

How trees respond to climate hazards

The impact of droughts and heatwaves on trees

Tutors:
Melissande Albert
Rebecca Coles
Anthony Reveillac



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?

An aerial photograph showing a vast landscape. In the foreground, a large, dark, and relatively smooth area of black sand or lava flow dominates the lower half of the frame. This dark area is interspersed with numerous small, young evergreen trees that appear to be growing in patches. Beyond this dark area, the terrain rises into a dense forest of taller, mature evergreen trees. In the background, several rounded hills or mountains are visible, also covered in forest. The sky is a clear, pale blue. Overlaid on the left side of the image is the text '01 Current situation' in a large, white, sans-serif font.

01 Current situation

No quantitative literature



Climate hazards studied



Heatwaves (HW)

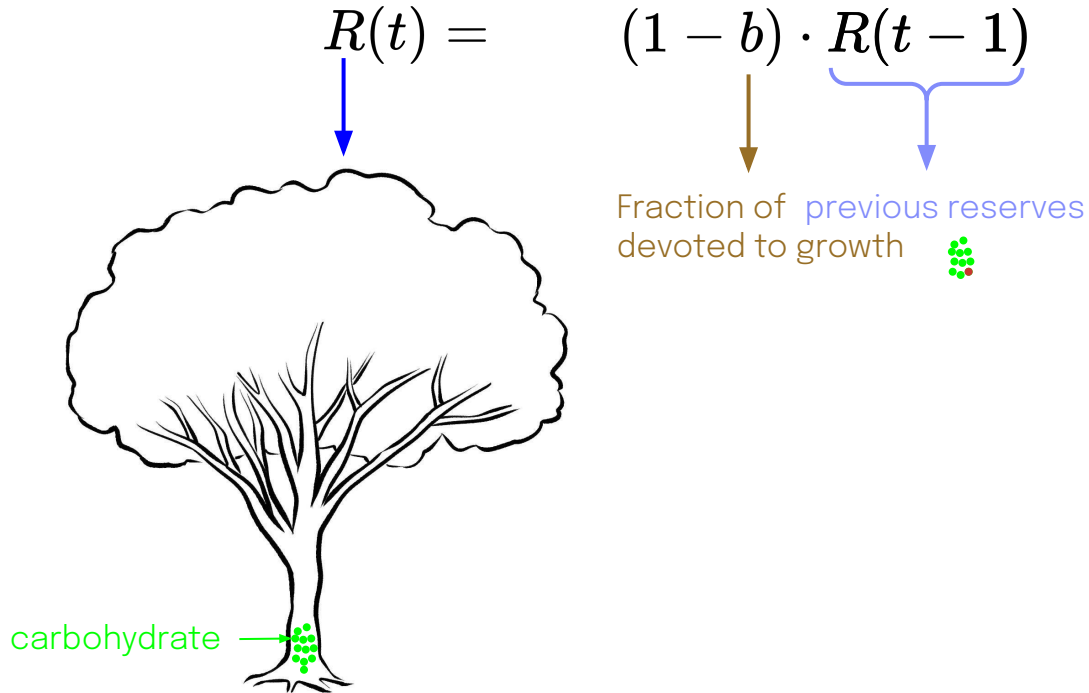
Number of dry days during a HW



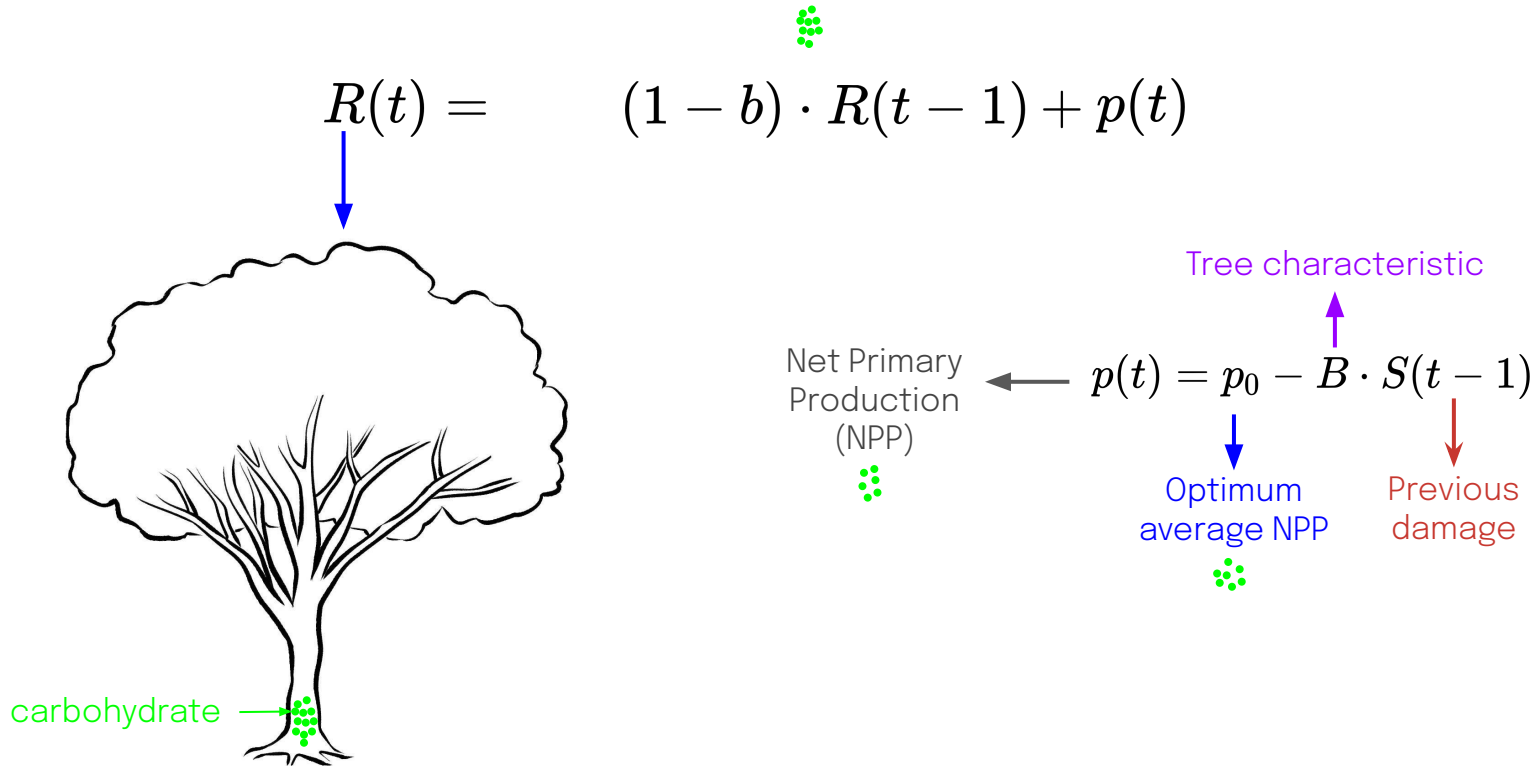
02

Modeling the Impact of Climate Hazards on Trees

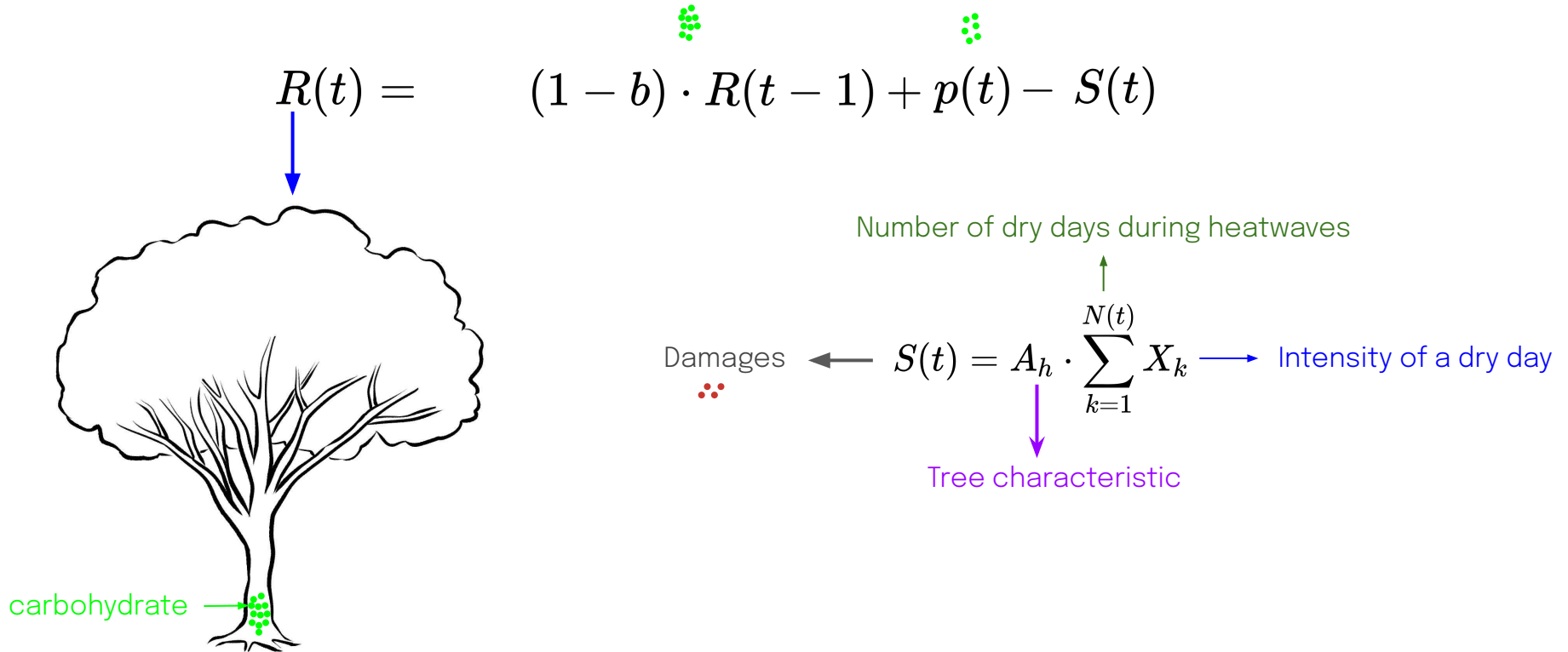
A ruin model for trees



A ruin model for trees

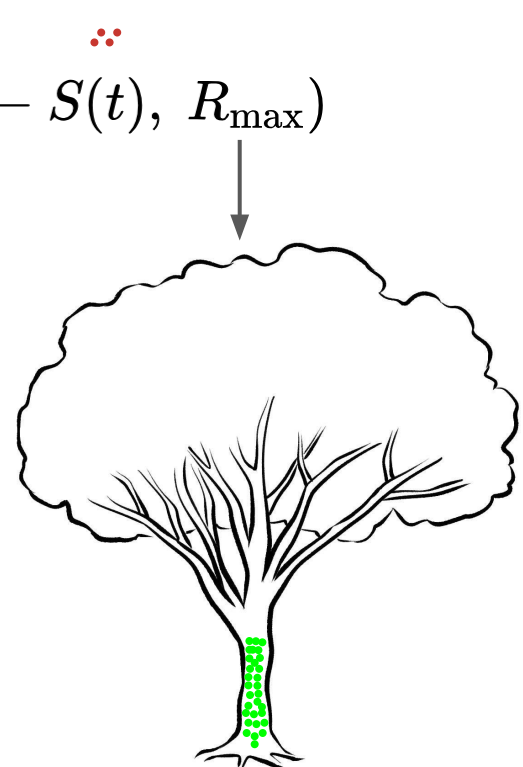
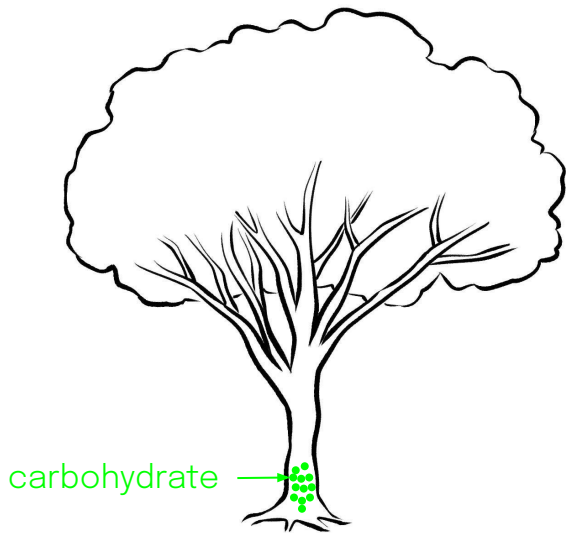


A ruin model for trees



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

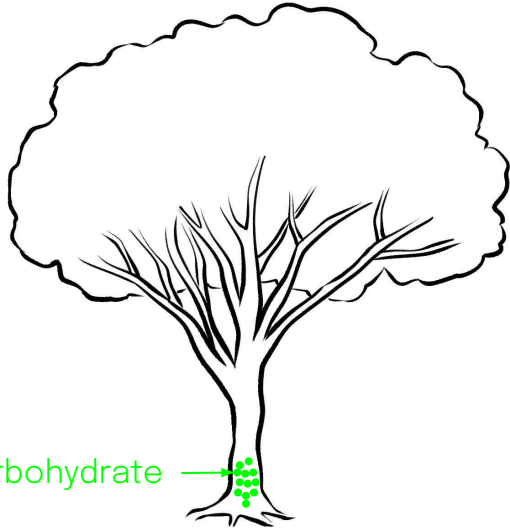
10

6

4



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



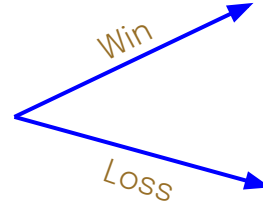
carbohydrate



Ruin probability



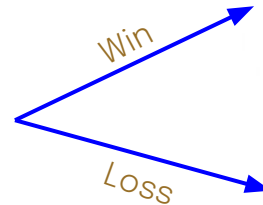
+



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**:

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

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?



Net profit condition

A condition that guarantees a profit?

A simplified model?

Random value

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

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

Expectation value

Many random
variables!

→ **Complicated model**

An aerial photograph of a vast forest landscape. In the foreground, a large, dark, and relatively flat area of black sand or lava flow stretches across the lower half of the frame. A narrow, winding path or stream bed cuts through this dark area. Beyond the dark foreground, a dense forest of green coniferous trees covers the rolling hills and mountains in the background. The sky is a clear, pale blue.

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

$$B = 1.5$$

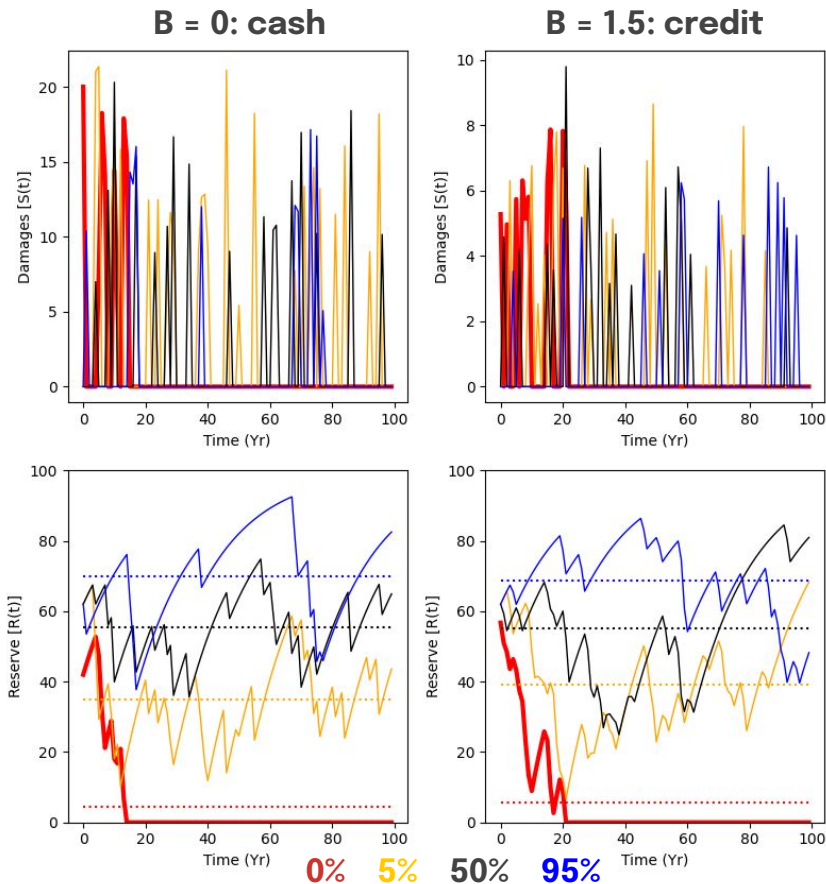
Simulation over 100 years

On average:

HW return period: 5 years

Dry days: 10

Ruin probability < 5%



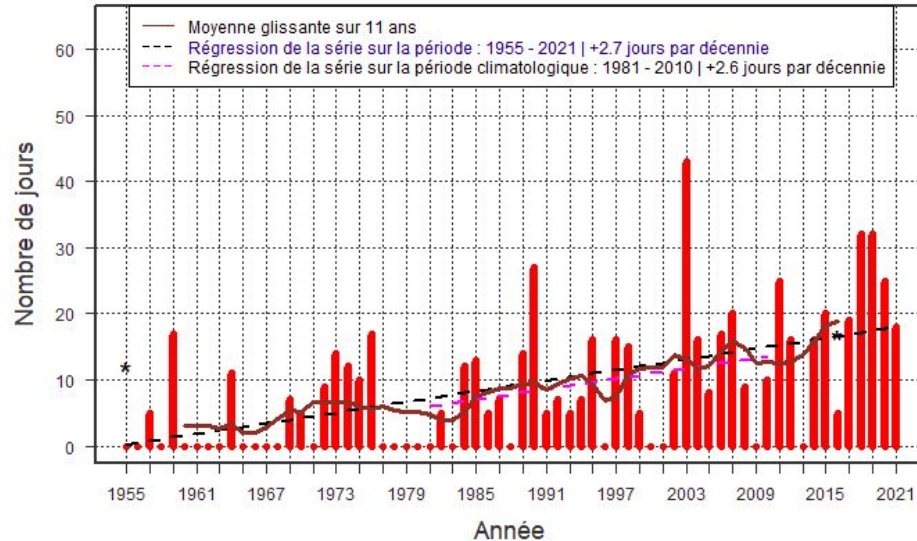
An aerial photograph of a vast forest landscape. In the foreground, a large, dark, and relatively smooth black lava flow spreads across the terrain. A narrow, winding road or path cuts through the lava field. Beyond the lava flow, a dense forest of green coniferous trees covers the hillsides. In the background, more forested hills are visible under a clear, light blue sky. The text '04 Trees longevity in a warming world' is overlaid in white on the left side of the image.

04 Trees longevity in a warming world

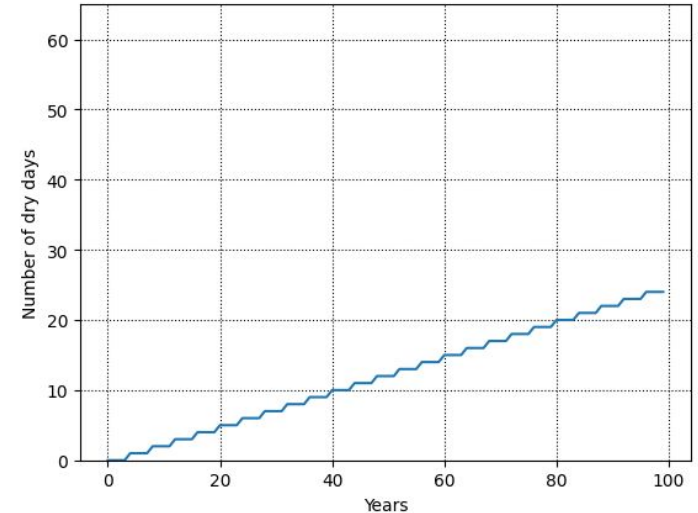
Taking climate change into account



NOMBRE DE JOURS DE VAGUE DE CHALEUR
(TEMPERATURE MAXIMALE SUPERIEURE DE PLUS DE 5°C A LA NORMALE
PENDANT AU MOINS 5 JOURS CONSECUTIFS)
STATION : CAMBRAI.EPINOY



0 days + 2.5 every 10 years



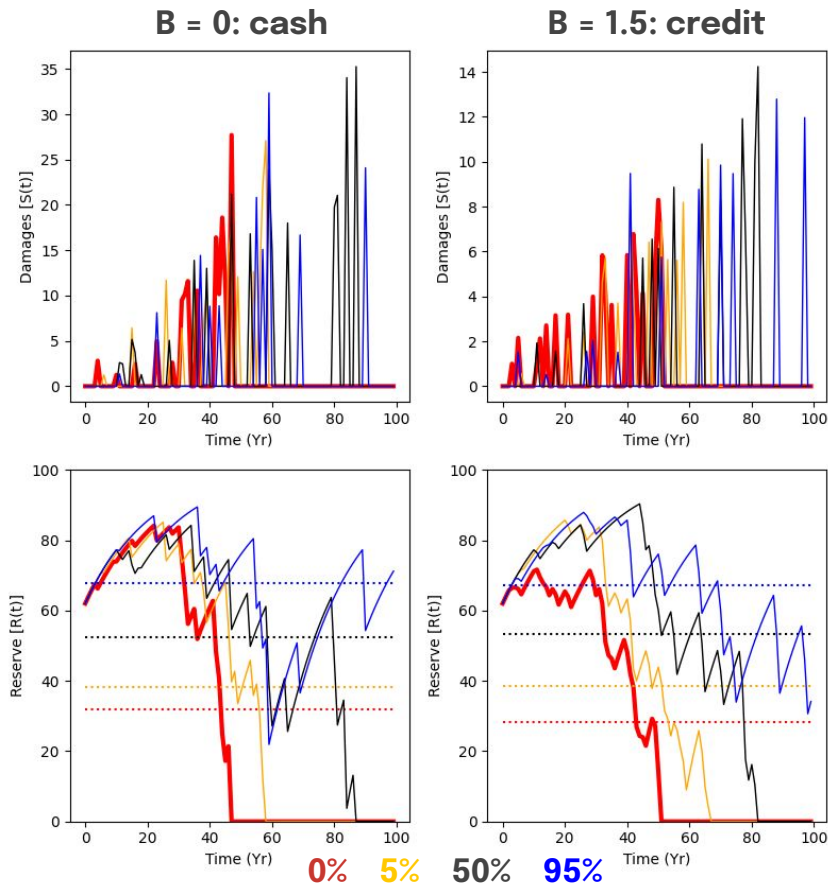
Taking climate change into account

On average:

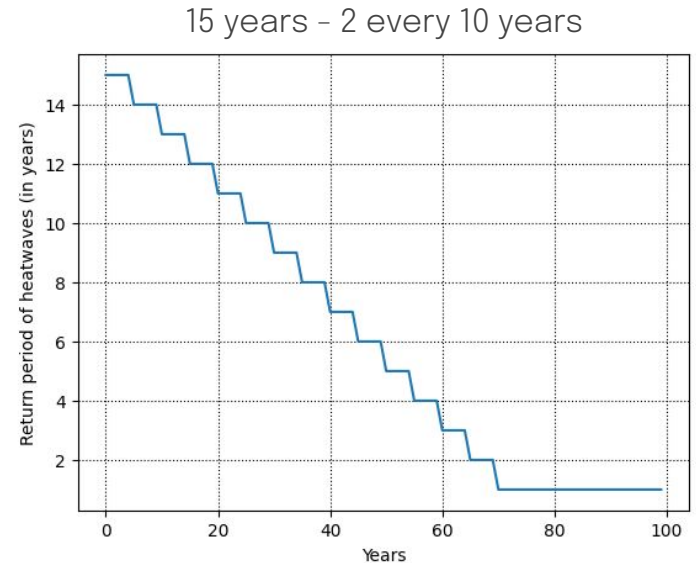
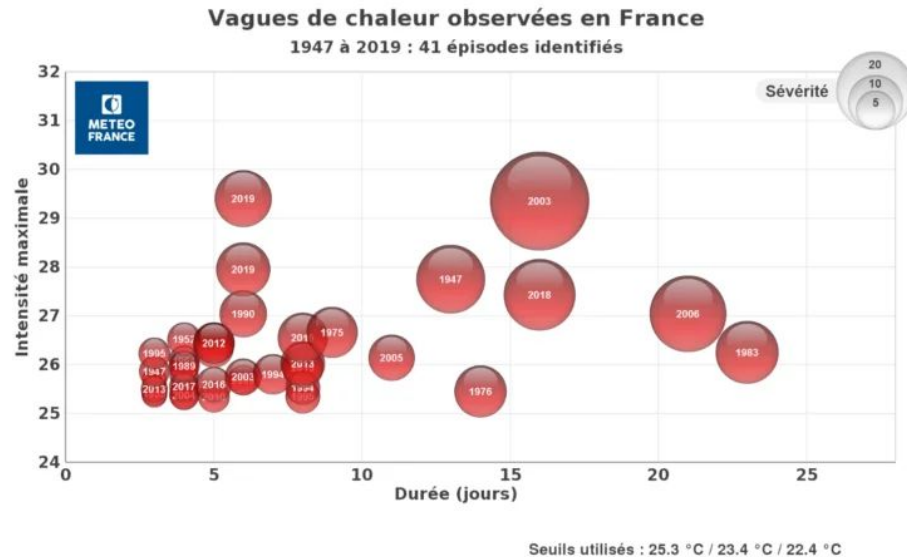
HW return period: 5 years

Dry days: 0 + 2.5 every 10 years

Ruin probability $\approx 70\%$



Taking climate change into account



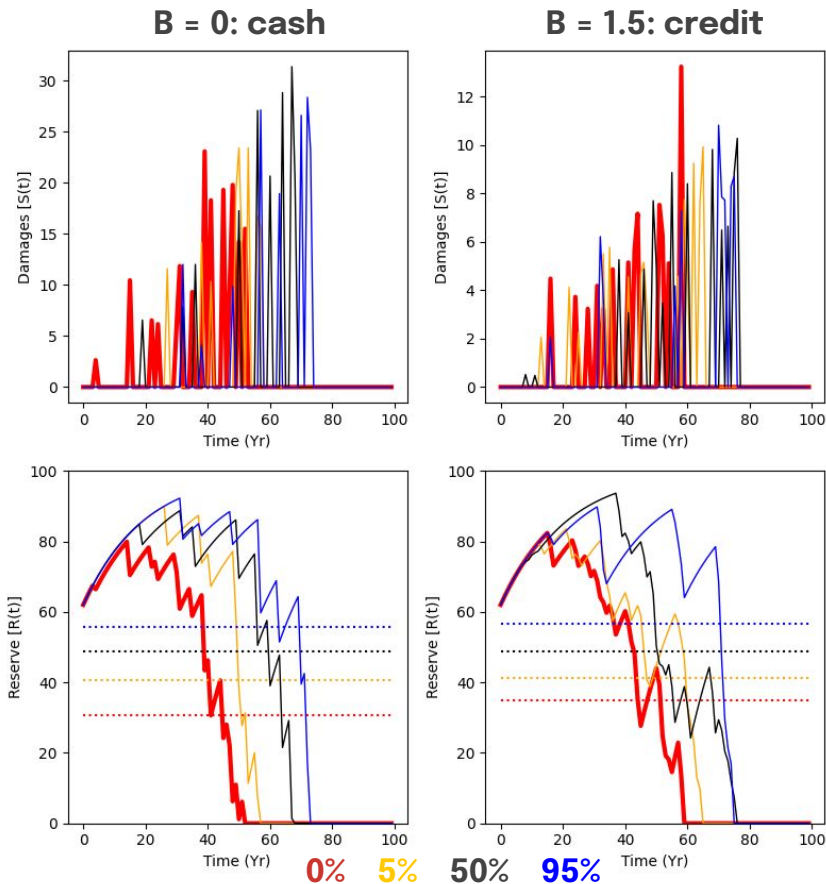
Taking climate change into account

On average:

HW return period: 15 years – 2 every 10 years

Dry days: 0 + 2.5 every 10 years

Ruin probability $\approx 100\%$





05 Can trees be saved?

Conditions to save trees

Now:

HW return period: 1 year

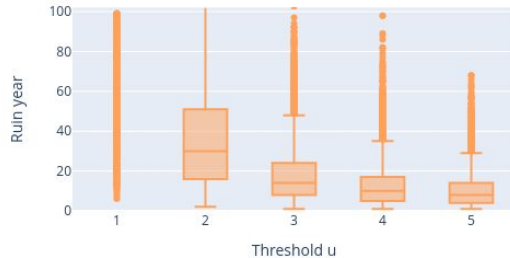
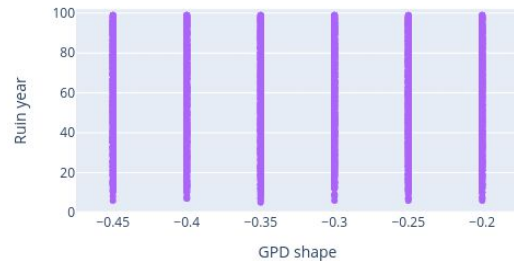
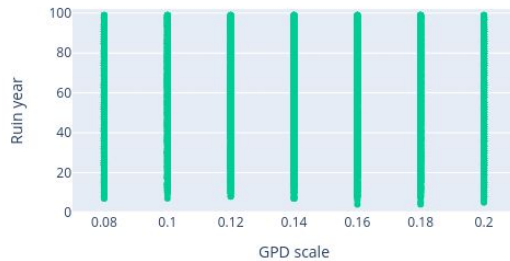
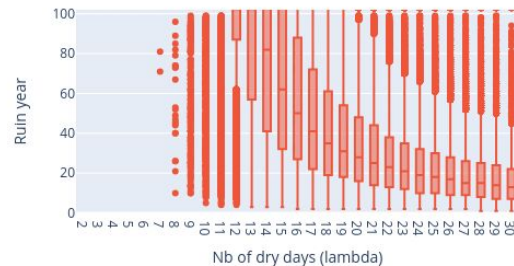
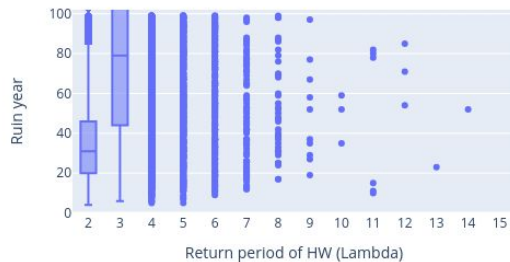
Dry days: ≈ 20

To save trees:

HW return period: > 4 years

Dry days: < 11

Impact of parameters for B=0



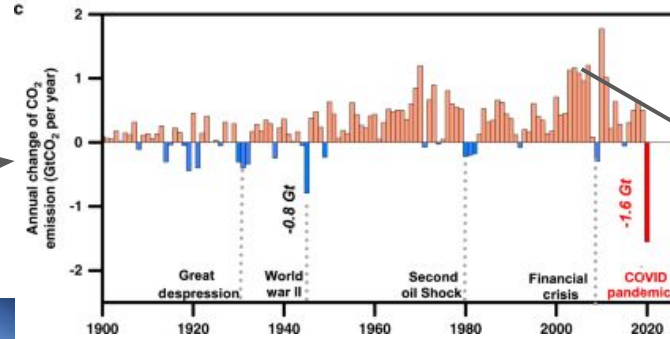
Irreversible situation?



Covid 19



Empty highways in France



Contacts

Rémi Colin

rcoli@insa-toulouse.fr

Karima Ghamnia

ghamnia@insa-toulouse.fr

Florian Grivet

grivet@insa-toulouse.fr

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-RMwAMgKgKLO3R746eeTDcUbbLVCTbm

(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/>