Antagonistic effects of shade on the epidemiological mechanisms driving coffee berry disease

Natacha Motisi, Julien Papaix, Sylvain Poggi

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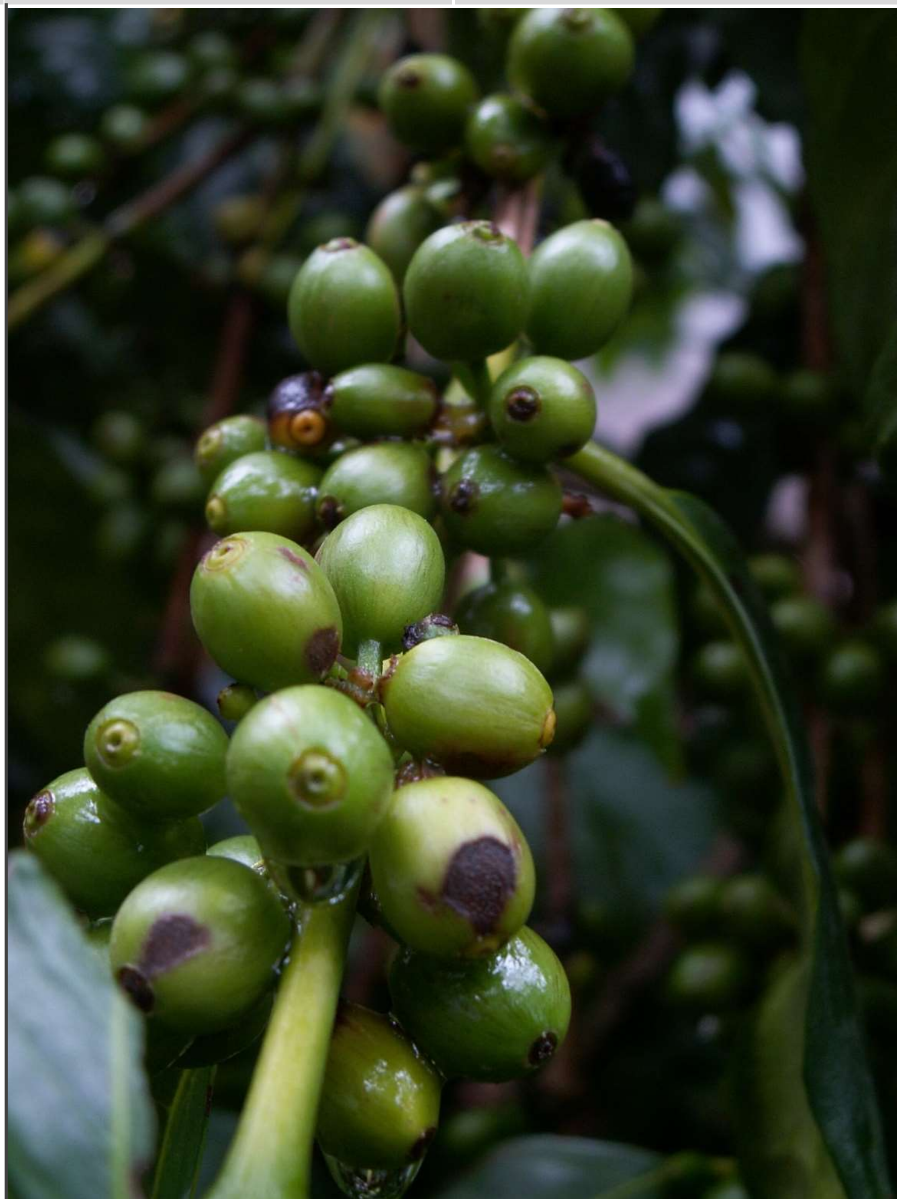
- In Cameroon, *Coffea arabica* is cropped
  - By small-holding farmers
  - In agroforestry systems (varying incomes)
- Coffee Berry Disease (CBD)
  - Fungal disease (*Colletotrichum kahawae*)
  - Until 90% of berry loss

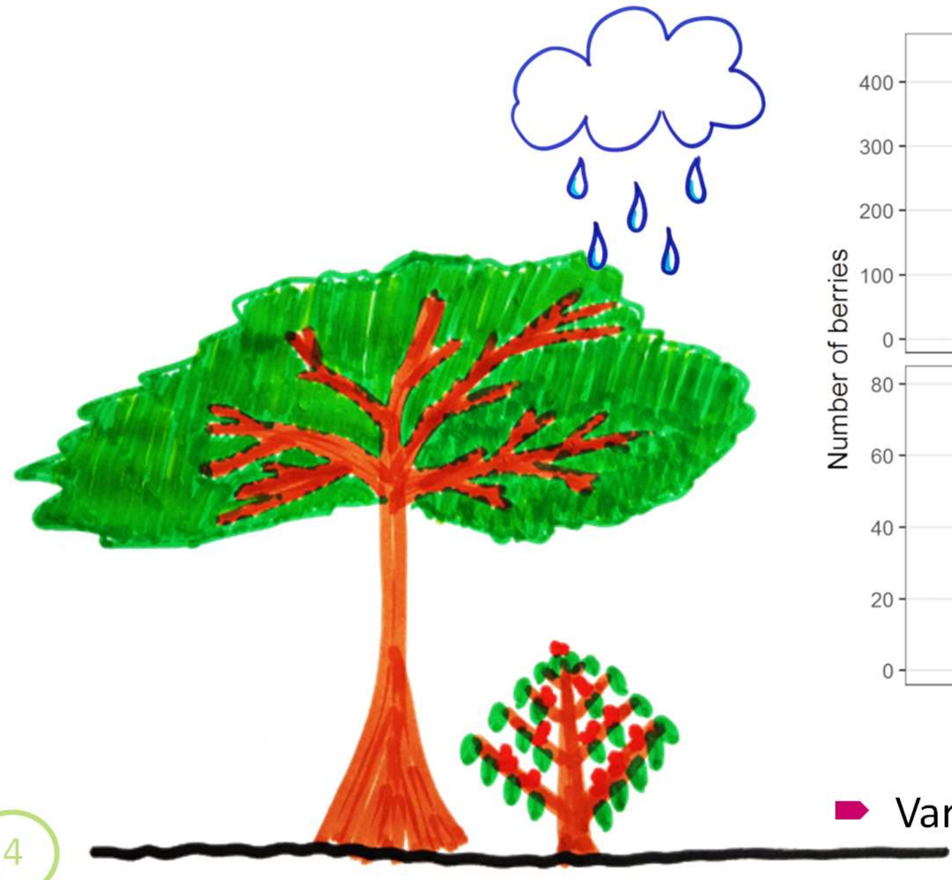


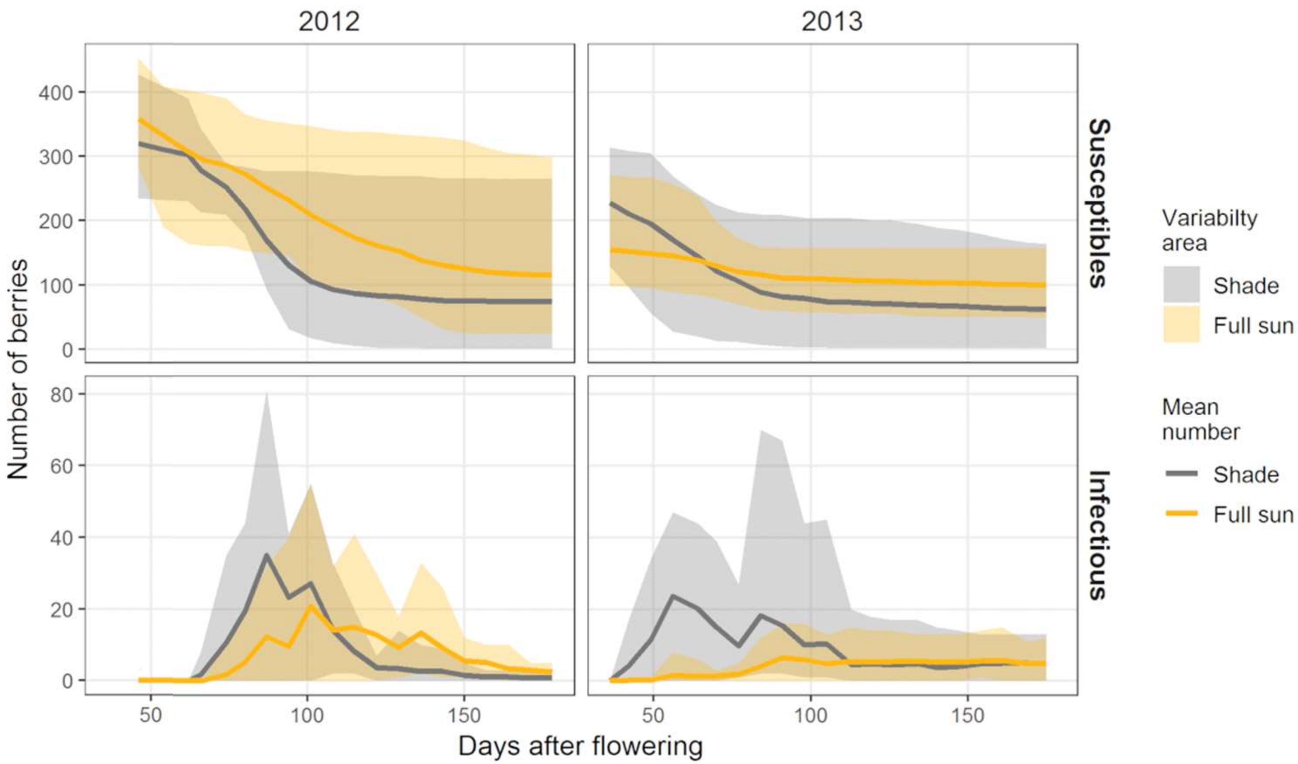
Disease dispersion by rain splash

In agroforestry systems

- Shade trees are supposed to **hamper disease dispersal** by creating a barrier to rain (Mouen et al., 2010)

BUT

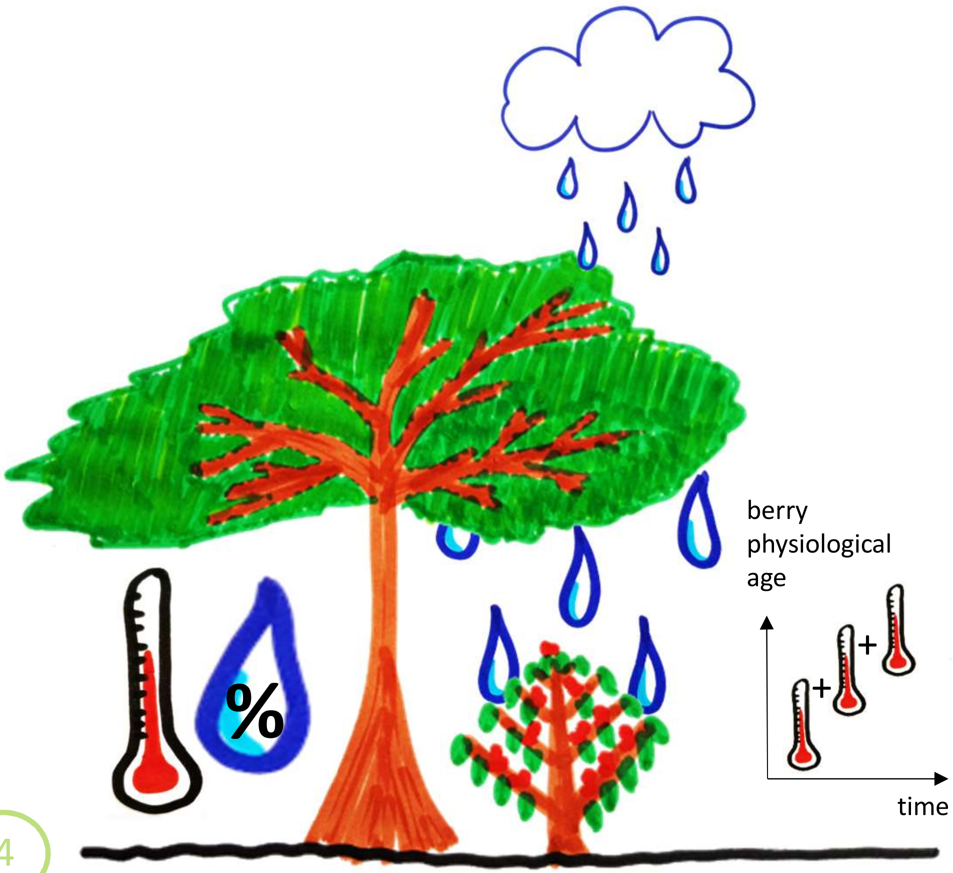




- Variability and amplitude of disease can be **increased** by shade

In agroforestry systems

- Shade trees are supposed to **hamper disease dispersal** by creating a barrier to rain (Mouen et al., 2010)



BUT

- **Dispersion** : Shade tree canopy may **increase** kinetic energy of rainfall
- **Infection** : Temperature / relative humidity more **favourable** to CBD
- **Berry susceptibility : Shade increases** the duration of berry maturation (Vaast et al., 2006)
  - increase in berry susceptibility?
- ...

Disentangle the (possibly antagonistic) effects of shade trees on CBD dynamics

Kola shade tree

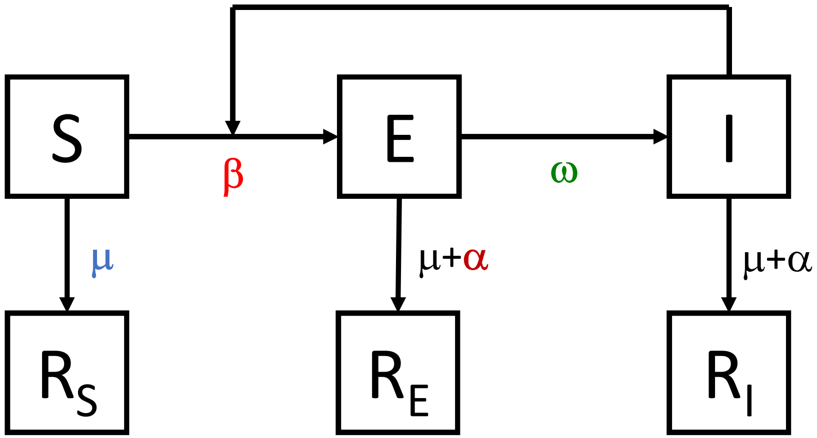
Full sun

A farm in West Cameroon

Hourly temperature and relative humidity

Weekly monitoring of berries

Daily rainfall



Climatic variables

- β : transmission rate
- 1/ω : latency period
- μ : physiological mortality
- α : disease-induced mortality

$$\begin{cases} \dfrac{dS}{dt} = -\beta IS - \mu S \\ \dfrac{dE}{dt} = \beta IS - \omega E - (\mu + \alpha)E \\ \dfrac{dI}{dt} = \omega E - (\mu + \alpha)I \\ \dfrac{dR_S}{dt} = \mu S \\ \dfrac{dR_E}{dt} = (\mu + \alpha)E \\ \dfrac{dR_I}{dt} = (\mu + \alpha)I \end{cases}$$

PROCESS MODEL

$$N_{obs} \sim Pois(S + E + I) \qquad I_{obs} \sim Bin\left(N_{obs}, \frac{I}{S + E + I}\right) \qquad R_{Iobs} \sim Pois(R_I)$$

OBSERVATION MODEL

Influence of climate on epidemiological parameters :

Generalised linear models incorporating climatic variables

Latency period (1/ω): $\text{logit}(\omega) = \omega_0 + \omega_1 \times TEMP + \omega_2 \times TEMP^2$

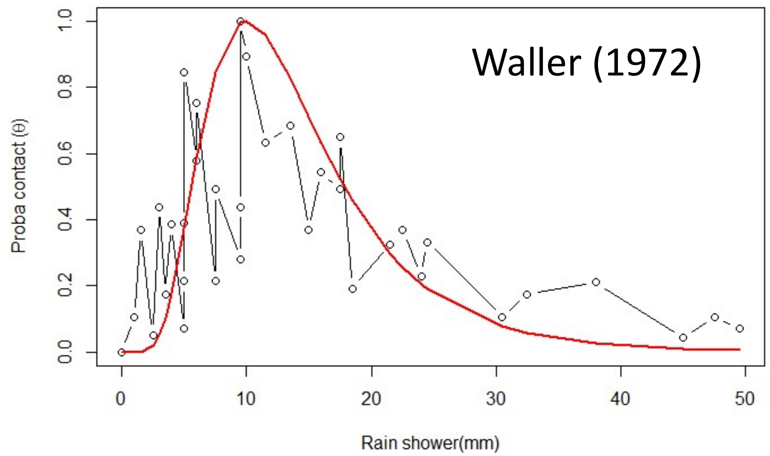
TEMP: daily temperature

Influence of climate on epidemiological parameters :

Generalised linear models incorporating climatic variables

Latency period ($1/\omega$): $\text{logit}(\omega) = \omega_0 + \omega_1 \text{ x TEMP} + \omega_2 \text{ x TEMP}^2$

Disease transmission rate (β): $\log(\beta) = \beta_0 + \underbrace{\beta_1 \text{ x RAIN} + \beta_2 \text{ x RAIN}^2}_{\text{contact probability } (\theta)}$



TEMP: daily temperature

RAIN: daily cumulative rainfall

Influence of climate on epidemiological parameters :

Generalised linear models incorporating climatic variables

Latency period ($1/\omega$): $\text{logit}(\omega) = \omega_0 + \omega_1 \times TEMP + \omega_2 \times TEMP^2$

Disease transmission rate (β): $\log(\beta) = \beta_0 + \beta_1 \times RAIN + \beta_2 \times RAIN^2 + \underbrace{\beta_3 \times SCI}$

Infection probability (ψ_{germ})

TEMP: daily temperature

RAIN: daily cumulative rainfall

SCI: suitable conditions of temperature and relative humidity for infection

Influence of climate on epidemiological parameters :

Generalised linear models incorporating climatic variables

Latency period ($1/\omega$): $$\text{logit}(\omega) = \omega_0 + \omega_1 \times \text{TEMP} + \omega_2 \times \text{TEMP}^2$$

Disease transmission rate (β): $$\log(\beta) = \beta_0 + \beta_1 \times \text{RAIN} + \beta_2 \times \text{RAIN}^2 + \beta_3 \times \text{SCI} + \underbrace{\beta_4 \times \text{TT}}_{\text{Probability of host tissue penetration } (\psi_{suscept})}$$

Probability of host tissue penetration ($\psi_{suscept}$)

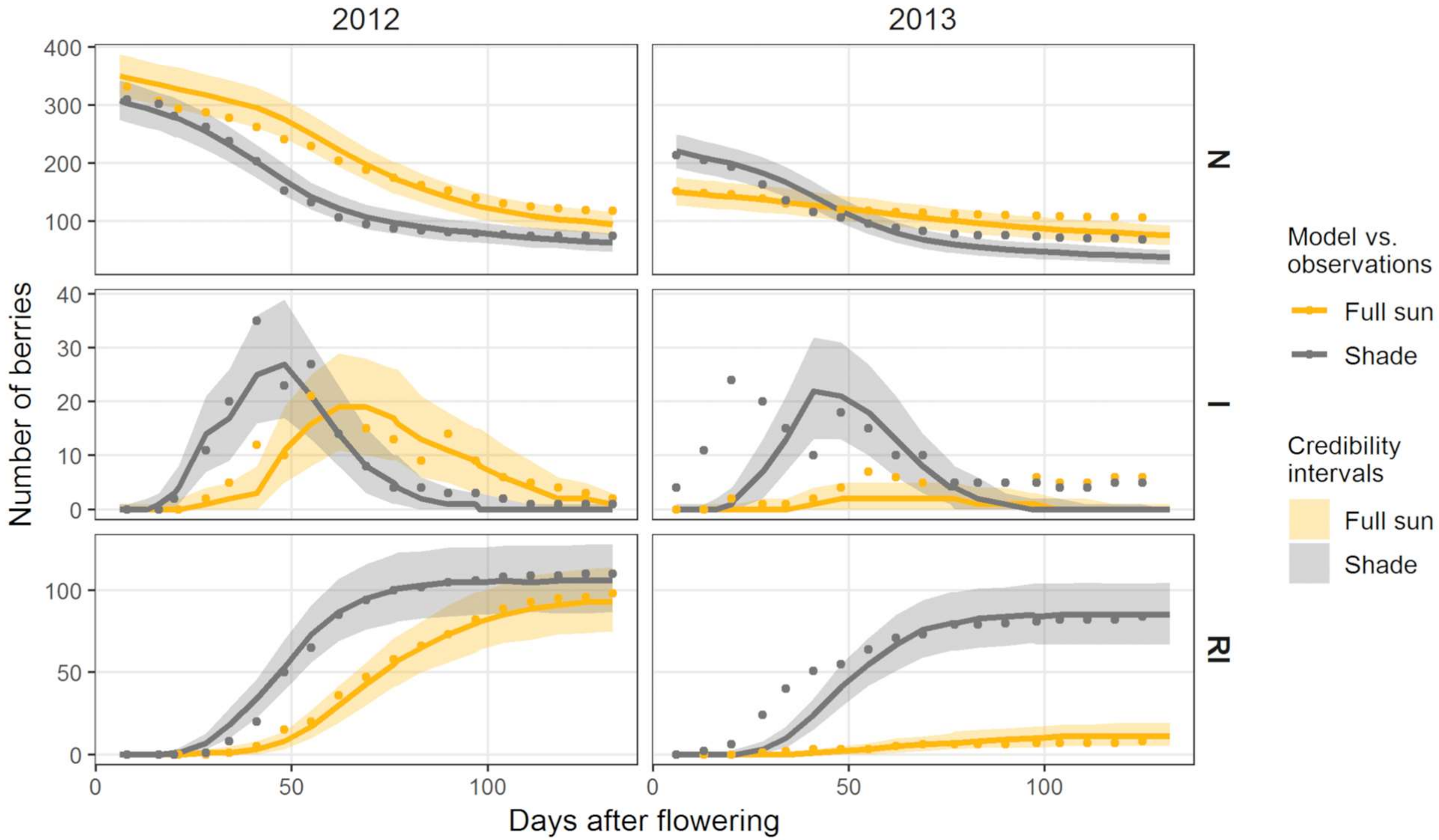
TEMP: daily temperature

RAIN: daily cumulative rainfall

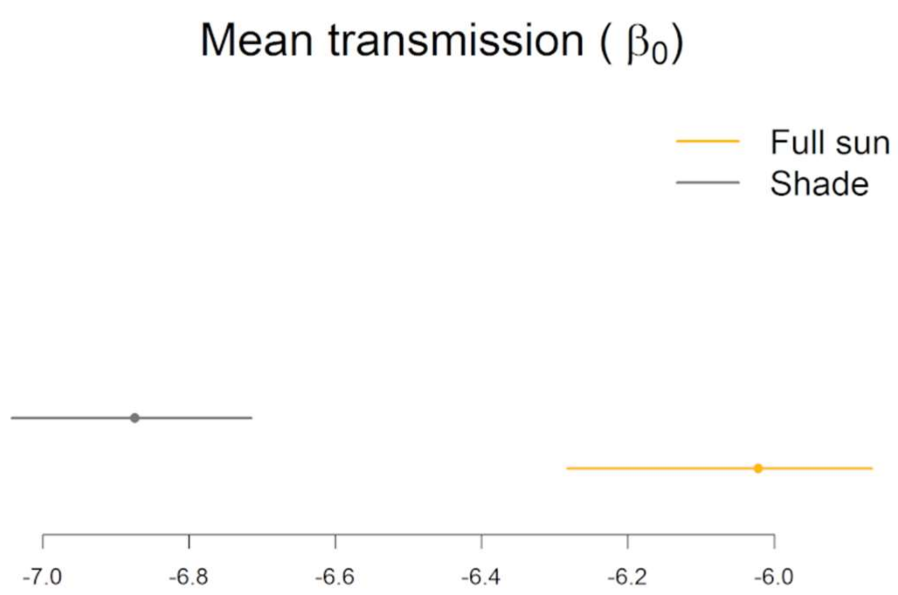
SCI: suitable conditions of temperature and relative humidity for infection

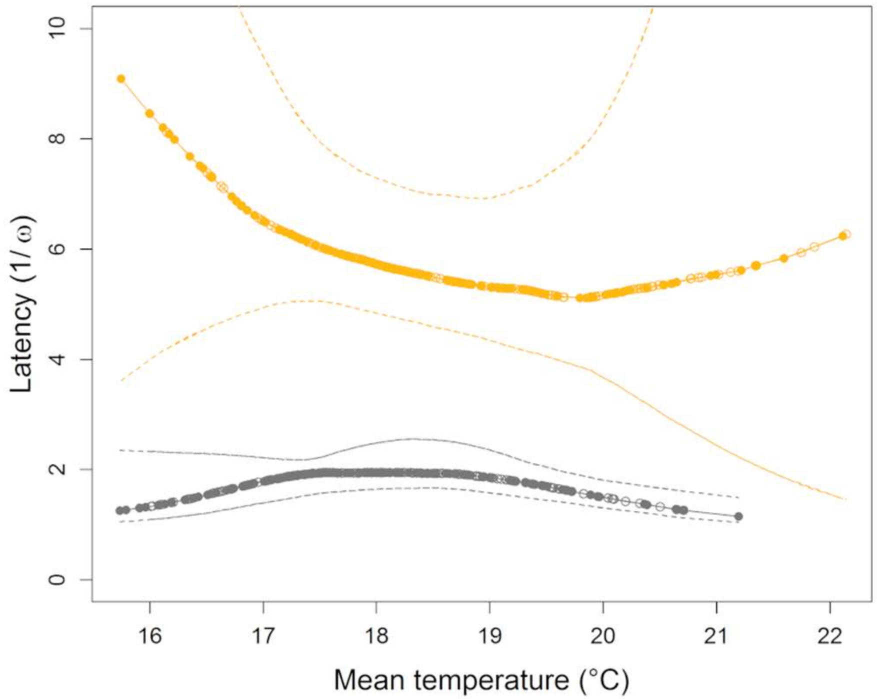
TT: thermal time

Reasonably good model fit in both years under study



Shade exhibits antagonistic effects on epidemiological mechanisms:

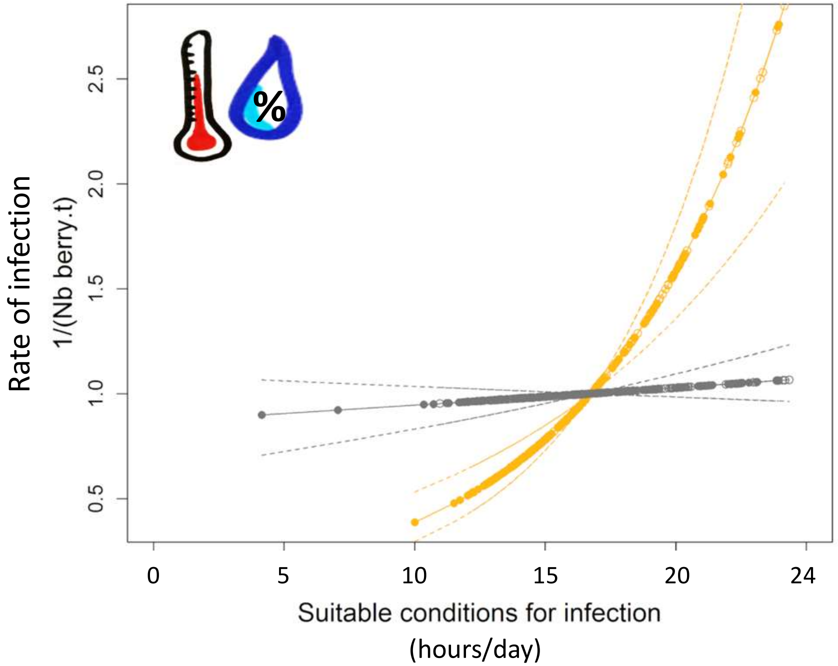




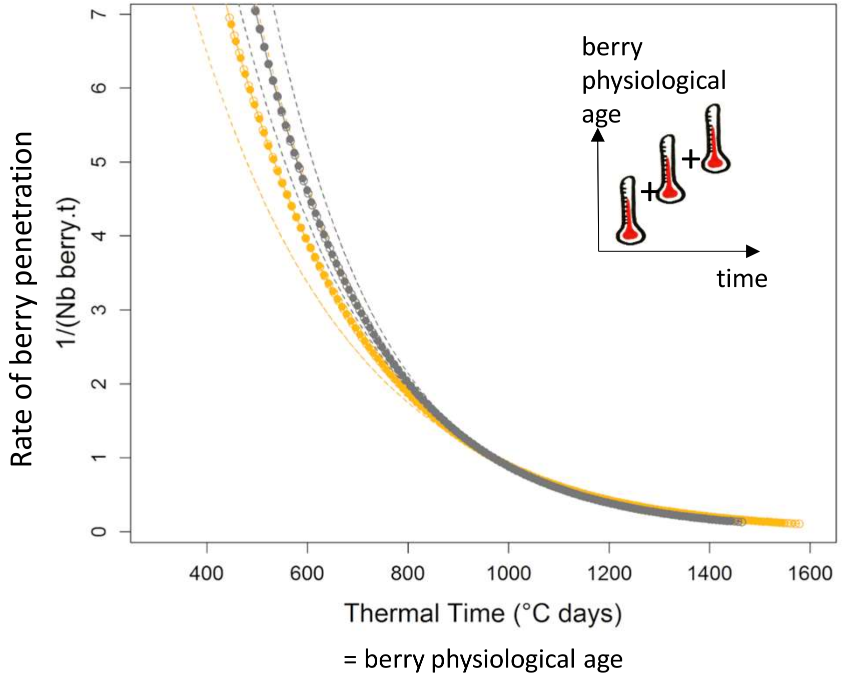
Shade **reduces** the mean disease transmission…

… **while it** also **reduces** the latency period

Shade exhibits antagonistic effects on epidemiological mechanisms:

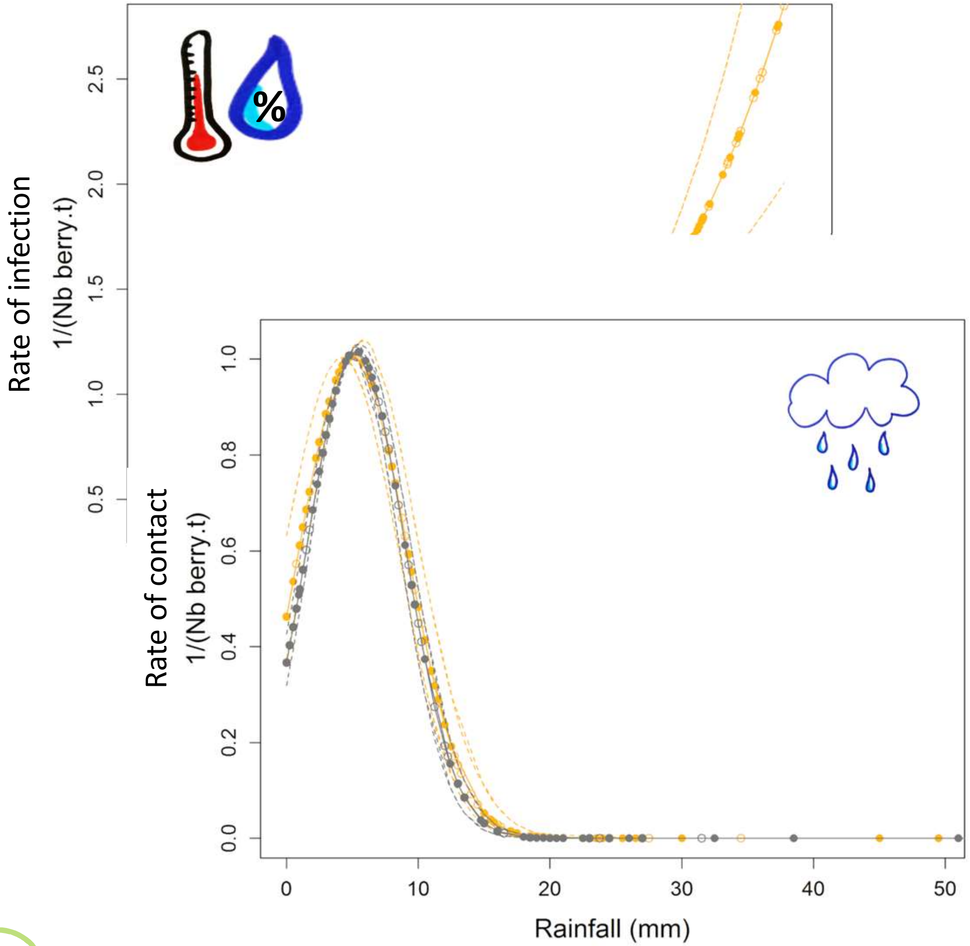


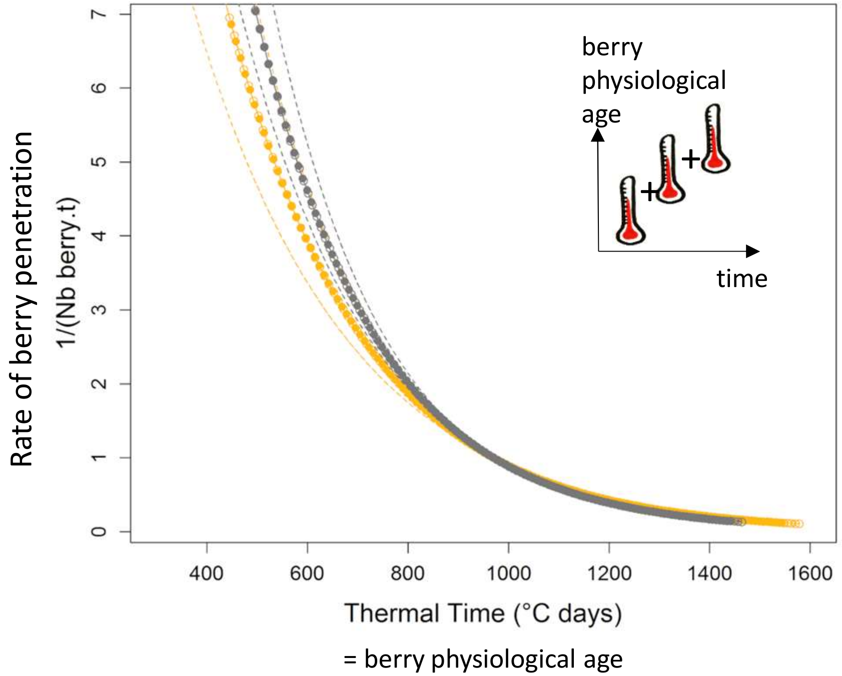
Shade **maintains** suitable conditions for infection



Shade **probably increases** berry susceptibility

Shade exhibits antagonistic effects on epidemiological mechanisms:





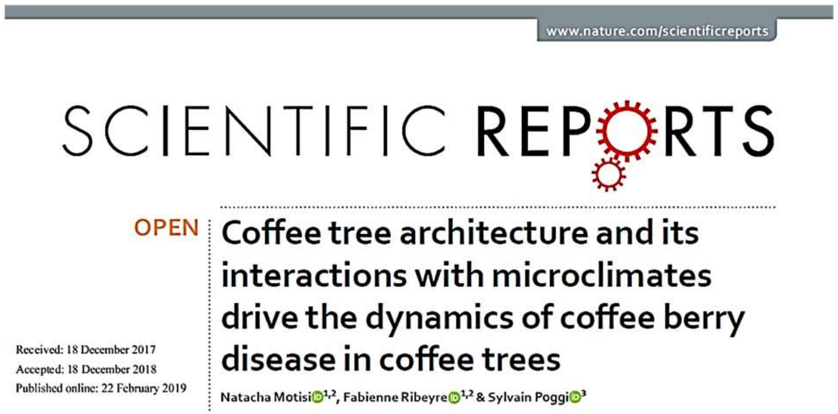
However shade **does not seem to affect** disease transmission through the quantity of rainfall

Main results:

- Shade exhibits **antagonistic effects** on epidemiological mechanisms through microclimates
- Depending on the **local climatic conditions**, one specific mechanism may be fostered, thereby entailing variability of disease control under agroforestry systems

Perspective:

- We promote the **combination of epidemiological and architectural modeling** to help design novel, more cost-effective and environmentally friendly management strategies at both the tree scale and plot scale



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Thank you!

Julien Papaïx

Sylvain Poggi

The coffee productor

The technicians