Optimization of the delimiting survey strategies for *Xylella fastidiosa* in the demarcated area in Alicante

E. Lázaro[1], D. Conesa[2], A. López-Quílez[2], V. Dalmau[3], A. Ferrer-Matoses[3] and A. Vicent[1]

[1] Centre de Protecció Vegetal i Biotecnologia, IVIA

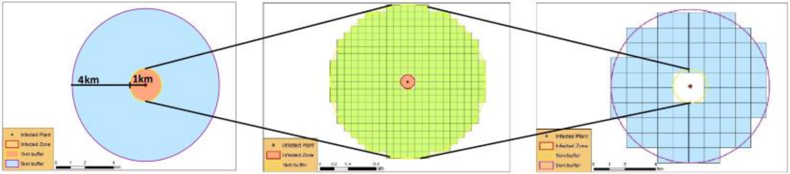
[2] Departament d'Estadística i Investigació Operativa, UV

[3] Servei de Sanitat Vegetal, GVA

Delimiting survey

Decision (EU) 2015/789:

- **Extent:** at least 5 km surrounding the infected zone (two zones)
- **Epidemiological units definition:**
  - **first kilometer → 0.01 km² grid**
  - **the rest of the zone → 1 km² grid**
- **Inspection and sampling:**
  - **Visual inspection** of all the **epidemiological units**
  - **Sampling** of symptomatic plants and asymptomatic around

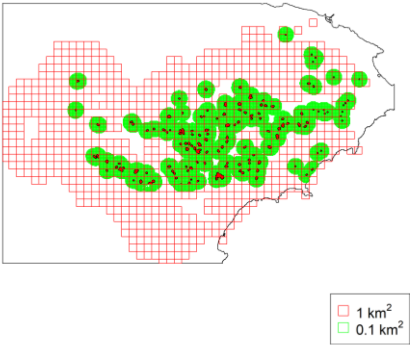


Source: DEFRA, UK.

Alicante demarcated area

- **First detection** and **demarcation** on **July 2017**
- **2018 official delimiting survey** (up to January 2019) ⇒ **Reference database**

- **83,300 has.**
- **134 infected zones**
- **552** cells of 1 km^2
- **28103** cells of 0.01 km^2
- **8142** samples
- **237 positives** vs. **7,905 negatives**



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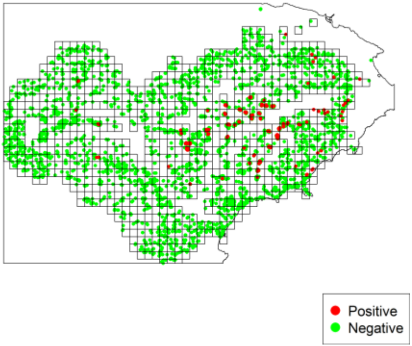

Alicante demarcated area

Leaves with apical scald and chlorotic zone

Burning generalized symptoms

Overall goals

- **Development of an alternative delimiting survey → optimisise inspection and sampling intensity**

- Assessment the performance of the alternative delimiting survey → sampling intensity

Alternative delimiting survey

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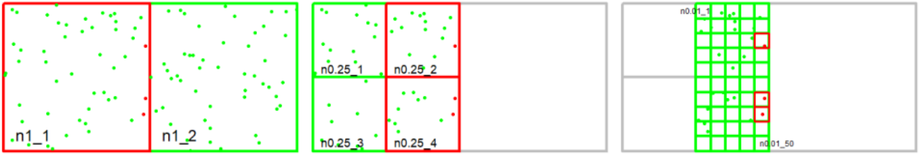
- **Improve** the efficiency and **keep** the efficacy → **optimization** of
  - **Inspection intensity** (number of cells)
  - **Sampling intensity** (samples/cell)

- **Sequential adaptive strategy**
  - **Sequential**: to organise in different **timeframes** the survey in the different resolutions
  - **Adaptive**: to **tailor** the inspection and sampling intensity for each survey resolution depending on the **previous** observed values
  - **Three-phase** design: 1 - 0.25 - 0.01 km^2
  - **Two-phase** design: 1 - 0.01 km^2

Alternative delimiting survey

- C_1, $C_{0.25}$, $C_{0.01}$ ⇒ number of cells to be inspected **(inspection intensity)**
- $C_{0.25} = C_{1,+} \times 4$ and $C_{0.01} = C_{0.25,+} \times 25$
- n_1, $n_{0.25}$, $n_{0.01}$ ⇒ samples/cell **(sampling intensity)**
- n_1, $n_{0.25}$, $n_{0.01}$ ⇒ **optimisation algorithm**
- $N = n_1 \times C_1 + n_{0.25} \times C_{0.25} + n_{0.01} \times C_{0.01}$ ⇒ total samples **(survey effort)**



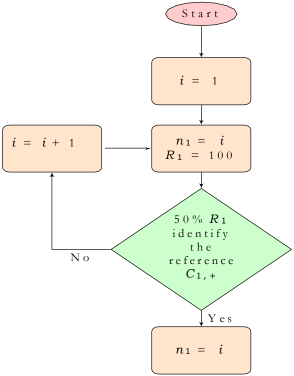
Alternative delimiting survey

Phase 1. For all 1 km^2 cells:

Phase 2. For all 1 km^2 positive cells and 0.25 km^2 resolution.

Phase 3. For all 0.25 km^2 positive cells and 0.01 km^2 resolution.

- Find an **optimum sampling intensity** (n_1) given that:
  - **Grid resolution:** 1 x 1 km
  - **Condition 1:** all 1 km^2 cells must be surveyed
  - **Condition 2:** all 1 km^2 cells must be sampled
  - R_1**=100** random sampling configurations
  - $C_{1,+}$: 1 km^2 positive cells found in the **reference database**

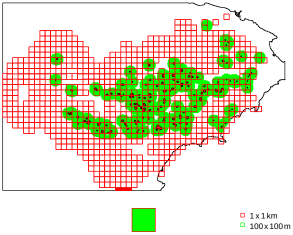


Alternative delimiting survey

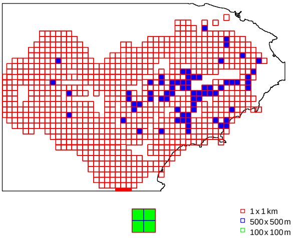
- **Inspection intensity (number of cells)** for the **current**, the **three-phase** and the **two-phase** delimiting strategies

Grid size	Decision	Three-phase	Two-phase
1 km^2	552	833	833
0.25 km^2		284	
0.01 km^2	**28,103**	**2,225**	**7,100**

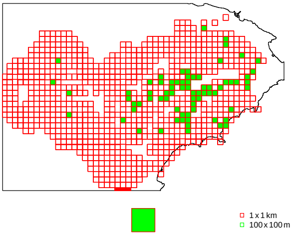
Decision



Three-phase



Two-phase



Alternative delimiting survey

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- **Sampling intensity (n) (samples/cell)** for the **three-phase** and the **two-phase** delimiting strategies

	Grid size	R_1	$R_{0.25}$	$R_{0.01}$	C_+ (+ cells)	*n* (samples/cell)
Three-phase	1 km^2	**50**	-	-	**71**	**51**
		25	-	-	70	46
		15	-	-	69	40
	0.25 km^2	**50**	**50**	-	**89**	**45**
			25	-	89	41
			15	-	88	37
	0.01 km^2	**50**	**50**	**50**	161	**14**
				25	160	13
				15	160	13
Two-phase	1 km^2	**50**	-	-	**71**	**51**
		25	-	-	70	46
		15	-	-	69	40
	0.01 km^2	**50**	-	**50**	**161**	**15**
			-	25	160	13
			-	15	159	12

Alternative delimiting survey

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- **Survey effort (N = C x n) (total samples)** for the **current**, the **three-phase** and the **two-phase** delimiting strategies

	Grid size	**C** (cells)	**n** (samples/cell)	**N** (Total samples)
Decision	**1 km^2** **0.01 km^2**	552 28,103	51 15	28,152 421,545 **449,697**
Three-phase	**1 km^2** **0.25 km^2** **0.01 km^2**	833 284 2,225	51 45 14	42,483 12,780 31,150 **86,413**
Two-phase	**1 km^2** **0.01 km^2**	833 7,100	51 15	42,483 106,500 **148,983**

Overall goals

- Development of an alternative delimiting survey → optimisise inspection and sampling intensity

- **Assessment the performance of the alternative delimiting survey → sampling intensity**

- **Aim:** Assess the effect of **sampling intensity** in **incidence estimates**
  - **Sampling intensity (samples/cell)** ⇒ output of the alternative delimiting strategy
  - **Incidence (proportion of infected plants per 1 km^2 cell)** ⇒ Bayesian hierarchical spatial model

- **Methodology:** Compare **incidence estimates** between the **reference database** (2018 official inspection) and different **data subsets** created limiting the maximum sampling intensity value

Alternative delimiting survey assessment ⇒ sampling intensity

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- **Data subsets** from the reference database
  - **Limit sampling intensity** (samples/cell) according to a reference value
  - **Reference values**
    - Data 9 (sampling intensity constrain to 9 samples/cell)
    - Data 23 (sampling intensity constrain to 23 samples/cell)
    - Data 37 (sampling intensity constrain to 37 samples/cell)
    - **Data 51** (sampling intensity constrain to 51 samples/cell)⇒ output of the alternative delimiting strategy
  - **Simulate** 100 replicates for each data subset according a random sampling scheme

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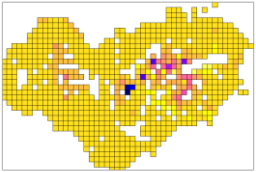
- **Incidence modelling** ⇒ Bayesian hierarchical spatial model

$$
\begin{aligned}
Y_i &\sim \text{Binomial}(m_i, \pi_i) \qquad i = 1, \ldots, n, \\
logit(\pi_i) &= \boldsymbol{X}_i \beta + \boldsymbol{v}_i + \boldsymbol{u}_i, \\
v_i | v_j &\sim \text{N}\left(\frac{1}{k_i} \sum_{i \sim j} v_j, \frac{1}{\tau_v k_i}\right) \qquad i \neq j, \\
u_i &\sim \text{N}(0, \tau_u) \qquad i = 1, \ldots, n, \\
\beta_j &\sim \text{N}(\mu = 0, \tau = 0.001) \qquad j = 0, \ldots, M, \\
log(\tau_v) &\sim \text{logGamma}(1, 5 \cdot 10^{-5}), \\
log(\tau_u) &\sim \text{logGamma}(1, 5 \cdot 10^{-5}).
\end{aligned}
$$

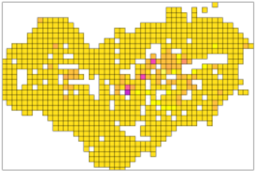
- **Model selection** of the reference database fit ⇒ **WAIC** and **CPO** criteria
  - **Selected model:**
    $Y_i \sim \text{Binomial}(m_i, \pi_i)$ $\quad logit(\pi_i) = \beta_0 + \mathbf{v}_i$ $\quad i = 1, \ldots, n$

Alternative delimiting survey assessment ⇒ sampling intensity

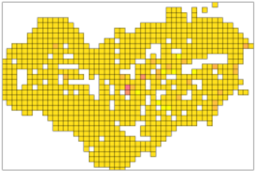
- **Incidence:** proportion of infected plants in a 1 km^2
- **Mean** of the posterior distribution of the **incidence**
- Comparison between the reference database and the data subsets estimates (averaged) ⇒ **Bias:** $\overline{\pi}_{i,ref\,.} - \overline{\pi}_{i,subset}$



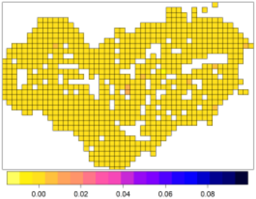
Data 9



Data 23



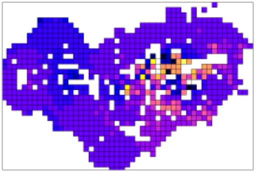
Data 37



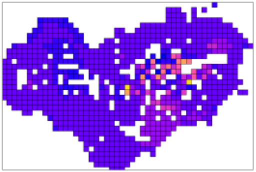
Data 51

Alternative delimiting survey assessment ⇒ sampling intensity

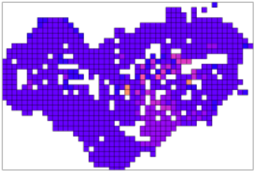
- **Standard deviation** of the posterior distribution of the **incidence**
- Comparison between the reference database and the data subsets estimates (averaged) ⇒ **Bias:** $sd_{\pi_i\,(ref.)} - sd_{\pi_i\,(subset)}$



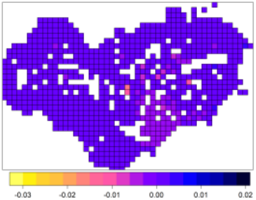
Data 9



Data 23



Data 37



Data 51

Conclusions

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- **The alternative delimiting strategy in Alicante demarcated area:**
  - **sequences** inspection and sampling **in time** considering different spatial resolution sizes → logistically more feasible
  - allows delimiting the **extension** of the disease in **larger** space resolutions while demarcating **infected areas** in **finer** resolutions
  - **improves inspection intensity** at the 0.01 km^2 grid size
    - **2,225** and **7,100** cells (**Three-phase** and **Two-phase**)
    - 28,103 cells (**Decision (EU) 2015/789**)
  - **improves survey efforts**
    - **86,413** and **148,983** samples (**Three-phase** and **Two-phase**)
    - **449,697** samples (**Current**)
  - finds an **optimum** sampling intensity value for 1 km^2 resolution **(51 samples/cell)** that seems to be an adequate **reference value**

Thank you!

Horizon 2020 projects (European Union): POnTE (Pest Organisms Threatening Europe), No 635646, and XF-ACTORS (Xylella Fastidiosa Active Containment Through a multidisciplinary-Oriented Research Strategy),No 727987, and the project E-RTA 2017-00004-C06-01 FEDER INIA-AEI Ministerio de Economía y Competitividad and Organización Interprofesional del Aceite de Oliva Español, Spain.