Estimating the rate of spread of Olive Quick Decline Syndrome, caused by *Xylella fastidiosa* ssp. *pauca*, in Puglia

April 30, 2021, Lia Hemerik

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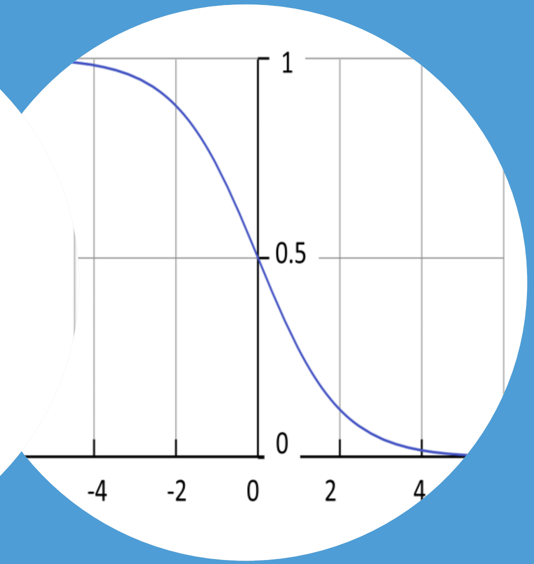

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BIOMETRIS
Quantitative Methods brought to Life

Spreading of *X. fastidiosa* into Italy

- In 2000 an epidemic of PD occurred in the United States in southern California
  - Spread by an invasive species of sharpshooters
- In 2013 *X. fastidiosa* was first identified in Europe in Gallipoli (Apulia, Italy)
  - Subspecies *pauca*
  - Causing olive quick decline syndrome (OQDS)

Location of Gallipoli

Map data ©2019 GeoBasis-DE/BKG (©2009). Google Inst. Geogr. Nacional

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Olive Quick Decline Syndrome (OQDS)

- Leaf scorching
- Desiccation of twigs and branches
- After a few years, the tree dies
- Large economic losses
  - Olive and olive oil are main sources of income for the region
  - No export of plants
- Cultural impact
  - Family orchards
  - Centuries old trees

Olive tree suffering from OQDS

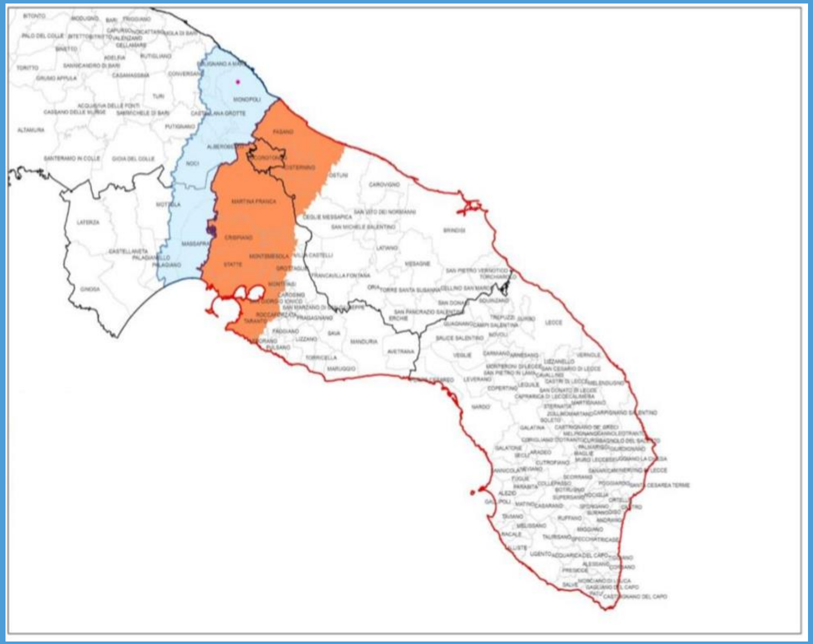
Vector: Spittlebug (*Philaenus spumarius*)

- Can be found throughout most of Europe
- Can survive in many climate types
- Female migrating behavior and dispersal cause short range spread of *X. fastidiosa*
- Possibly hides in clothing or vehicles, causing long range spread of *X. fastidiosa*

Spittlebug

Models

- Many models have been developed
  - Spatially explicit spread model (White et al., 2017)
  - SIR model (Soubeyrand et al., 2018)
  - Network model (Strona, Carstens & Beck, 2017)
- No models analyzing the shape of the invasion front or rate of spread
  - Even though data is available



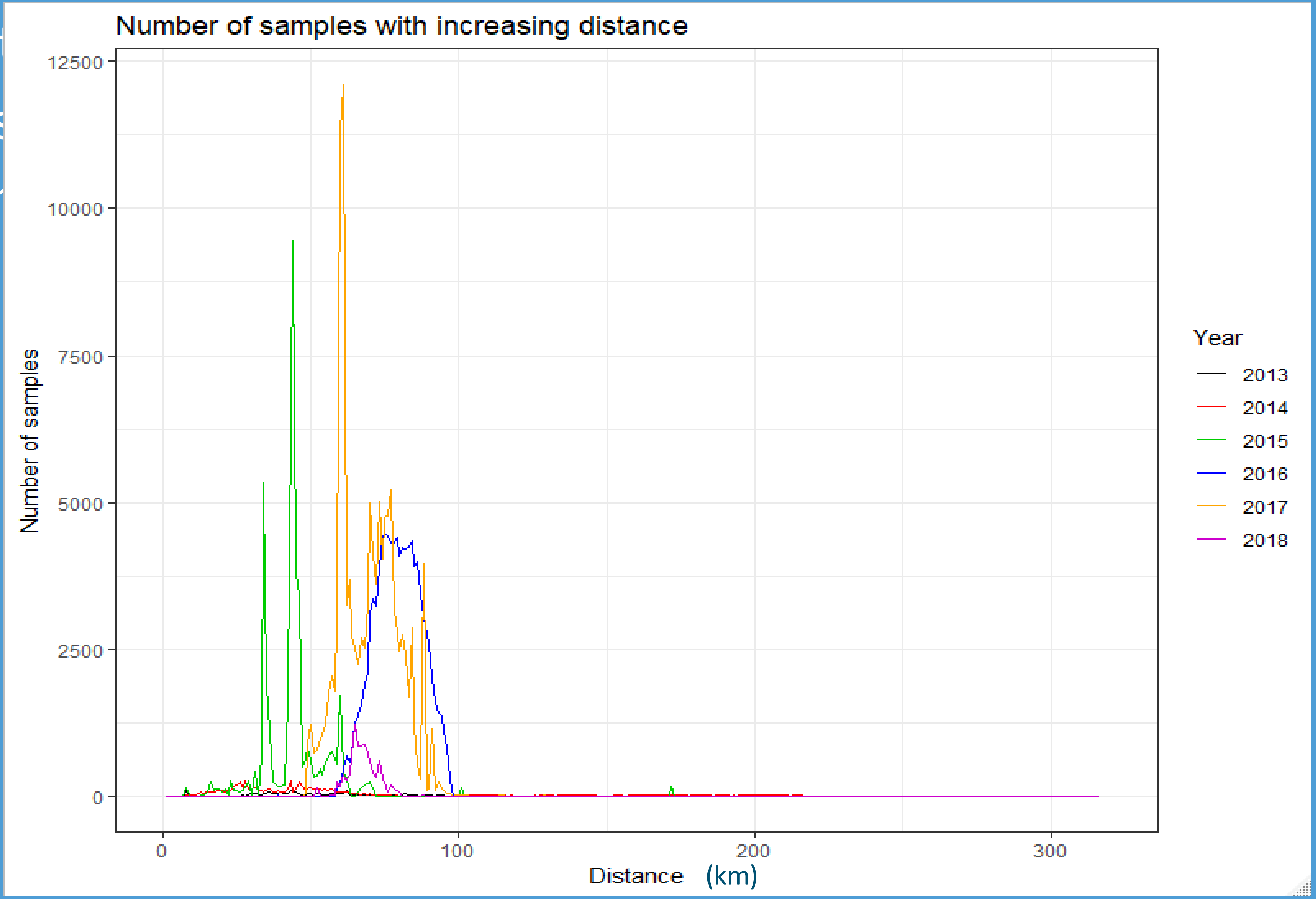
Demarcated zones in Puglia, Italy (European Union, 2019).

- Expert knowledge before study: in one year time 90% of newly infected plants will be within 5.2 km from previously infected area (95% CI of 0.7 – 14 km)

Sampling data

- Spatio-temporal dat
- Very heterogeneous
- Until 2016, no clear

Locations of sampling in Puglia



Research questions and Data

- What is the shape of the travelling invasion front of *Xylella fastidiosa* in Puglia?
- What is the rate at which this front moves through Puglia?
- What is the width of the front?

- The columns
  - no: number, lon: longitude, lat: latitude
  - Result
    - 0: *Xylella* is absent (these I call negatives)
    - 1: *Xylella* is present (these I call positives)
  - Date, Year, Month

- 409,515 rows
  - 298,230 rows after removal of NA's and missing coordinates

	no	lon	lat	result	date	year	month
1	1	17.95389	40.50889	0	2013-11-13	2013	11
2	2	17.92639	40.52167	0	2013-11-13	2013	11
3	3	17.97722	40.54639	0	2013-11-13	2013	11
4	4	18.02444	40.48750	0	2013-11-13	2013	11
5	5	18.04250	40.48694	0	2013-11-13	2013	11
6	6	18.02056	40.52417	0	2013-11-13	2013	11
7	7	18.06889	40.53000	0	2013-11-13	2013	11
8	8	18.08194	40.51389	0	2013-11-13	2013	11
9	9	18.04611	40.53167	0	2013-11-13	2013	11
10	10	17.86722	40.53806	0	2013-11-13	2013	11

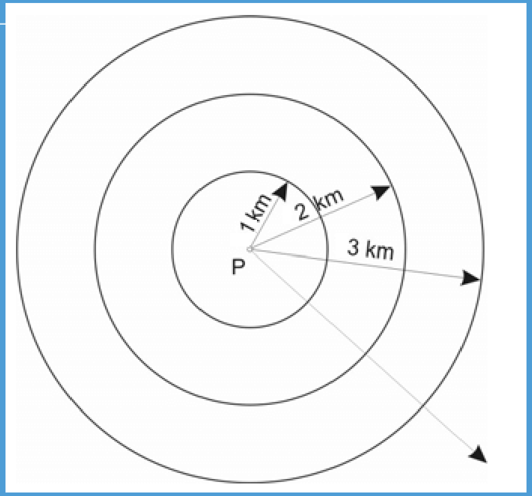
Methods: Rate of Spread

- Eight datasets (four types of information sharing & two temporal cut-offs)

- Data transformation:

Calculate for each calendar year or year from April to April, and in each concentric ring

  - number of positives,
  - number of measurements,
  - proportion of positives (= number of positives / number of measurements)



Adapted from Kloch & Krynski, 2008.

Concentric circles around a central point with 1 km widths.

	dist	pos	n	prop
1	1	0	0	NaN
2	2	0	0	NaN
3	3	0	0	NaN
4	4	0	0	NaN
5	5	0	0	NaN
6	6	0	2	0.00000000
7	7	0	9	0.00000000
8	8	14	127	0.11023622
9	9	0	11	0.00000000
10	10	0	6	0.00000000

The transformed data. Showing the first 10 rows of the 2013 data frame.

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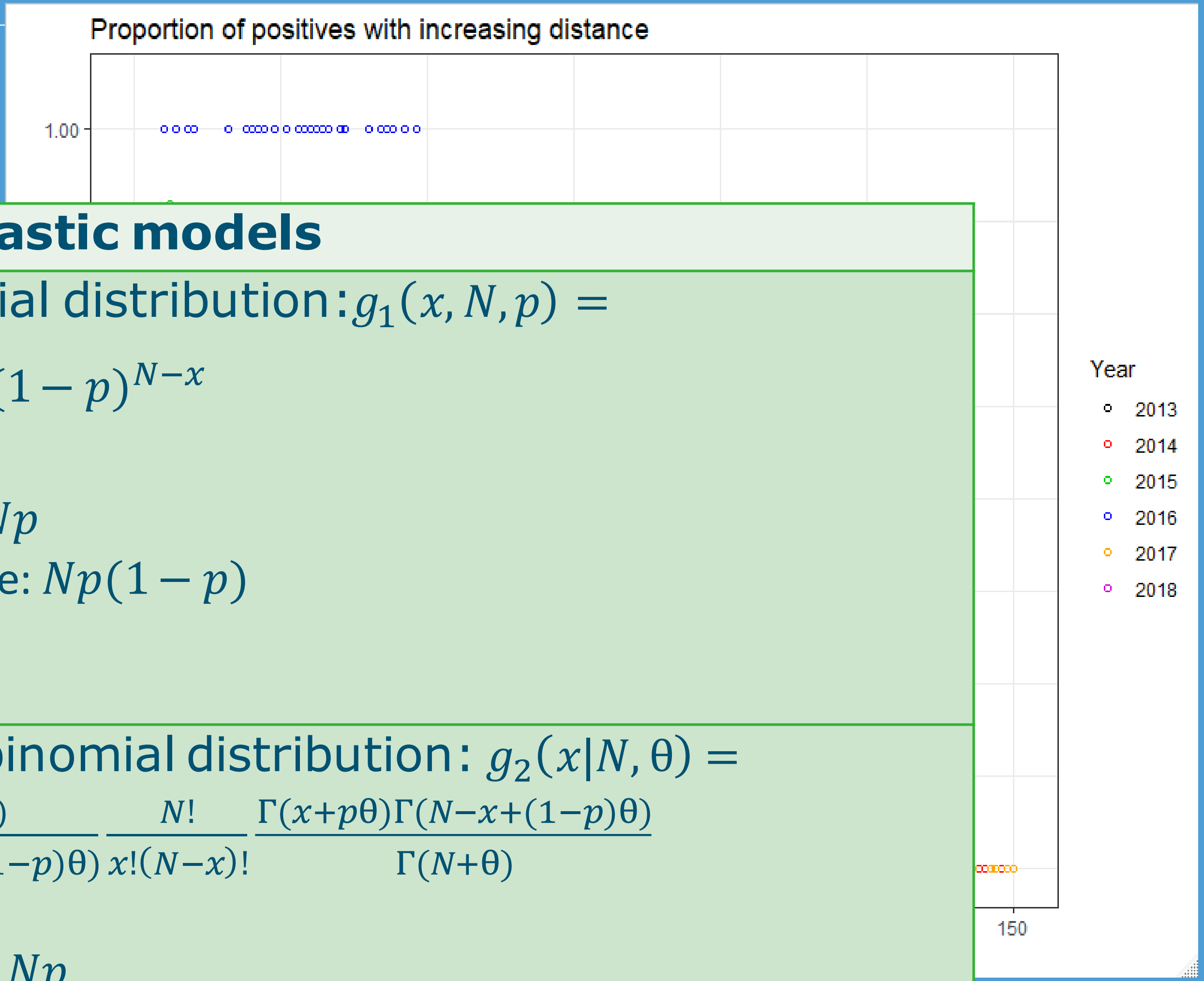
Data and models



Deterministic models	**Stochastic models**
Negative exponential (NE): $f_1(x) = a\exp(-rx)$ Logistic function: $f_2(x) = \dfrac{1}{1+\exp(r(x-x_{50}))}$	Binomial distribution: $g_1(x,N,p) = \binom{N}{x} p^x (1-p)^{N-x}$ Mean: Np Deviance: $Np(1-p)$
Constrained negative exponential function (CNE): $f_3(x) = \begin{cases} 1 & \text{if } x < x_{100}, \\ \dfrac{1}{\exp(-r(x_{100}))}\exp(-rx) & \text{if } x \geq x_{100}. \end{cases}$ Hill function: $f_4(x) = a\left(1 - \dfrac{x^n}{h^n + x^n}\right)$	Beta-binomial distribution: $g_2(x\|N,\theta) = \dfrac{\Gamma(\theta)}{\Gamma(p\theta)\Gamma((1-p)\theta)} \dfrac{N!}{x!(N-x)!} \dfrac{\Gamma(x+p\theta)\Gamma(N-x+(1-p)\theta)}{\Gamma(N+\theta)}$ Mean: Np Deviance: $Np(1-p)\left(1+\dfrac{N-1}{\theta-1}\right)$

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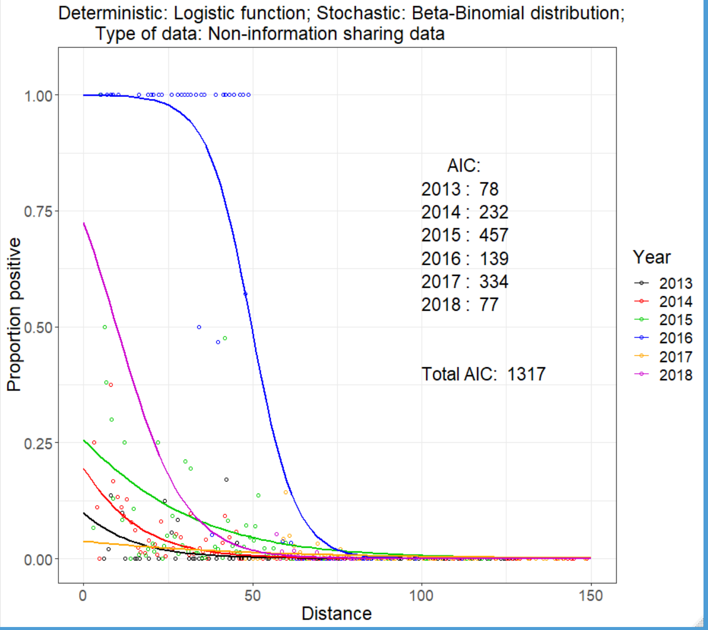
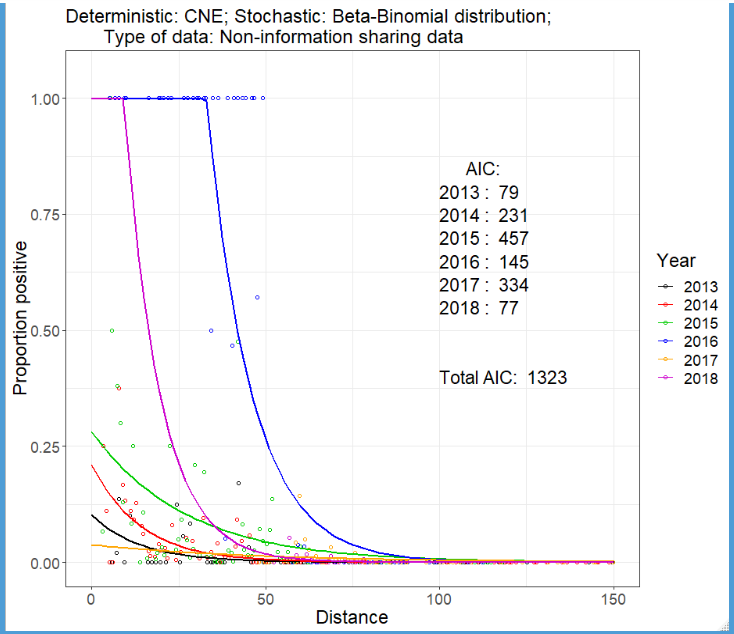
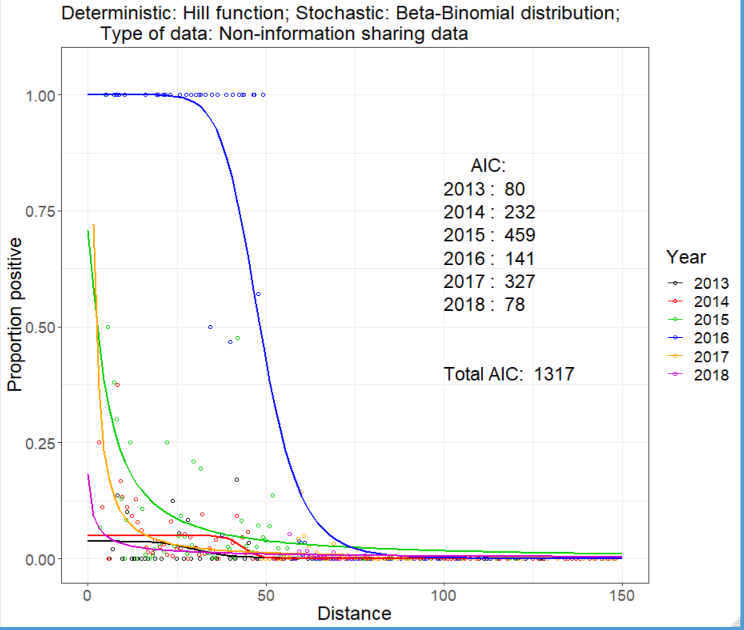
Results

AIC

Year	Binomial distribution: Negative exponential	Binomial distribution: Logistic	Binomial distribution: CNE	Binomial distribution: Hill	Beta-binomial distribution: Negative exponential	Beta-binomial distribution: Logistic	Beta-binomial distribution: CNE	Beta-binomial distribution: Hill
2013	159	159	159	159	**78**	**78**	**78**	80
2014	344	344	344	356	**232**	**232**	**232**	**232**
2015	8853	8847	8847	8133	**457**	**457**	**457**	459
2016	587	239	239	265	221	**139**	145	141
2017	4673	4442	4442	4612	334	334	334	**327**
2018	87	87	87	90	108	**77**	**77**	78
Total	14703	17227	14169	13603	1430	**1317**	1323	**1317**







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The fitted logistic, CNE, and Hill functions for each calendar year.

Determining the rate of spread

- Logistic function: $pp_l = \frac{1}{1+\exp(r(x-(x_{50}+ct)))}$

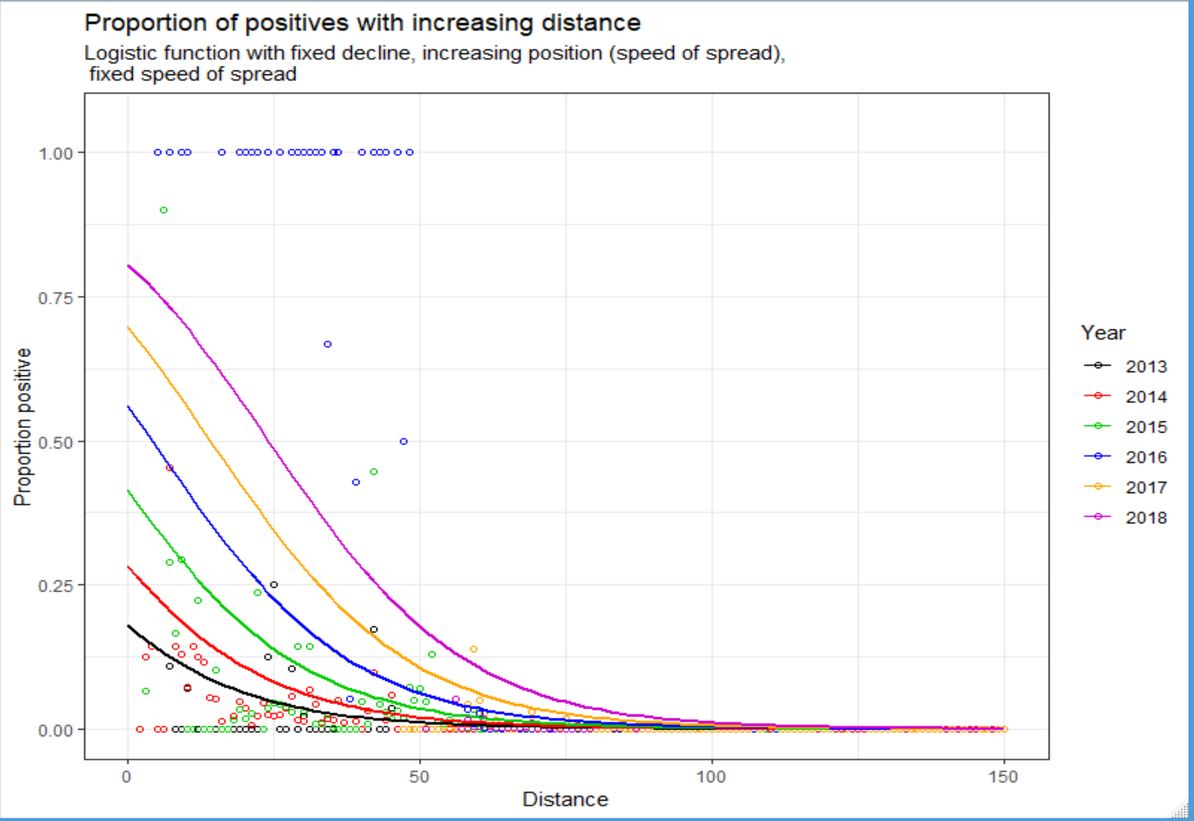
c: rate of spread in km/year
t: time in years since 2013

Assumption:

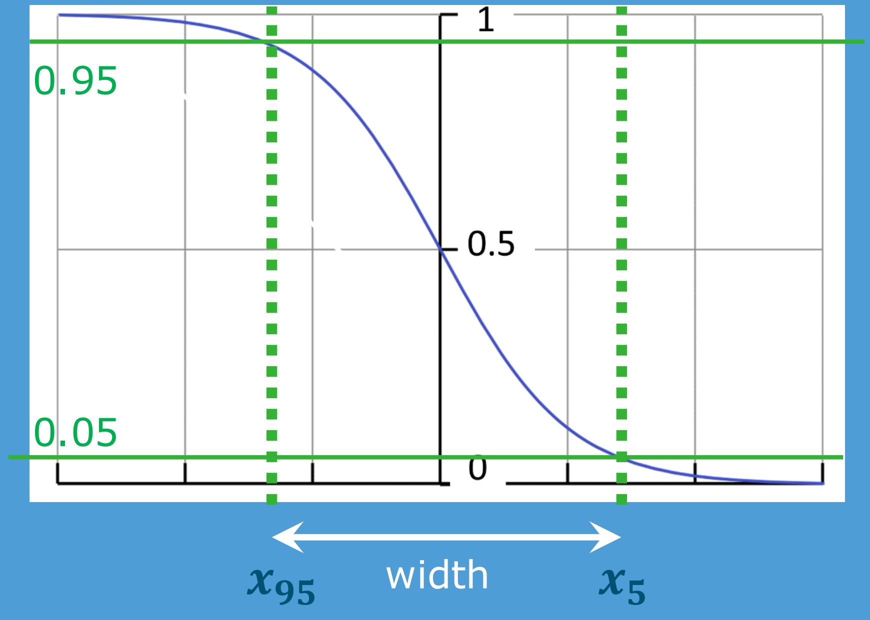
The rate of spread and the shape of the front are constant over the years

Parameters	
r	0.059 km^{-1}
x_{50}	-25.76 km
c	9.95 km/year

The fitted logistic curves to estimate the rate of spread.



Width of front



Starting with

$$\frac{1}{1+\exp\left(r\left(x_{95}-\left(x_{50}+ct\right)\right)\right)}=0.95$$

$$\frac{1}{1+\exp\left(r\left(x_{5}-\left(x_{50}+ct\right)\right)\right)}=0.05$$

We get

$$x_5 - x_{95} = \frac{2\log(95)}{r}$$

Resulting in an estimate of

$x_5 - x_{95} = 99.8$ km.

$x_1 - x_{99} = 2\log(99)/0.059 = 155.8$ km.

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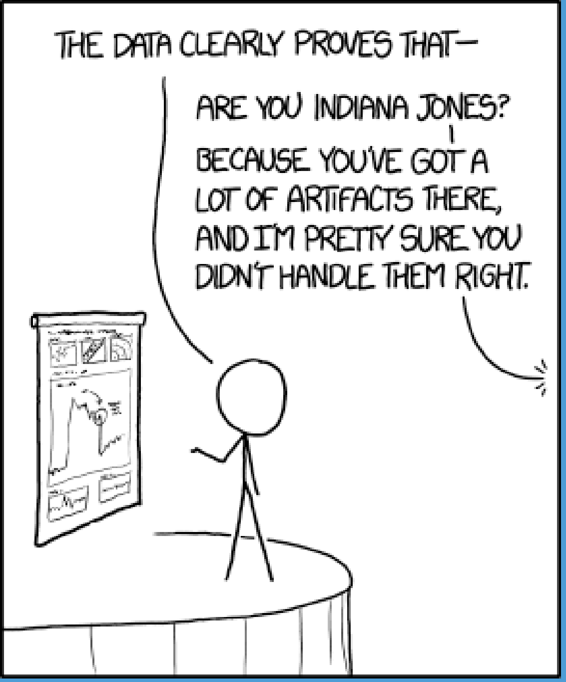
Discussion

- First analysis that estimates the shape of an invasion front
- Non-trivial task because of the difficult data
- Because of this we have simulated the sampling process
- and performed simulations with different assumed points of origin

- First empirical estimate of the rate of spread of an *X. fastidiosa* invasion in Europe 10 km per year (95% CI 7.5-12.5 km per year)
- The width of the front is 100 to 160 km
- This knowledge on the spread of *X. fastidiosa* can aid management decisions in controlling the disease

Kottelenberg D., L. Hemerik, M. Saponari, W. van der Werf (2021) Scientific Reports 11:1061 https://doi.org/10.1038/s41598-020-79279-x



Thanks to David Kottelenberg, Maria Saponari and Wopke van der Werf

Thank you for your attention!

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