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How trees respond to climate hazards

The impact of droughts and heatwaves on trees

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OUTLINE

01 Current situation

02 Modeling the Impact of Climate Hazards on Trees

03 The Life Expectancy of Trees

04 Trees longevity in a warming world

05 Can trees be saved?

01 Current situation

No quantitative literature

Climate hazards studied

Heatwaves (HW)

Number of dry days during a HW

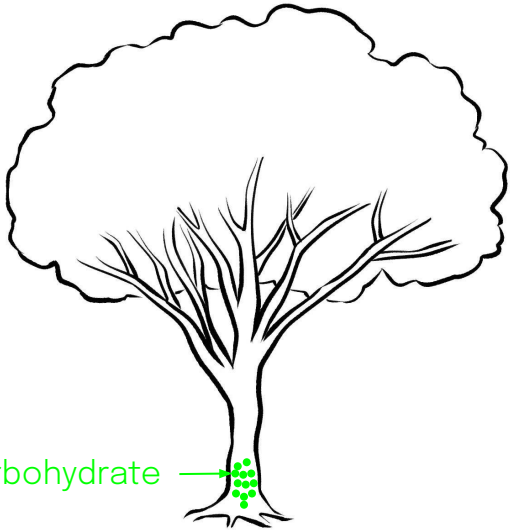
02
Modeling the Impact of Climate Hazards on Trees

A ruin model for trees

$$R(t) = (1-b) \cdot R(t-1)$$

Fraction of devoted to growth

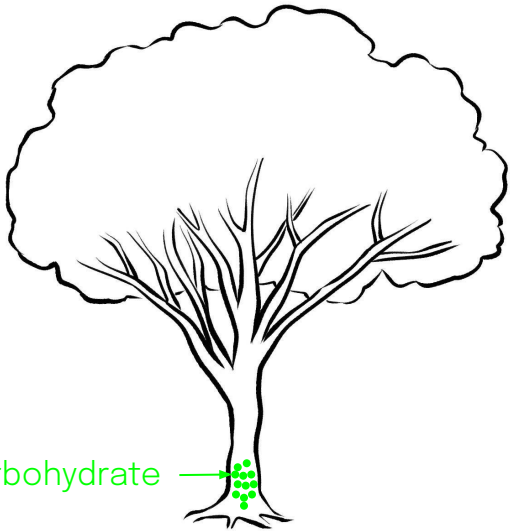
previous reserves



carbohydrate

A ruin model for trees

$$R(t) = (1-b)\cdot R(t-1) + p(t)$$



Net Primary Production (NPP)

$$p(t) = p_0 - B \cdot S(t-1)$$

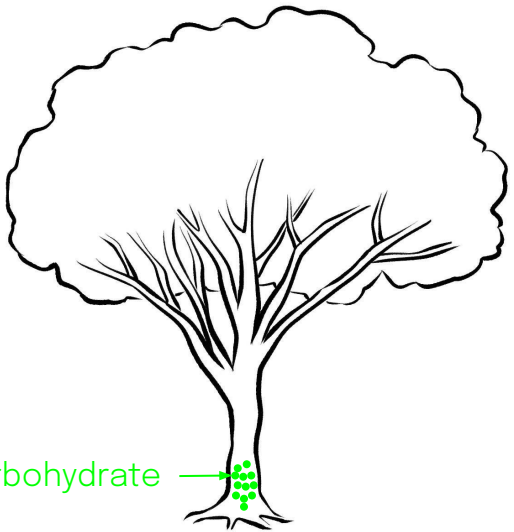
Tree characteristic

Optimum average NPP

Previous damage

A ruin model for trees

$$R(t) = (1-b)\cdot R(t-1) + p(t) - S(t)$$



carbohydrate

Number of dry days during heatwaves

Damages ← $S(t) = A_h \cdot \sum_{k=1}^{N(t)} X_k$ → Intensity of a dry day

Tree characteristic

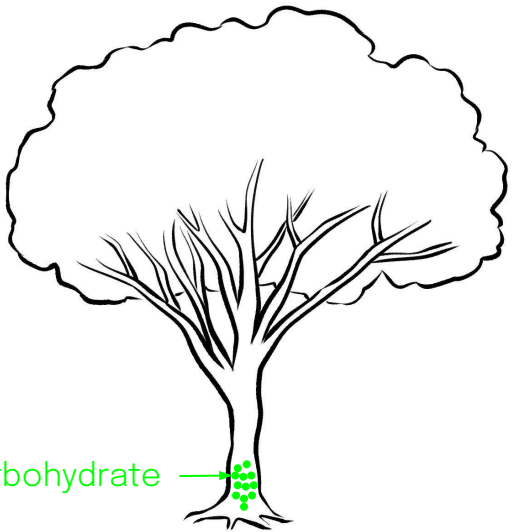
A ruin model for trees

$$R(t) = \min((1-b)\cdot R(t-1) + p(t) - S(t),\ R_{\max})$$

A ruin model for trees

12 10 6 4

$$R(t) = \min((1-b)\cdot R(t-1) + p(t) - S(t),\ R_{\max})$$

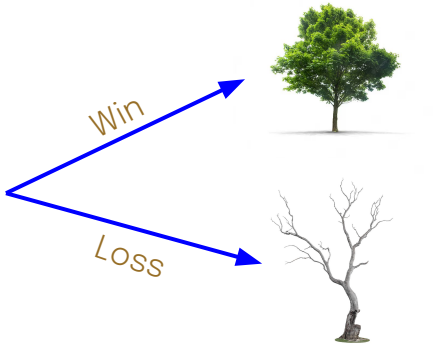


Ruin probability

+

RUIN!

+



RUIN! (R=0)

⟶ A way to measure how likely are trees going to reach ruin

Ruin probability

How likely are we going to reach ruin **before time T**:

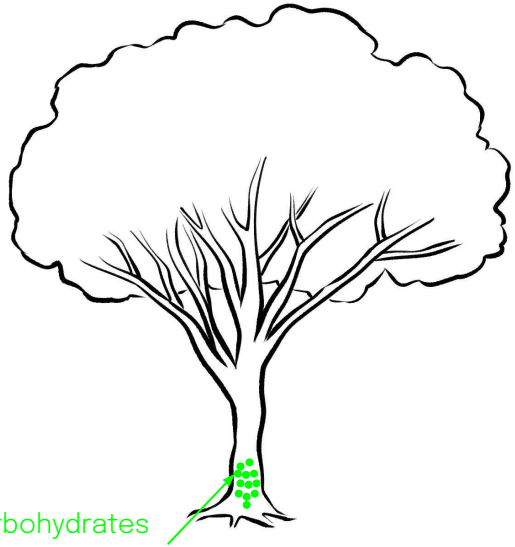
$$\underbrace{\Psi(R_0, t)}_{\text{Depends on time and the initial capital}} = \underbrace{\mathbb{P}\left(\inf_{0 \le t \le T} R(t) \le 0\right)}_{\text{Ruin is reached}}$$

For our model, when $t \longrightarrow +\infty$

$$\Psi(R_0) = \left(\frac{\beta}{R_0}\right)^{\alpha-1}$$

Net profit condition

What is a profit situation?



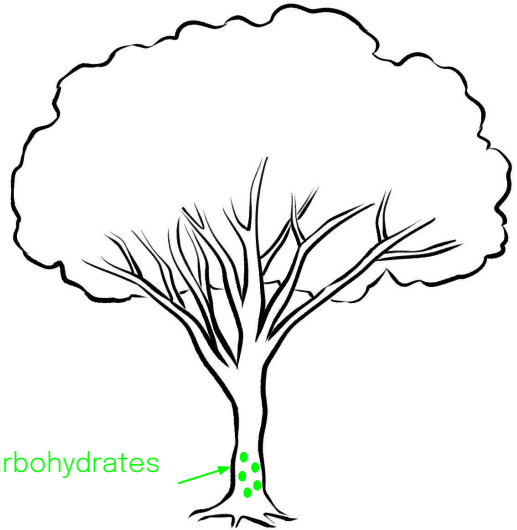
12 Carbohydrates

+

-7 Carbohydrates

=

Profit situation !



5 Carbohydrates

Net profit condition

A condition that guarantees a profit?

A simplified model?

Random value

$$R(t) = \min((1-b) \cdot R(t-1) + p(t) - S(t),\ R_{\max})$$

$$\mathbb{E}(R(t)) = \mathbb{E}(\min((1-b).\, R(t-1) + p(t) - S(t),\ R_{max}))$$

Expectation value

Many random variables!

Complicated model

03
The Life Expectancy of Trees

Two defense strategies

Isohydric or “cash”
= stop growing during hazards

B = 0

Anisohydric or “credit”
= grow but pay for it the next year

B = 1.5

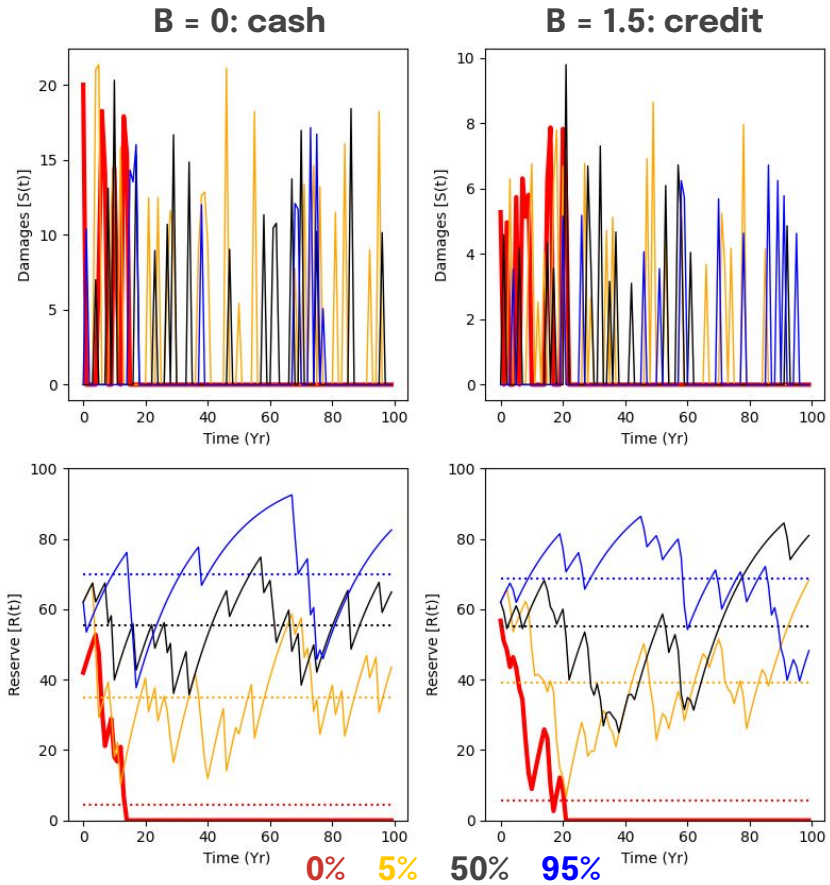
Simulation over 100 years

On average:

HW return period: 5 years

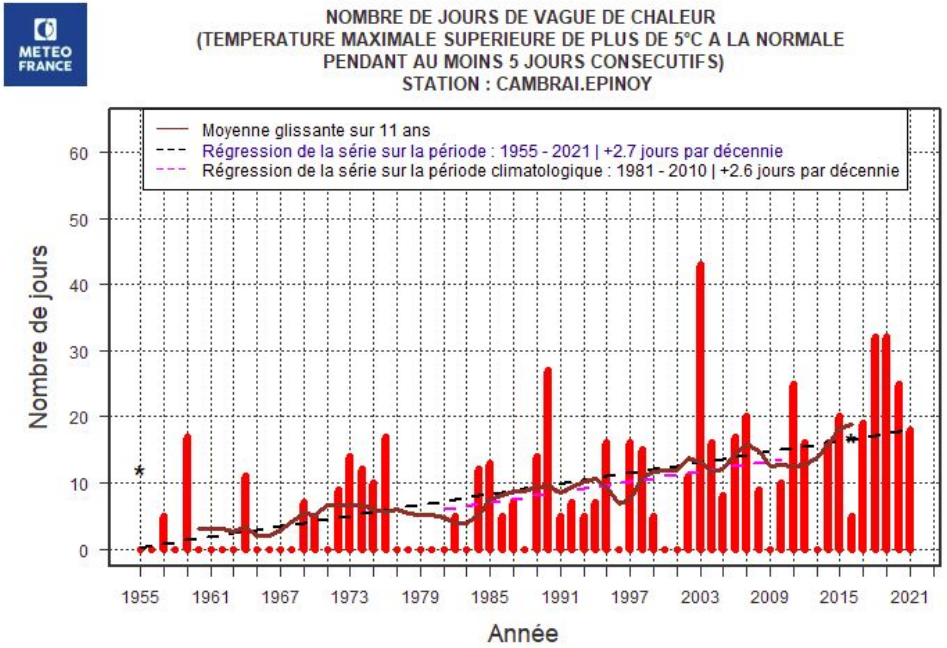
Dry days: 10

Ruin probability < 5%

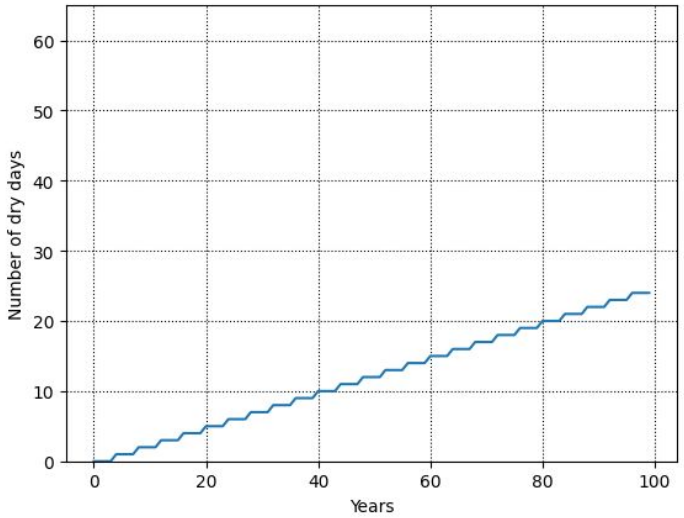


04
Trees longevity in a warming world

Taking climate change into account



0 days + 2.5 every 10 years



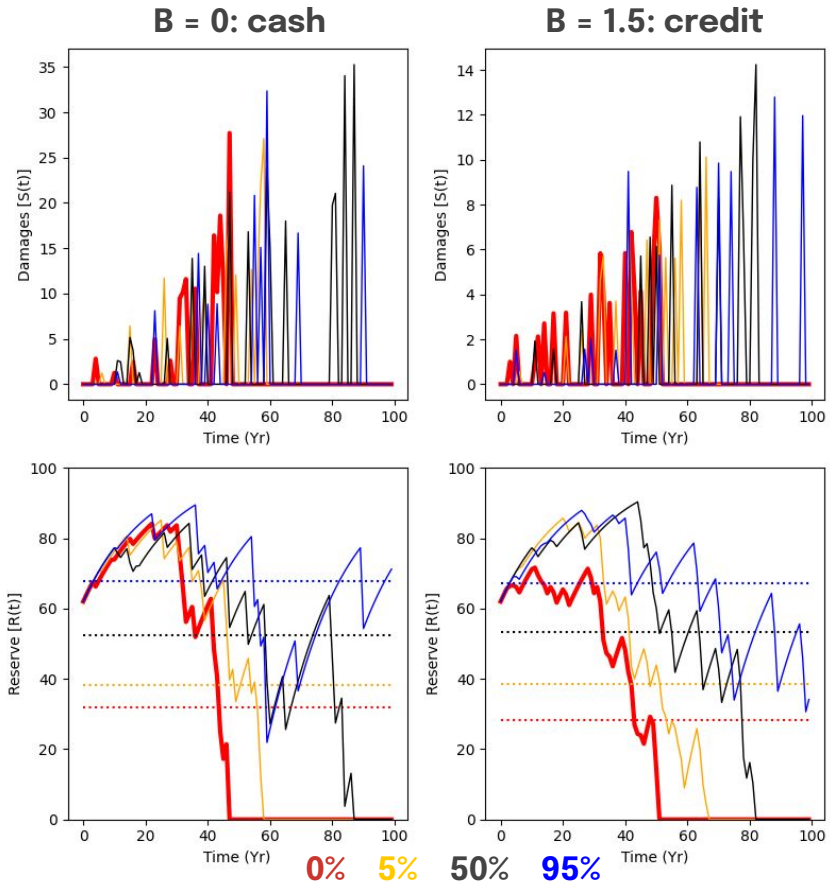
Taking climate change into account

On average:

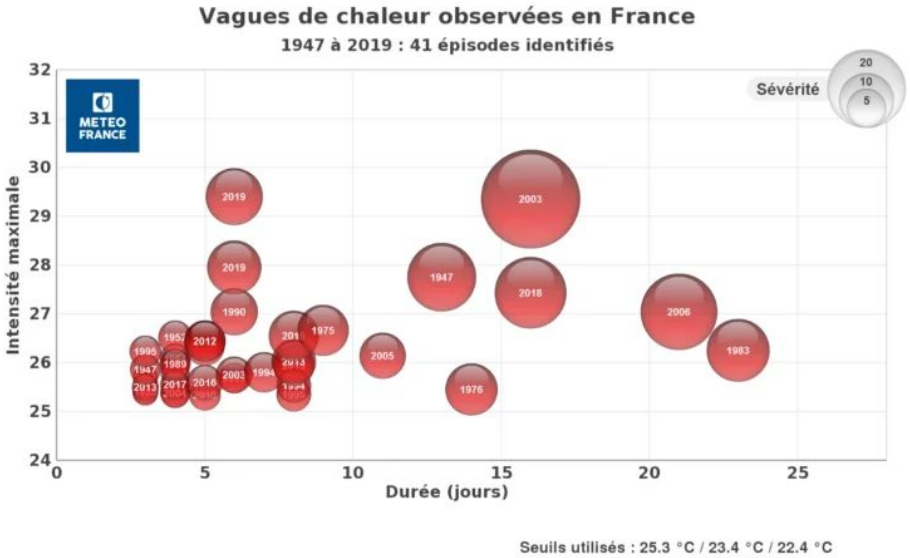
HW return period: 5 years

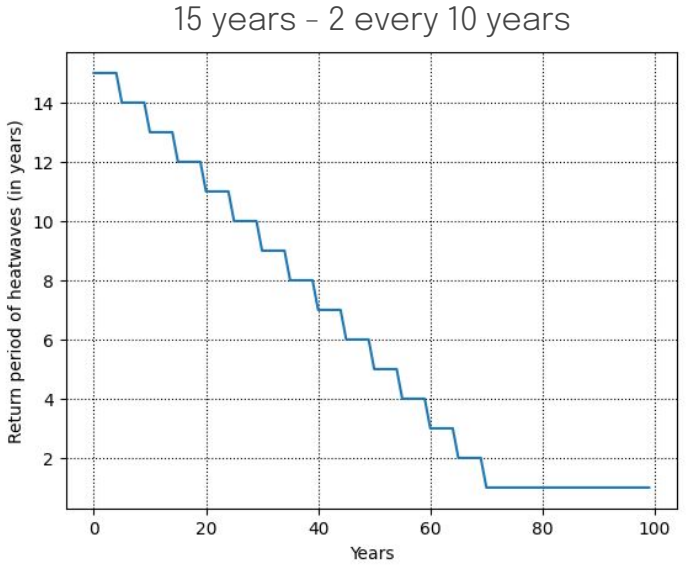
Dry days: 0 + 2.5 every 10 years

Ruin probability ≈ 70%



Taking climate change into account



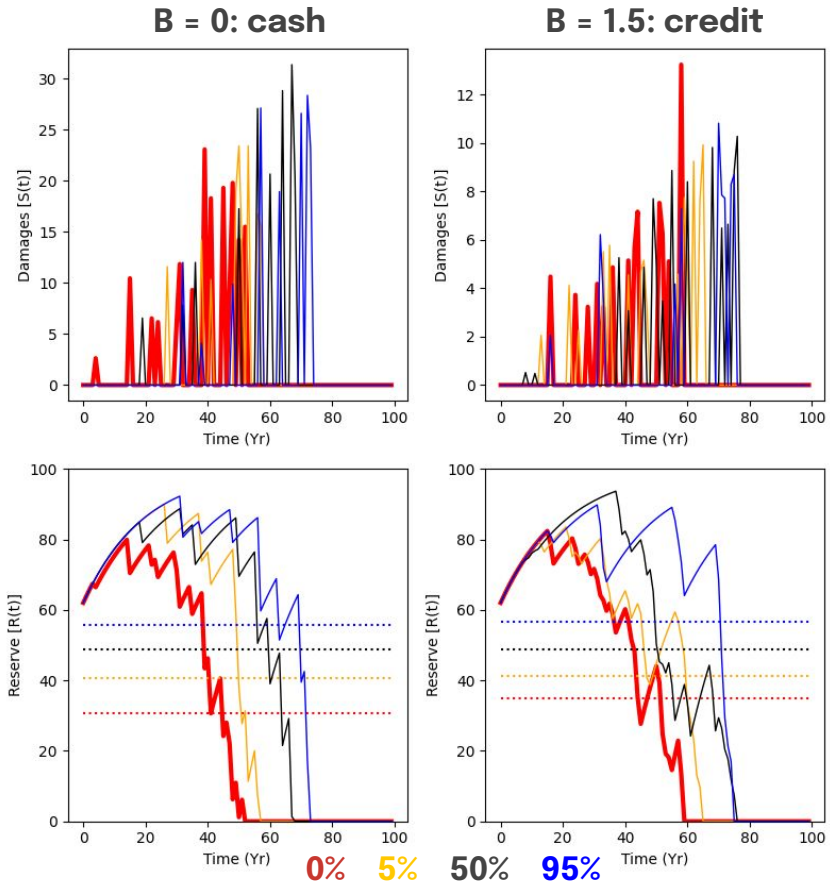


Taking climate change into account

On average:

HW return period: 15 years - 2 every 10 years
Dry days: 0 + 2.5 every 10 years

Ruin probability ≈ 100%



05
Can trees be saved?

Conditions to save trees

Now:

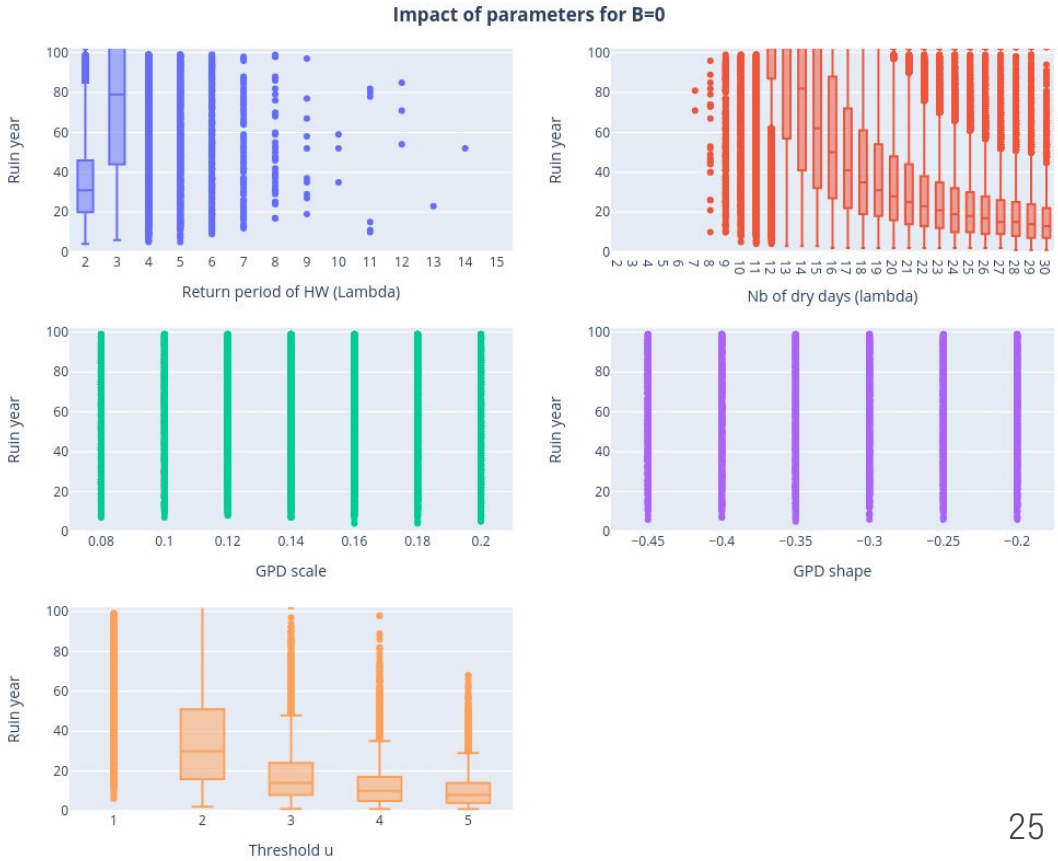
HW return period: 1 year

Dry days: ≈ 20

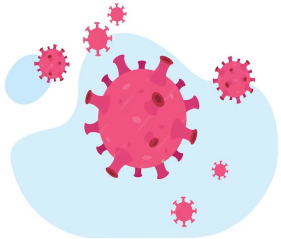
To save trees:

HW return period: > 4 years

Dry days: < 11

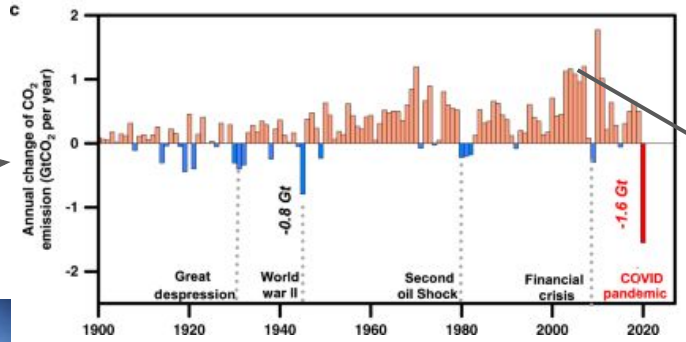


Irreversible situation?



Covid 19

Empty highways in France



Contacts

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References

(1) Project Report:
R. Colin, K. Ghamnia, F. Grivet

(2) Reference article:
P. Yiou and Viovy N. Modelling forest ruin due to climate hazards. Earth System Dynamics, 33, 2021

(3) Peach tree:
https://www.plantmegreen.com/cdn/shop/products/ContenderPeachMaturePMG.jpg?v=1616527794

(4) Poplar tree:
https://t1.gstatic.com/images?q=tbn:ANd9GcQStjTWo_Ssb0nE7cjQt-RMwAMgKgKLQ3R746eeTDcUbbLVCTbm

(5) Tree drawing:
https://media.colomio.com/how-to-draw/tree-drawing-easy-4.jpg

(6) Annual change of CO2:
https://www.tsinghua.edu.cn/__local/D/97/6F/48E6FBACE0A008CA40A5F220C2A_545588A2_1675F.png

(7) All the visuals (money, game, trees) :
https://www.freepik.com/