Dry heat explains outbreak dynamics and altitudinal range expansion of *Ips typographus* (L.) in Southern Europe

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Tackling climate change: the contribution of forest scientific knowledge
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Climate change and bark beetle outbreaks

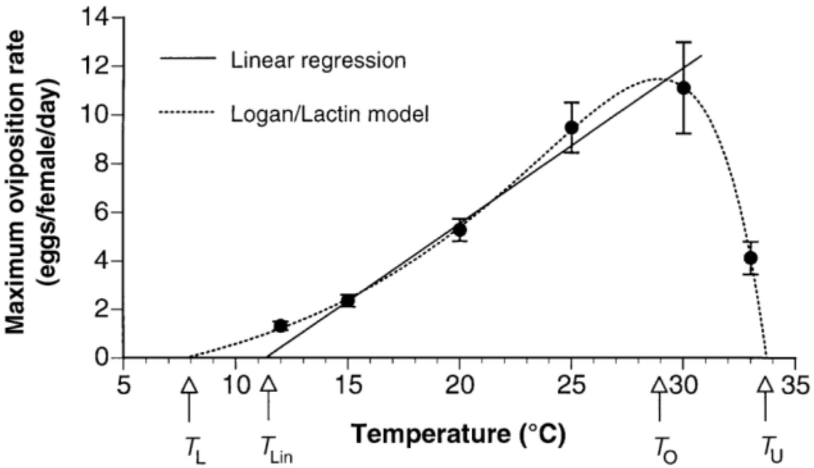
● **Temperature warming** and the increased frequency of **drought or heat waves** are expected to trigger larger bark beetle outbreaks

● ***Ips typographus*** **(L.)** is one of the most destructive pests of European forests and **is expected to quickly respond** to climatic changes

Climate change and bark beetle outbreaks

Climate effects on *I. typographus*

Direct effects of insect development and voltinism



1. Temperature

Indirect effects via modified host tree quality

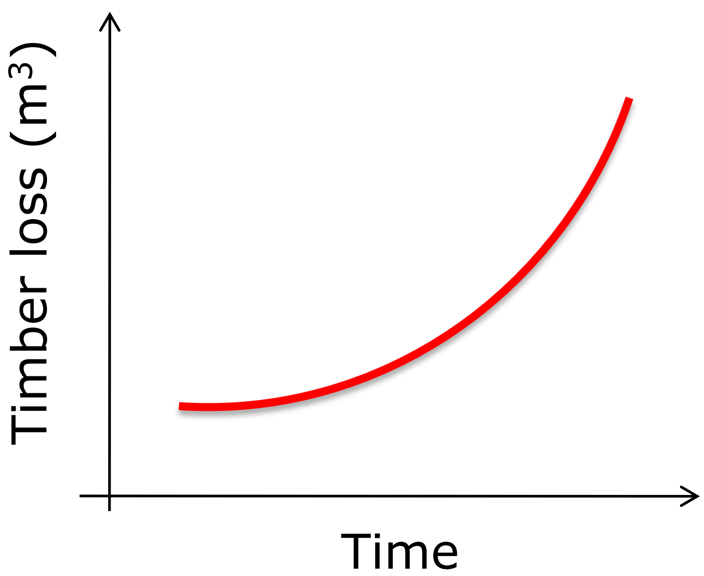
2. Drought

3. Storms

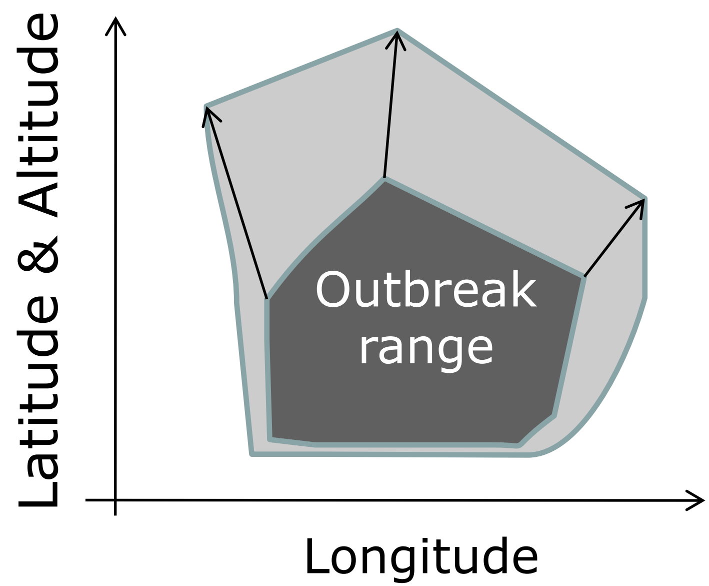
Climate change and bark beetle outbreaks

Expected consequences for forests

Increased outbreak intensity and occurrence



Temperature-related expansions of outbreak range



Aims

1. To quantify the relative importance of the direct and indirect effects of climatic factors vs. density-dependent regulation on *I. typographus* **timber loss dynamics**

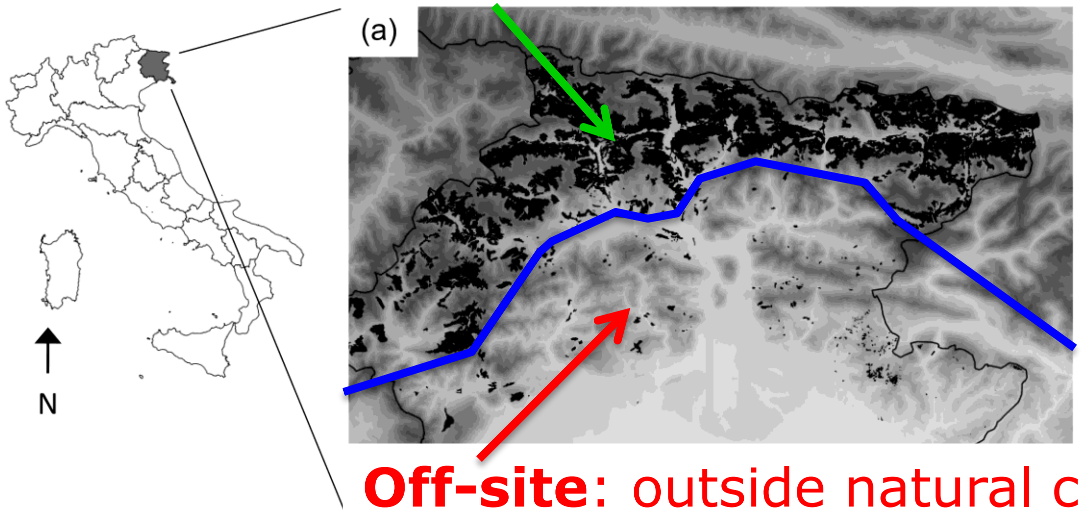
2. To investigate the drivers of the observed variation in the **altitudinal distribution** of the infestation spots

Temperature? **Drought?** **Storms?**

Density-dependent regulation?

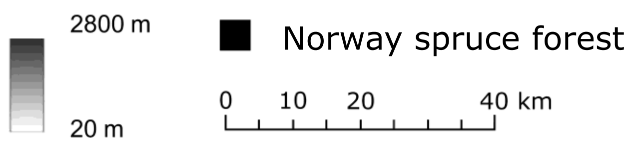
Data: time series (16 years)

On-site: within natural climatic range (95% of forests)

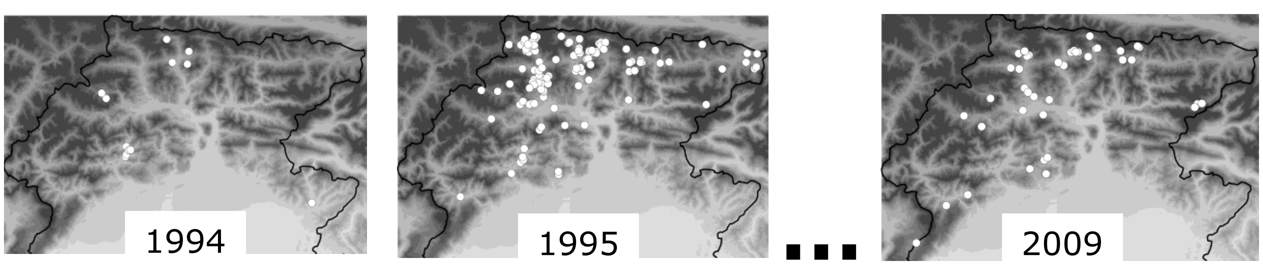


Southernmost range margin of Norway spruce

Off-site: outside natural climatic range (5% of forests)



Time series 1994-2009



For each spot:

1. Timber loss (N_t)
2. Altitude

Data analysis

Discrete population model:

CLIMATE

Timber loss rate: $R_t = \ln(N_t / N_{t-1})$,
where N is annual timber loss

Exogenous abiotic factors and sampling error

$$R_t = f(N_{t-1}, N_{t-2}) + \varepsilon$$

Density dependent component
(t_{-1}: direct and t_{-2}: lagged)

$\varepsilon = f$(Site, $T\text{-}spring_{t-1}$, $T\text{-}summer_{t-1}$, $T\text{-}autumn_{t-1}$, $Rain_{t-1}$, $Forest\ damage_{t-1}$, all interactions with site)

Same approach for explaining changes in altitude:

$\ln(Altitude_t / Altitude_{t-1}) = f$(Site, N_{t-1}, $Altitude_{t-1}$, $T\text{-}spring_{t-1}$, $T\text{-}summer_{t-1}$, $T\text{-}autumn_{t-1}$, $Rain_{t-1}$, all interactions with site)

Data analysis

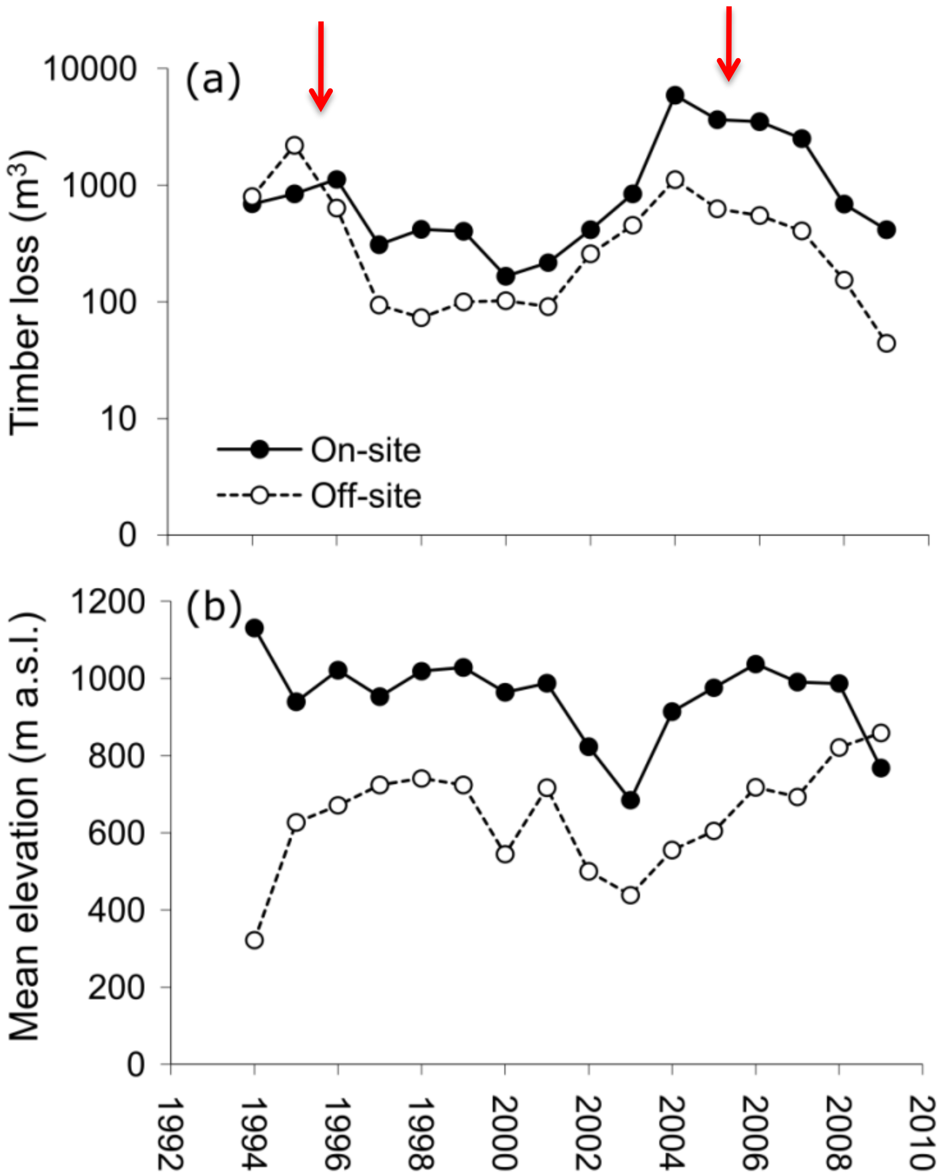
Multi-model inference using AICc
This method allows evaluating simultaneously several competing hypotheses

Examples of competing hypotheses:

H_1: $R_t \sim f$(Temperature)
H_2: $R_t \sim f$(Drought)
…
H_4: $R_t \sim f$(Density dependence)
H_5: $R_t \sim f$(Drought + Density dependence)
…

Which are the most plausible hypotheses?

General results



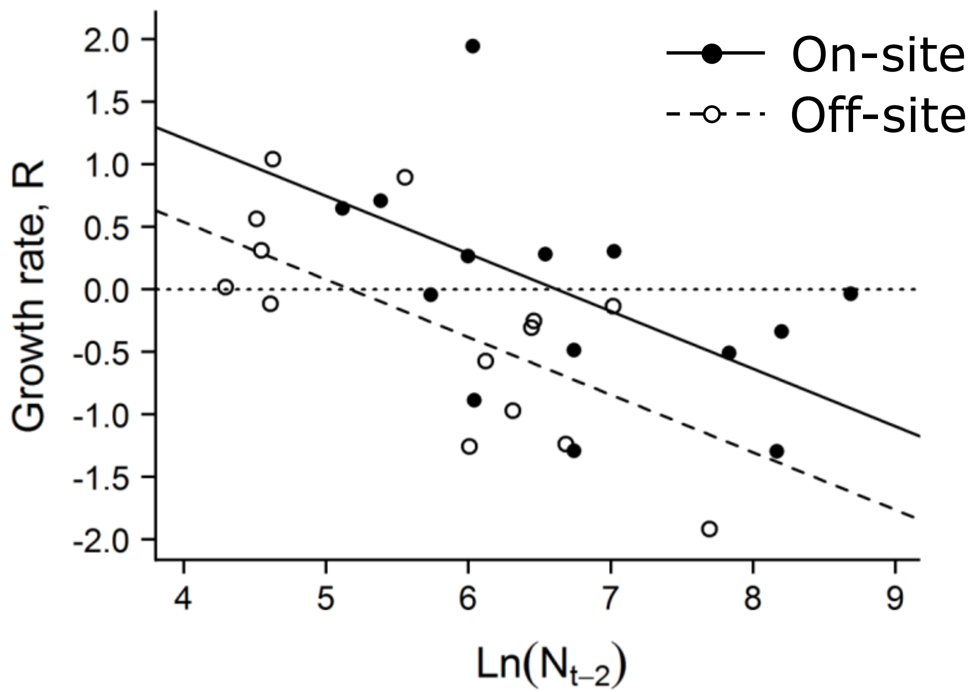
Timber loss dynamics

Two main outbreaks in the study period

Altitudinal distribution

Higher altitude in on-site than in off-site forests

Timber loss dynamics: Density dependence



Strong support for a 2-year delayed density dependence

Potential explanations:

-Stronger impact of natural enemies (parasitoids?)

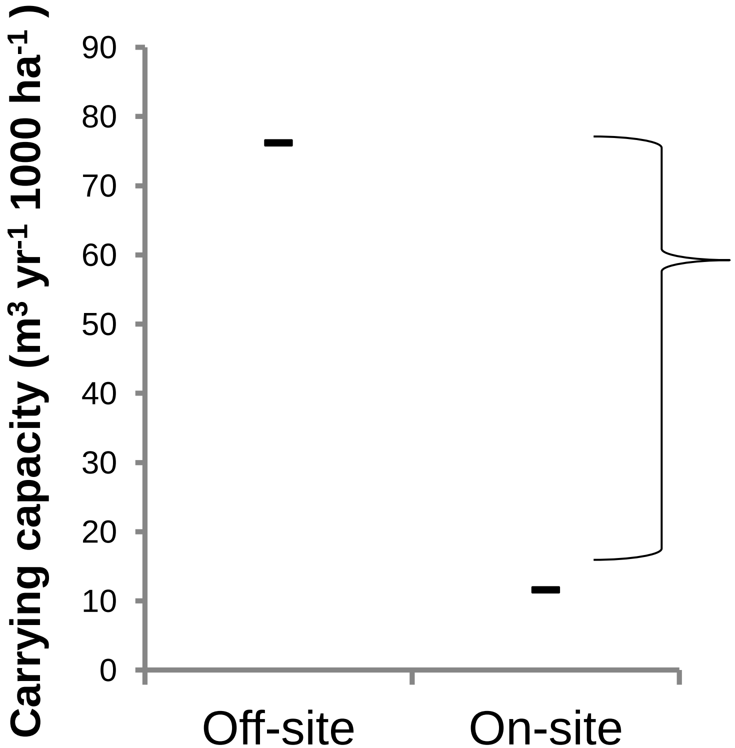
-Potential delayed drought-effect on tree resistance

-Small size of the outbreaks (less intra-specific competition)

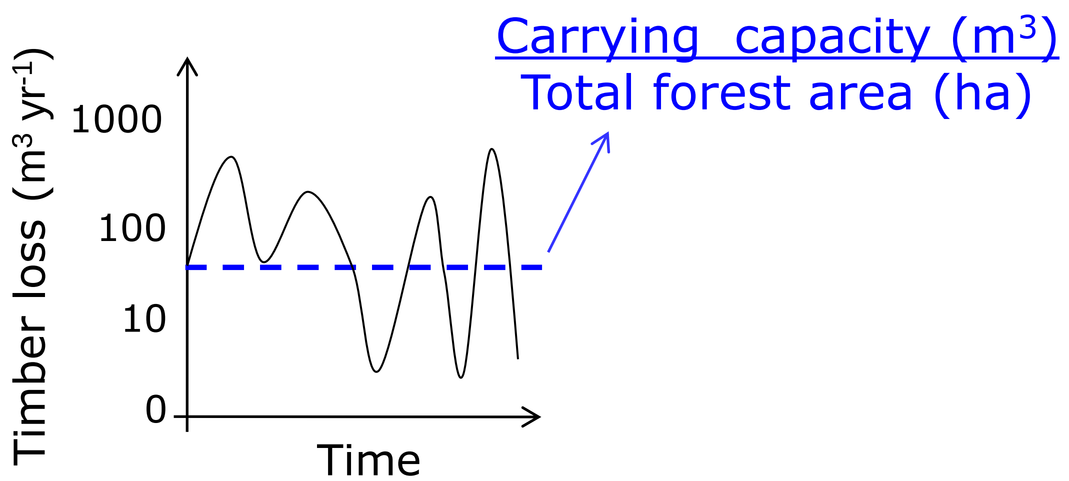
$R_t \sim N_{t-2} + \text{Site} + Rain_{t-1} + Rain_{t-1}^2$

Timber loss dynamics: Carrying capacity (K)

Effect of spruce climate suitability (on- vs. off-site)

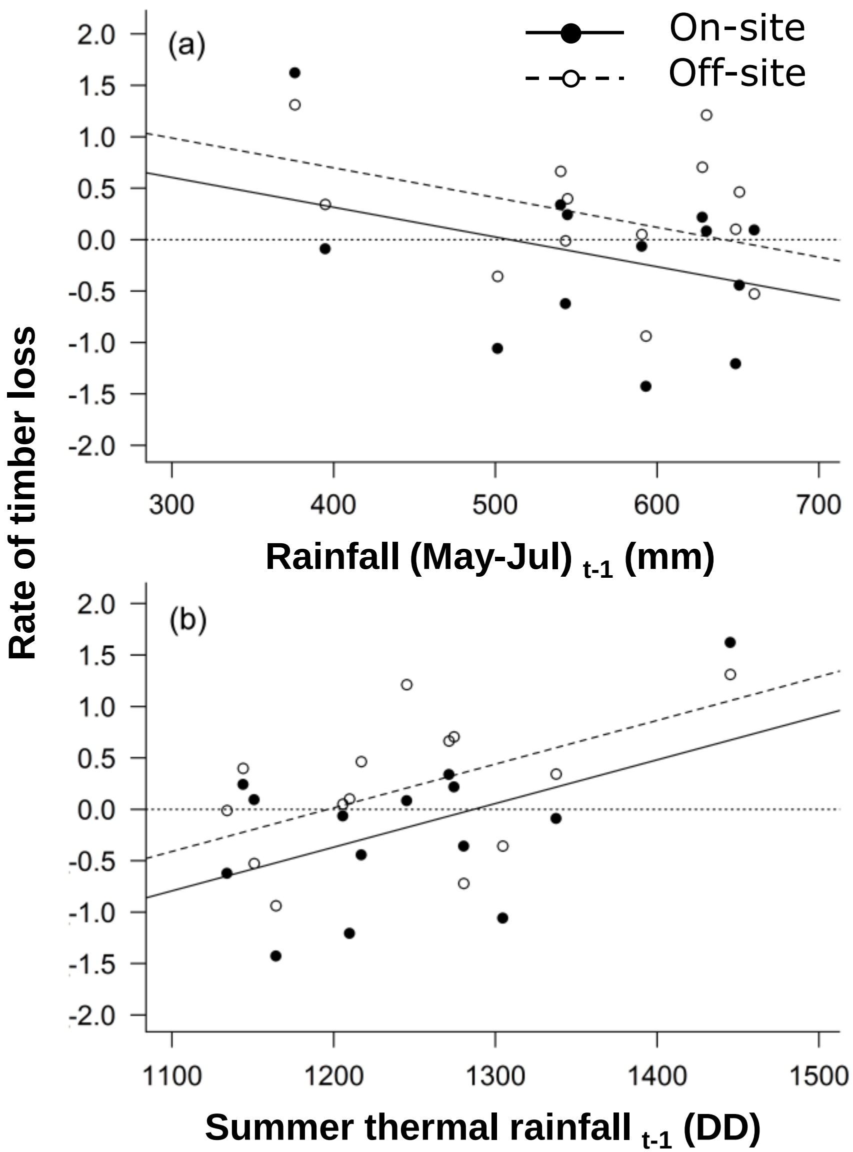


At equilibrium (R=0) ~7 times higher timber loss in **off-site forests** than **on-site forests**



$R_t \sim N_{t-2} + \text{Site} + Rain_{t-1} + Rain_{t-1}^2$

Timber loss dynamics: Abiotic factors (ε)

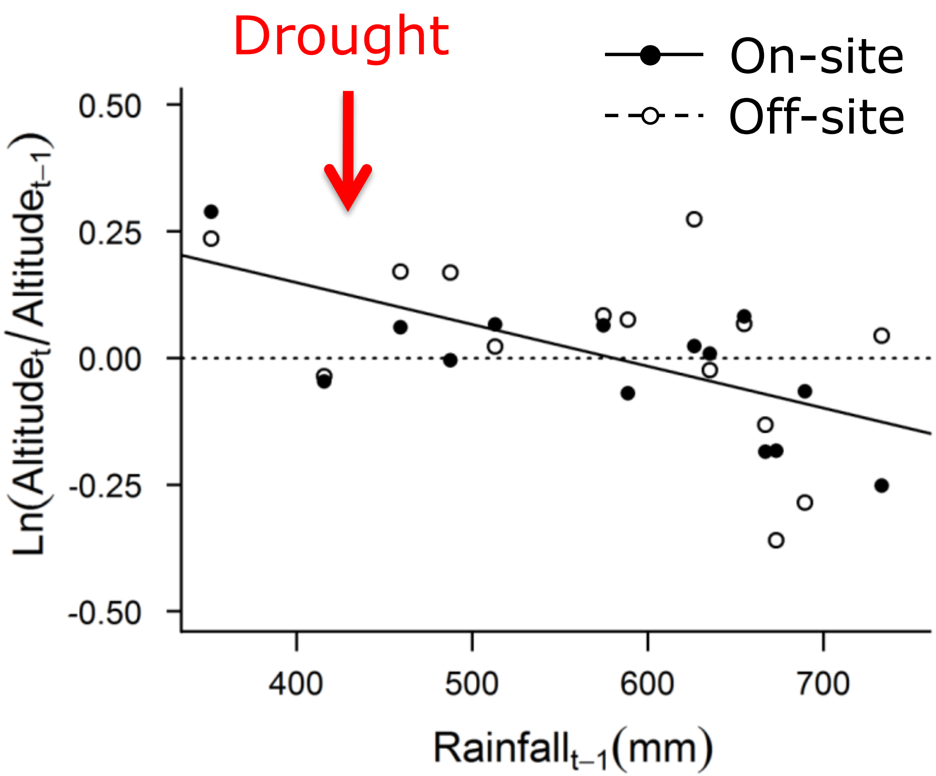


Specific tests are needed but this could be understood as a result of drought compromising the inducible tree defense systems

Probably direct positive effect on insect and/or indirect effect on tree susceptibility

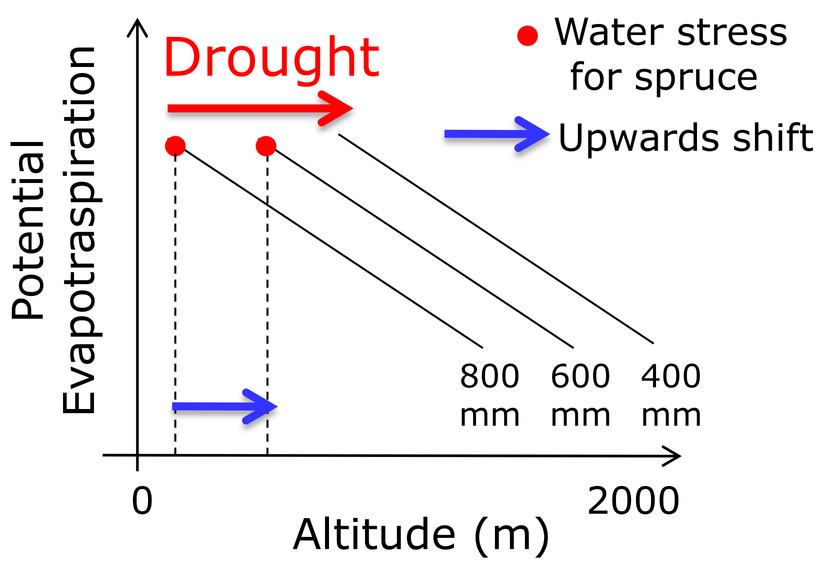
$R_t \sim N_{t-2} + \text{Site} + Rain_{t-1} + Temperature_{t-1}$

Altitudinal range expansion



Drought affects induced a **rapid upwards shift** of the attacked areas

No effect of temperature!



The availability of suitable of host trees is a stronger driver of the altitudinal distribution of the infestations spots than the average thermal conditions

$ln(Altitude_t/Altitude_{t-1}) \sim Rain_{t-1}$

Conclusions

- Drought increased timber loss and induced a rapid upwards shift of the infestation spots

- Temperature warming further contributes to increase timber loss but not the altitudinal distribution of the spots

- Average timber loss was higher outside the climatic range of spruce

- Greater efforts should be made to integrate drought effect into future scenarios of insect outbreaks and forest disturbances under global change

Thank you for your attention

BACCARA project information: *www.**baccara-project**.eu/*

Marini L., Ayres M.P., Battisti A., Faccoli M. (on-line first) Climate affects severity and altitudinal distribution of outbreaks in an eruptive bark beetle. *Climatic Change*

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