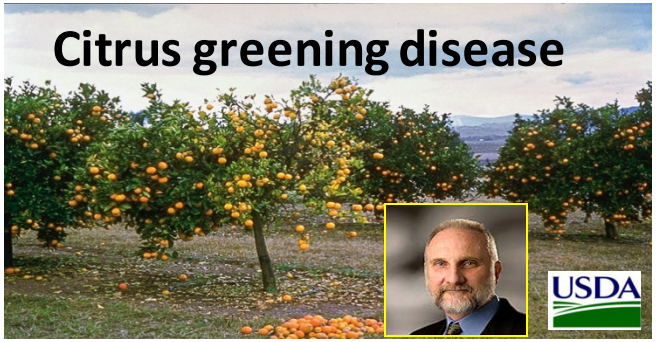


Testing the stochastic method

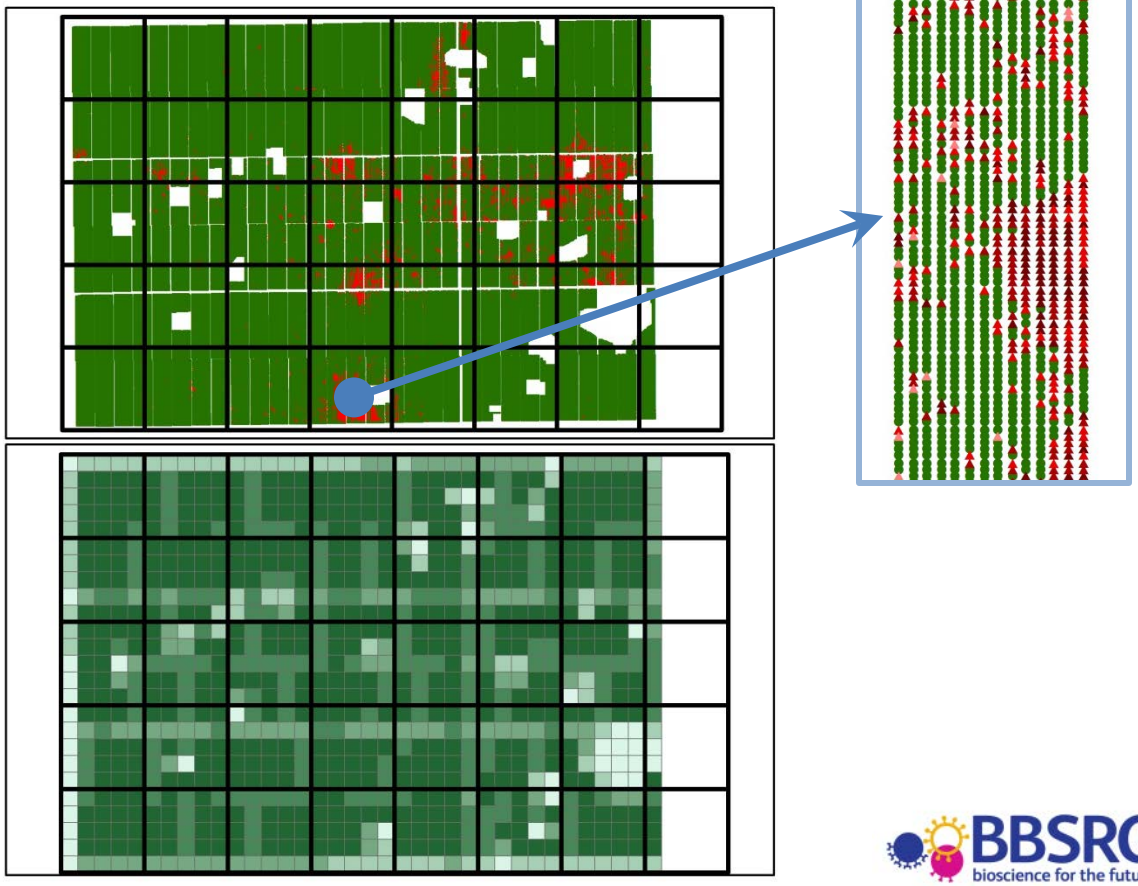


Southern Gardens

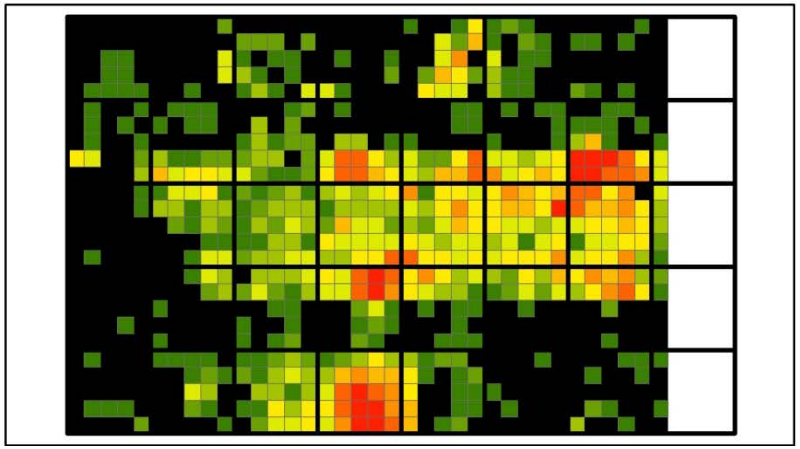
261,715 citrus trees

Individually monitored for disease

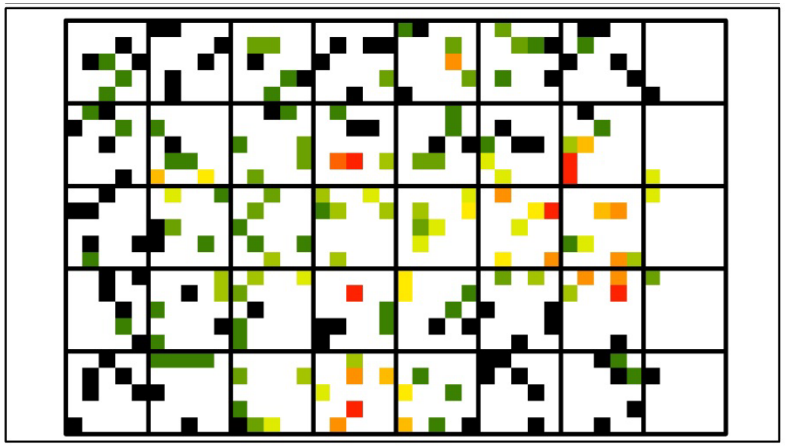
Data summarised by 1ha square



Observed incidence



24% Sample



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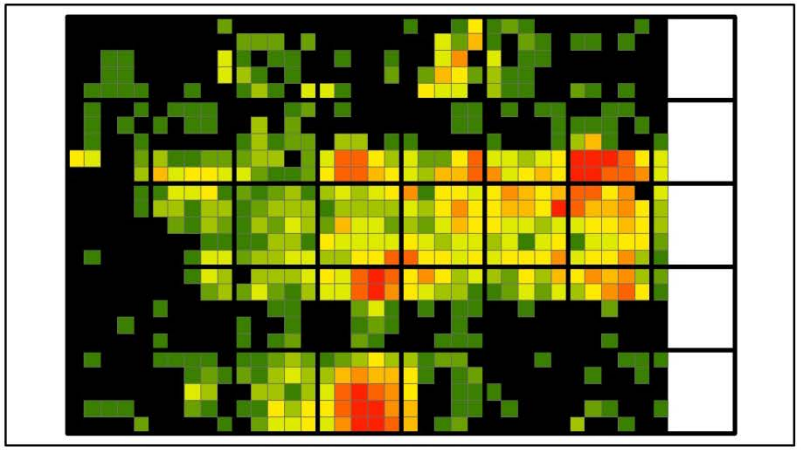
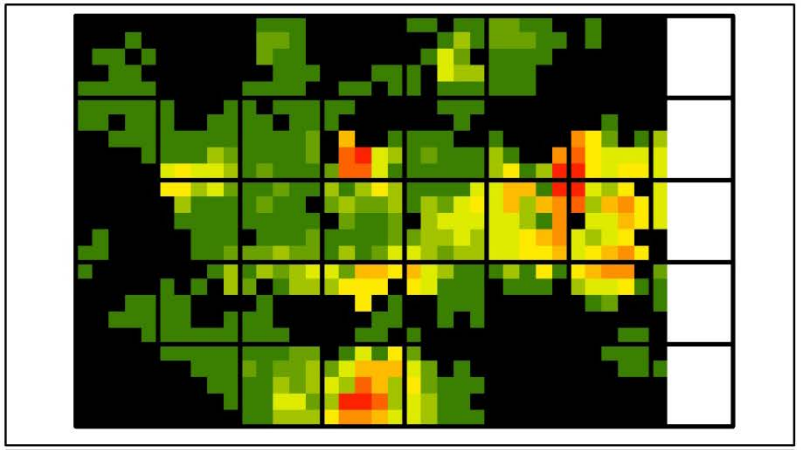
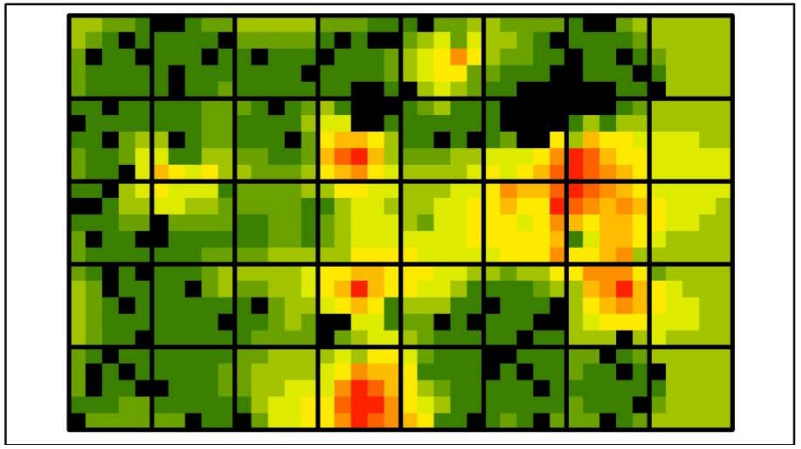


Stochastic method



Kriging



Summary

- The study of disease complexes requires a multidisciplinary approach.
- Field observations of symptom development can reveal the cumulative affect of agents.
- Sequential patterns can be seen in spatial and temporal records.
- Landscape scale survey is necessary to reveal interactions with environmental factors.

Acknowledgements

National survey in collaboration with:
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- TSU Staff: Emyr Algieri, Lee Cooper, Steve Coventry, Craig Griffiths, Justin Hardy, Mark Hilleard, John Manning, Joe McMinn, Liz Richardson, Nicola Rivett, Tony Reeves, Zac Sibthorpe, Paul Turner and Stephen Whall.

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- Management of site data collection: Robyn McAlister (IFOS) and Rory Vereker (FR)

- Distribution of oak woodland: Woodland Trust, National Trust, Wildlife Trusts, SSSI sites (Natural England, Countryside Council for Wales and Dr Scott Wilson)

This work was supported by the Forestry commision and Defra project TH0108

Ripleys k

k (*t*) = **λ^{-1} Expected [number of extra events within distance *t* of a randomly chosen event]**

But I used:

$$L_{ij} = \sqrt{\frac{k_{ij}}{\pi}} - t$$

For rings:

$$O_{ij}(t) = \lambda\ g_{ij}(t)$$

Where,

$$g_{ij}(t) = \frac{dk_{ij}(t)}{dt} \Big/ 2\pi\ t$$