General assumption: Beech forests do not burn. Evidence from recent years: Yes they do!

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Fire in beech forests

Beech forests rarely burn due to ...
... compact litter layer with low oxygen content
... a lack of understory vegetation
... typical forest structure („Hallenwälder“)
Beech fire-adaptive traits

- thin bark
- limited resprouting
- irregular masting seeder
But ...
2003 summer fires in beech stands

Someo 130 ha

Bodio 325 ha

Forest fires (> 100 ha) 1980-2013
summer fires in beech 2003
2003 summer fires in beech stands

- Varallo 12/08/2003, 300 ha
- Bussoleno 27/08/2003, 480 ha
- Valdieri 28/08/2003, 1076 ha
- Someo 130 ha
- Bodio 325 ha

Forest fires (> 100 ha) 1980-2013

summer fires in beech 2003
2018 spring fire in beech stands
Research questions

How resistant and resilient are beech forests to fire?
Do fires change ecosystem services - protection functions in particular?
Are post-fire measures needed?

Salvage logging?

Afforestation vs. natural regeneration
Chapter 1 | Beech mortality
Chapter 2 | Beech regeneration
Chapter 3 | Protection capacity
Study region

- Ticino, Glarus, Solothurn, Piemont

Space-for-time approach

- Number of plots vs. Year of fire

Switzerland

Italy
Heterogeneity in fire behaviour
Burn severity
Burn severity

- low severity
- moderate severity
- high severity
Chapter I   Beech mortality
Chapter 1 | Beech mortality

How resistant are beeches to single fires?
What drives the post-fire mortality process?
Chapter 1 | Beech mortality

How resistant are beeches to single fires?
What drives the post-fire mortality process?

New approach

Modeling delayed (1 – 20 years post-fire) tree mortality
Survival analysis (Kaplan-Meier estimator, Cox-PH model)
Chapter 1 | Kaplan-Meier estimator

Survival probability

0.0 0.2 0.4 0.6 0.8 1.0

Years post-fire

0 2 4 6 8 10 12 14 16 18

low severity
Chapter 1 | Kaplan-Meier estimator

**Survival probability**

- **low severity**
- **moderate severity**
- **high severity**

**Years post–fire**

0 2 4 6 8 10 12 14 16 18
Chapter 1 | Cox-proportional hazards models

Explanatory variables

- Site characteristics (elevation, aspect, slope, ...)
- Tree characteristics (DBH, fungi investation, growth habit, ...)
- Climate (temperature, precipitation, SPEI, ...)
Chapter 1 | Cox-proportional hazards models

<table>
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HR < 1 reduce the hazard to die
HR > 1 increase hazard to die
HR = 1 no changes
### Chapter 1 | Cox-proportional hazards models

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Post-fire fungi infestation

In moderate and high severity burns trees getting infested by fungi have a 3.6-times higher probability to die.

*Daldinia spec.*  
*Cerrena unicolor*  
*Stereum hirsutum*  
*Schizophyllum commune*  
*Irpex lacteus*
Chapter II  Beech regeneration
Chapter 2  |  Beech regeneration

What grows after fire?
What drives the regeneration process?
Chapter 2 | Beech regeneration

What grows after fire?

[Graph showing regeneration density over years post-fire with categories like unburnt, burnt, and others, with data points indicating the density levels for each category.]
Chapter 2 | Beech regeneration

What grows after fire?

burn severity

unburnt low

regeneration density

years post-fire

unburnt gering brandschwere

beech pioneer other
Chapter 2 | Beech regeneration

What grows after fire?

![Graph showing regeneration density over years post-fire with different burn severities.](image-url)
What grows after fire?

Chapter 2 | Beech regeneration

burn severity

- unburnt
- low
- moderate
- high

years post-fire

regeneration density

0

10000

20000

30000

40000

beech
pioneer
other
Chapter 2 | Beech regeneration

What drives beech regeneration processes?
Chapter 2 | Beech regeneration

What drives beech regeneration processes?

Mixed-effect-model

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## What drives beech regeneration processes?

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What drives beech regeneration processes?

seedlings need close-by mother trees
Chapter 2 | Beech regeneration

What drives beech regeneration processes?

saplings need light

years post-fire
### Chapter 2 | Beech regeneration

What drives beech regeneration processes?

#### Mixed-effect-model

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What drives the regeneration process?
Chapter 2 | Beech regeneration

What drives beech regeneration processes?

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Chapter 2 | Beech regeneration

What drives the regeneration process?
Chapter 2 | Beech regeneration

What drives the regeneration process?

- close-by mother trees
- absence of competing ground vegetation
- coarse woody debris

How long is the regeneration window open?
Chapter 2 | Beech regeneration

How long is the regeneration window open?

![Graph showing germination frequency over years post-fire for different burn severities: low, moderate, and high. The x-axis represents years post-fire, ranging from 0 to 30, and the y-axis represents germination frequency, ranging from 0.0 to 0.3.]
How long is the regeneration window open?

Chapter 2 | Beech regeneration

How long is the regeneration window open?

The graph shows the frequency of germination over years post-fire for different burn severities: Low, Moderate, and High. The x-axis represents years post-fire, and the y-axis represents germination frequency.
## Chapter 2 | Beech regeneration

How long is the regeneration window open

Zero-inflated-model with random effect

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<td>0.7 ***</td>
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<tr>
<td>half</td>
<td>0.5 ***</td>
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<tr>
<td>local</td>
<td>0.3 **</td>
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<tr>
<td>canopy cover (caco)</td>
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<td>observation intervals</td>
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<td>Vegetation competition</td>
<td>-0.26 **</td>
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How long is the regeneration window open

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Chapter 2 | Beech regeneration

years post-fire
Chapter III  Protection capacity
Chapter III Protection capacity

Change fires ecosystem services - especially protection functions?
Chapter III Protection capacity against rockfall

burn severity

Years post-fire

- low protection capacity
- sum of basal area
- pre-fire beeches
- regeneration other tree species
- beech regeneration
Chapter III Protection capacity against rockfall

- Basal area ($m^2 ha^{-1}$)
- Burn severity

- Low protection capacity
- Sum of basal area
- Pre-fire beeches
- Regeneration of other tree species
- Beech regeneration

Years post-fire
Chapter III Protection capacity against rockfall

burn severity

low moderate high

Basal area (m$^2$ ha$^{-1}$)

sum of basal area

pre-fire beeches

regeneration other tree species

beech regeneration

Years post-fire

low protection capacity
Chapter III Protection capacity against rockfall

![Graph showing the relationship between burn severity, basal area, and years post-fire for low, moderate, and high burn severity.](image)

- **Low burn severity**
  - Basal area (m² ha⁻¹)
  - Sum of basal area
  - Pre-fire beeches
  - Regeneration of other tree species
  - Beech regeneration

- **Moderate burn severity**
  - Basal area (m² ha⁻¹)
  - Sum of basal area
  - Pre-fire beeches
  - Regeneration of other tree species
  - Beech regeneration

- **High burn severity**
  - Basal area (m² ha⁻¹)
  - Sum of basal area
  - Pre-fire beeches
  - Regeneration of other tree species
  - Beech regeneration
What do we learn for the practice?

Depending on the ecosystem service ...

... single tree removal for public safety
... be aware of fire severity in protection forests
... always keep in mind the interaction between mast years and tree cover

If it is no protection forest...
... leave dead wood
... leave dying trees

Just assist natur!
What do we learn for the practice?
Die Feuerökologie der Rotbuche (Fagus sylvatica L.)
Thank you for your attention!

funding: Federal Office for Environment Swiss

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Roberta Beretti
Franco Fibbioli
Matteo Gaberino
Sven Hofmann
Marianne Steffen
Michael Stuber
James Winder