In-field distribution of *Plasmodiophora brassicae* inoculum and its relationship to soil pH, Ca and B

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Introduction

- Epidemiological studies on the spatial patterns of *P. brassicae* inoculum are scarce
  - May be useful for the design and implementation of improved clubroot management strategies
- **Objective:** to assess the relationship between pathogen spatial patterns and soil chemical characteristics

Introduction

Clubroot levels are affected by many environmental factors

pH → Low (Acidic)

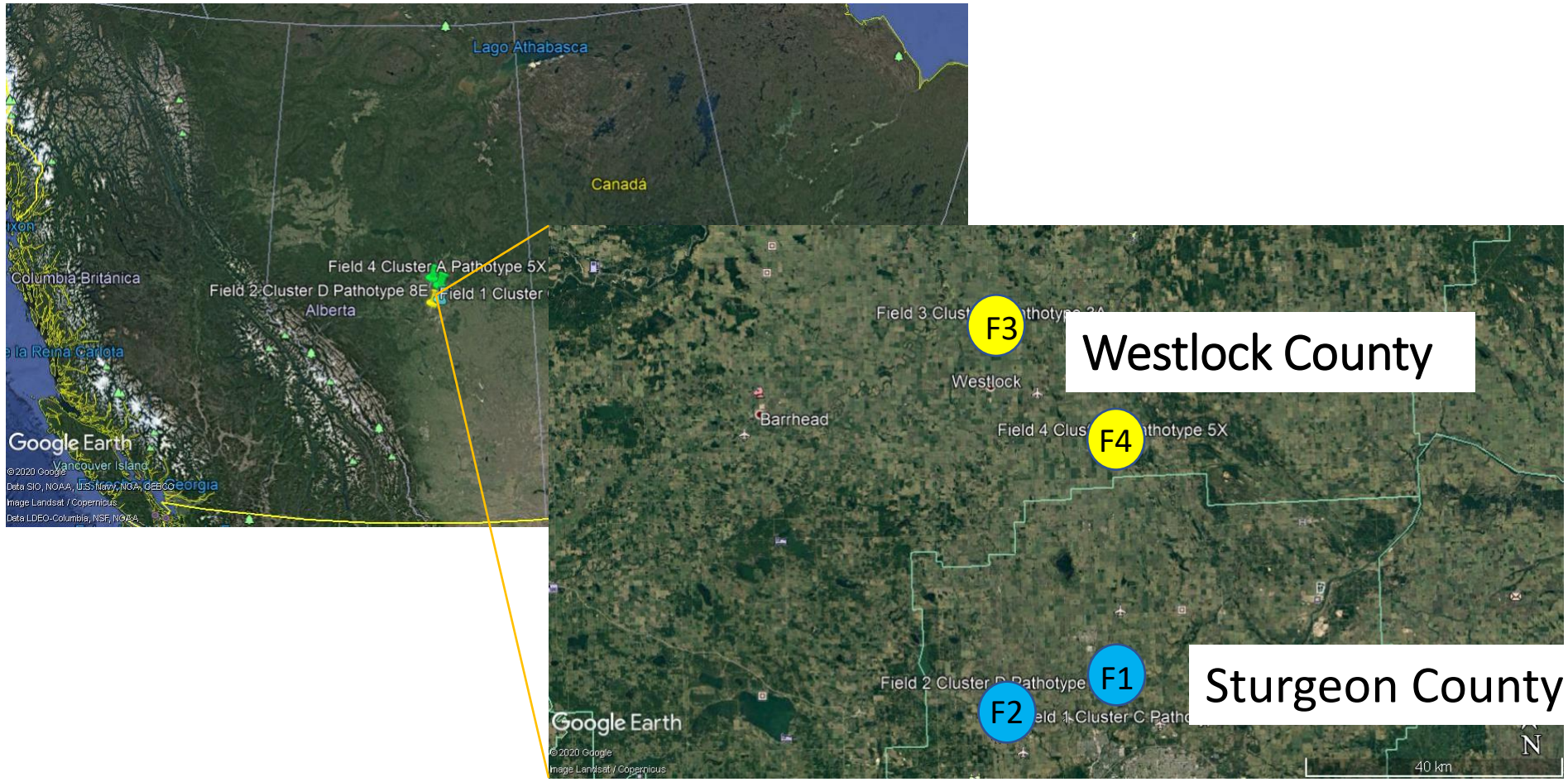
Ca^{2+} → Low

B^{3+} → Low

Is there any relationship between these factors and *P. brassicae* inoculum density in soil?

Sampling and Field Locations

Four fields (F1 – F4) sampled in Central Alberta



Sampling strategy

2017

- Regular grid 80m×80m
  - F1= 99 samples
  - F2= 97 samples
  - F3= 100 samples
  - F4= 100 samples

2019

- Intensification of sampling around positive samples for *P. brassicae* in F1, F2 & F3
  - F1=89 Samples
  - F2= 81 Samples
  - F3= 76 Samples
  - F4 =100 Samples

Soil samples 500 g → 15 cm depth

Inoculum quantification

- q-PCR analysis
- All samples (2017 & 2019)

pH

- 1:1 (water: soil soln.)
- All samples (2017 & 2019)

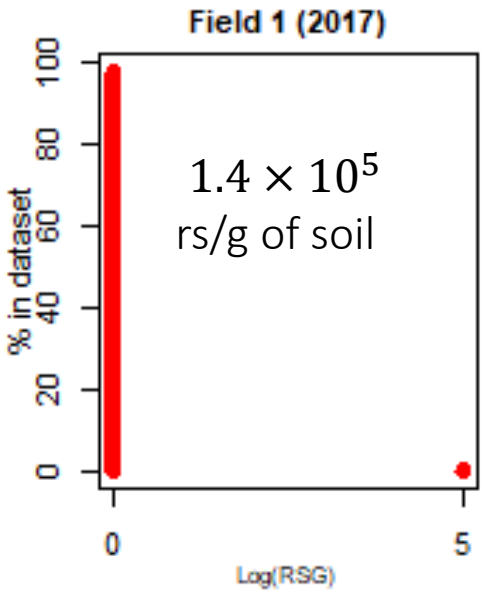
Quantification of available Ca, Mg, B and Na

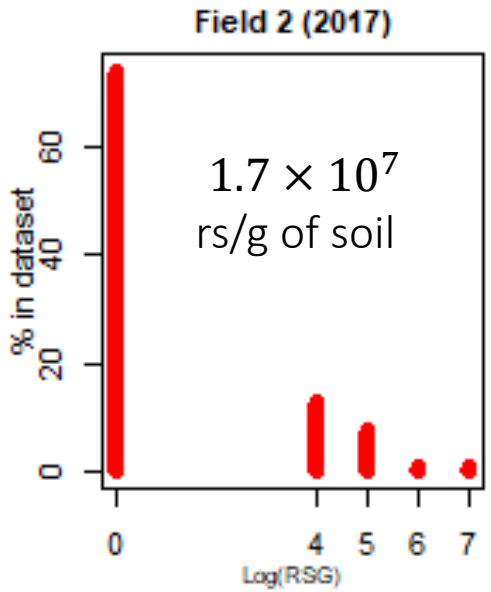
- Available Ca, Mg and Na by ammonium acetate extraction
- Available B by hot water extraction
- 50 samples (2017)

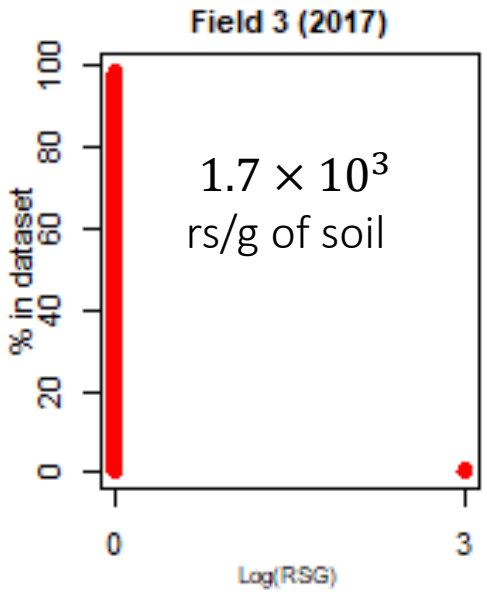
Spatial Analysis

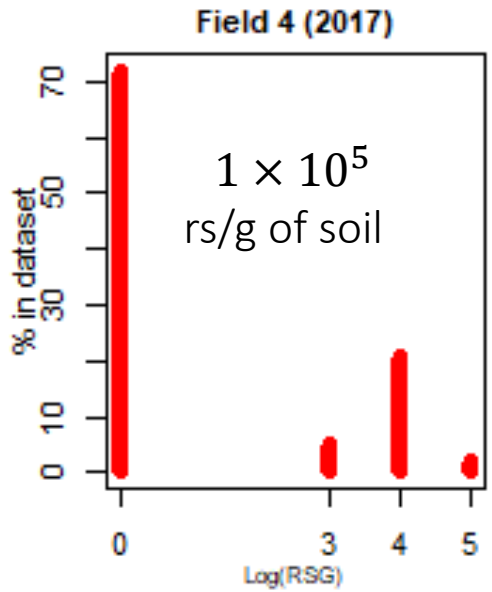
- Evaluation of spatial autocorrelation and clustering
  - Moran's I and Variograms
- Spatial models using Stochastic Partial Differential equations
  - Continuous spatial processes using a Matérn covariance function
  - Bayesian methods using INLA (Integrated Nested Laplace Approximation)
    - Takes into account uncertainty in predictors
    - Allows for misalignment in response variables and covariates (Joint models)
    - Modelling of zero-inflated datasets

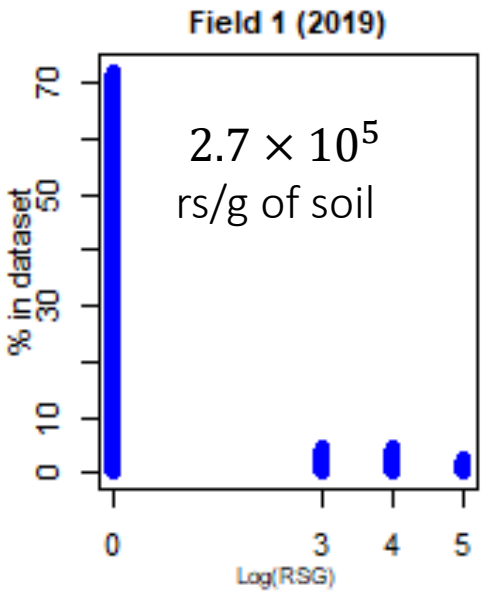
Results: Inoculum Density

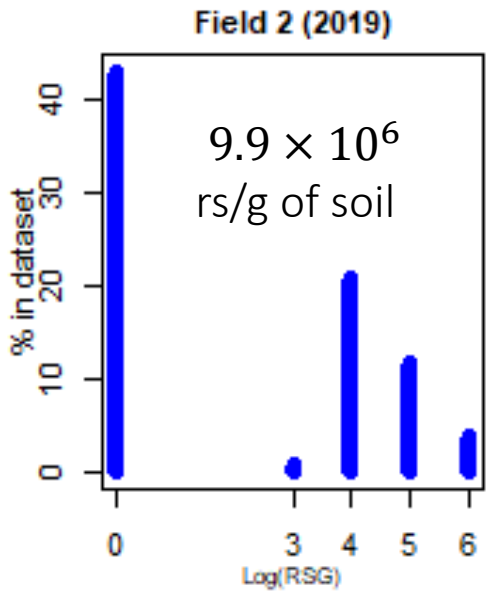


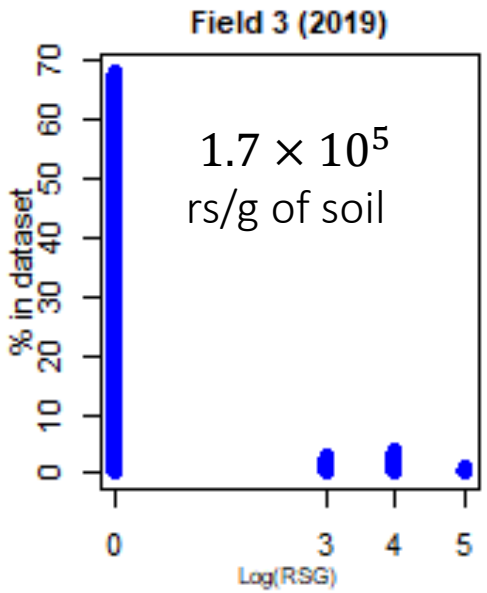


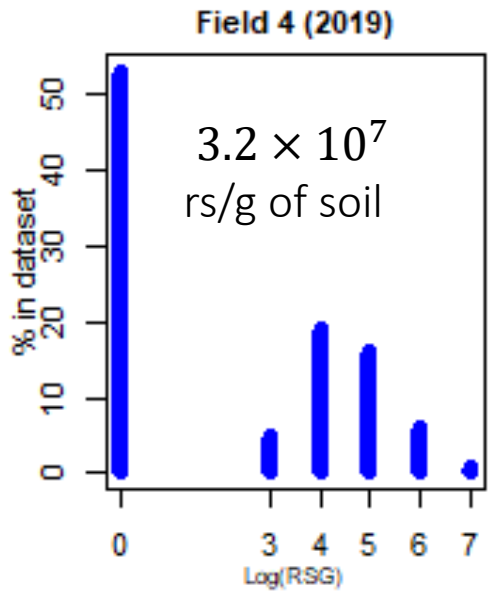








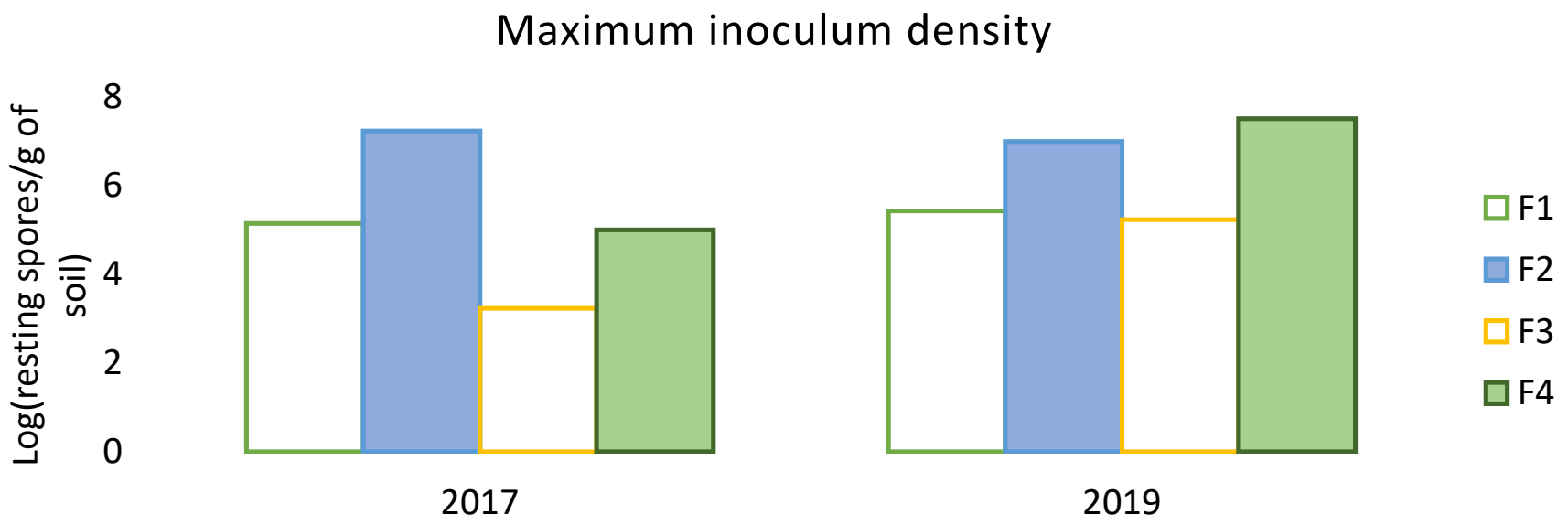




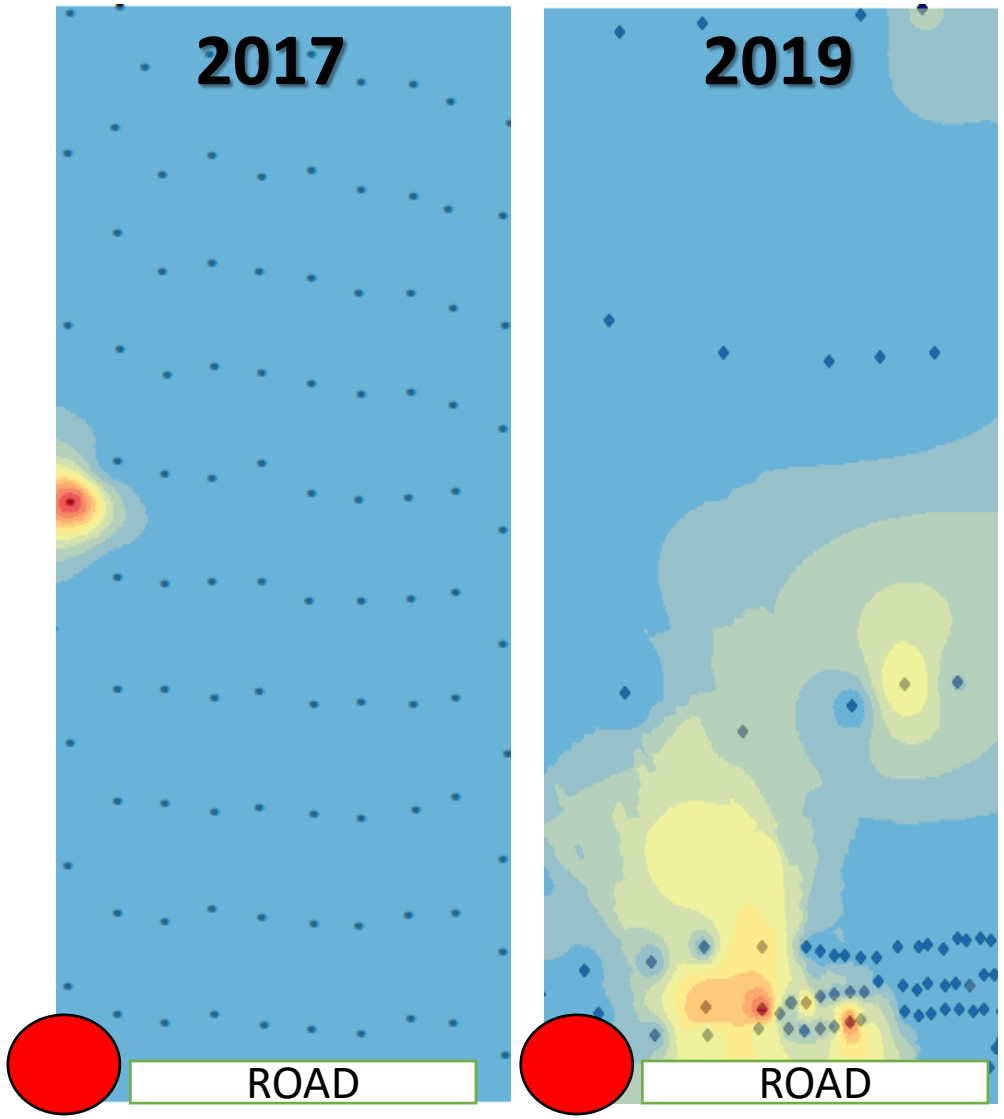
Distribution

Range (m)	F1	F2	F3	F4
2017	<80	346.1	<80	113.6
2019	289.3	585.9	77.8	422.9
ΔRange	~250	239.8	~37.7	309.3

Average patch growth → 209 m in two years

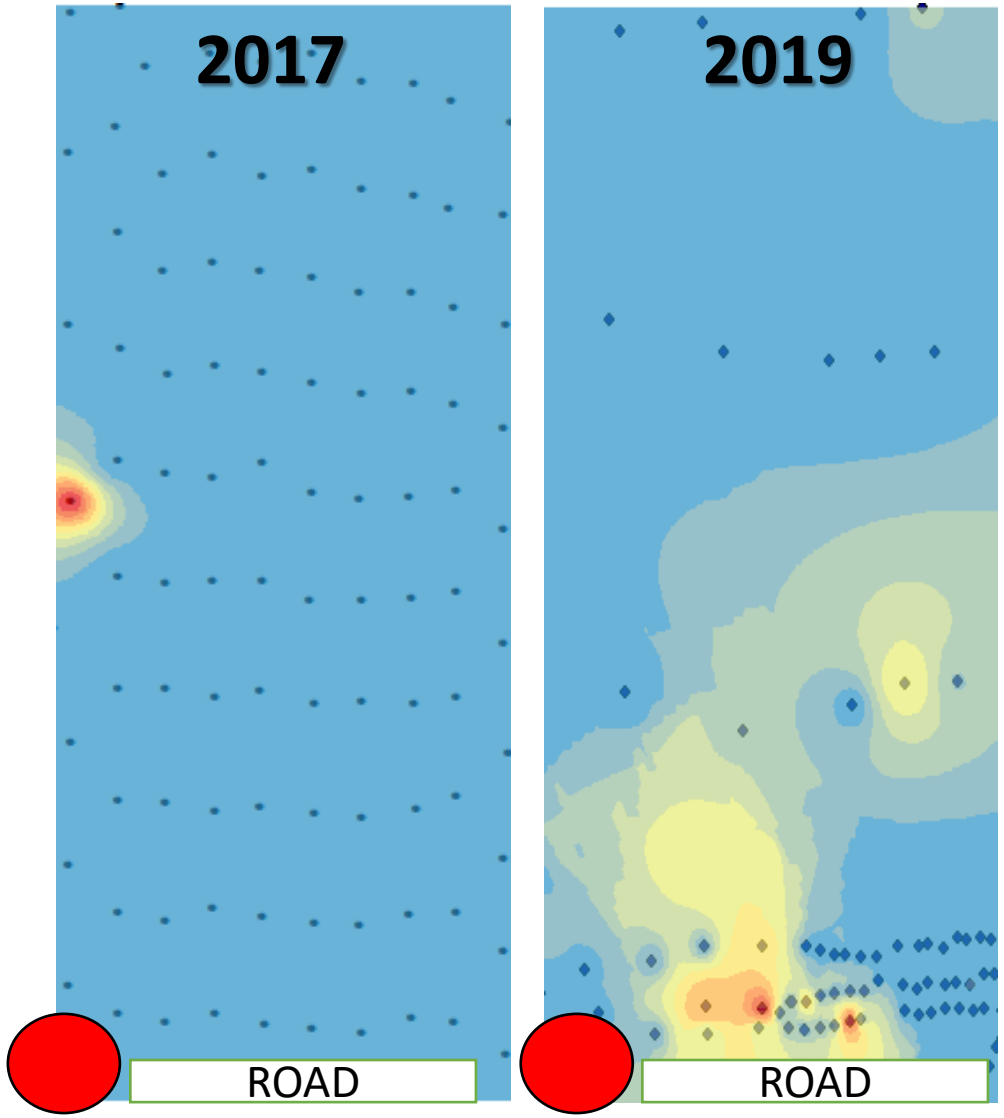


Field 1



- Max inoculum density
  - 2017→ 1.4×10^5 resting spores/g soil
  - 2019→ 2.7×10^5 resting spores/g soil
- Positive samples
  - 2017→ 1 of 99
  - 2019→ 13 of 85
- Modelling soil variables and inoculum
  - 2017→Not possible to define relationship
  - 2019→No important relationship between inoculum density and pH, Ca^{2+} or B^{3+}

Field 1

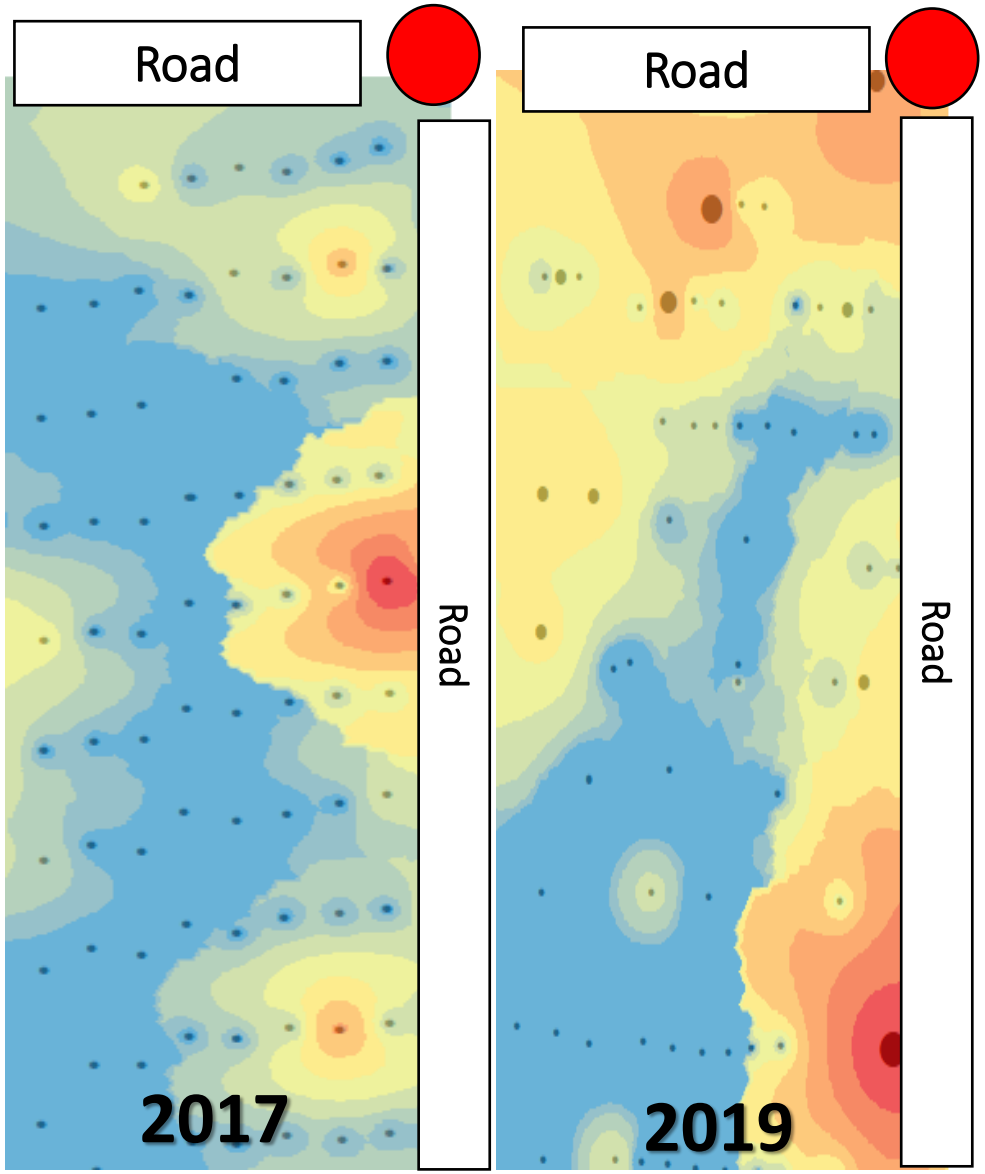


	Moran's I	p-value	Expected value	Conclusion
2017	-0.008	0.2855	-0.01	No spatial autocorrelation
2019	-0.020	0.5821	-0.011	

Does not mean randomness→ Spatial patterns may be explained by random spatial processes

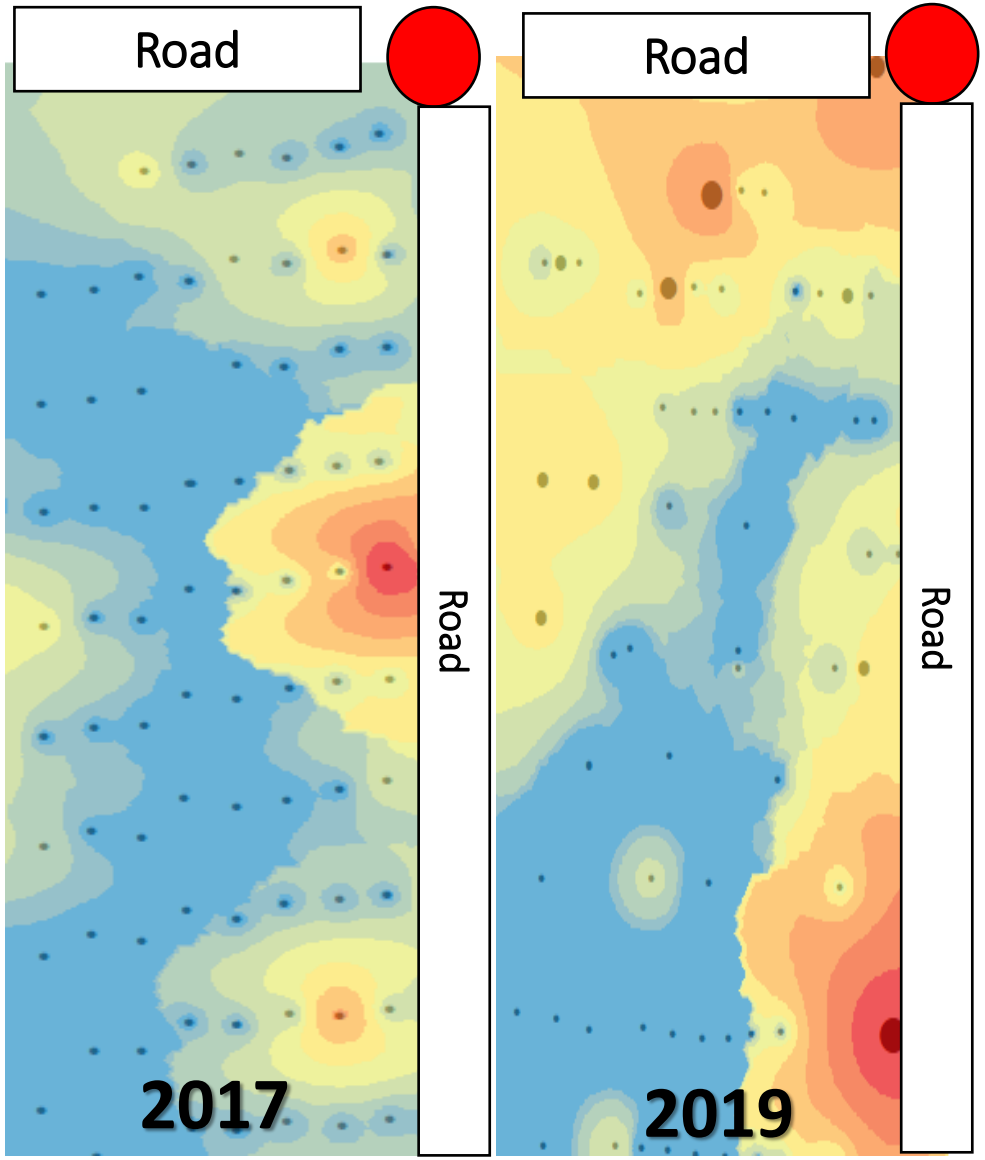
Year	Range (m)
2017	<80
2019	289.3
ΔRange	~250

Field 2



- Max inoculum density
  - 2017→ 1.7×10^7 resting spores/g soil
  - 2019→ 9.9×10^6 resting spores/g soil
- Positive samples
  - 2017→ 23 of 97
  - 2019→ 38 of 81
- Modelling soil variables and inoculum
  - No important relationship between inoculum density and pH, Ca^{2+} or B^{3+}

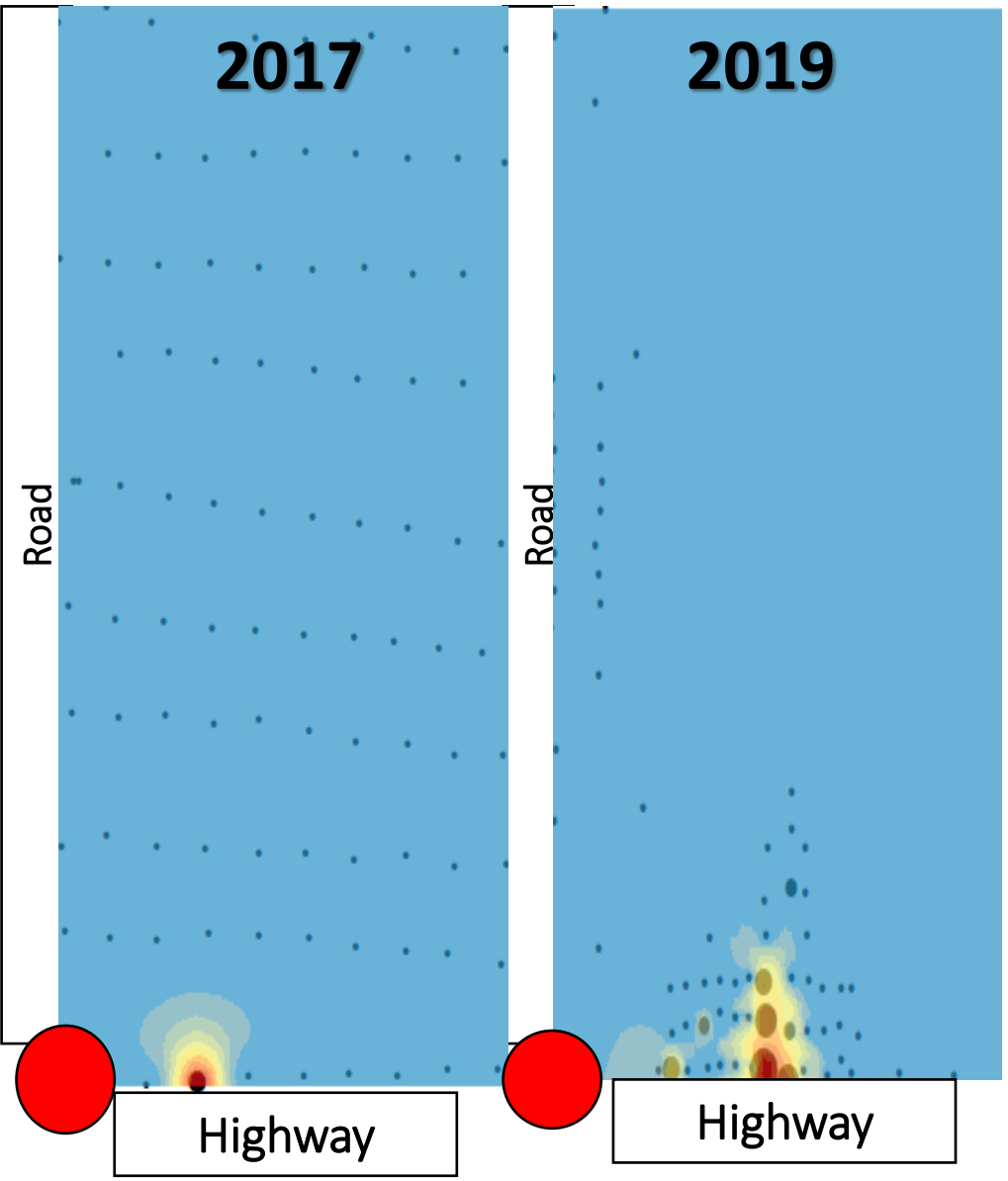
Field 2



	Moran's I	p-value	Expected value	Conclusion
2017	0.042	0.0225	-0.01	Clustering
2019	0.168	0.007	-0.125	

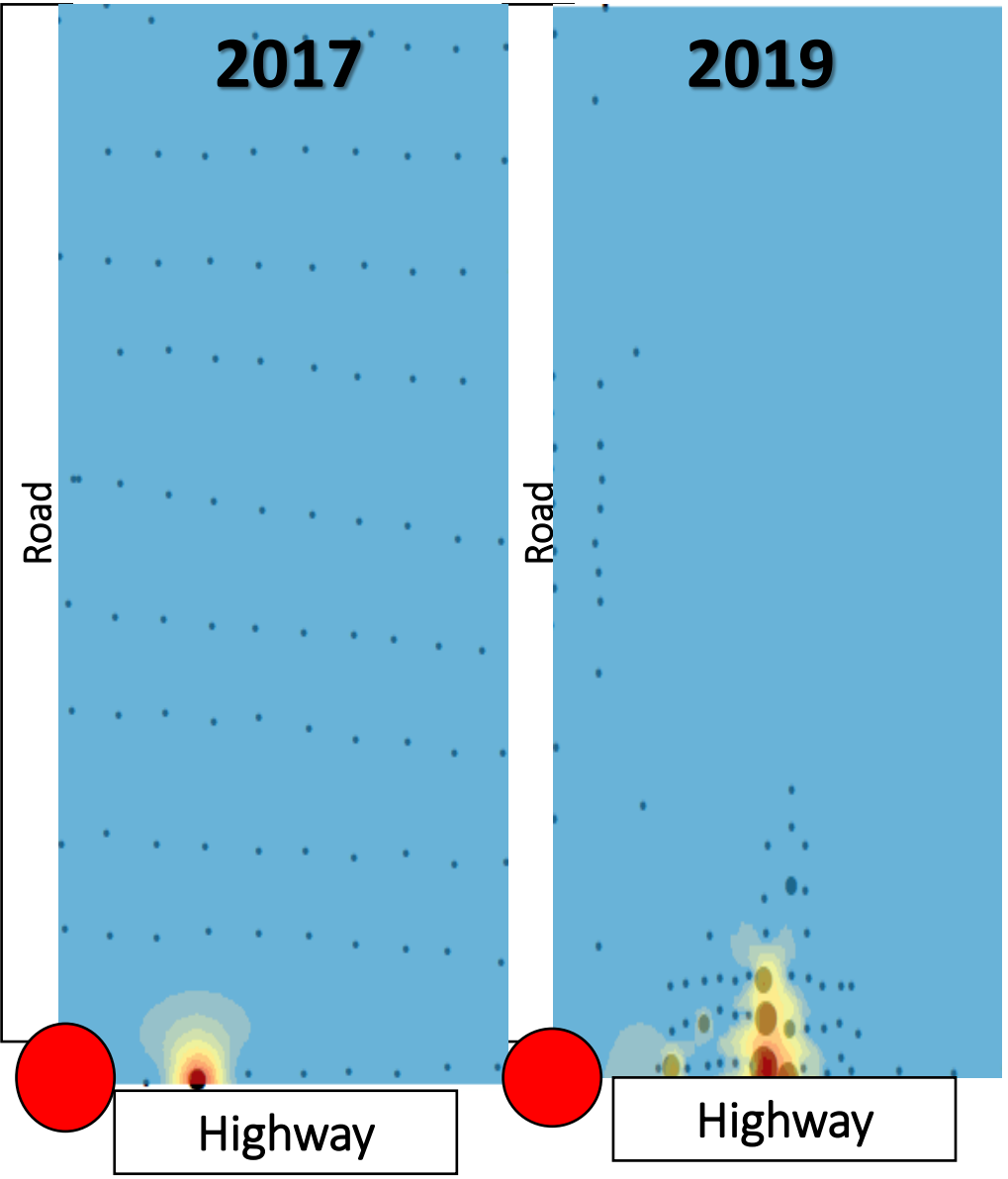
Year	Range (m)
2017	346.1
2019	585.9
ΔRange	239.8

Field 3



- Max inoculum density
  - 2017→ 1.7×10^3 resting spores/g soil
  - 2019→ 1.7×10^5 resting spores/g soil
- Positive samples
  - 2017→ 1 of 100
  - 2019→ 8 of 76
- Modelling soil variables and inoculum
  - 2017→Not possible to define relationship
  - 2019→No important relationship between inoculum density and pH, Ca^{2+} or B^{3+}

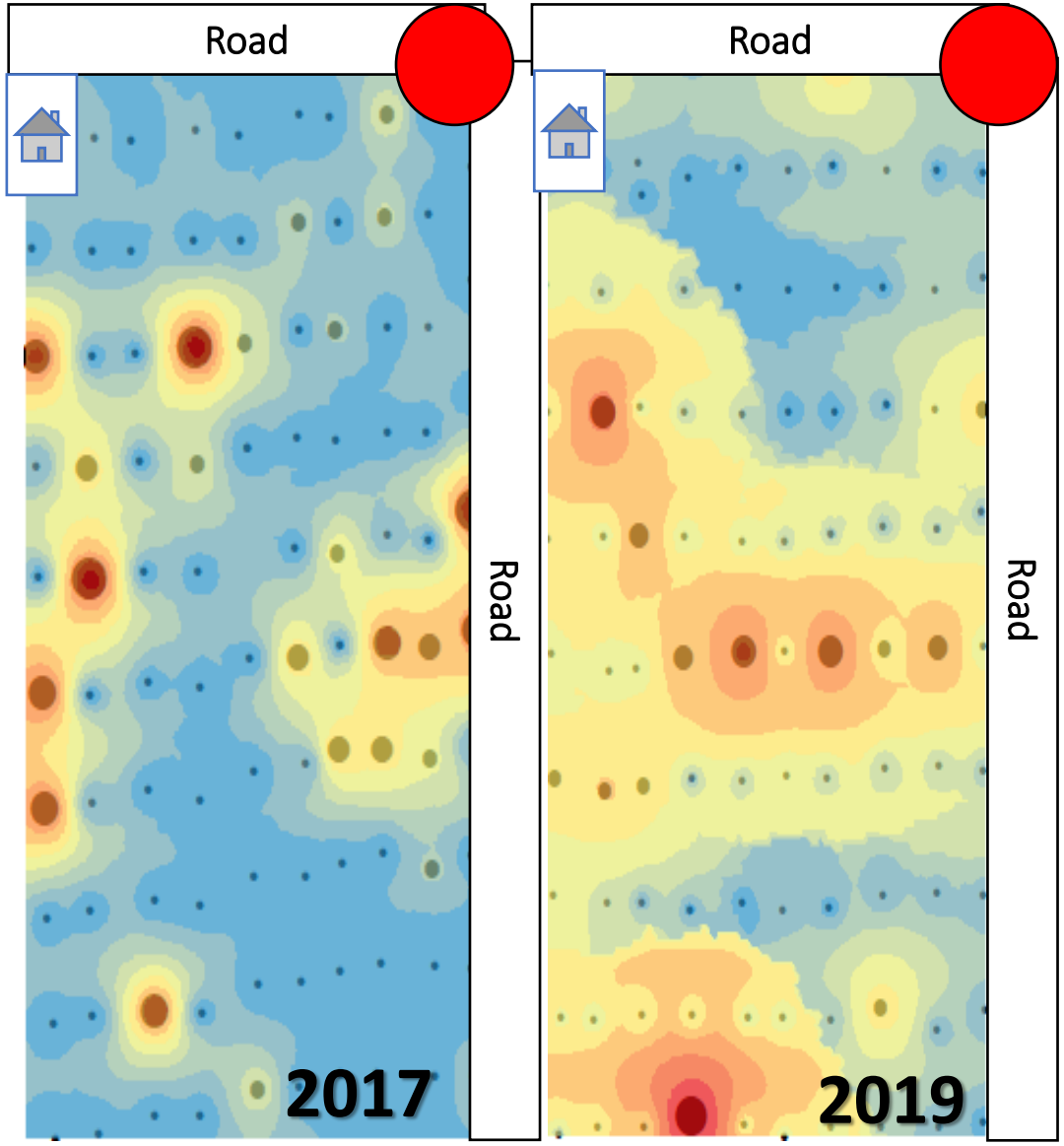
Field 3



	Moran's I	p-value	Expected value	Conclusion
2017	-0.006	0.112	-0.01	No spatial autocorrelation
2019	0.036	0.005	-0.013	Clustering

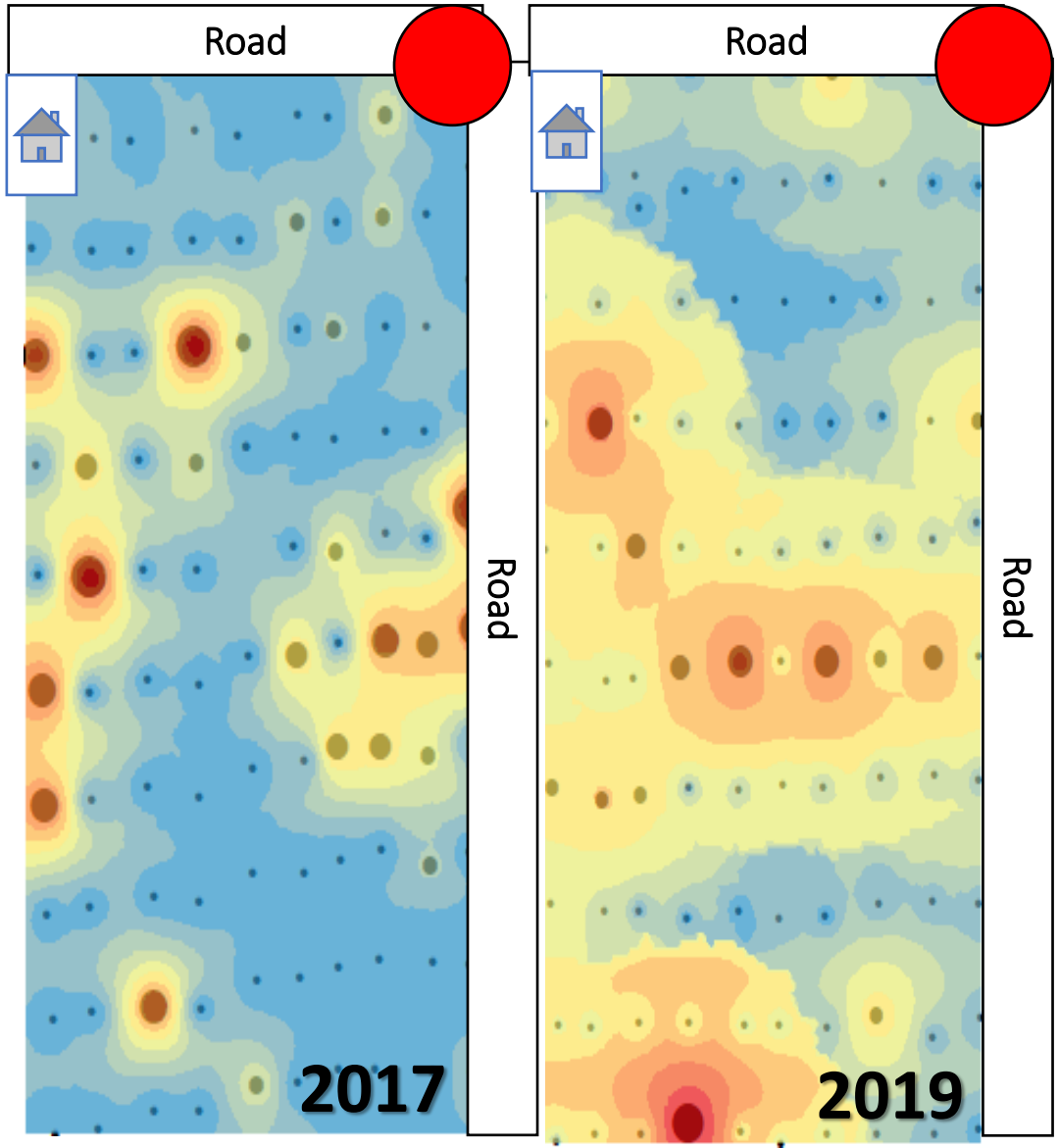
Year	Range (m)
2017	<80
2019	77.8
ΔRange	~37.7

Field 4



- Max inoculum density
  - 2017→ 1×10^5 resting spores/g soil
  - 2019→ 3.2×10^7 resting spores/g soil
- Positive samples
  - 2017→ 28 of 100
  - 2019→ 47 of 100
- Modelling soil variables and inoculum
  - No important relationship between inoculum density and pH, Ca^{2+} or B^{3+}

Field 4



	Moran's I	p-value	Expected value	Conclusion
2017	0.014	0.3234	-0.01	No spatial autocorrelation
2019	0.049	4×10^{-7}	-0.01	Clustering

Year	Range (m)
2017	113.6
2019	422.9
$\Delta Range$	309.3

Conclusions

- *P. brassicae* inoculum
  - Patchy distribution→ Patch sizes ranged from ~40 m up to ~586 m
    → Average patch growth = 209 m in two years
  - Increase in patch size related to > inoculum density and > number of positive samples
- No effect of pH, Ca^{2+} or B^{3+} on the pathogen inoculum density was observed in any of the fields
- Observed spatial patterns may be explained by random spatial processes

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