Une approche économique des risques multiples en forêt européenne

Séminaire SADAPT

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RÉPUBLIQUE FRANÇAISE
Liberté
Égalité
Fraternité

INRAE

Plan

- Context
- Literature review of multi-hazard studies in forest economics
- 3 case studies
- Research opportunities?

Context

Context: natural hazards

- Some few facts:
  - At the global scale (van Lierop et al, 2015), period: 2000-2010
    - Wildfires: 67 Mha/yr
    - Windstorms: 3 Mha/yr
    - Drought: 3 Mha/yr
    - Insects : 8 Mha/yr
    - Diseases : 1 Mha/yr
  - At the European scale (Schelhaas et al, 2003), period: second half of the XXth century
    - Accidental harvest: 8.1% of the total harvest
    - Windstorms: 53%
    - Fire: 16%
    - Beetles: 16%
- But many other hazards:
  - Browsing
  - Gravitational hazards
  - Flood
  - ……..

A typology of risks in agriculture

Komarek et al 2020

- Literature review of more than 3200 peer-reviewed publications
  - Production risk
  - Market risk
  - Financial risk (often linked to both production risks and market risks): ability of a farmer to cope with volatile incomes
  - Health risk: what are the risks of the agriculture on human health?
  - Institutional risk: what is the risk of a sudden change in regulations? (e.g. a change in the products authorized, CAP, etc…)

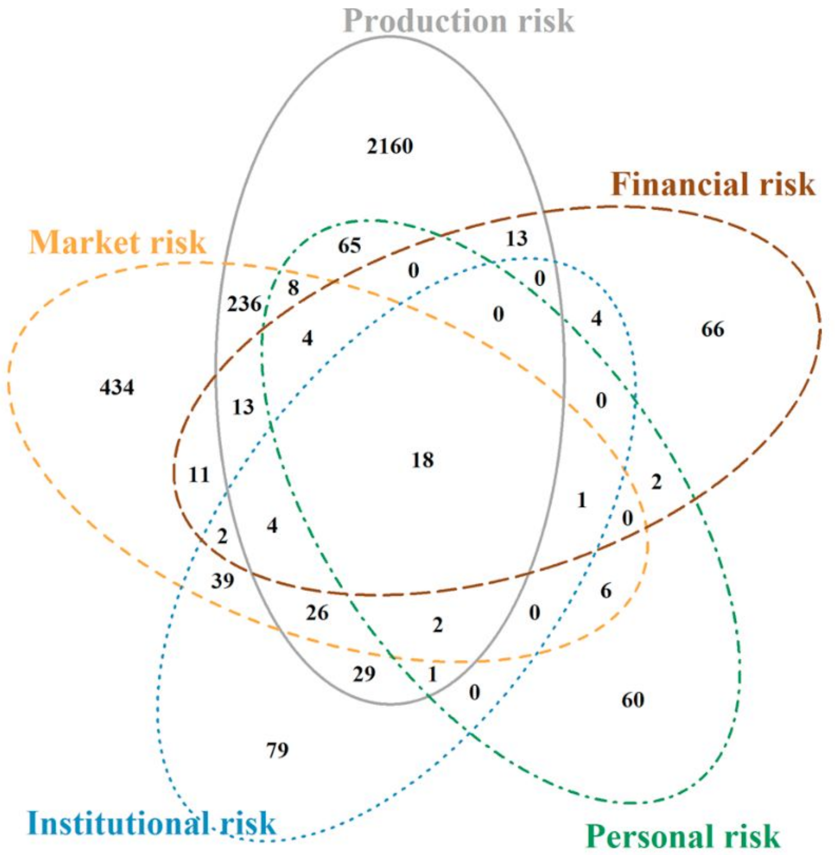

Fig. 1. Venn diagram for distribution of the number of studies across five types of risk between 1974 and 2019. Data from authors' literature search.

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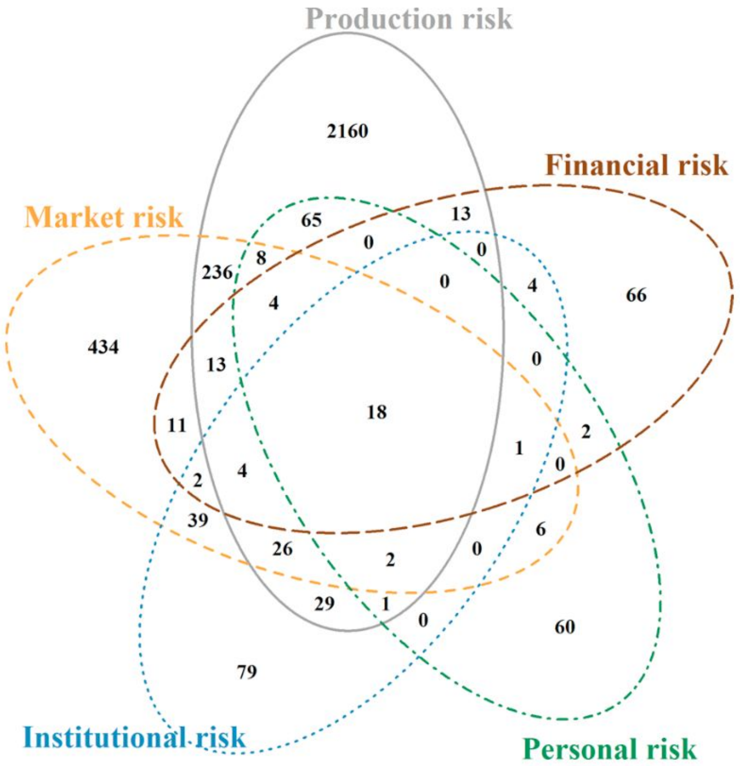
We will mainly focus on production and market risks
in the case of forest natural disturbances



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European estimation of natural hazard damages

Patacca et al (2023)

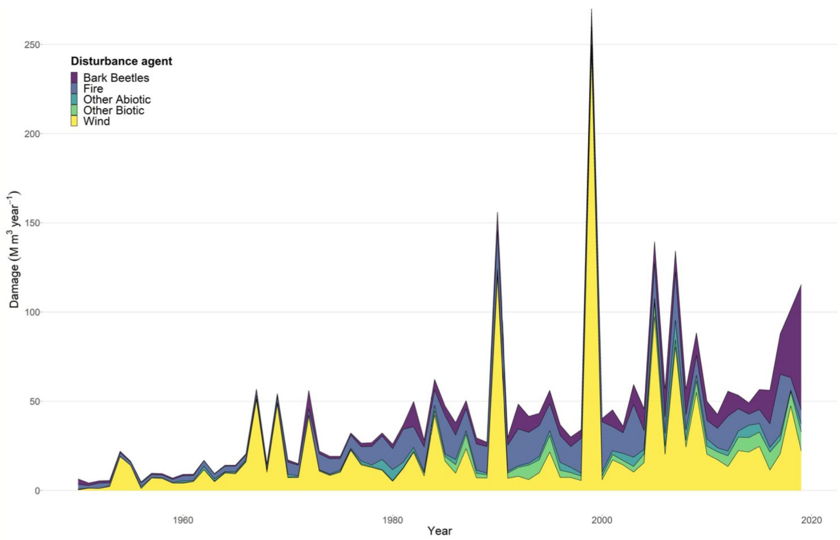
Period 1950-2017

Mean quantity of timber disturbed: 62.1 Mm^3/yr (+845 km^3/yr)

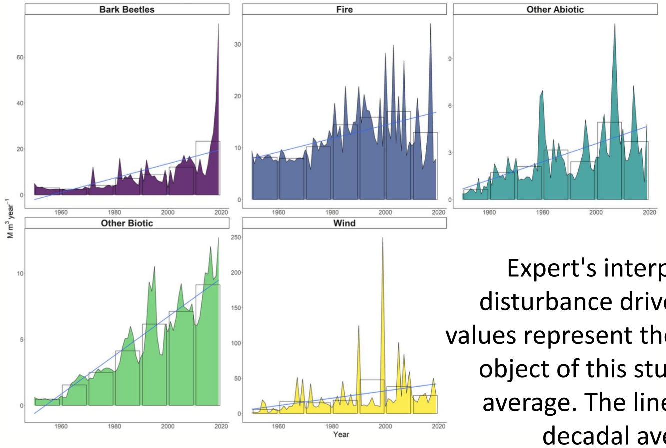
- 46% storms
- 24% fire (significative increase over the period)
- 17% bark beetles (23 Mm^3/yr over 2010-2019, comparable to windstorms

0.23% of the growing stock is disturbed each year (0.27% for the period 2001-2019)

15% of the mean annual harvest



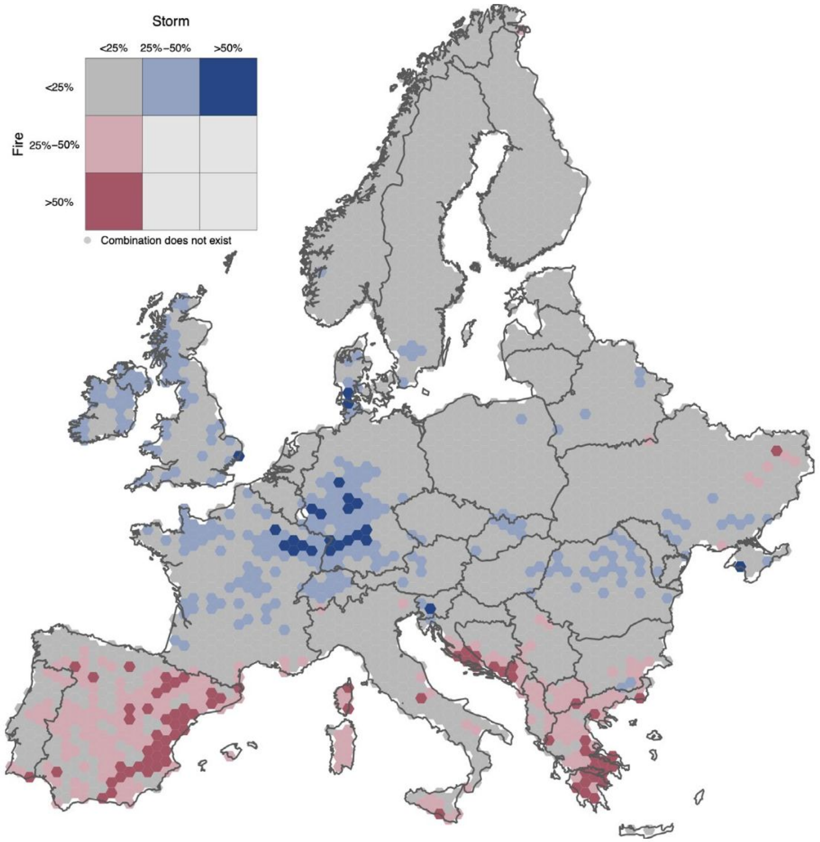
Total reported damage caused by natural disturbance in Europe between 1950 and 2019 (Patacca et al, 2023)



Expert's interpreted gap-filled time-series of disturbance drivers between 1950 and 2019. The values represent the sum of the 34 European countries object of this study. The bars represent a decadal average. The lines are linear models fitted to the decadal averages (Patacca et al, 2023)

Past disturbances

Senf et Seidl, 2021a



Spatial variability in the prevalence of storm- and fire-related disturbances over the period 1986– 2016.
Note that light-grey combinations do not exist in the data, that is, there is no overlap between high prevalence in storm- and fire-related disturbances in Europe. See Figures S4 and S5 for annual prevalence maps by agent

Future possible pulses?

Senf et Seidl, 2021b

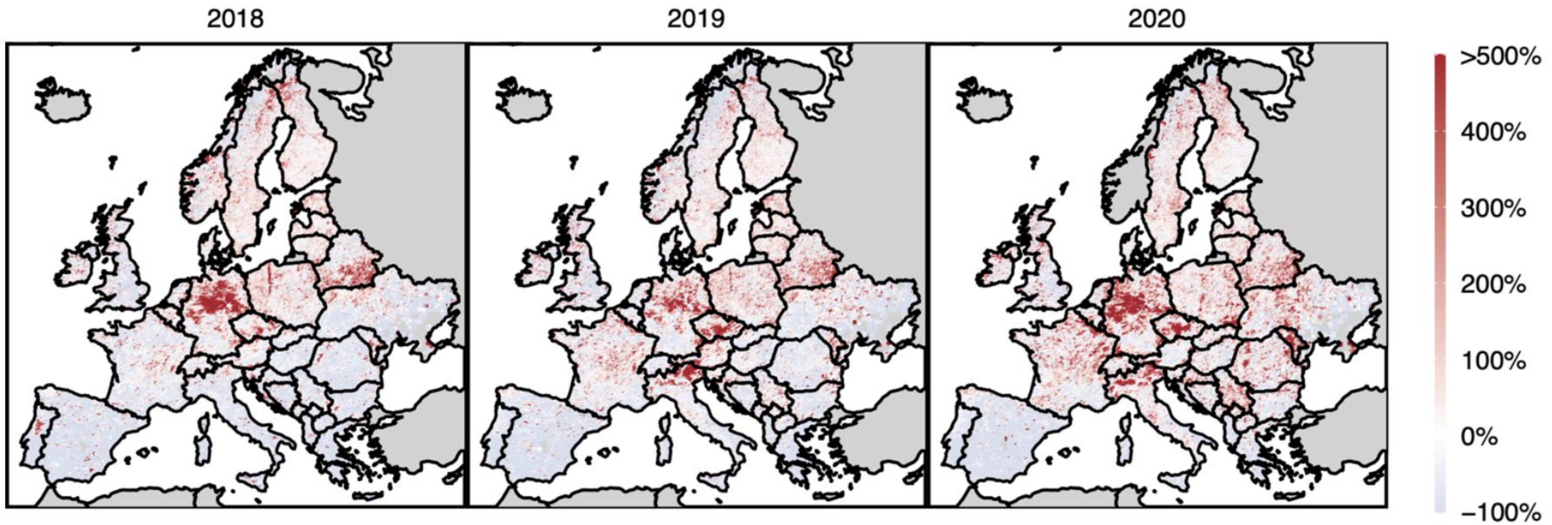
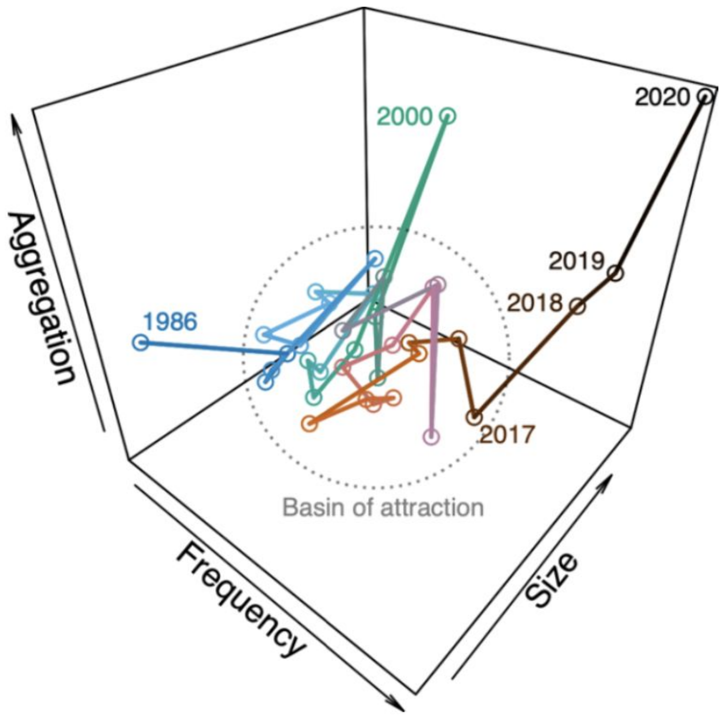
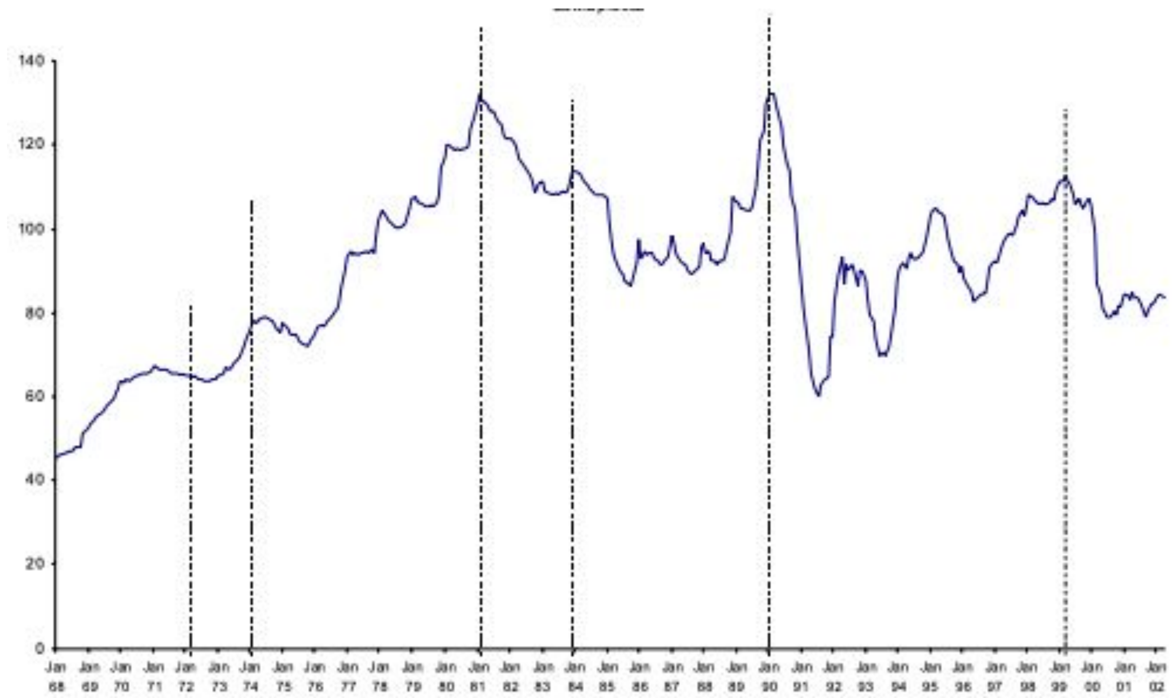


Figure 1: Forest disturbance anomalies in the years 2018-2020 in reference to 1986-2015, estimated from satellite-based disturbance maps across Europe. Anomalies are expressed in percent, that is +100% indicates a doubling of disturbed area in reference to the average disturbed area 1986-2015. Anomalies were calculated at a grid of ~9 km. Background maps are from https://gadm.org.



Link between production risk and market risk

Windstorms (short and long-term) effects on German timber prices

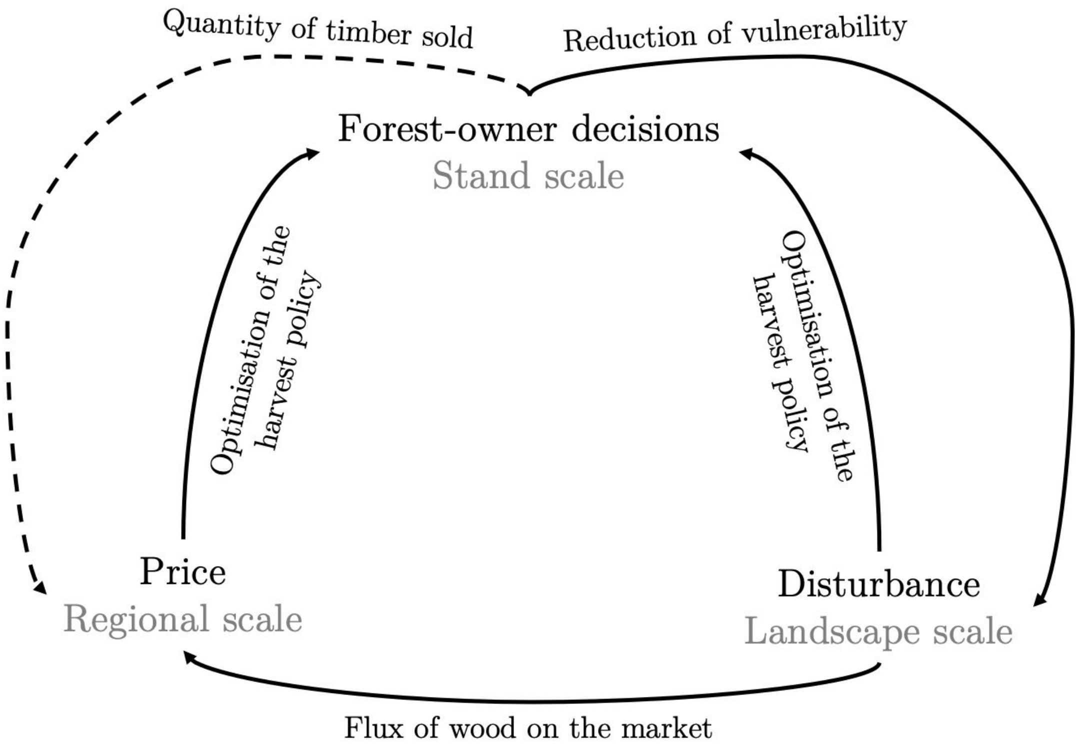


Prices for Norway spruce from 1968 until 2002 in Germany illustrating the drop in price following storms in 1972, 1974, 1981, 1984, 1990 and 1999. (From Gardiner et al, 2010)

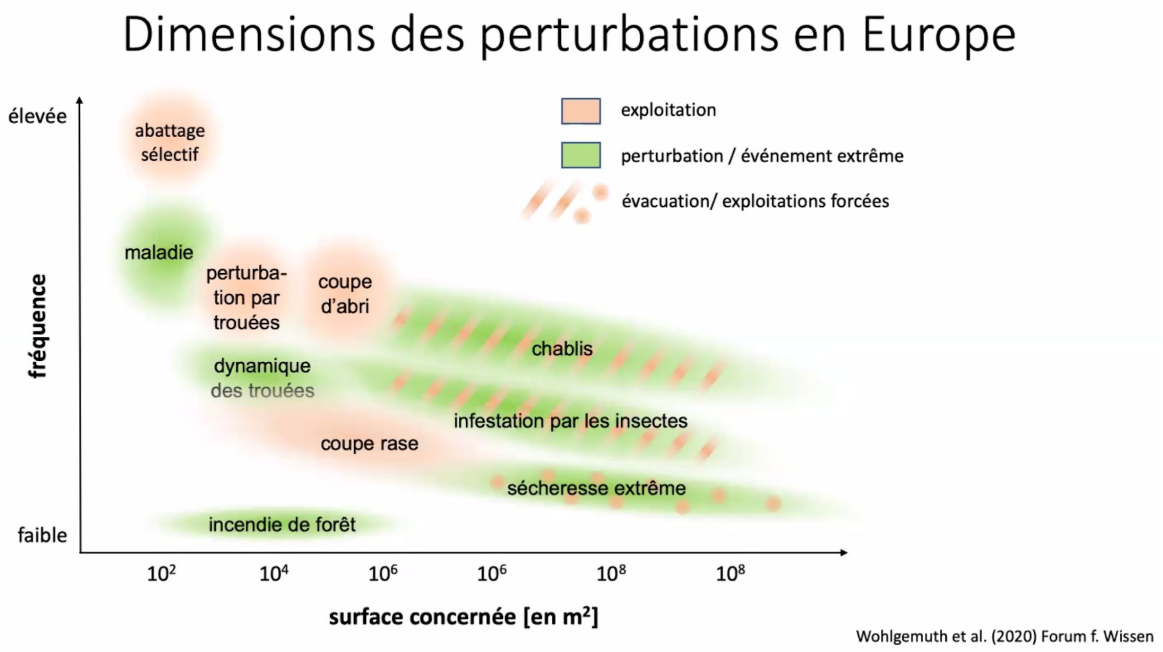
Year	Windstorm	Countries	Max gust (km/h)
1972	Quimburga	UK, FR, GE, IT, PL	245
1974	Norway	UK, NW	200
1981	Storm series	UK, FR	
1984	Unnamed	DK	
1990	Vivian + Wiebke	UK, NW, FR, GE	268
1999	Martin + Lothar	FR, GE	200

A multi-scale issue

How do each scale influence each other ?



Management perspective



Hazard perspective

Production risk: the case of multi-hazard risk

Theoretical aspects (Buma, 2015)

Change in resilience

Change in resistance

Compound vs. Linked events

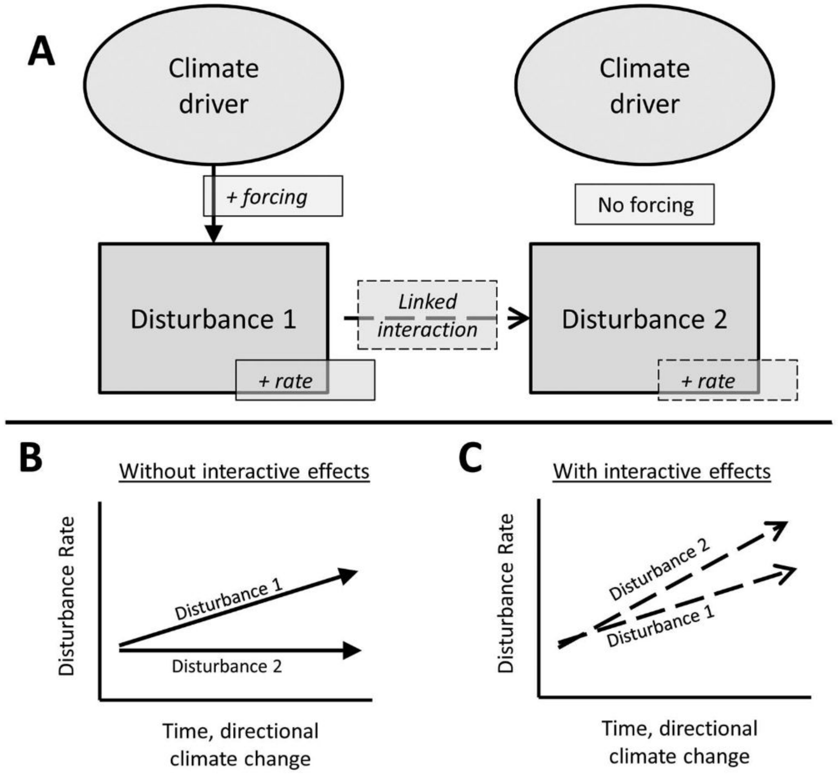
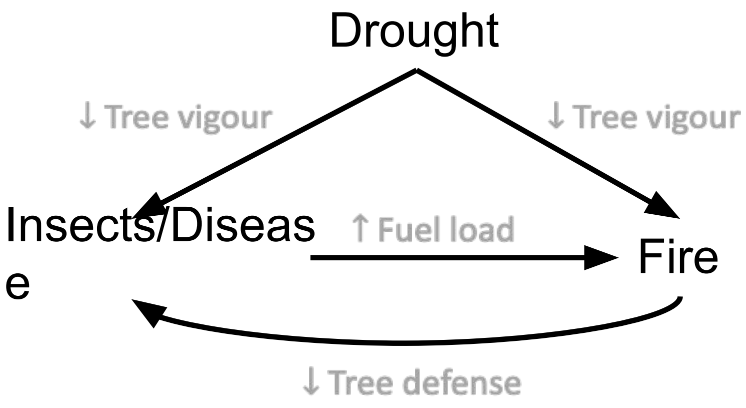


Fig. 3. Cascading effects of disturbance interactions. (A) Cascading effects can occur when one disturbance type is altered by an external driver, such as directional climate change or increasing anthropogenic presence. This predictably leads to an increase in associated disturbances. Without an interaction, rate of disturbance increases are limited to disturbance types directly affected by that driver (B). But through interactive effects, increases in disturbance types unrelated to the affected driver may also occur (C).

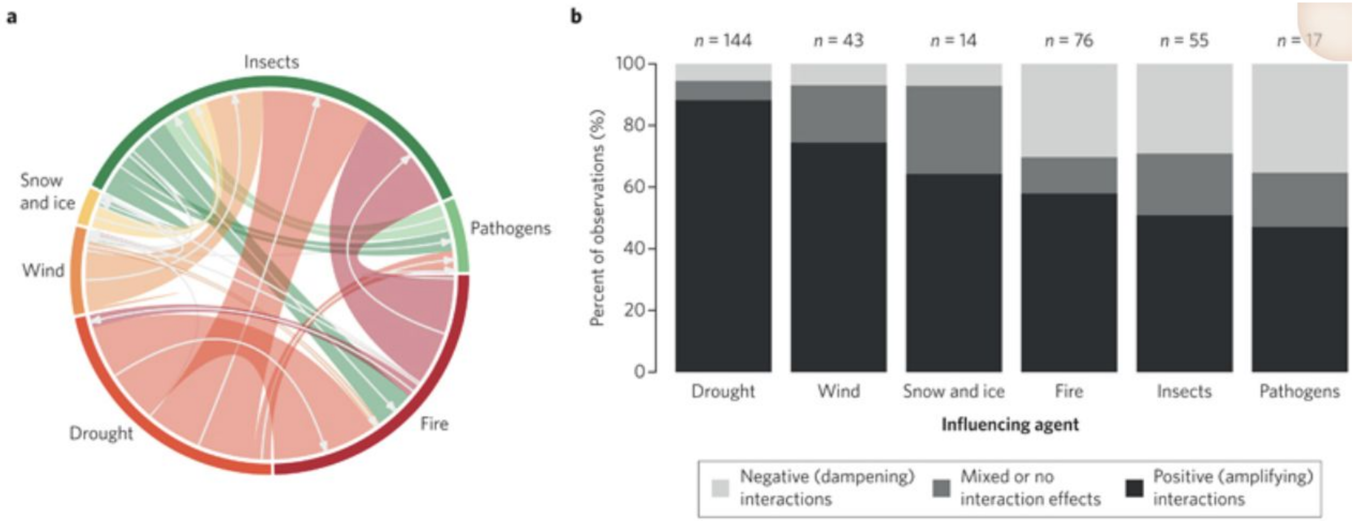
Cascading effects

Production risk: the case of multi-hazard risk

Why do multiple hazards matter ?

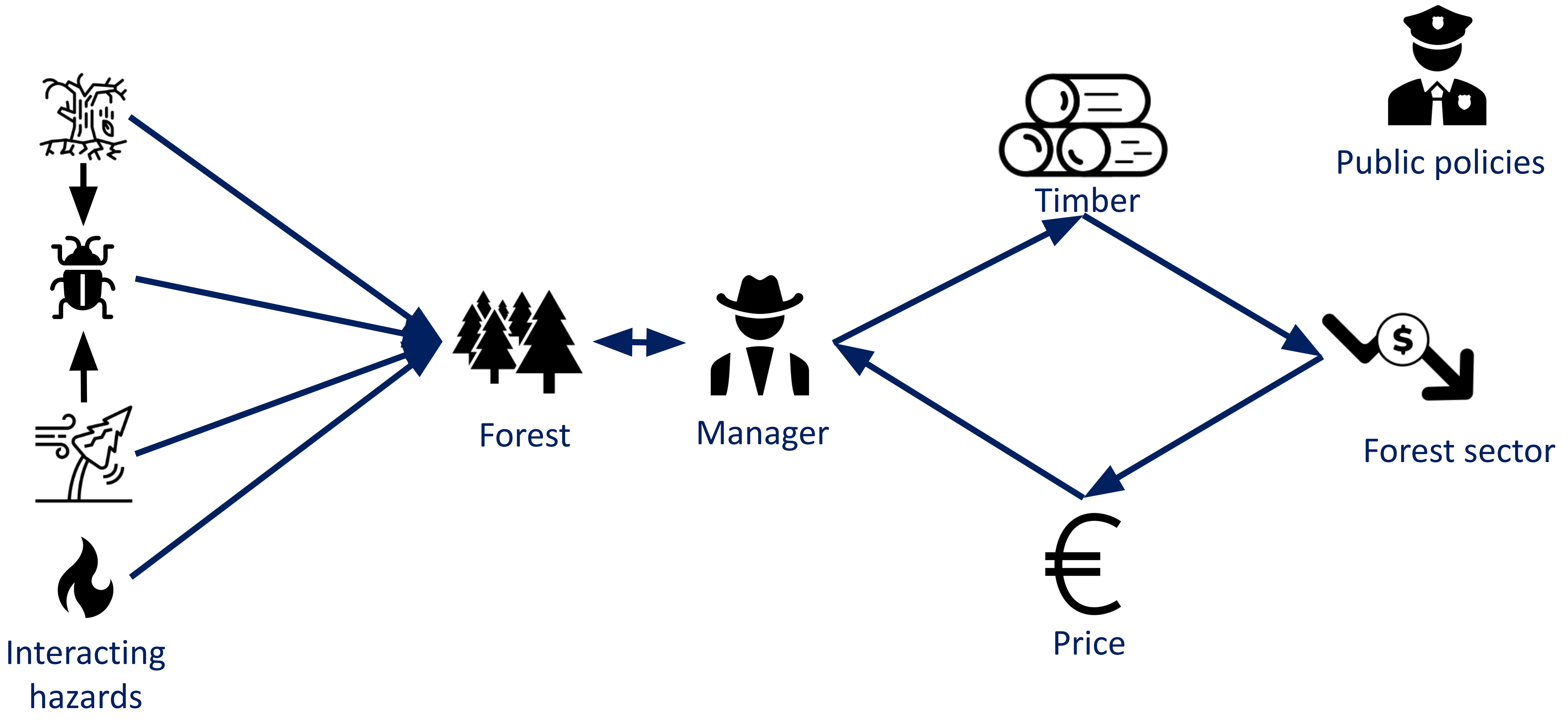


Dale et al (2001)



Interactions between hazards are expected to strongly increase in the context of climate change
(Seidl et al, 2017)

A complex system



Initial PhD title: An economic approach of the **management** of multi-risks in French forests

Current title: An economic approach of multi-risks in European forests

Literature review of multi-hazard studies in forest economics

1st chapter

What has been done? What should be done?

Pests, wind and fire : A multi-hazard risk review for natural disturbances in forests

Bastit, F., Brunette, M., & Montagné-Huck, C. (2023)

https://doi.org/10.1016/j.ecolecon.2022.107702

Research question

- Questions
  - Are the interactions between hazards already considered in the literature and how ?
  - What are the most commonly studied hazards interactions ?
  - What are the methods at stake in literature to assess multi-natural hazards risk ?
  - What are the relevant perspectives for the future research ?

- Objective
  - To review publications in forest economics and forest management-oriented ecology to assess the multiple hazards interactions methods

- Methodology
  - Systematic research of the articles dealing with multiple natural hazards - Multi-hazard risk assessment (Gallina et al., 2016)
  - Build a database gathering more than hundred English peer-reviewed articles published between 1916 and 2020

Previous literature reviews

- Yousefpour et al (2012): focused on a review of the methods used in forest economics to study climate change induced risks and uncertainties.
- Montagne-Huck & Brunette (2018): reviewed 340 forest economics articles on single hazard risk management.
- Zhai & Ning (2022): reviewed 25 papers to create a typology of economics studies of forest disturbances.

 A review of multi-hazard risk in forest economics is still lacking

Methodology

Systematic literature review

- Eligibility criteria
  - English-language
  - Peer-reviewed publications
  - Until 2020
  - Four databases: ScienceDirect, JSTOR, Ingentaconnect and NRCResearch Press.
  - Relevant cited literature was added

- Keywords for the original search

forest AND

economics AND

{*catastroph* OR damage OR mortality OR disturbance OR hazard OR risk OR stochastic OR uncertainty OR interaction OR cascad* OR multi-risk*}

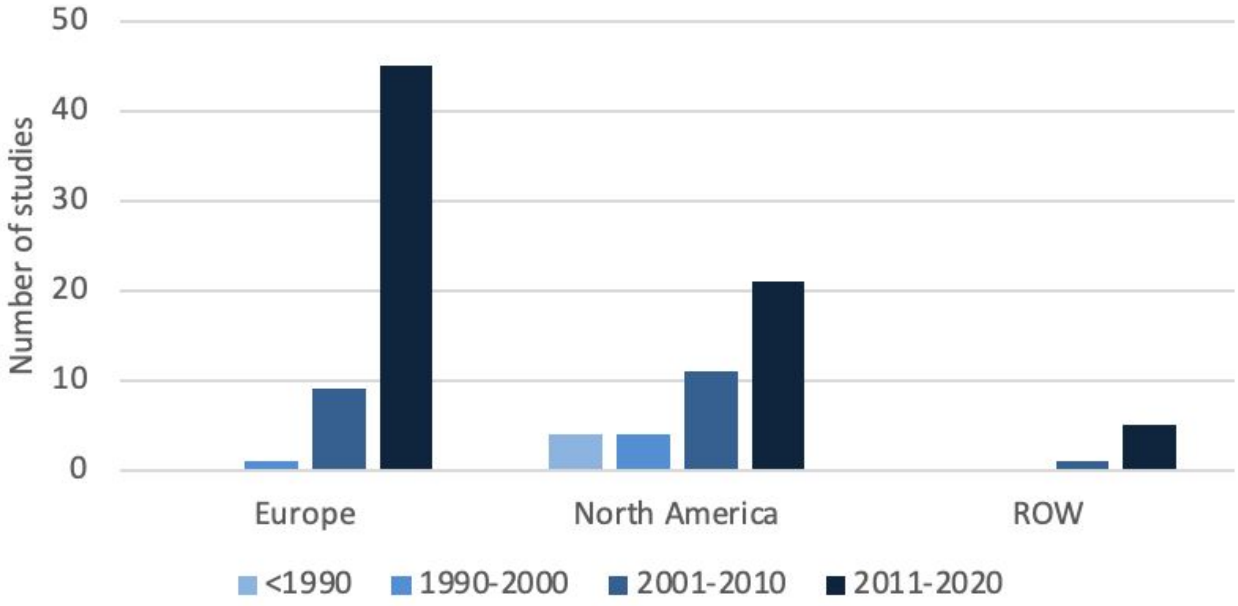
- Hazards considered
  - Fire, Wind, Insects, Drought, Ice & Snow, Pathogens & Disease
  - Unspecified hazards

Methodology

Variables included in the database

Attribute	Describing
Bibliometric indicators	
Author	Name of all the authors
Year	Year of publication
Journal	Journal in which the article was published
Keywords	Keywords indicated by the authors on the title page of the article and index keywords chosen by content suppliers (standardised based on publically available vocabularies)
Country	Country of the first author
Investigated parameters	
Orientation	Economics/Ecology/Both
Group	$\text{Group}_{\text{Ind}}$ if independence; $\text{Group}_{\text{Dep}}$ if dependence
Hazard	Wind: 0/1 (N_W); Fire: 0/1 (N_F); Drought: 0/1 (N_D); Insects: 0/1 (N_I) Ice & Snow: 0/1 (N_{IS}); Pathogens & disease: 0/1 (N_{PD})
Category	Hazard modelling/Impact assessment

An emergent issue

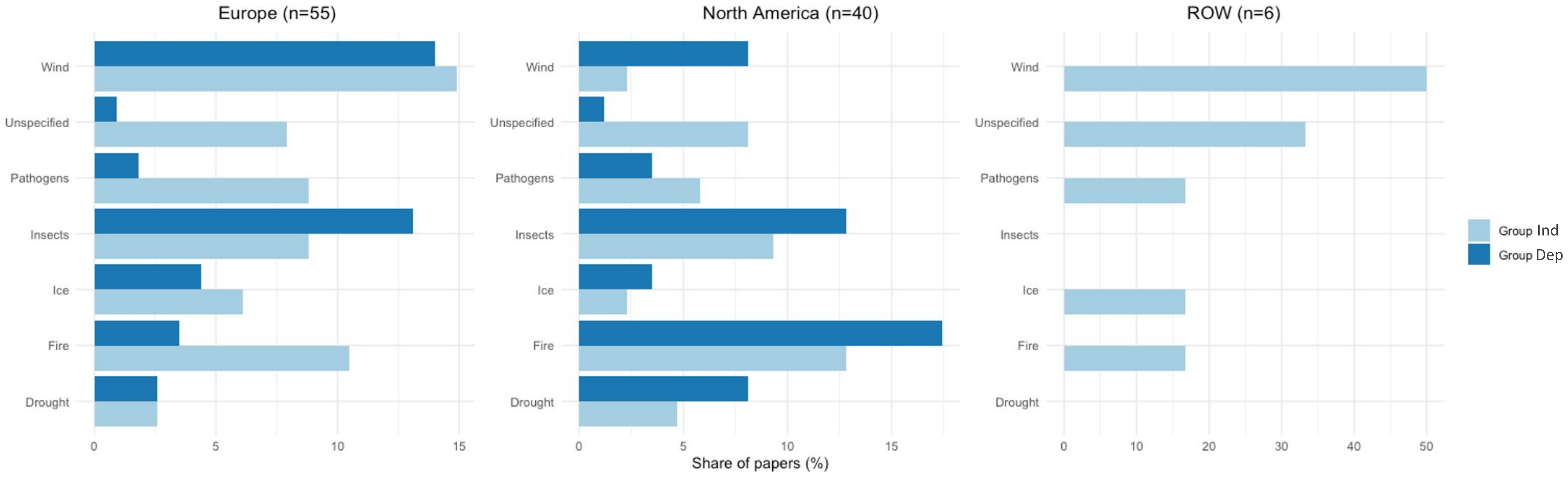


Number of publications by continent and period

2 possible explanations for the trend:

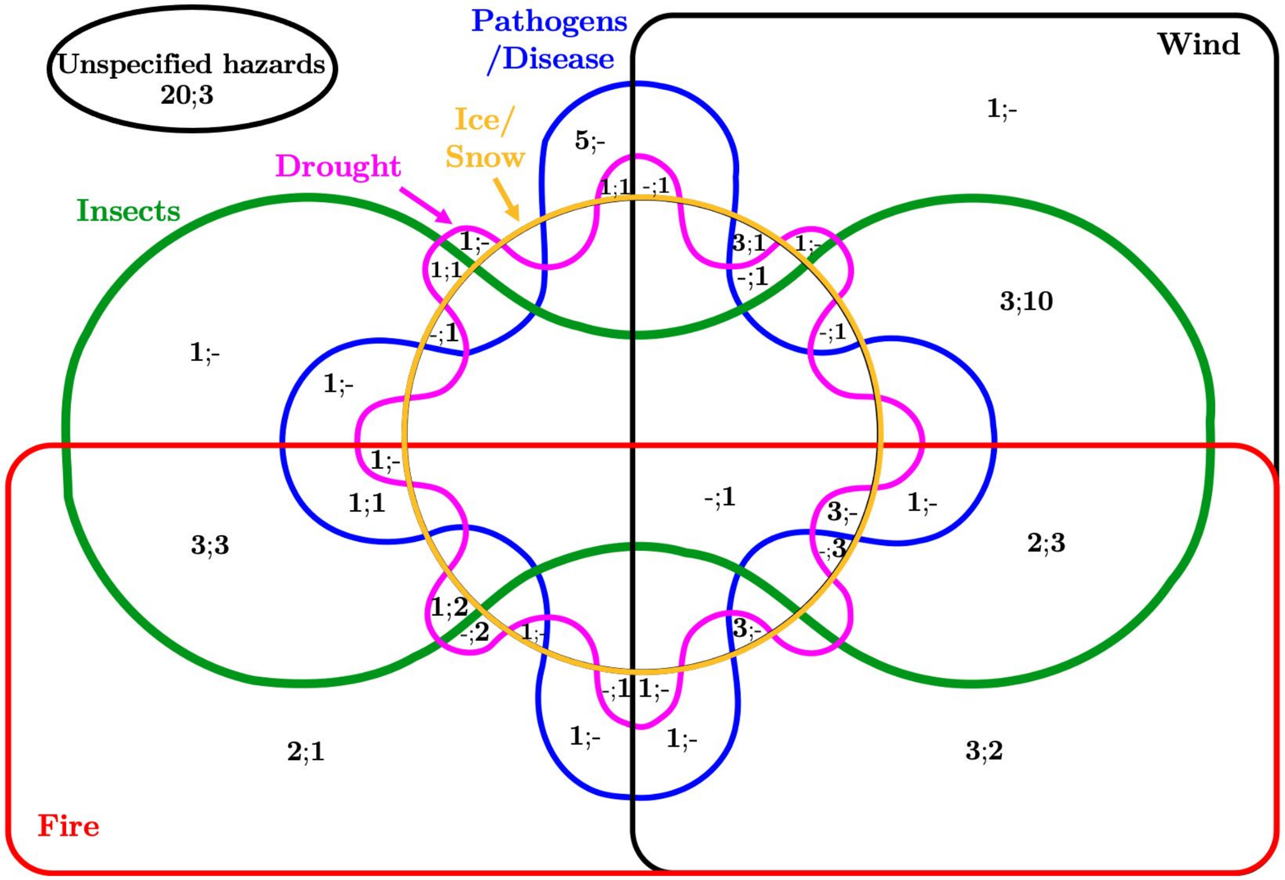
- Recent topic
- Transfer from own-language to English publications

Which hazards are considered in the literature?



Which interactions are considered ?

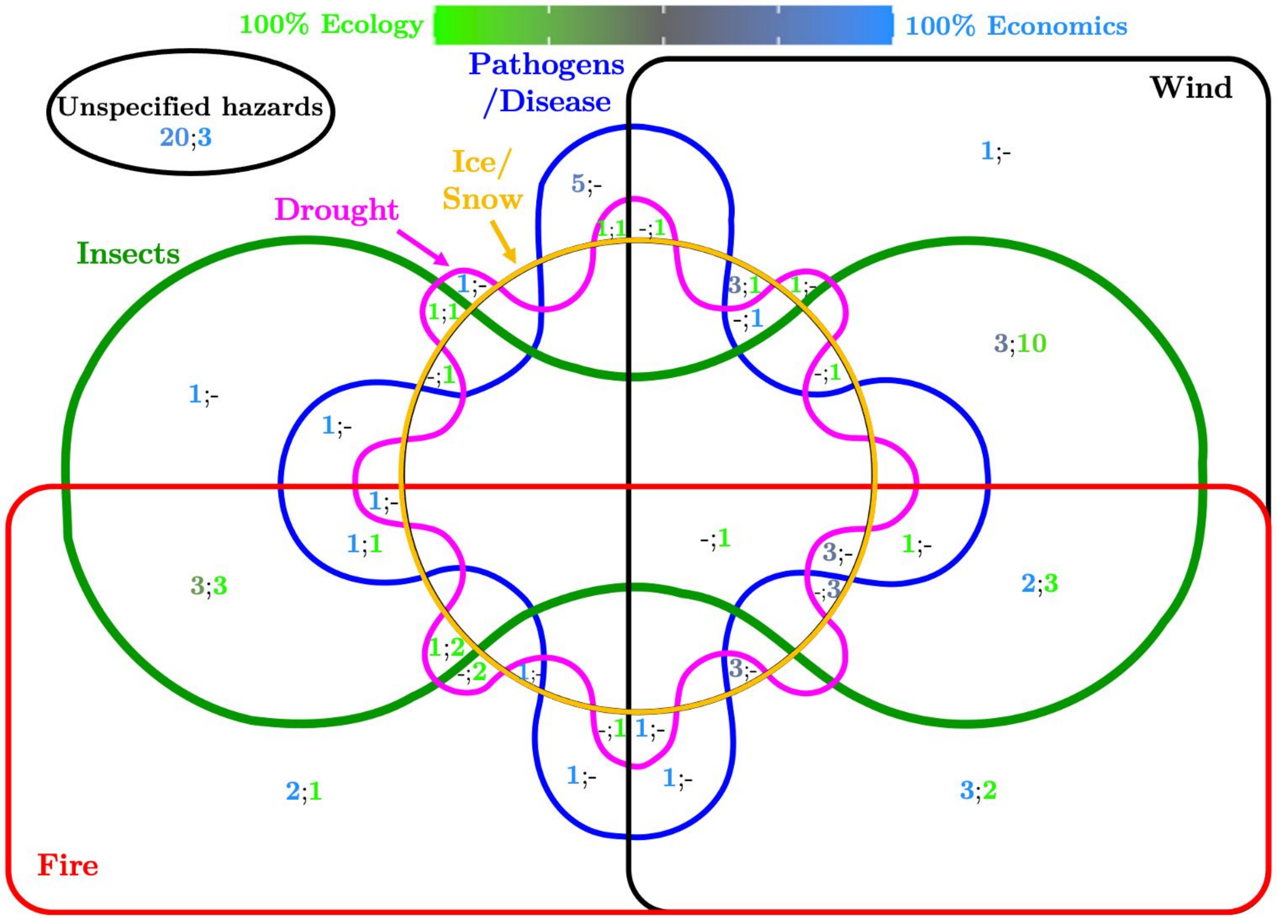
Venn diagram



$Group_{Ind}$; $Group_{Dep}$

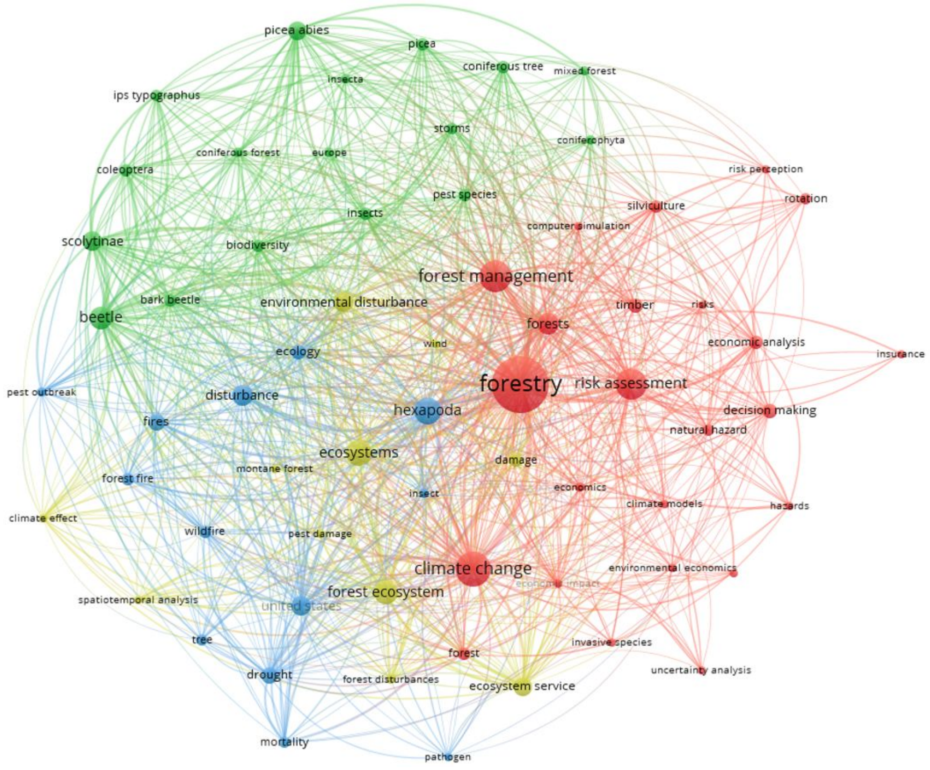
Which interactions are considered ?

Venn diagram 2.0 (unpublished)



There is still a large avenue for economists to publish on multi-hazards risk!

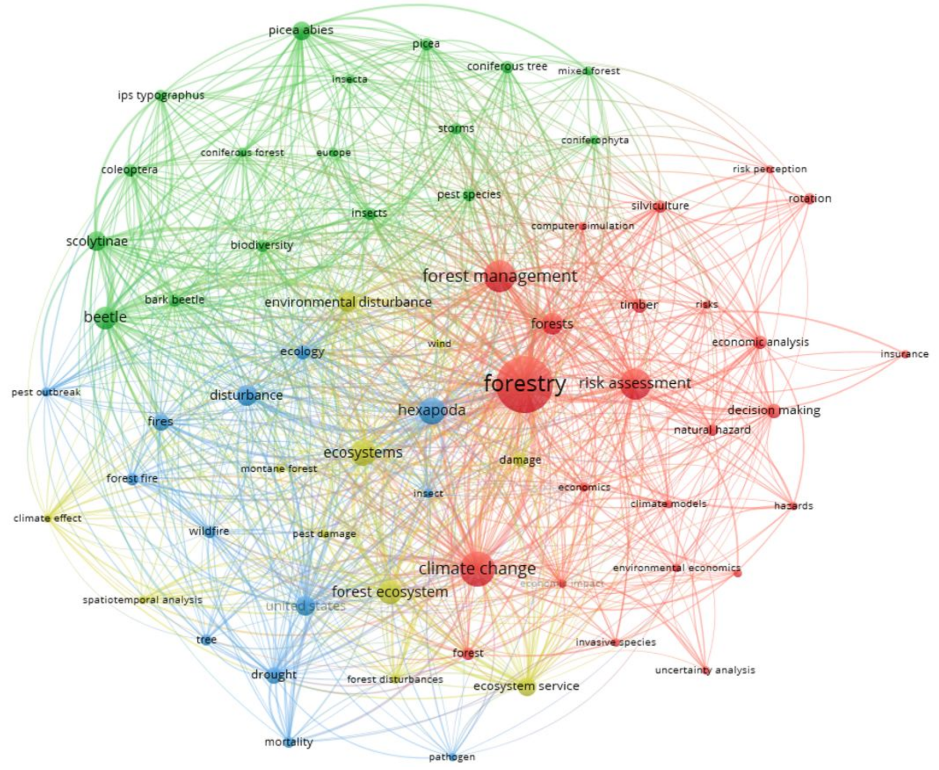
An eventual typology for research topics?



- Impact Assessment
- Ecosystem
- Fire modelling
- Insect/Storm modelling

VosViewer Software

A possible typology of research topics?



Impact Assessment

Ecosystem

Fire modelling

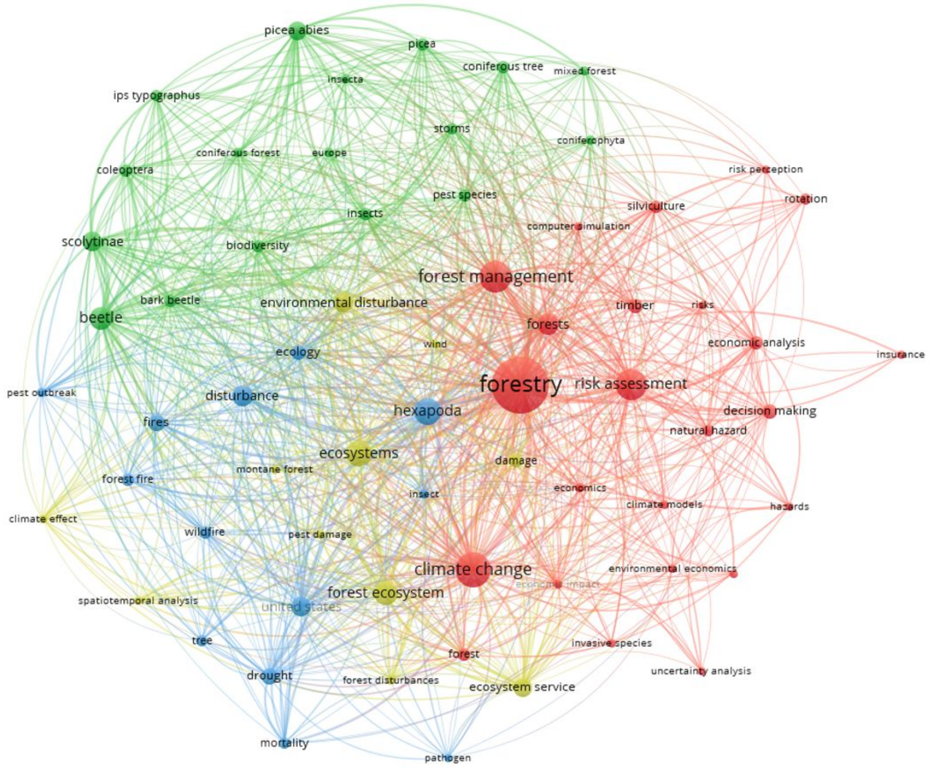
Insect/Storm modelling

Hanewinkel et al (2011) steps to manage risks:

1. Analysis of the framework
2. Modelling of hazards Likelihood, Exposure, Vulnerability
3. Costs Estimation
4. Choice of action

VosViewer Software

A possible typology of research topics?



- Impact Assessment
- Ecosystem
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Hanewinkel (2011) steps to manage risks:

1. Analysis of the framework
2. Modelling of hazards Likelihood, Exposure, Vulnerability **Hazard Modelling**
3. Costs Estimation **Impact assessment**
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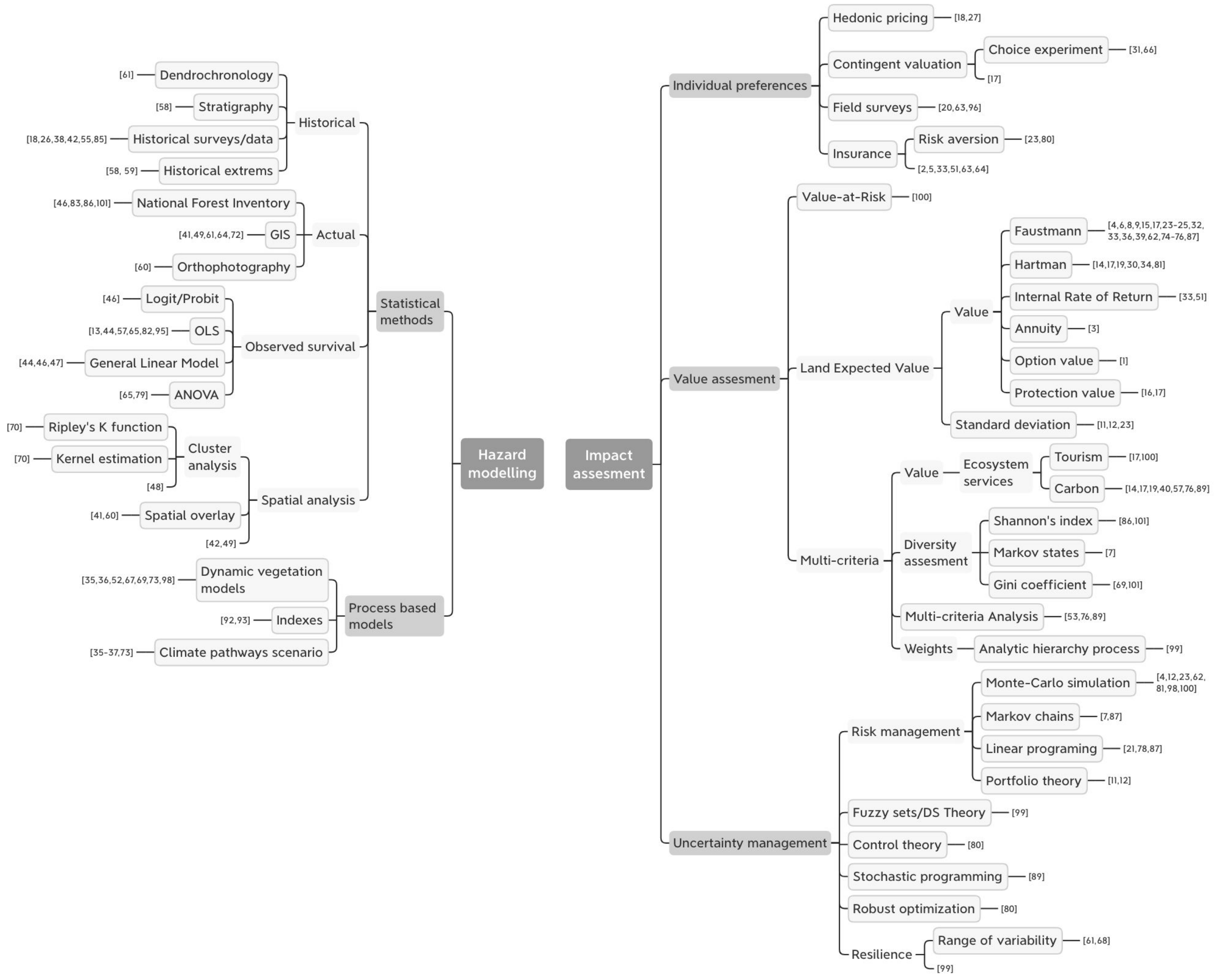
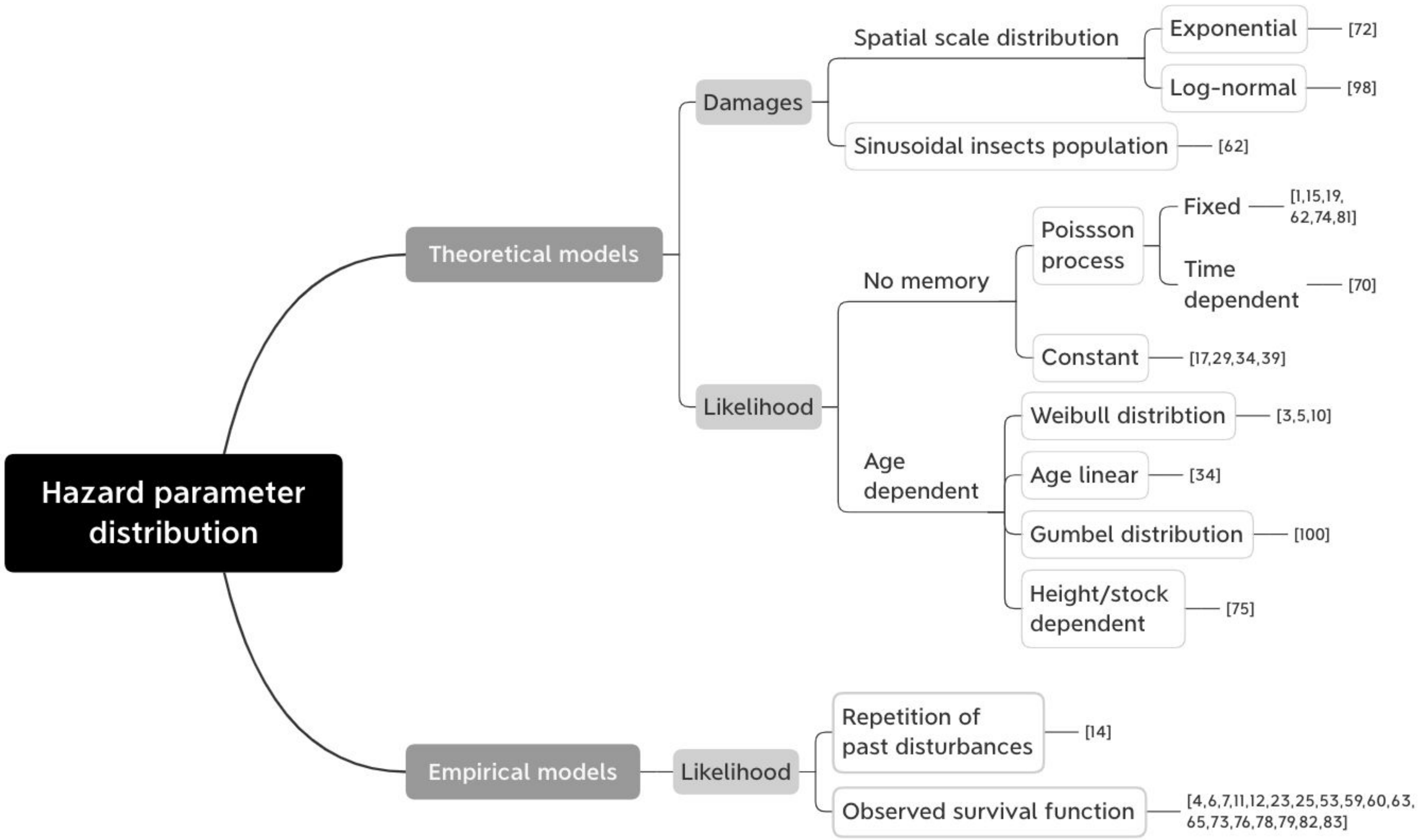
VosViewer Software

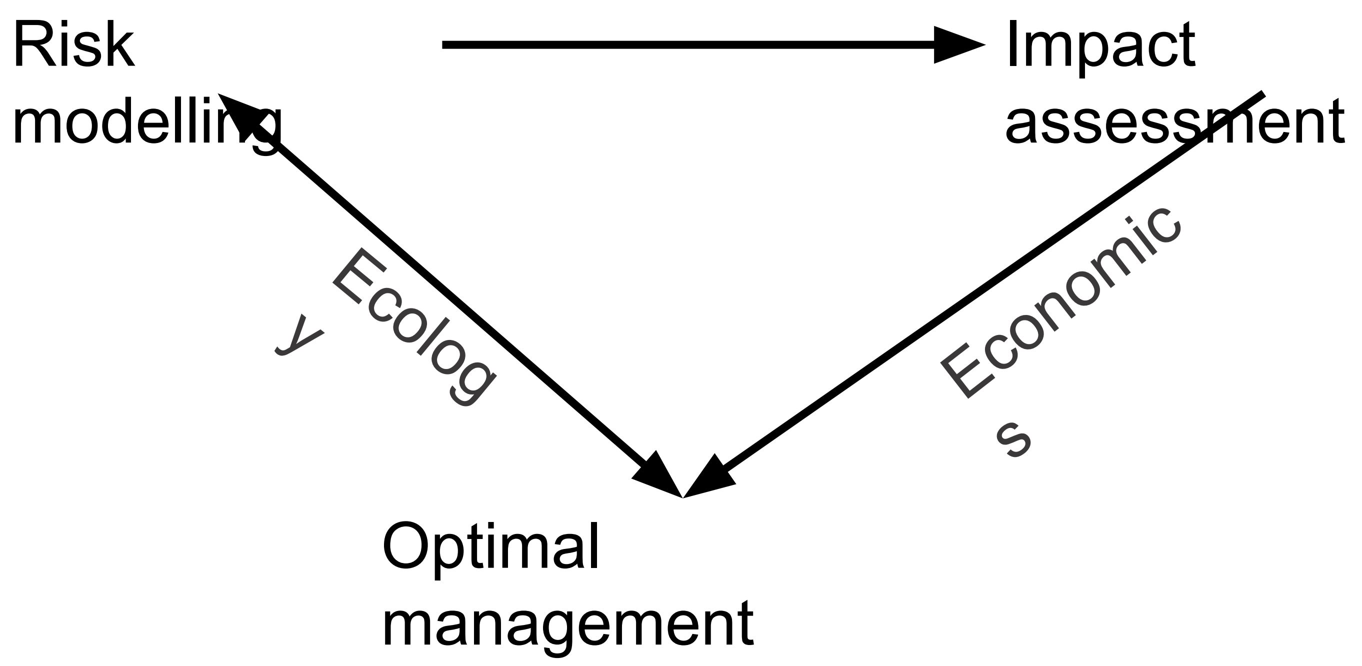
Mind map of the different methods existing in the literature



Focus on hazard modelisation



Discussion


Risk modelling
Impact assessment
Ecology
Economics
Optimal management

What can economics bring to ecology ?

Quantify the heterogeneity in individuals' behavior (risk, uncertainty aversion for example)

 Use of several elicitation methods to find the determinants of the forest management (Dai et al, 2015; Qin et al, 2016)

To have efficient management, large scale coordination between forest owners is necessary (insects outbreaks, fires, biodiversity conservation,…)

 Economic tools to study the strategies of the actors

 Possibility to suggest public policies to solve this issue

What can ecology bring to economics ?

The optimal strategy of the forest manager depends on the interaction between risks (Courbage, 2017; Xu et al, 2016)

 The way (spatial extent, temporality) hazards impacts the forest is a purely ecological matter

 The different type of interactions (compound, cascading, etc…) could lead to different strategies

At the macro scale: link between price volatility and disturbances (Rakotoarison et Loisel, 2017; Prestemon et Holmes, 2000)

Three case-studies

Typology of disturbance analysis in forest economics

Zhai et Ning (2022)

- Selection of 25 highly relevant publications:
  - « With and without » analysis
    - Hurricane Hugo (Guimaraes et al, 1993), German spruce (Knoke et al, 2021)
  - Equilibrium models
    - Ash dieback in France (Petucco et Caurla), Mountain Pine Beetle in Canada (Corbett et al, 2016)
  - Intervention model
    - Southern Pine Beetle (Holmes, 1991), hurricane Hugo (Prestmon et Holmes, 2000), The Biscuit fire (Zhai and Kuusela, 2020)
  - Social welfare model
    - Six severe hurricanes (Prestemon et Holmes, 2010)

Typology of disturbance analysis in forest economics

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  - « With and without » analysis
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    - **Chapter 4: European forests**
  - Equilibrium models
    - Ash dieback in France (Petucco et Caurla), Mountain Pine Beetle in Canada (Corbett et al, 2016)
    - **Chapter 3: French forest sector**
  - Intervention model
    - Southern Pine Beetle (Holmes, 1991), hurricane Hugo (Prestmon et Holmes, 2000), The Biscuit fire (Zhai and Kuusela, 2020)
    - **Chapter 2: regional scale**
  - Social welfare model
    - Six severe hurricanes (Prestemon et Holmes, 2010)

Stability and resilience of a forest bio-economic equilibrium under natural disturbances

Bastit, F., Brunette, M., Shanafelt D.

Context, motivation & literature

Context

- Sustainable management: quantity of timber sold is equal to the timber biologically produced by the forest each year (Hahn & Knoke, 2010)
- Link between disturbances and prices on the market is lacking

Three bodies of literature:

- Theoretical forest economics studies on natural disturbances (Rakotoarison et Loisel, 2017)
- Environmental economics on resilience of socio-ecosystems (Perrings, 1998; Walker, 2004)
- Empirical forest economics to include a response of the market (Prestemon et Holmes, 2000; Sun, 2020)

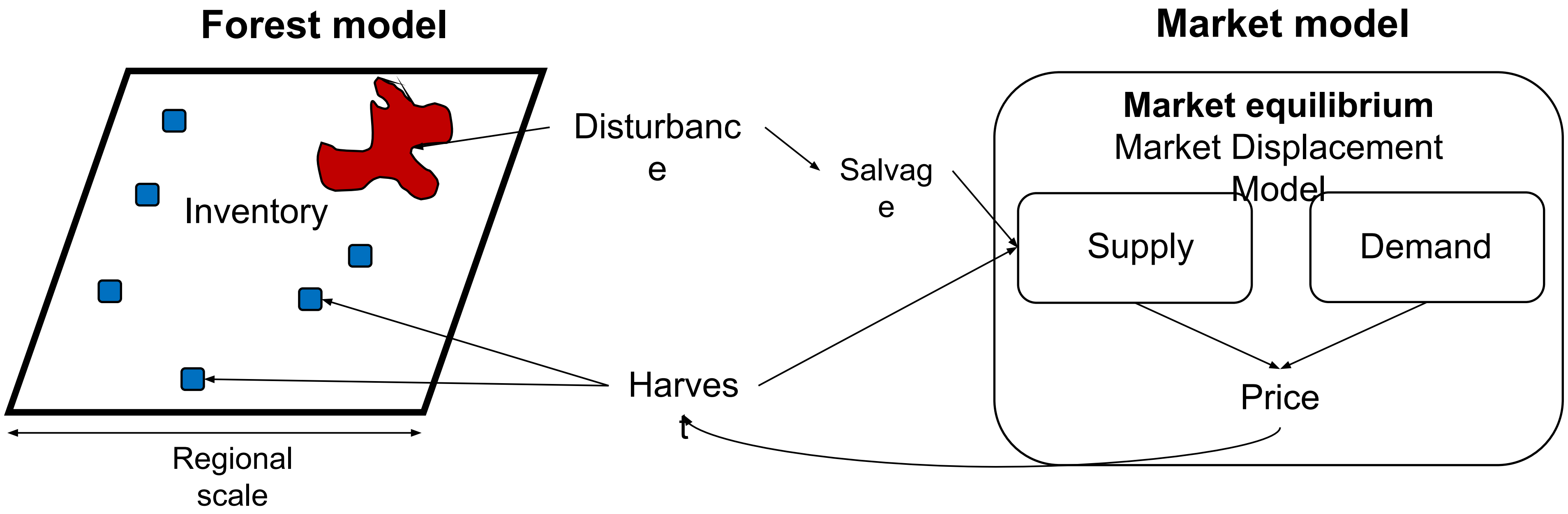
Research questions

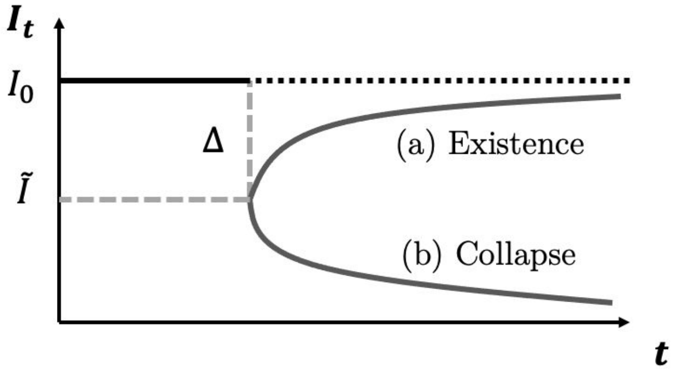
What are the conditions for a stable bio-economic equilibrium, what are the main drivers of this equilibrium, and how sensitive is it to variations in these drivers?

If such an equilibrium is stable, what level of damages can a forest cope with and still maintain timber production?

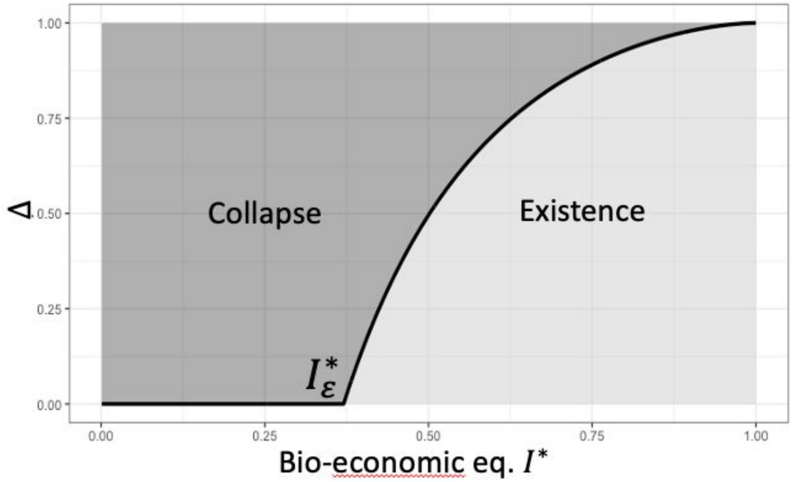
What is the impact of the frequency of natural hazards on the existence of such equilibrium?

Methodology

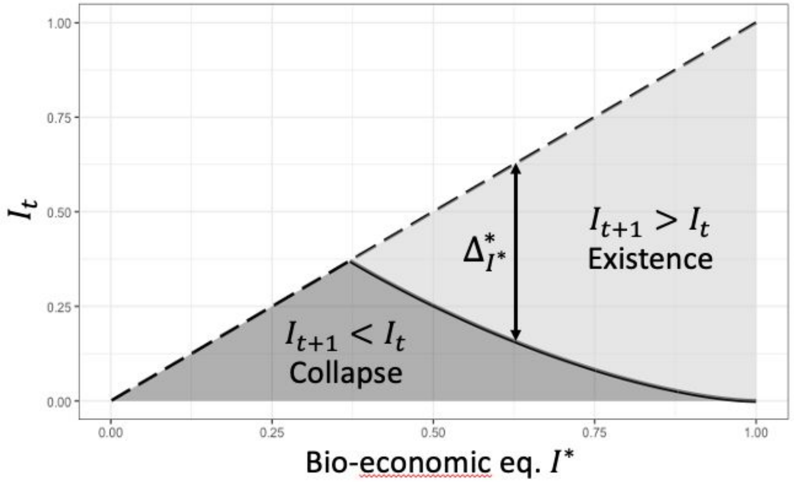




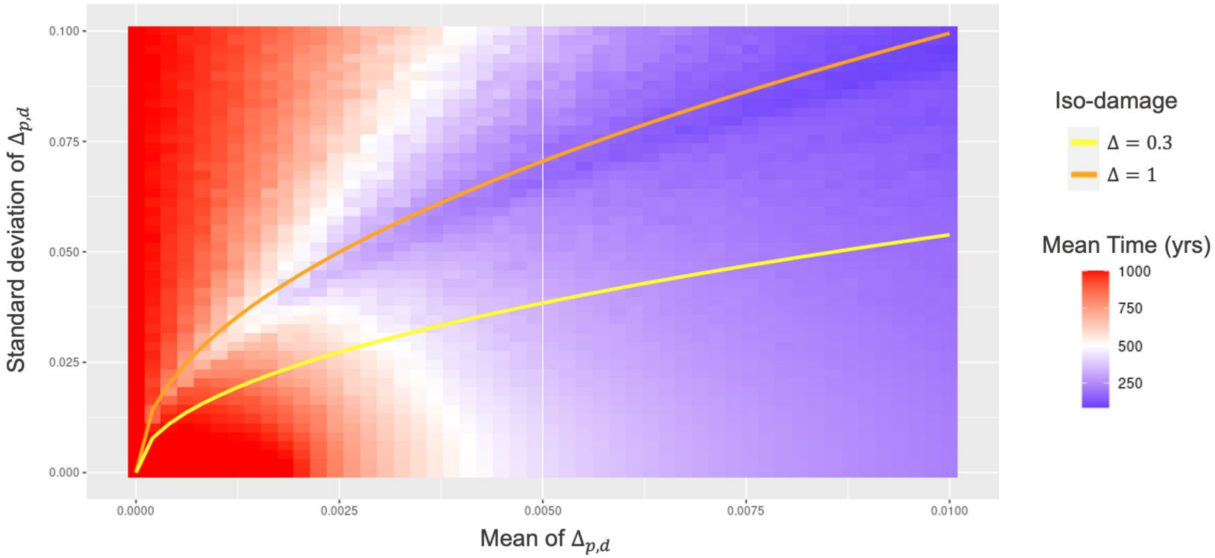
Results



Collapse
Existence
Δ
I_ε^*
Bio-economic eq. I^*
0.00
0.25
0.50
0.75
1.00



I_t
$\Delta_{I^*}^*$
$I_{t+1} > I_t$
Existence
$I_{t+1} < I_t$
Collapse
Bio-economic eq. I^*
0.00
0.25
0.50
0.75
1.00



Standard deviation of $\Delta_{p,d}$
Mean of $\Delta_{p,d}$
Iso-damage
$\Delta = 0.3$
$\Delta = 1$
Mean Time (yrs)
1000
750
500
250
0.000
0.025
0.050
0.075
0.100
0.0000
0.0025
0.0050
0.0075
0.0100

3rd chapter

Estimating the economic impact of multiple natural hazards on the French forest sector

Bastit, F., Lobianco A., Gardiner B., Riviere M.

Context, motivation & literature

Context

- French Forest sector: 17 Mha, 2.8 Mm^3 of timber, 1.3 GtC stored, 400 000 jobs (IGN, 2022)
- 1985-2022: forest area + 20%, growing stock + 50%.
  - Trend is the same in all French regions excepted 2 departments strongly impacted by 1999 Lothar & Martin and 2009 Klaus windstorms.
  - Major spruce bark beetle attacks 2019-2021 due to severe drought

Literature

- Roux et al (2020)
- Riviere et al (2022): extended to several risks, but without climate change effects

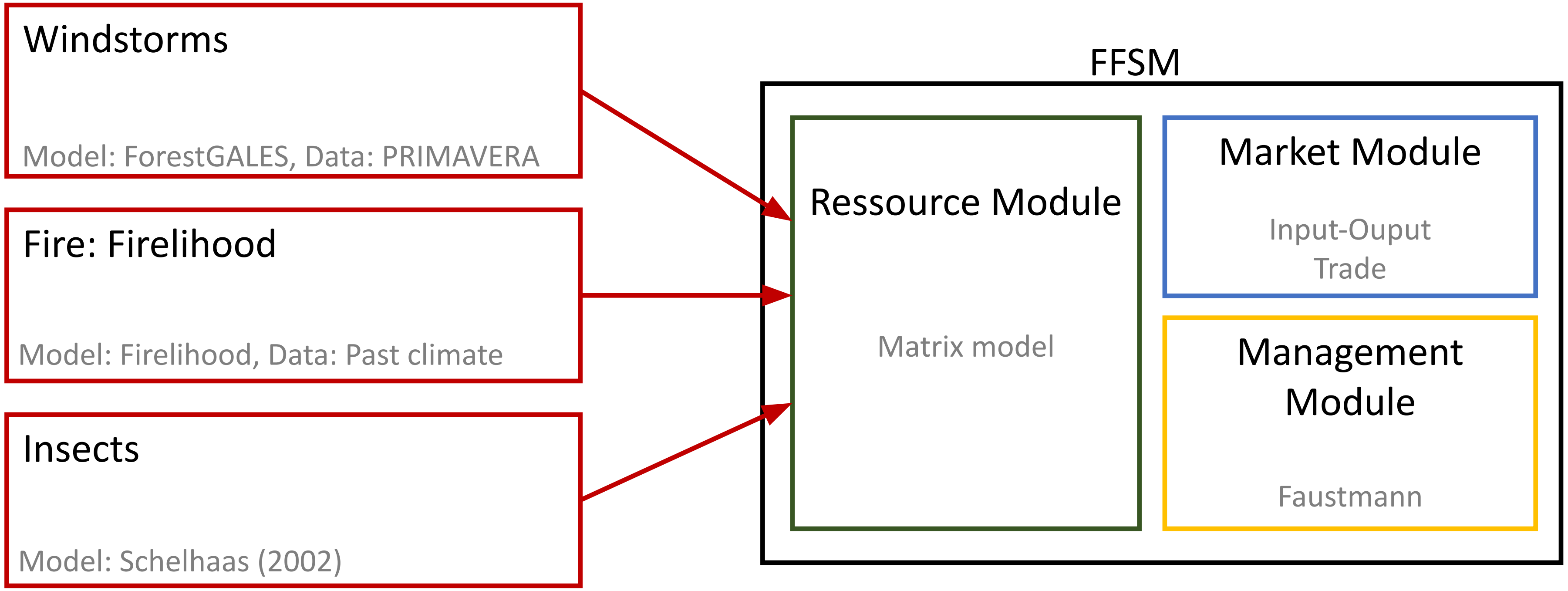
Research questions

- Windstorms:
  - Can we predict the full potential effect of windstorms?
  - What are the redistribution effects in the entire forest sector across the different French regions?

- Interactions
  - In a prospective perspective, can we investigate the eventual interactions between windstorms, wildfires and insects outbreaks ?
  - Is the effect of interacting natural hazards larger than the sum of hazards?

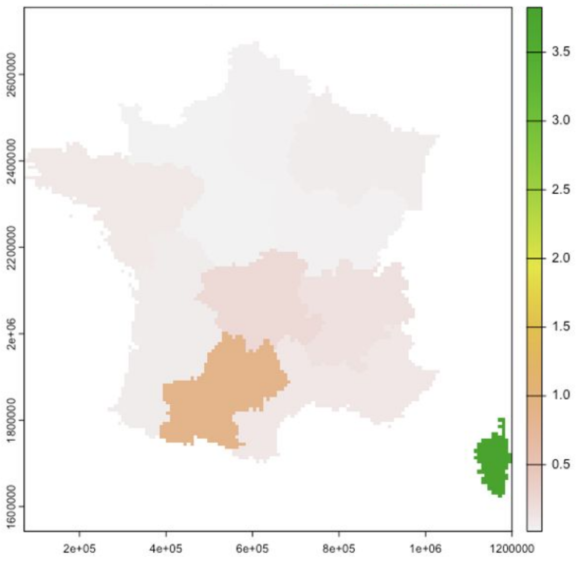
Method

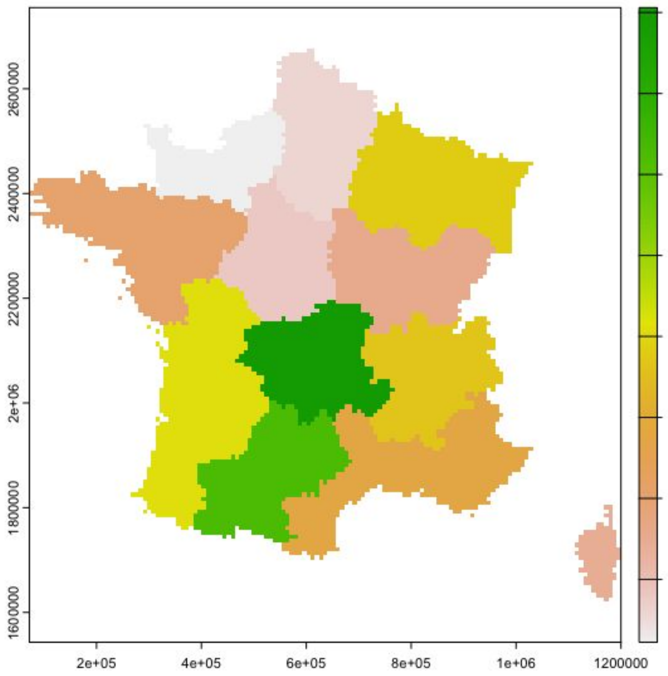
French Forest Sector Model (Caurla et al, 2010; Lobianco et al, 2015)



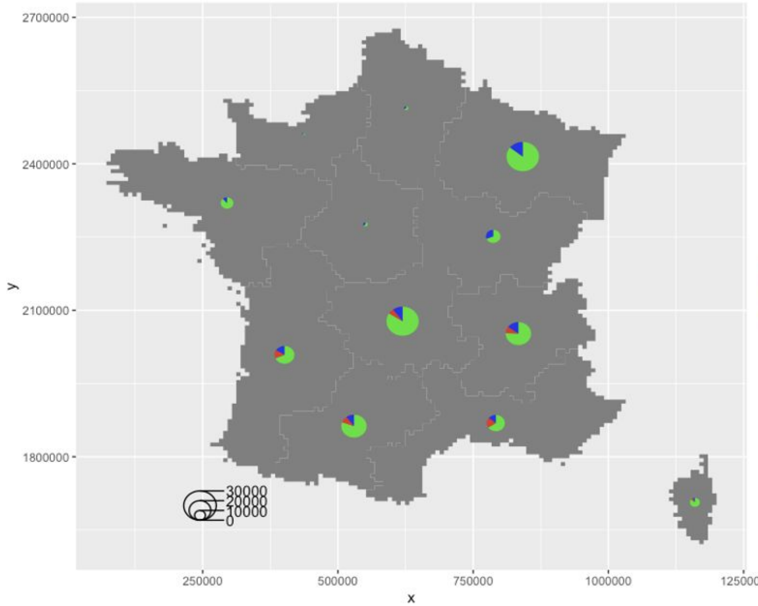
Main findings (WORK IN PROGRESS)

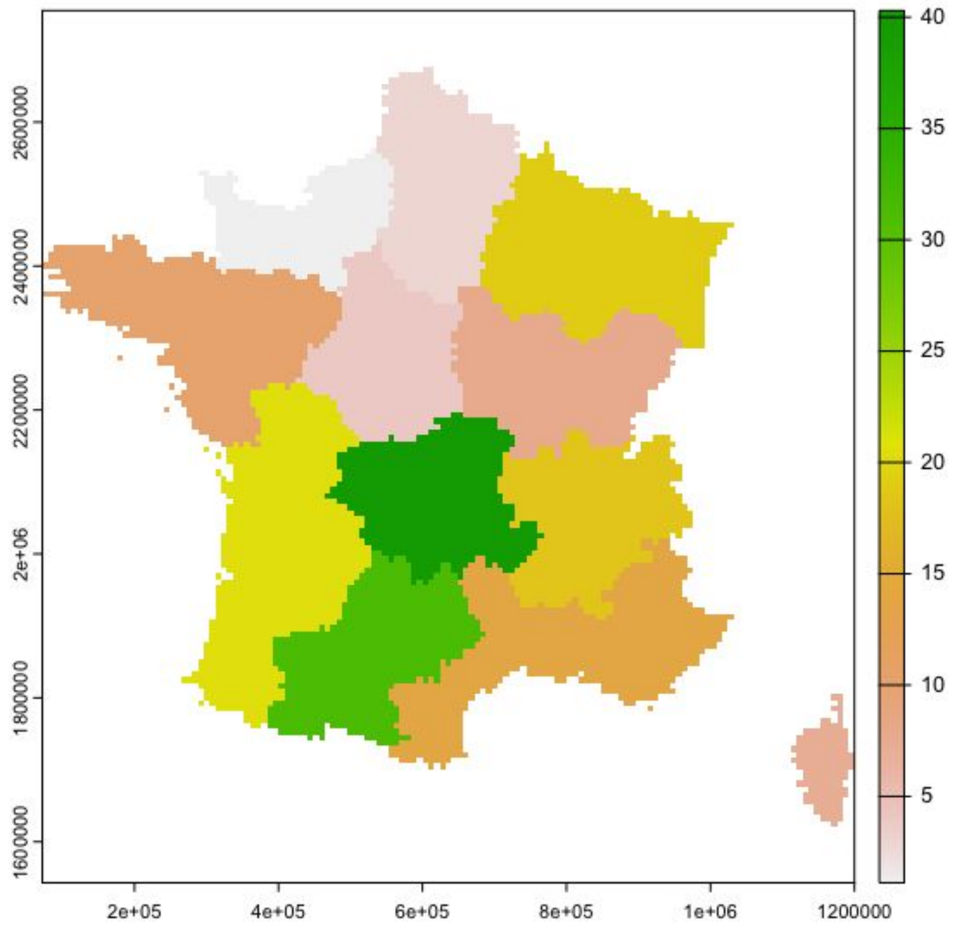
Total mortality / Total harvest





Mean additional mortality (Mm3) due to windstorms
for the period 2012-2050





Mean additional mortality (Mm3) due to windstorms for the period 2012-2050

Cost of natural disturbances on European forests under different climate scenarios

Bastit F., Mohr J., Knoke T., Rammer W., Thom D., Seidl R.

Context, motivation & literature

Study area

- Total forest area: 35% (227 Mha) of European land (without Russian Federation).
- Natural disturbances = part of ecosystems and play an important role in long-term shaping and adjustments of these lasts. European forests are vulnerable to several natural disturbances and 58% of the total area faces a risk of biomass loss (Forzieri et al., 2021).
- The main drivers of these hazards are management choices and climate change (Seidl et al., 2011).

Literature

- Most of the literature often focuses on a single crisis to estimate its cost: Hurricane Hugo in the US (Guimaraes et al, 1993), Bark beetle in the US (Pye et al, 2011), Pine nematode in China (Zhao et al, 2020), wildfires in Florida (Butry et al, 2001)
- Large body of literature in forest ecology/management to assess the effect of disturbances on the forest at large scale (Schelhaas et al, 2002, Seidl et al, 2011, Senf et al, 2020) no economic evaluation
- Hanewinkel et al (2013): niche-based model to evaluate the cost of climate change at the European scale
- Knoke et al (2021): Monte Carlo simulations to estimate the cost of disturbances on Norway spruce in Germany

Research questions

What is the cost of natural disturbances on the European forests in constant past climate?

What is the value of the standing timber stock with respect to the bare soil value?

What is the expected cost of climate change? How does this depend on the climate scenario and the potential level of catastrophic climatic pulses?

What are the more sensitive parameters to estimate these economic losses?

Model

Monte Carlo framework

4 species (Beech, Oak, Pine and Spruce)

 Represents 20 Gm^3 of timber (60% of the total volume)

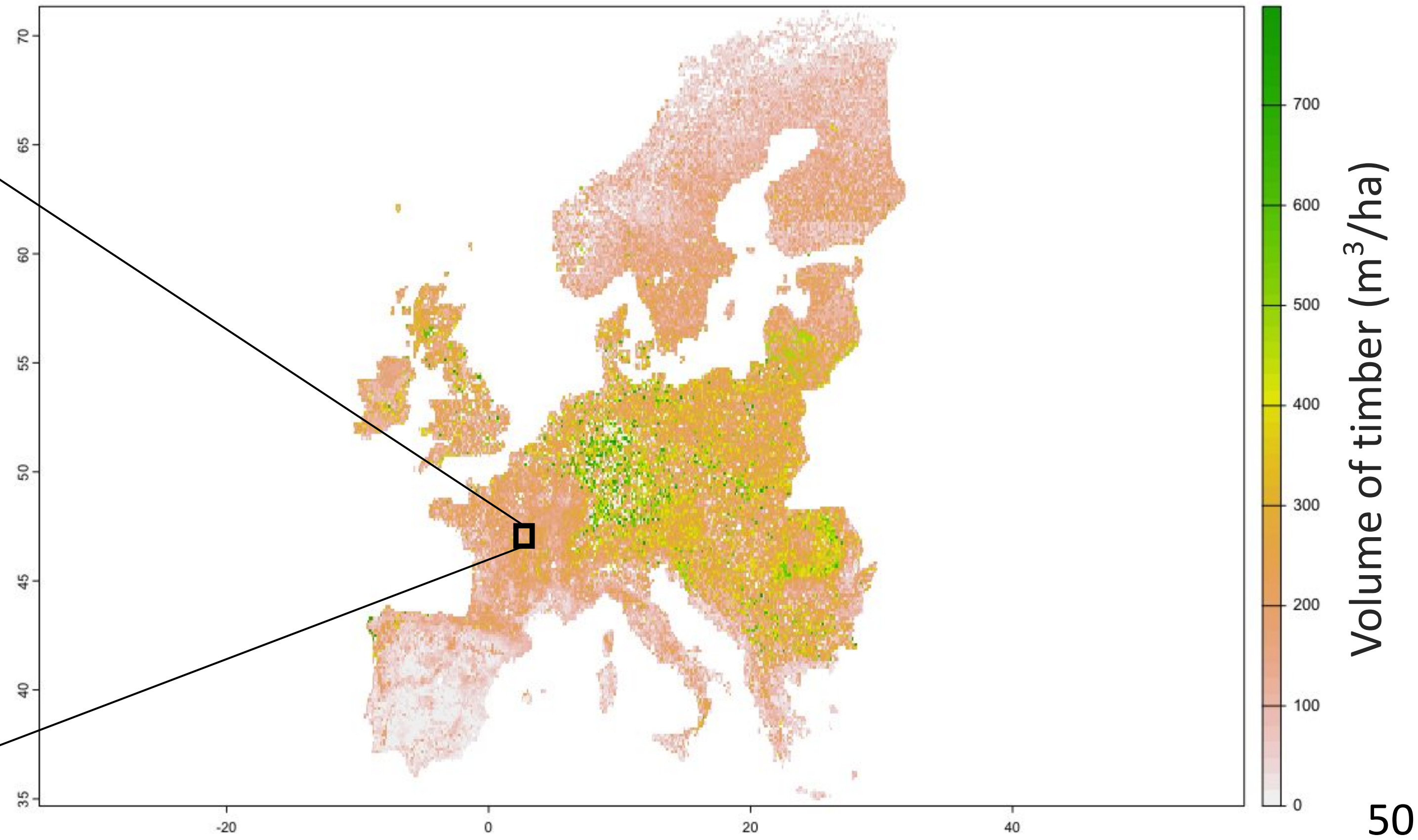
23 age classes (0 to 220 years)

3 climate models, 4 climate scenarios

Monte Carlo simulations to estimate the Faustmann value of each pixel

$$Value = \sum_{i=1}^{N} \sum_{px} \sum_{t=0}^{T} \frac{B_{t,px,i} - C_{t,px,i}}{(1+r)^t}$$

With $B_{t,px,i}$, $C_{t,px,i}$ r.v. for benefits and costs at time t for pixel px simulation i



European estimation of natural hazard damages

Patacca (2023)

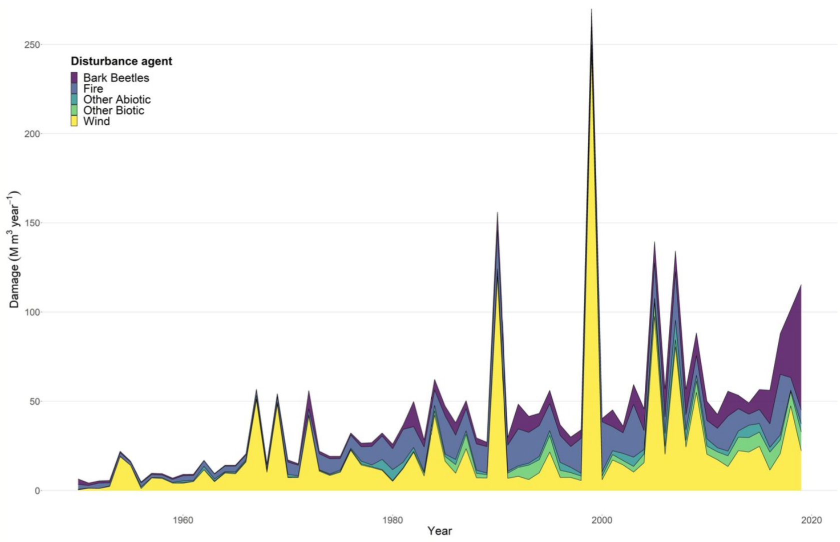
Period 1950-2017

Mean quantity of timber disturbed: 62.1 Mm^3/yr (+845 km^3/yr)

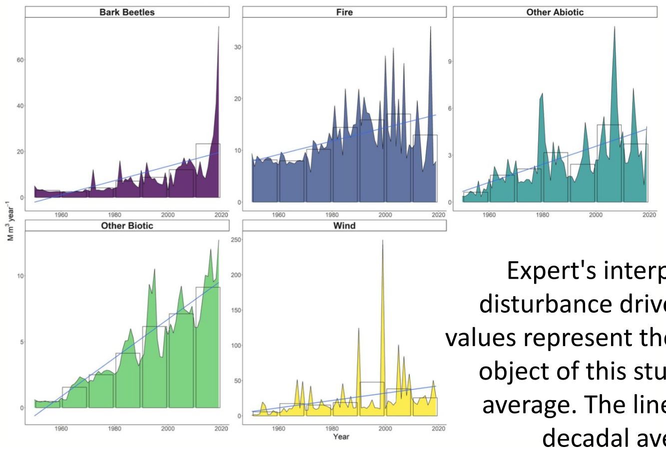
- 46% storms
- 24% fire (significative increase over the period)
- 17% bark beetles (23 Mm^3/yr over 2010-2019, comparable to windstorms

0.23% of the growing stock is disturbed each year (0.27% for the period 2001-2019)

15% of the mean annual harvest



Total reported damage caused by natural disturbance in Europe between 1950 and 2019 (Patacca et al, 2023)



Expert's interpreted gap-filled time-series of disturbance drivers between 1950 and 2019. The values represent the sum of the 34 European countries object of this study. The bars represent a decadal average. The lines are linear models fitted to the decadal averages (Patacca et al, 2023)

Main findings

WORK IN PROGRESS

Forest Value 1.5% Discount Rate Climate model : MPI.SMHI-RCA4.r1i1p1										
Specie	**Beech**		**Spruce**		**Scots Pine**		**Oak**		**TOTAL**	
	€	%	€	%	€	%	€	%	**€**	**%**
No risk	60.9	0.372	263.0	0.296	126.4	0.272	51.5	0.406	**515.5**	**0.305**
Historical	44.4	Ø	202.9	Ø	99.4	Ø	36.6	Ø	**395.1**	Ø
RCP26	42.3	-0.046	197.3	-0.028	98.2	-0.012	33.9	-0.074	**383.3**	**-0.03**
RCP45	40.3	-0.093	194.8	-0.04	97.5	-0.019	32.4	-0.115	**376.5**	**-0.047**
RCP85	38.2	-0.139	191.0	-0.059	96.3	-0.032	30.0	-0.181	**366.8**	**-0.072**

Avenues for research

Avenues for research

- Theoretical analysis: build a framework for future analysis
  - How to deal with deep uncertainty?
    - Knoke et al (2022)
  - The problem of multi-objective optimization
  - What is the concrete effect of multiple disturbances on the forest owner and how should this modify her decision process?
- Dig the notion of resilience
- Spatially explicit modelisation
- Agent based models ?
  - First step: Petucco et al (2020)

Thank you for your attention

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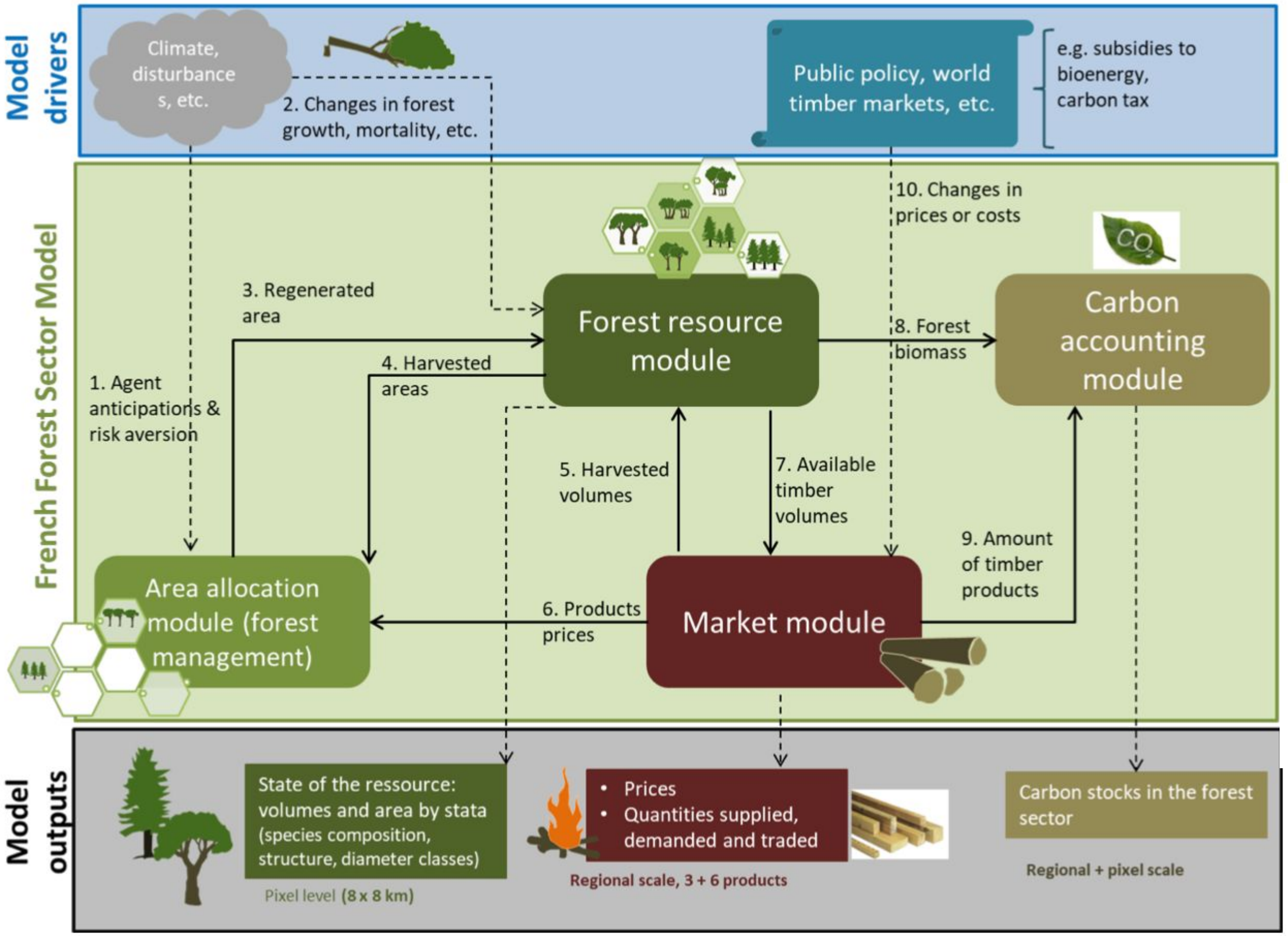
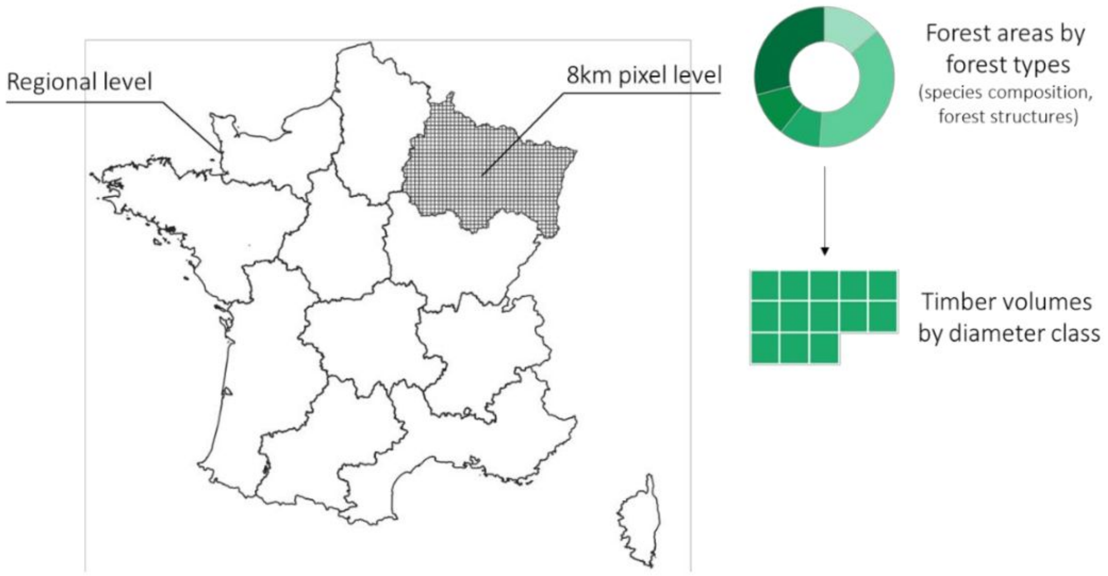
FFSM: How it works ?

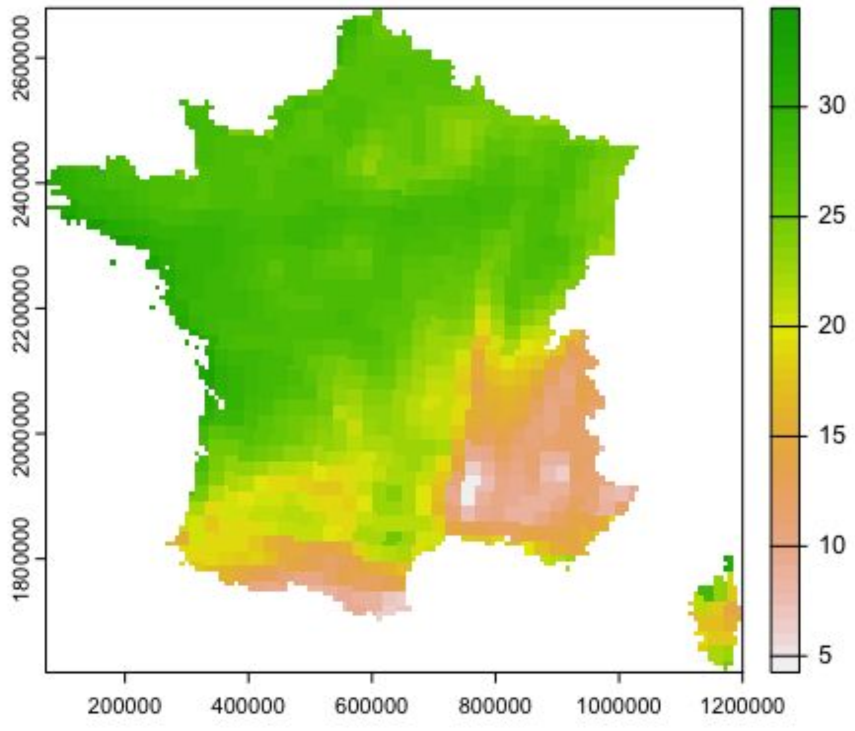


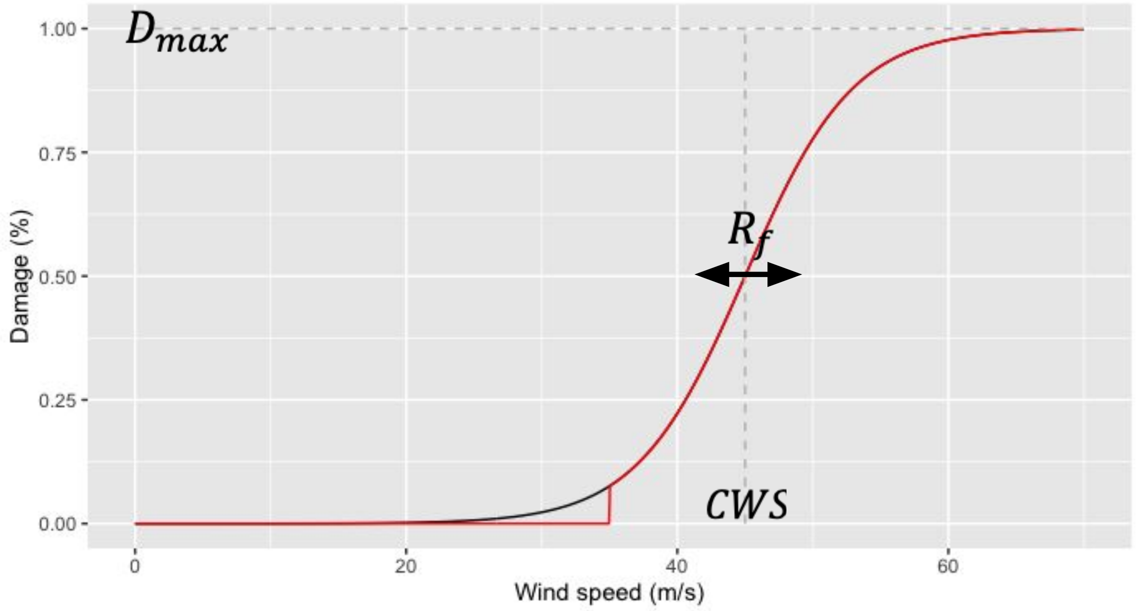


Caurla et al (2010), Lobianco et al (2015)

Windstorms

Windspeed for windstorm Lothar (m/s)





Database: PRIMAVERA (Lockwood et al, 2022)

□ 1332 winters are simulated

$$D(W) = D_{max} \cdot \left(\frac{1}{1 + e^{\left(\frac{CWS - W}{R_f}\right)}} - \frac{1}{1 + e^{\left(\frac{CWS}{R_f}\right)}} \right)$$

Fire disturbance

Riviere et al (2022): Statistical approach

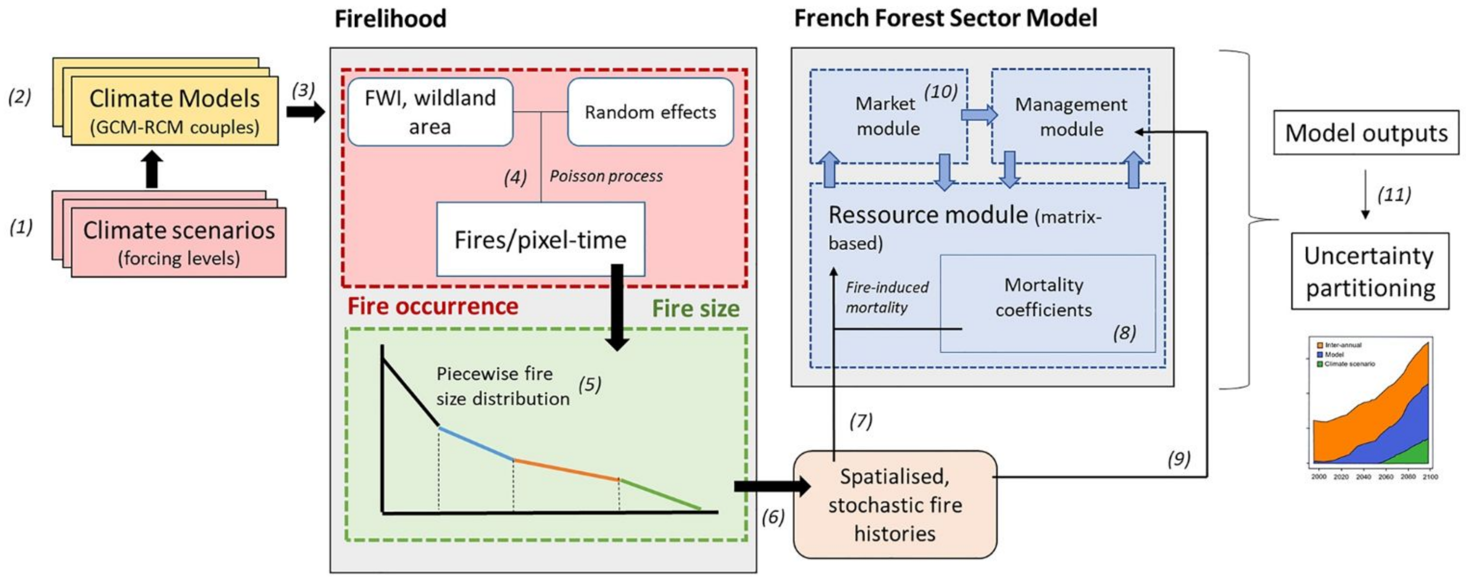
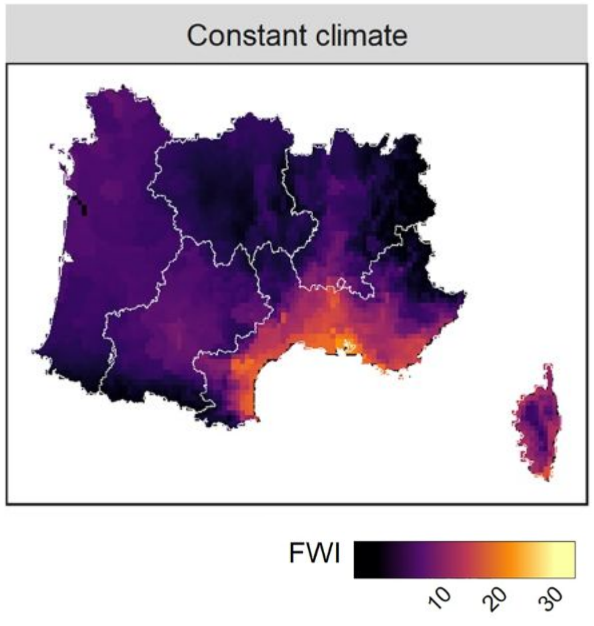
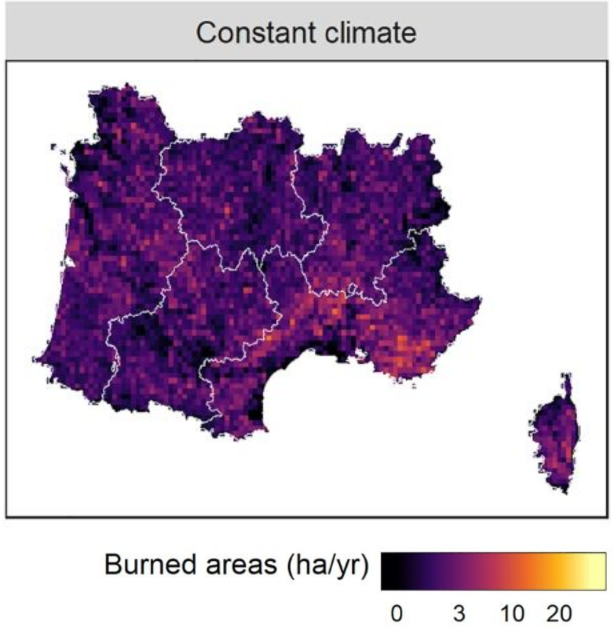


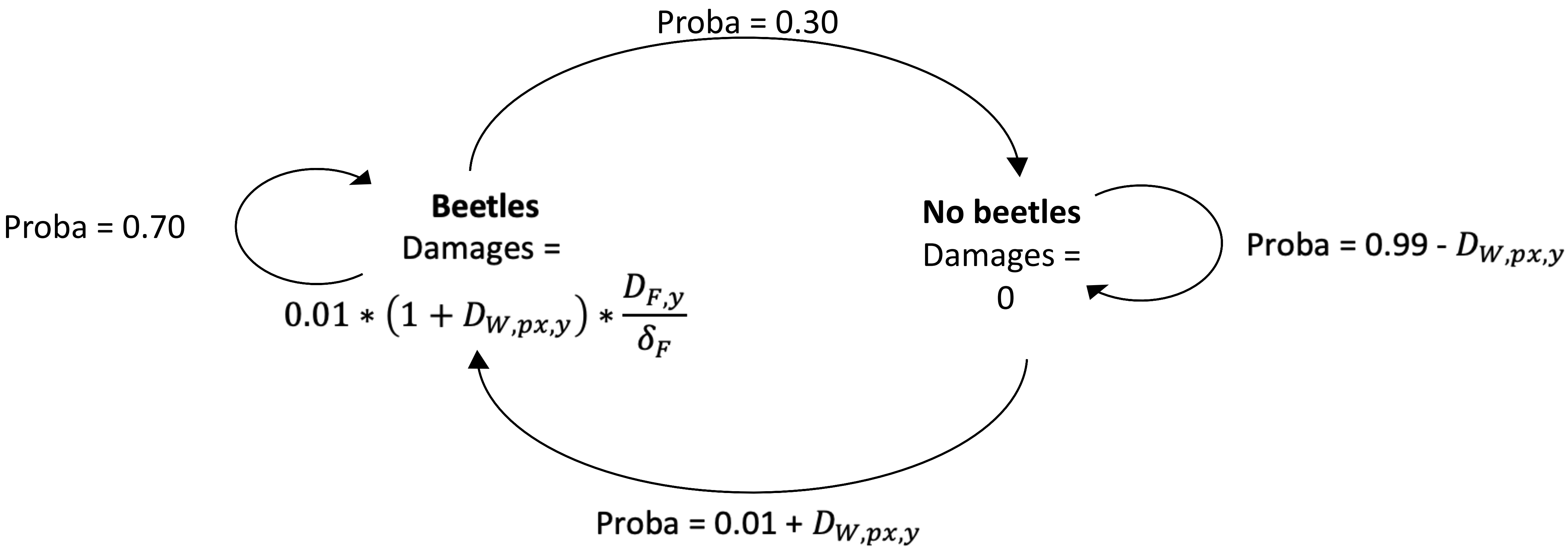
Figure 2. Illustration of the coupling framework. From left to right: simulation data from several GCM-RCM pairs (2) under various levels of radiative forcing (1) are used to drive Firelihood (3). Individual fires larger than 1 ha are simulated in a 8 km pixel grid in a hierarchical process where fire occurrence (4), fire size classes and burned areas (5) are computed daily, and several stochastic replications are carried out (6). Areas burned are distributed to the forest types of the FFSM proportionately to their fraction of forest area cover in pixels (7). Fire-induced mortality is computed using mortality coefficients (8), and fires also impact the forest sector through owners' anticipations of future fires (9) and impacts on product prices (10). Model outputs are used to partition different sources of uncertainty (11).



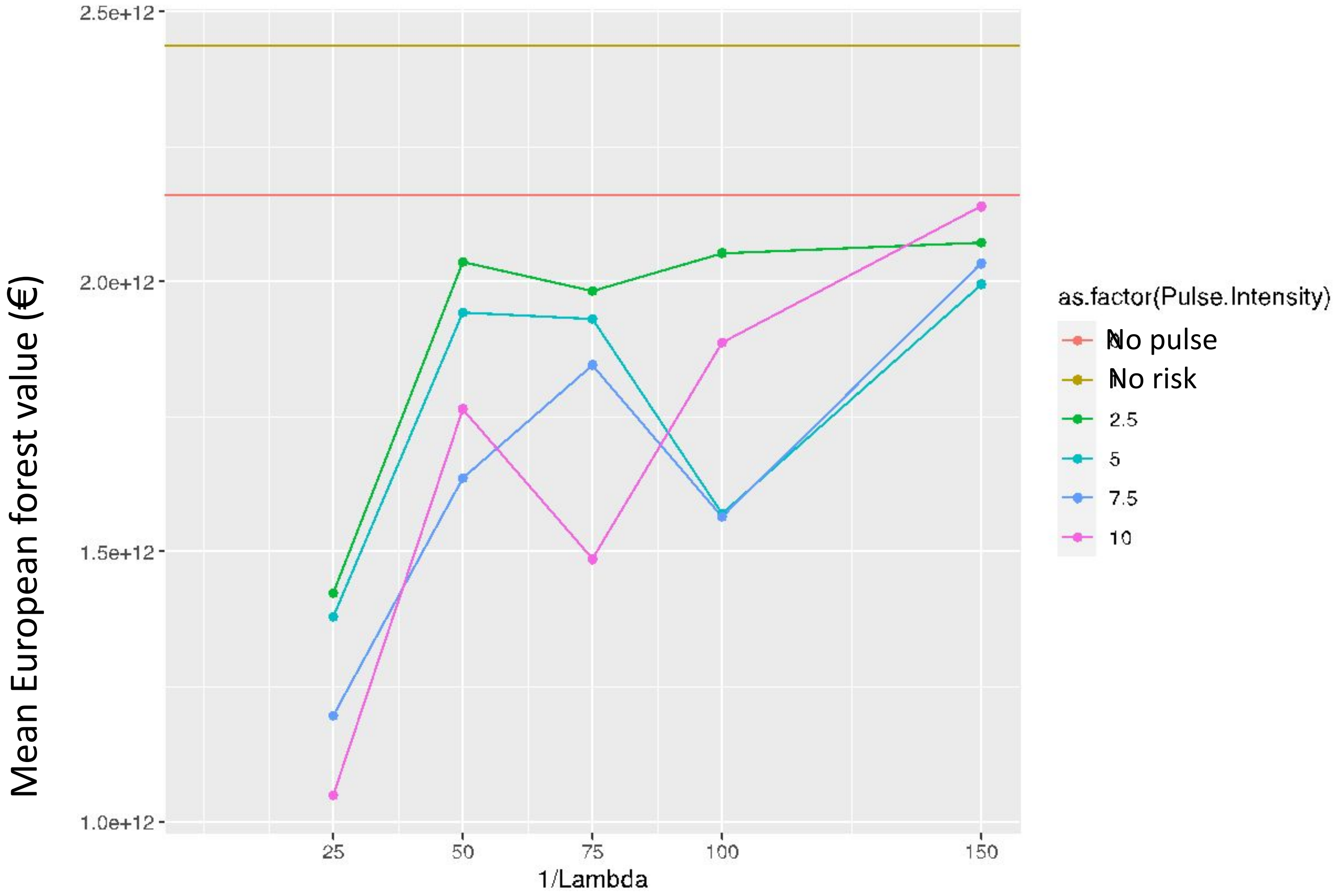


Insect disturbance

Schelhaas et al (2002), Roux et al (2017)



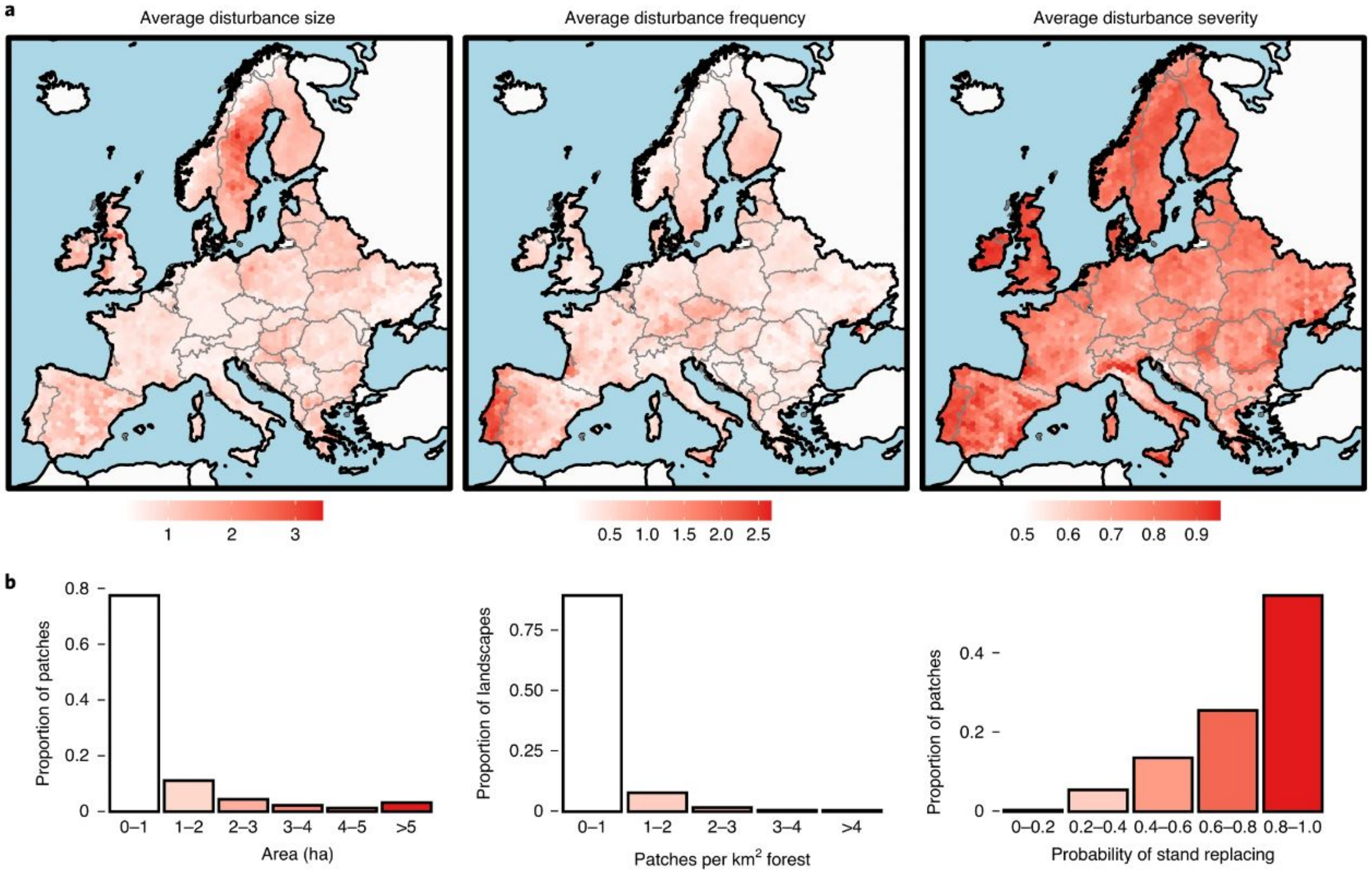
$D_{W,px}$: Windstorm damage on pixel px during year y
D_F: Mean wildfire damages over France during year y
δ_F: Mean wildfire damages over France during historical period



Mean European forest value function of mean time of return (for different pulse intensities)

Historic disturbances (remote sensing analysis)

Senf et Seidl (2020)

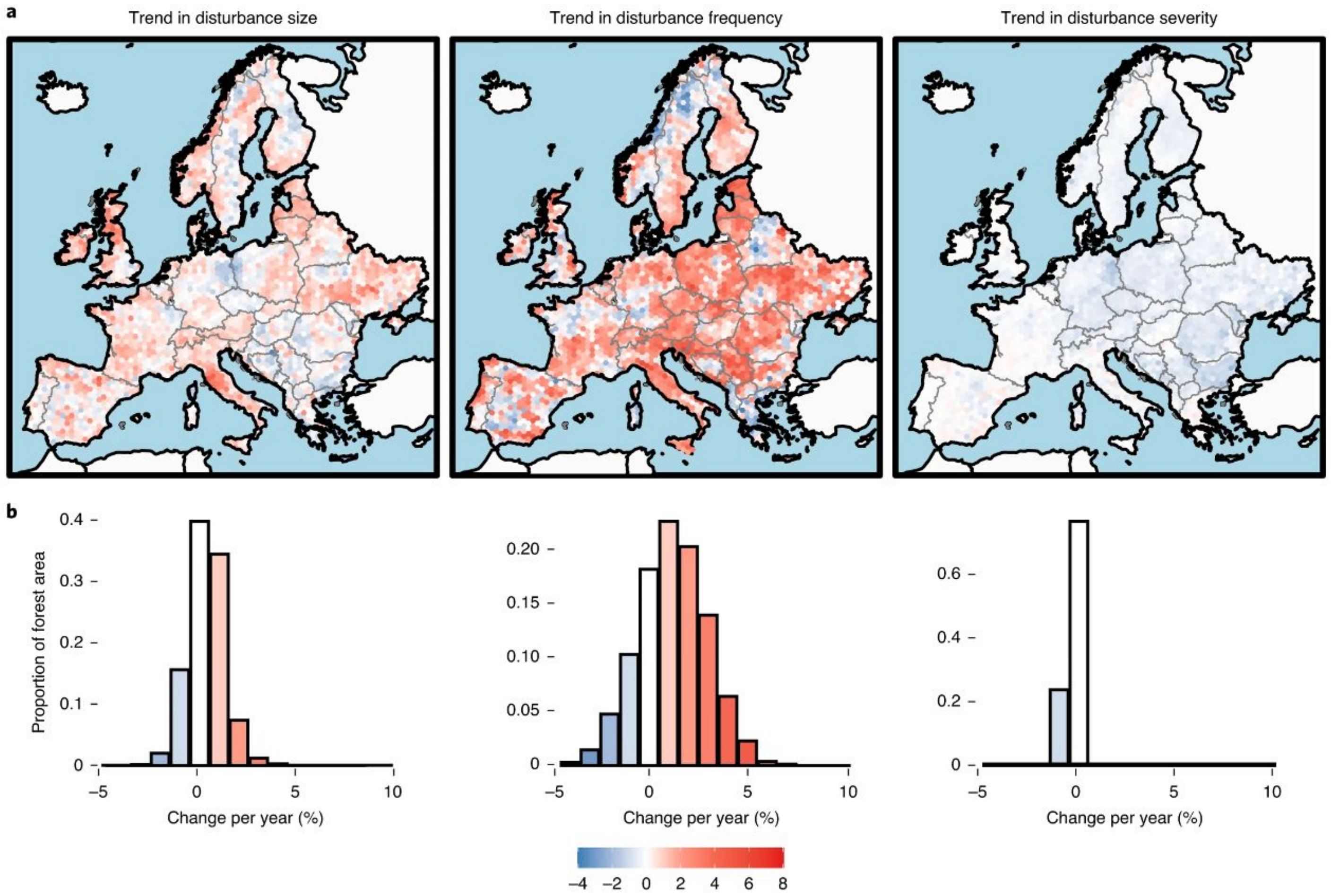


a, Maps of average disturbance size (ha), frequency (patches per km^2 forest area) and severity (scale, 0–1) calculated for hexagons on a 50-km grid across continental Europe. Background maps are derived from https://gadm.org. **b**, Distribution of average disturbance size, frequency and severity across Europe.

Attention!
This includes harvest

Recent trend for the disturbance

Senf et Seidl (2020)



a, Maps of trends in disturbance size, frequency and severity calculated as a 50-km hexagon grid across continental Europe. Background maps are derived from https://gadm.org. **b**, Distribution of forest area among trend classes.