XXII Convegno Nazionale di Micologia

Siena, 6 -8 settembre 2018

Effect of forest management on fungal productivity and diversity in Mediterranean forest ecosystems (in a global change context)

Sergio de Miguel

Universitat de Lleida

Effect of forest management on fungal productivity and diversity in Mediterranean forest ecosystems (in a global change context)

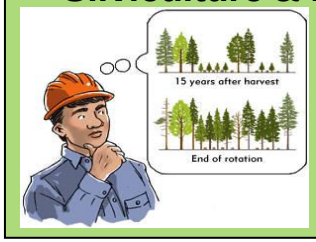
1. **Overview on current scientific knowledge on mycosilviculture**

2. **Overview of our experimental setup (in Catalonia region, northeastern Spain), some relevant findings and ongoing research on the relationship between fungal resources, forest management and global change.**

1. Overview of current scientific knowledge on mycosilviculture

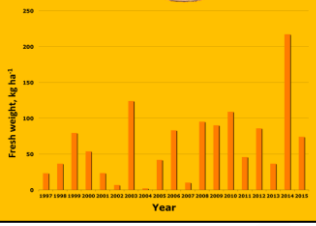
Environment (natural disturbance)

Silviculture & Forest management



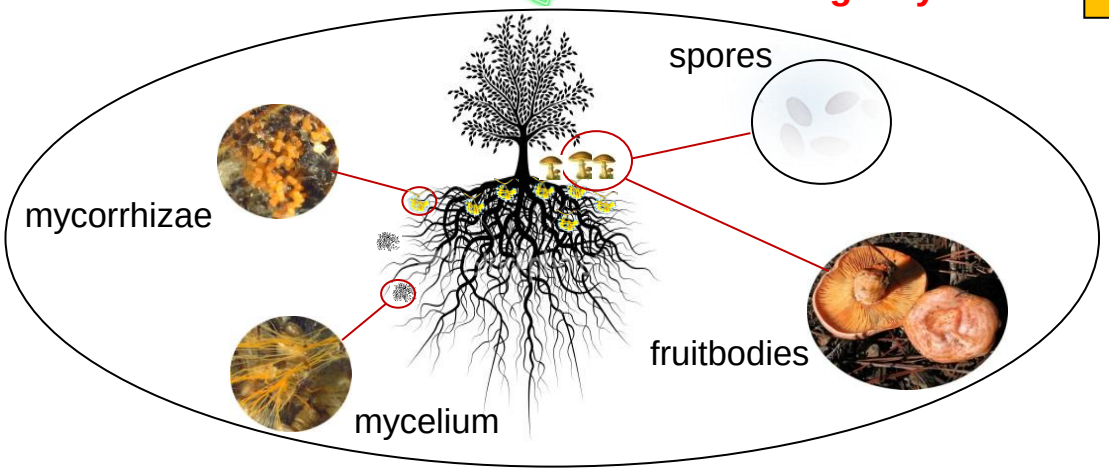
Forest structure & dynamics

Mutiple fungal ecosystem services



- Provisioning
  - Wild food
- Cultural
  - Mushroom picking
- Regulating
- Supporting

Fungal dynamics



Forest Ecology and Management 402 (2017) 102–114

Contents lists available at ScienceDirect

Forest Ecology and Management

journal homepage: www.elsevier.com/locate/foreco

Is silviculture able to enhance wild forest mushroom resources? Current knowledge and future perspectives

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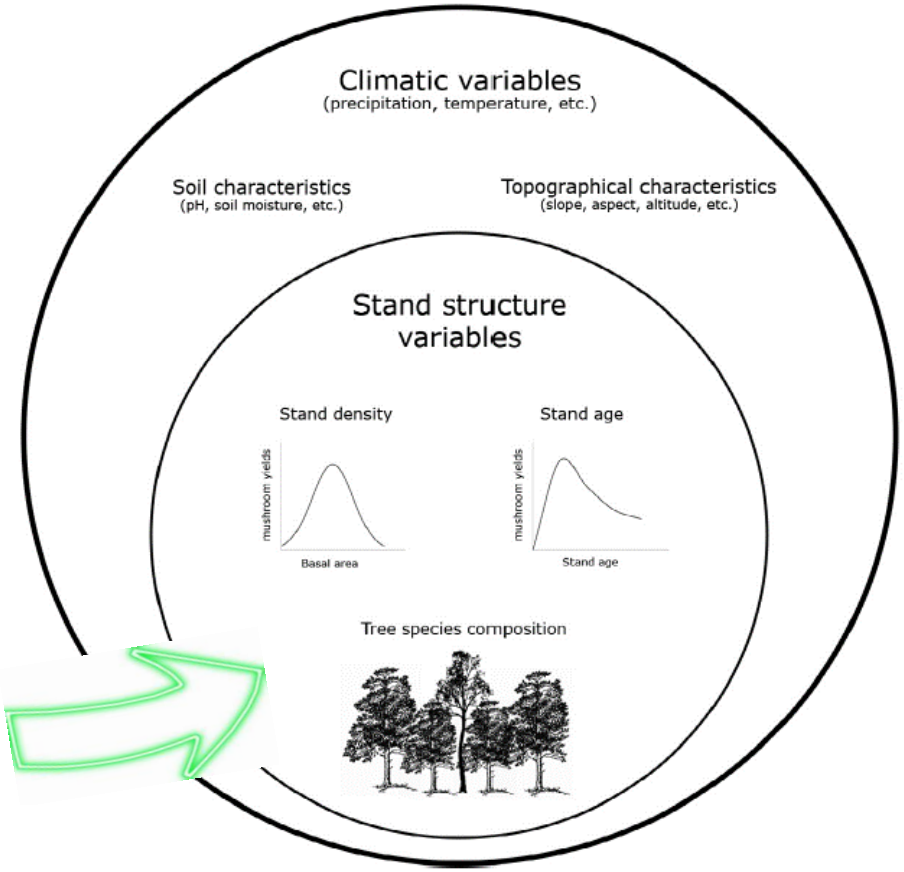
Mycosilviculture:

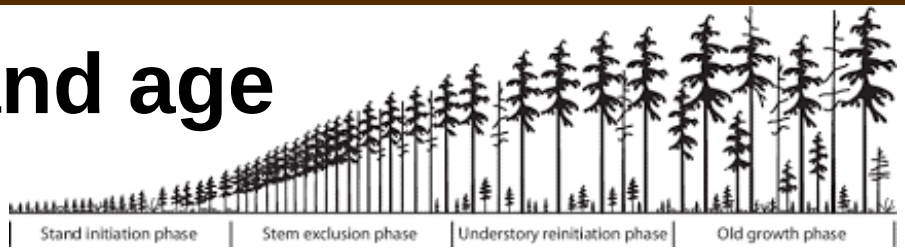
"Experimental **science** studying the interactions between the **natural dynamics** of forest ecosystems and their **management**, with the aim of defining the best practices for the **sustainability and profitability of fungal resources**".

Silviculture & management



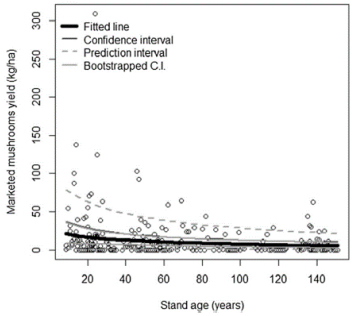
Stand structure and fungal productivity

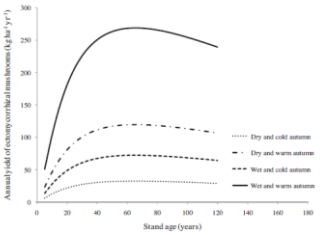
Stand age



Some species present in **both early and late successional stages**: e.g., *Suillus granulatus* in pine forests (Savoie and Largetau, 2011)

In general, sporocarps of mycorrhizal fungi are **more abundant in rather young stands** (Martínez-Peña et al. 2012 Taye et al., 2016)



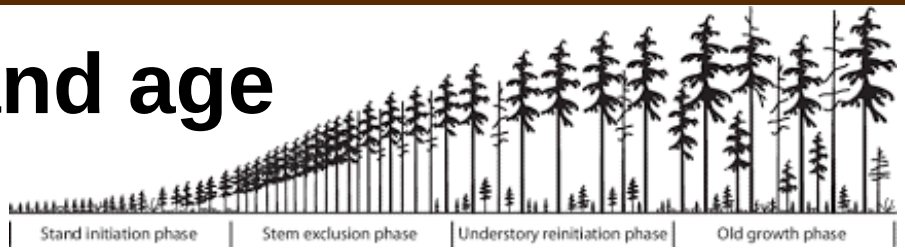


But not always: American Matsutake (*Tricholoma magnivelare*) generally found in **mature stands** that are **more than 70 years old** (Kranabetter et al., 2002, 2005)

Forest management implications: old-growth forests **not necessarily optimal for the delivery of provisioning and cultural ecosystem services**

Stand structure and fungal diversity

Stand age



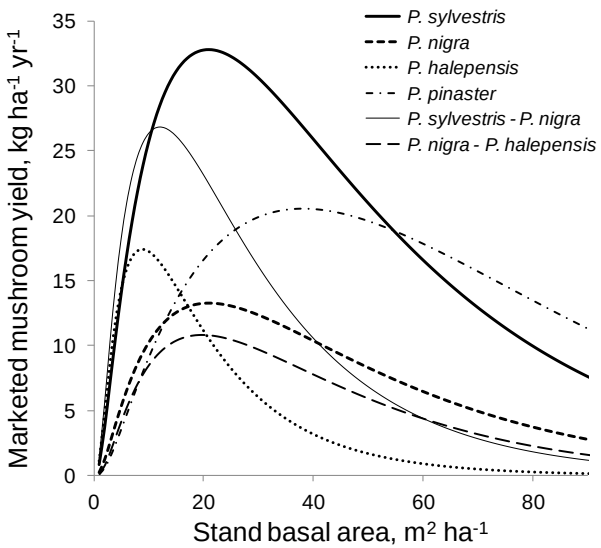
Greater species richness in **mature** closed-canopy forest (Senn-Irlet and Bieri, 1999)

Old-growth forests very important for the conservation of **rare fungal species** (Runnel and Lõhmus 2017, Halme et al. 2017)

Forest management implications: old-growth forests **absolutely crucial for fungal diversity**

Stand density & canopy cover

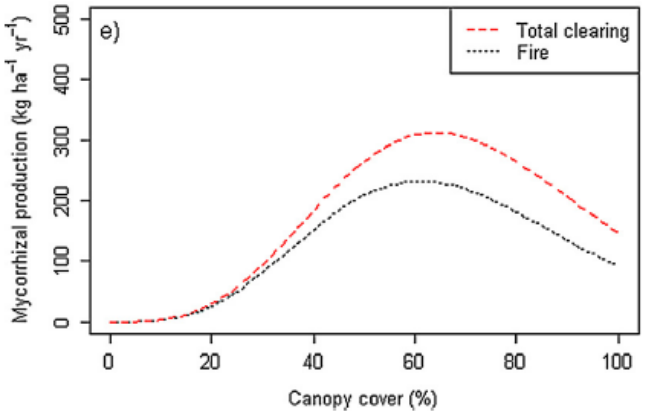




Optimal stand basal areas? (de-Miguel et al. 2014; Tahvanainen et al, 2016)

In general, sporocarps of mycorrhizal fungi are **more abundant in rather open stands** (Hernández-Rodríguez et al., 2015; Martínez-Peña et al. 2012; Salerni & Perini; 2004).





Forest management implications: active forest management

Stand density & canopy cover

Positive relationships between the **diversity** of mycorrhizal fungi and **tree cover** (Villeneuve et al. 1989, Laganà et al. 1999, Santos Silva et al. 2011, Baral et al. 2015)

Greatest species diversity seems to occur under canopy closure (Dighton et al. 1985, Twieg et al. 2007, Spake et al. 2016)

Forest management implications: promote **dense stands** under conditions of **canopy closure** to **enhance fungal diversity**

Tree species composition






Host-tree specificity depending on fungal species (generalists *versus* specialists):

- *Boletus edulis* and *Cantharellus* spp. (generalists)
- *Lactarius deliciosus s.l.* (*Pinaceae*)

Pure versus mixed stands?

- Productivity: unclear, maybe more related to the abundance of certain host trees within the stand (but little scientific knowledge)
- Diversity: fungal species richness above- and belowground increases with tree species diversity (Spake et al. 2016)

Forest management implications: 1) favor target host tree species for fungal productivity, 2) maximize tree diversity to enhance fungal diversity

Thinning

Impact on fungal productivity

Some references: Kropp and Albee (1996), Egli and Ayer (1997) , Shaw et al. (2003), Perini and Salerni (2004), Luoma et al. (2004), Pilz et al. (2006), Egli et al. (2010), Bonet et al. (2012), Tahvanainen et al. (2016)

Thinning reaction may depend on:

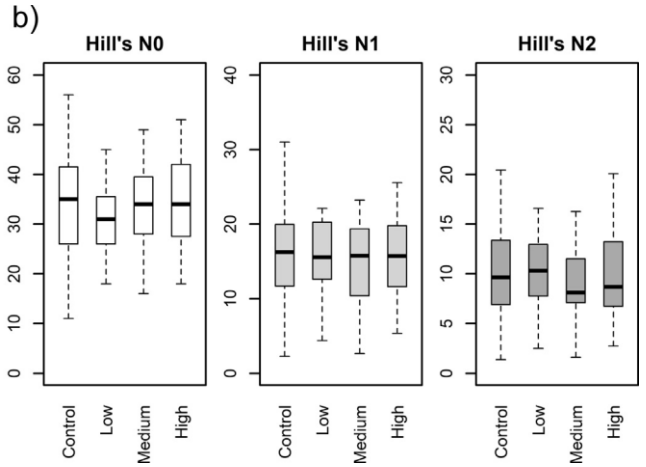
- **Thinning intensity**
- **Time after disturbance**
- **Fungal species**
- **Fungal guild**
- **Soil disturbance**

Impact on fungal diversity

In general, **negative**: decrease of species richness and/or changes in community composition (Baral et al. 2015, Lin et al. 2015, Maghnia et al. 2017, Müller et al. 2007)

… But maybe some positive effects on certain species (stump-related fungi) (Müller et al. 2007, Parisi et al. 2018)

… And **lack of effects belowground** have been reported (Castaño et al. 2018):



Regeneration methods (even-aged)

Peter et al. (2013)
Ágreda et al. (2014)

POSITIVE EFFECT

SHELTERWOOD METHODS

May still produce mycorrhizal fungi

NEGATIVE EFFECT

Kardell & Eriksson (1987)
Ohenoja (1988)
Durall et al. (2006)
Parladé et al. (2017)

CLEARCUTTING

Wait for new cohort…

But maybe some

Pilz et al. (2004)

Role of retention trees on fungal diversity?

Higher fungal diversity in retention forestry as compared to completely clear-cut stands (Luoma et al. 2004, Rosenvald and Lohmus 2008)

… but may be due to forest management-induced changes in environmental conditions at the site level rather than by the continuity of trees (Varenius et al. 2017)

Localised effects

Even-aged *versus* uneven-aged forestry

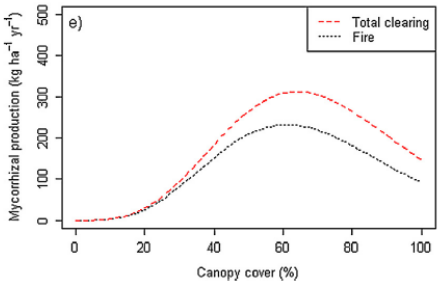
<u>Lack of scientific knowledge</u> about potential differences concerning the impact <u>on fungal productivity</u>

Uneven-aged forestry has lower impact **<u>on fungal diversity</u>**:

- Similar diversity of as in unmanaged forests and higher than in even-aged stands (Purahong et al. 2014, Dove and Keeton 2015)
- But non-negligible forest gap effects (Grebenc et al. 2009, Bassler et al. 2014, De Groot et al. 2016)

Fire: prescribed burning

NEGATIVE EFFECT

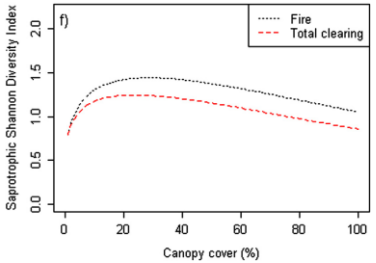


Martín-Pinto et al. (2006), Taudière et al. (2017)
Hernández-Rodríguez et al. (2015)

but may enhance…

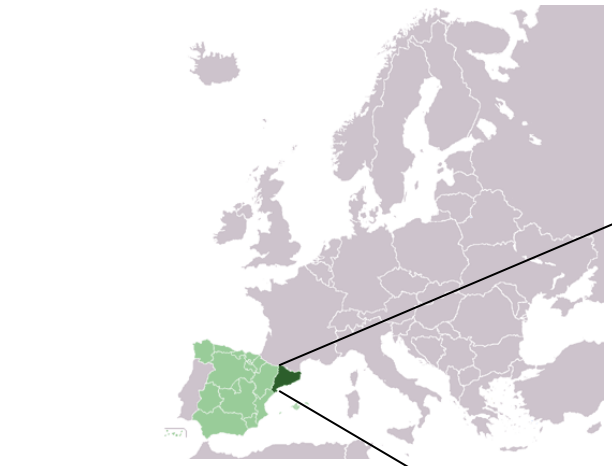
Pilz et al. (2004), Larson et al. (2016)

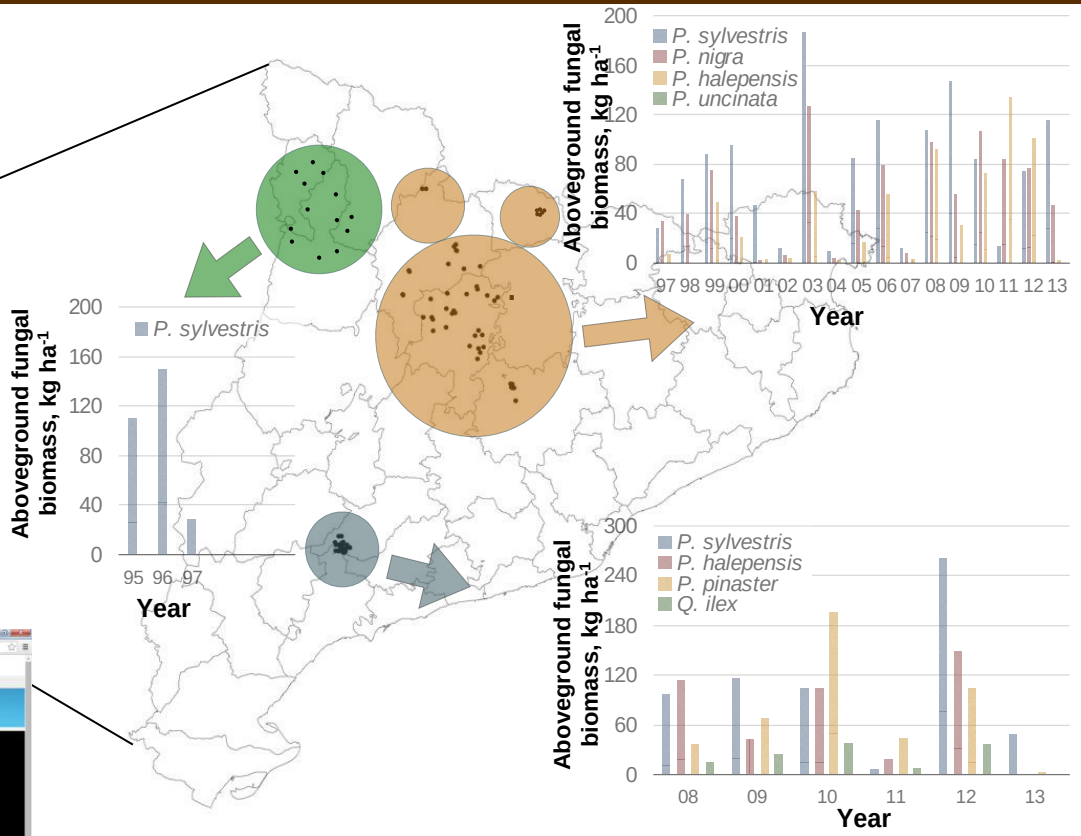
and better for diversity than clearcutting?

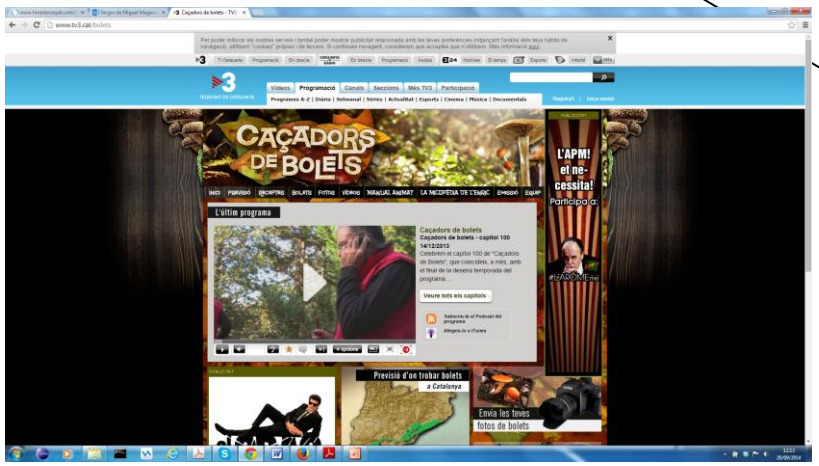


Hernández-Rodríguez et al. (2015)

2. Gaining knowledge on mycosilviculture in Mediterranean forests: our experimental set up





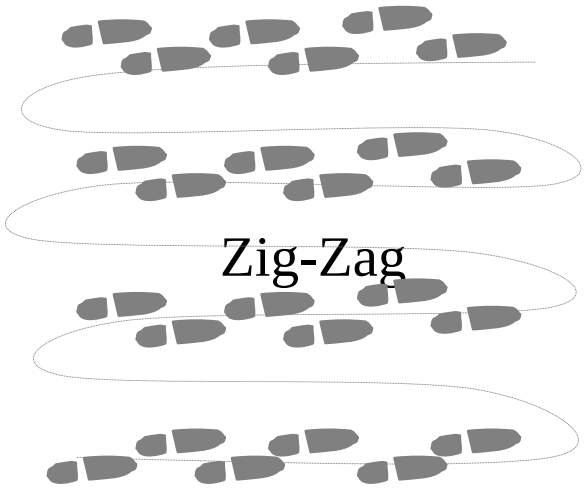


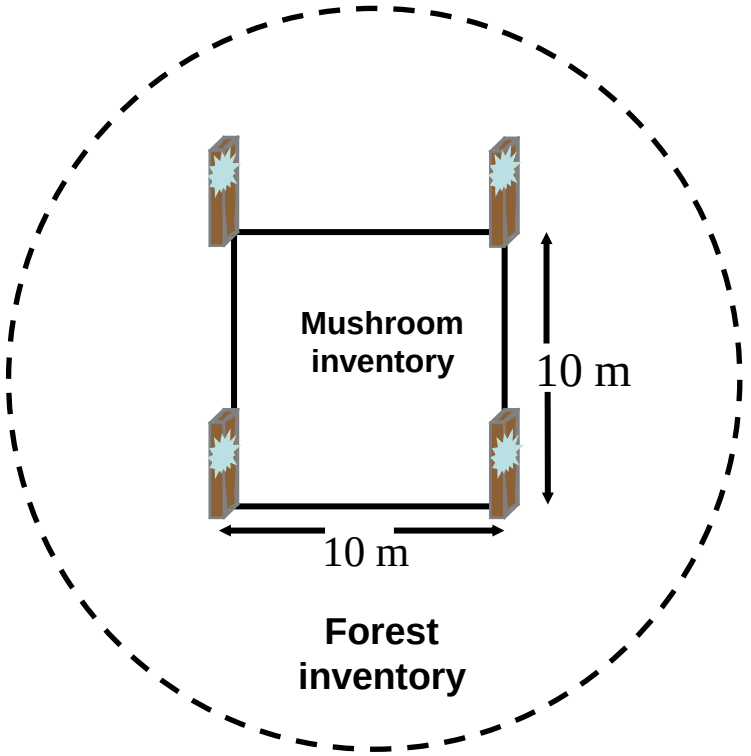
Almost 25% of the population are “mushroom pickers” (at least once a year) = 1.2 million people (adults)

500,000 picking mushrooms more tan 3 times/year (Górriz et al. 2014)

Mushroom monitoring

- Mushrooms are ephemeral
- Continuous inventory: every week, from August until December
- More than 1000 km per week!



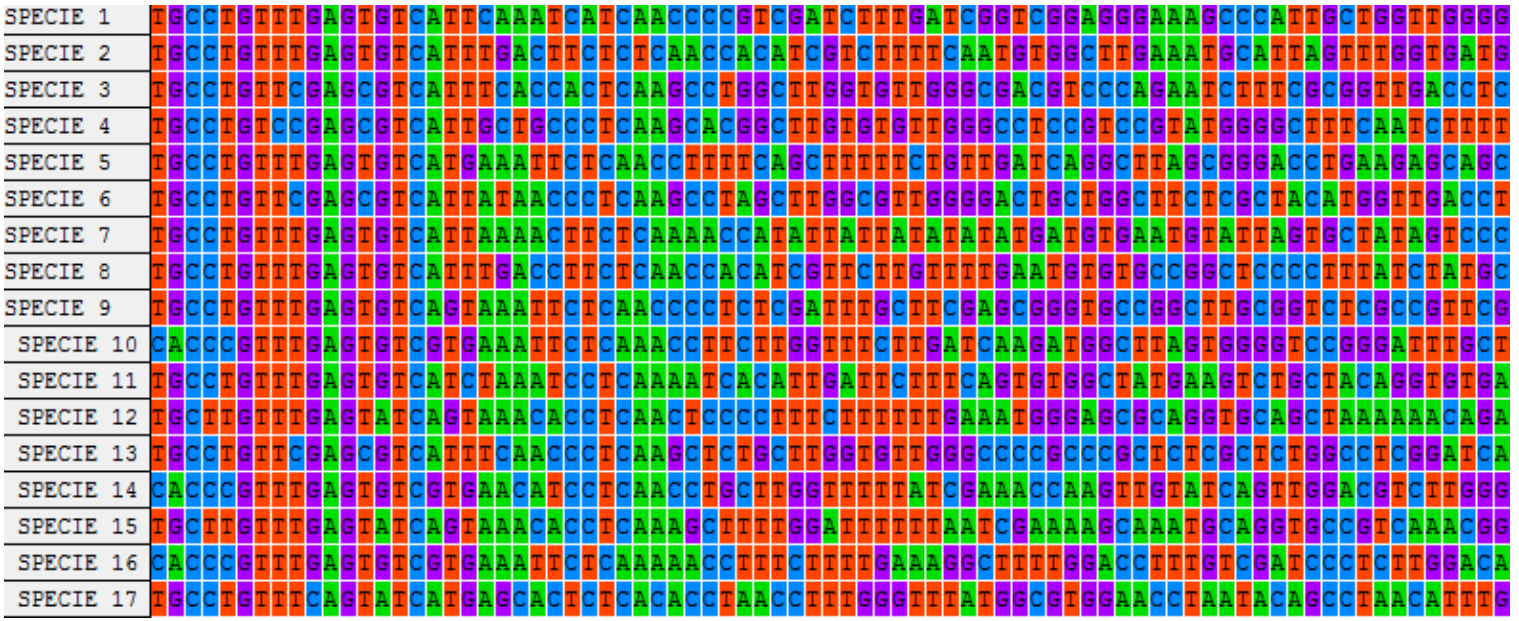


Classification and identification of fungal taxa

Fresh/Dry biomass per species

And also soil sampling…

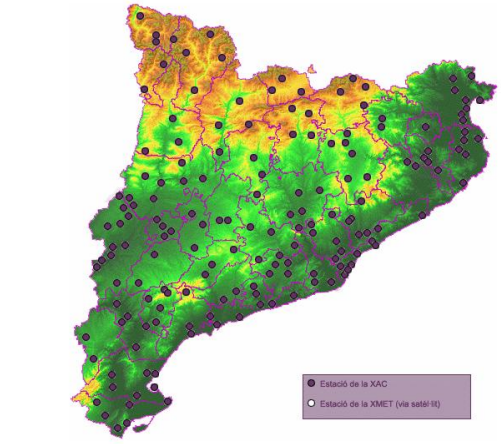
DNA-based methods: Quantification, species identification



- More than 700 species aboveground (i.e., sporocarps)
- Around 4000 OTUs belowground

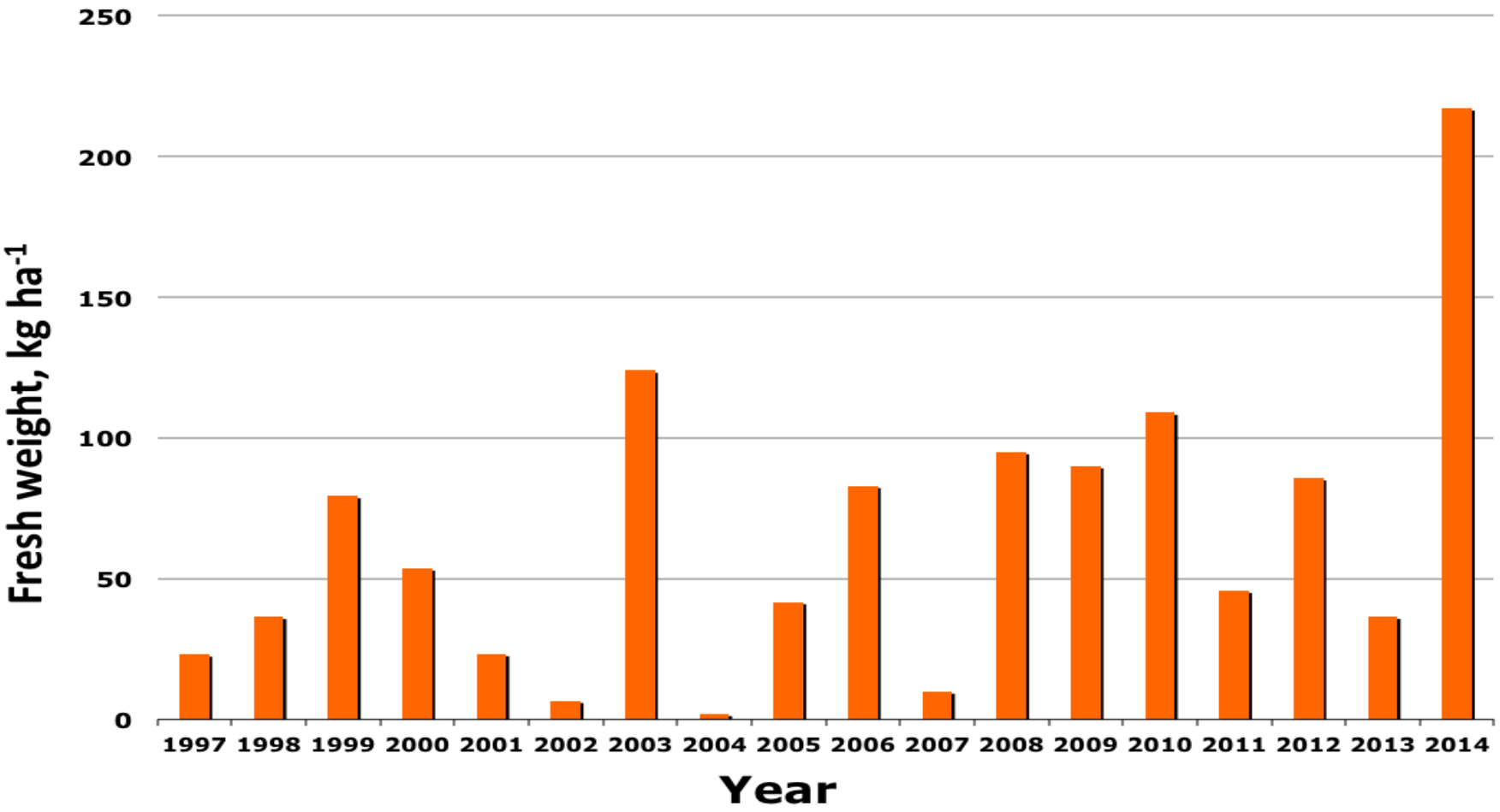
Dendrochronology: tree ring analysis

Recording meteorological conditions



IMPORTANCE OF LONG-TERM DATA SERIES & STUDIES

Huge variability in mushroom yield!



Two approaches…

… to inspect the impact of forest management on fungal diversity and productivity:

1. **indirectly,** by accounting for forest management-induced changes in stand structure (e.g., basal area) based on growth and yield models and simulation/optimization.

2. **directly,** by evaluating the direct impact of the anthropogenic disturbance (i.e. forest thinning) based on thinning experiments.

APPROACH 1

Evaluating the impact of forest management intensity on regional mushroom productivity: a model-based scenario analysis

Forest Ecology and Management 330 (2014) 218–227

Contents lists available at ScienceDirect

Forest Ecology and Management

journal homepage: www.elsevier.com/locate/foreco

Impact of forest management intensity on landscape-level mushroom productivity: A regional model-based scenario analysis

Sergio de-Miguel [a,*], José Antonio Bonet [b,c], Timo Pukkala [a], Juan Martínez de Aragón [c]

[a] Faculty of Science and Forestry, University of Eastern Finland, P.O. Box 111, 80101 Joensuu, Finland
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OBJECTIVE

To develop predictive **mushroom yield models**

in order to assess:

the **impact** of forest management **intensity** on **landscape-level** mushroom **productivity** in Catalonia

using:

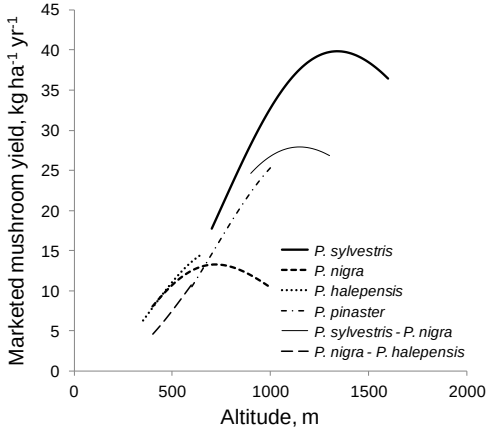
a **model-based scenario** analysis.

Simulation of forest management intensity scenarios

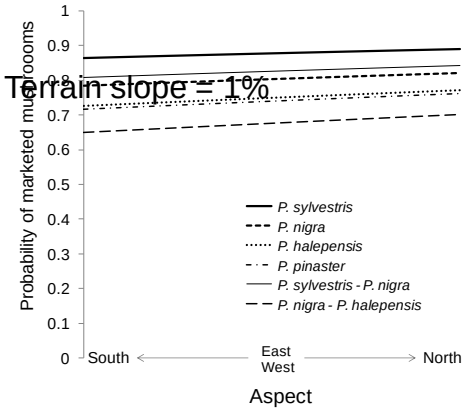
- **Scenario 1 or baseline**: current forest management intensity in Catalonia i.e., felling rate = **25%**,
- **Scenario 2**: absence of forest management i.e., felling rate equal to zero,
- **Scenario 3**: average forest management intensity in Europe i.e., felling rate = **65%**,
- **Scenario 4**: maximum sustained yield i.e., felling rate = **100 %** (annual timber harvesting = annual growth).

Mushroom yield models

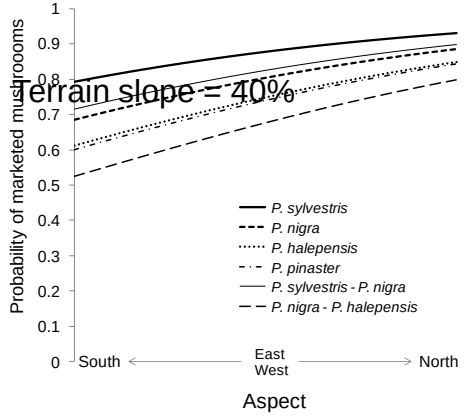
Site conditions



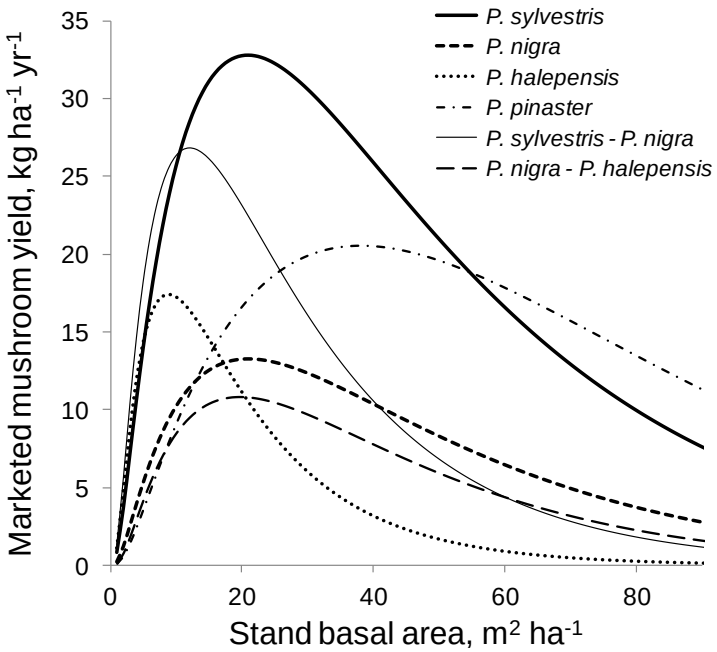
Terrain slope = 1%



Terrain slope = 40%

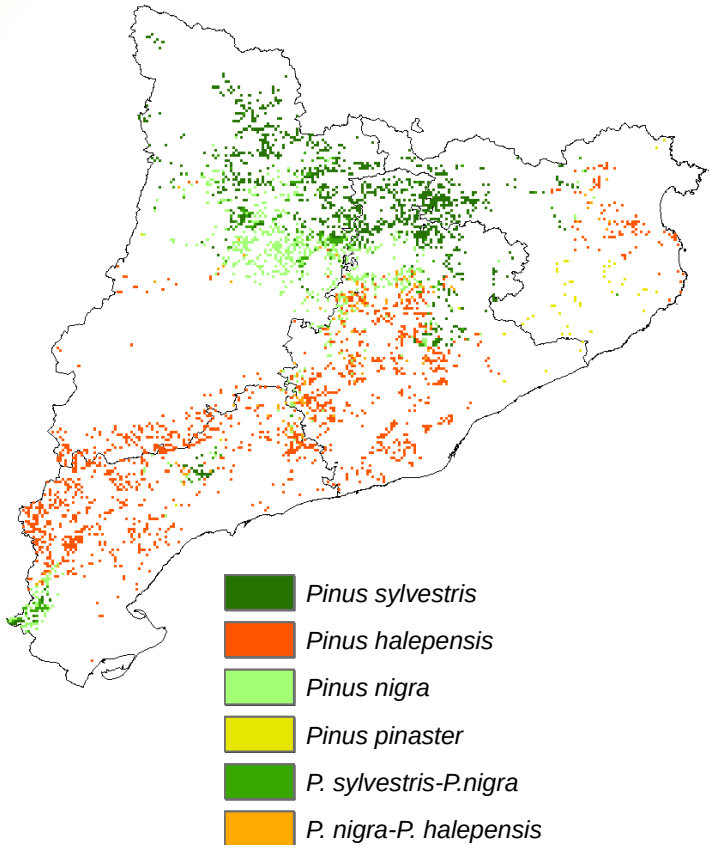


Stand structure

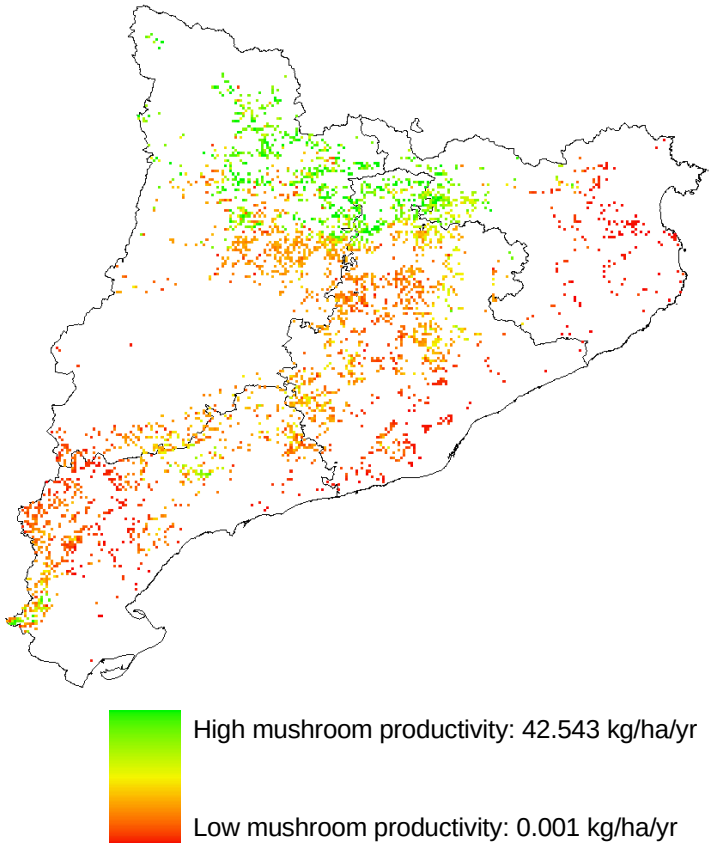


Scaling-up forest management impact on mushroom productivity (de-Miguel et al. 2014)

Distribution of pine forest ecosystems in Catalonia

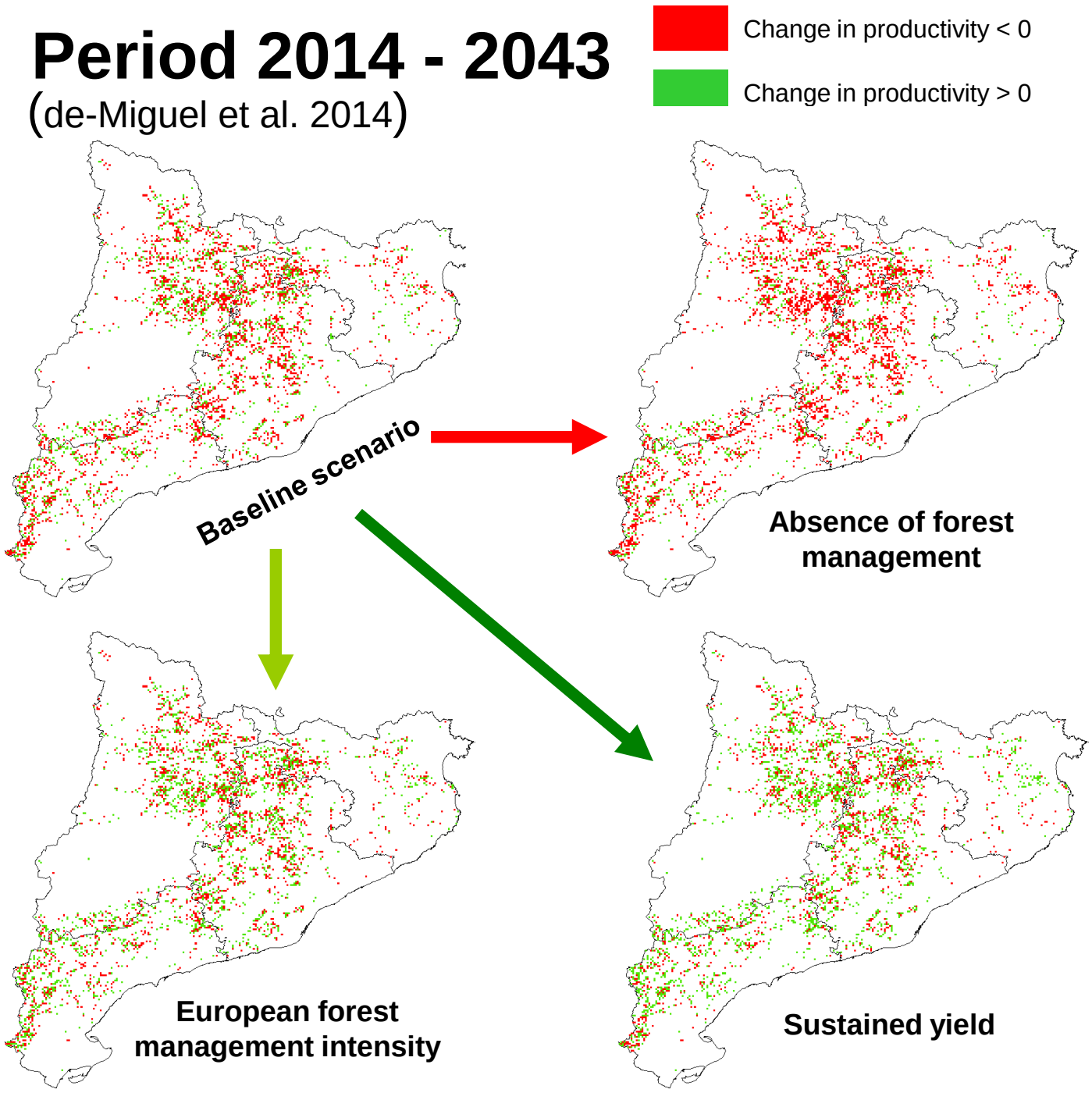


Regional productivity of marketed mushrooms

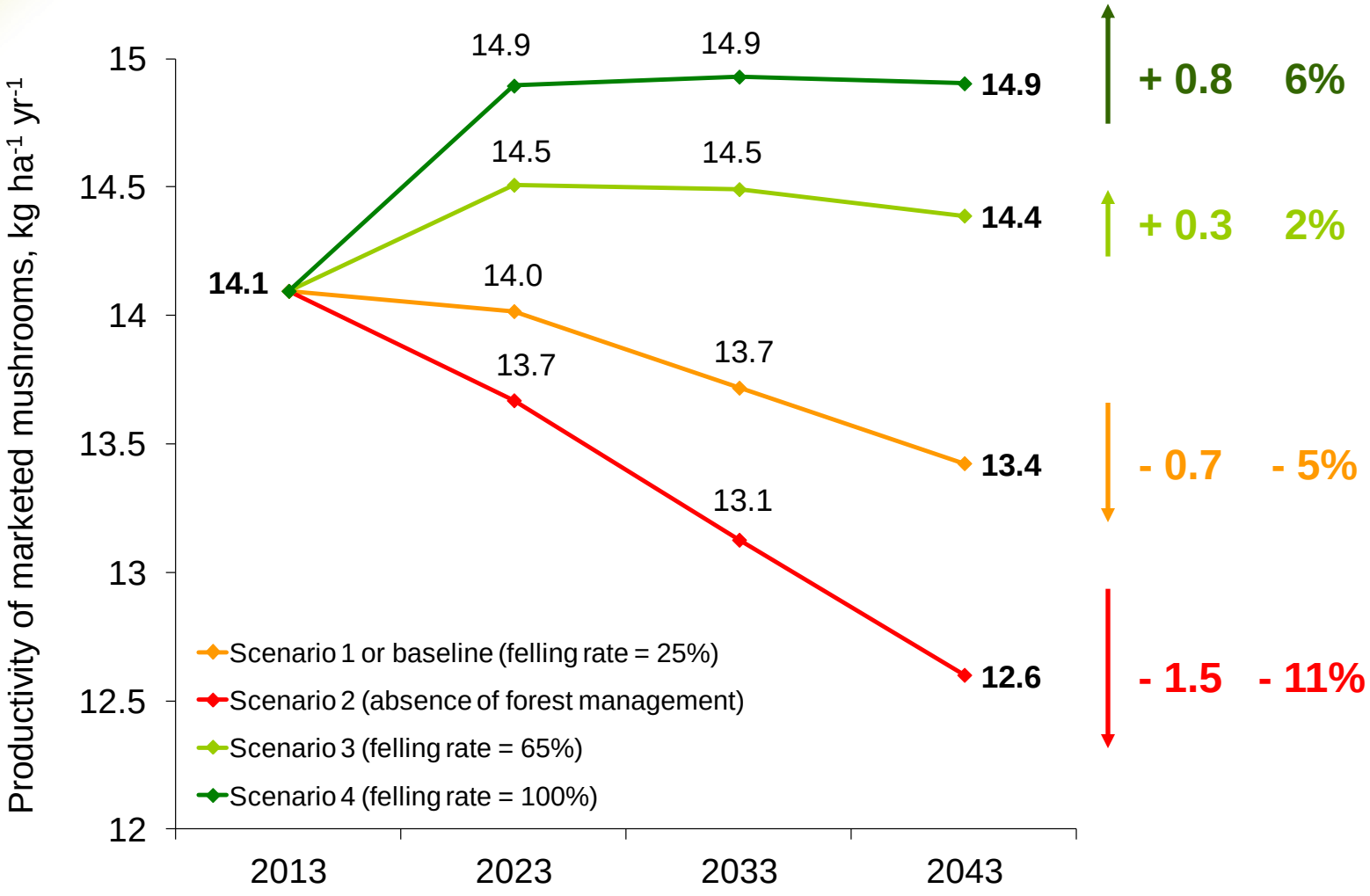


Period 2014 - 2043

(de-Miguel et al. 2014)



Evolution of average regional mushroom productivity in alternative scenarios



APPROACH 2

Findings from thinning experiments

Forest Ecology and Management 265 (2012) 211–217

Contents lists available at SciVerse ScienceDirect

Forest Ecology and Management

journal homepage: www.elsevier.com/locate/foreco

Immediate effect of thinning on the yield of *Lactarius* group *deliciosus* in *Pinus pinaster* forests in Northeastern Spain

J.A. Bonet [a,b,*], S. de-Miguel [c], J. Martínez de Aragón [b], T. Pukkala [c], M. Palahí [d]

[a] Departament de Producció Vegetal i Ciència Forestal, Universitat de Lleida, Av. Rovira Roure, 191, E-25198 Lleida, Spain
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Forest Ecology and Management 422 (2018) 223–232

Contents lists available at ScienceDirect

Forest Ecology and Management

journal homepage: www.elsevier.com/locate/foreco

Linking fungal dynamics, tree growth and forest management in a Mediterranean pine ecosystem

Eduardo Collado[a,*], J. Julio Camarero[c], Juan Martínez de Aragón[b], Juan Pemán[a], José Antonio Bonet[a,b], Sergio de-Miguel[a]

[a] Departament de Producció Vegetal i Ciència Forestal, Universitat de Lleida-Agrotecnio Center (UdL-Agrotecnio), Av. Rovira Roure, 191, E-25198 Lleida, Spain
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Forest Ecology and Management 424 (2018) 420–427

Contents lists available at ScienceDirect

Forest Ecology and Management

journal homepage: www.elsevier.com/locate/foreco

Lack of thinning effects over inter-annual changes in soil fungal community and diversity in a Mediterranean pine forest

Carles Castaño[a,b,*], Josu G. Alday[b], Björn D. Lindahl[c], Juan Martínez de Aragón[d], Sergio de-Miguel[b], Carlos Colinas[b,d], Javier Parladé[e], Joan Pera[e], José Antonio Bonet[b,d]

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Agricultural and Forest Meteorology 248 (2018) 432–440

Contents lists available at ScienceDirect

Agricultural and Forest Meteorology

journal homepage: www.elsevier.com/locate/agrformet

Research paper

Effect of climatic and soil moisture conditions on mushroom productivity and related ecosystem services in Mediterranean pine stands facing climate change

Asaf Karavani[a], Miquel De Cáceres[b,c], Juan Martínez de Aragón[b], José Antonio Bonet[a,b], Sergio de-Miguel[a,*]

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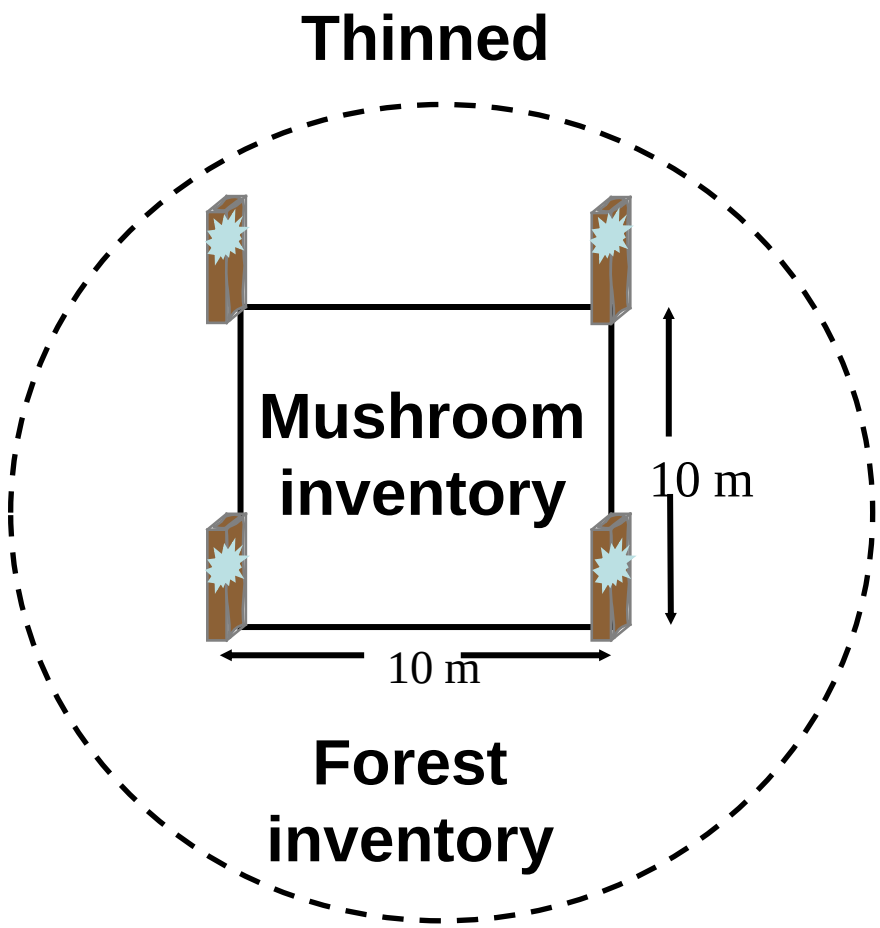
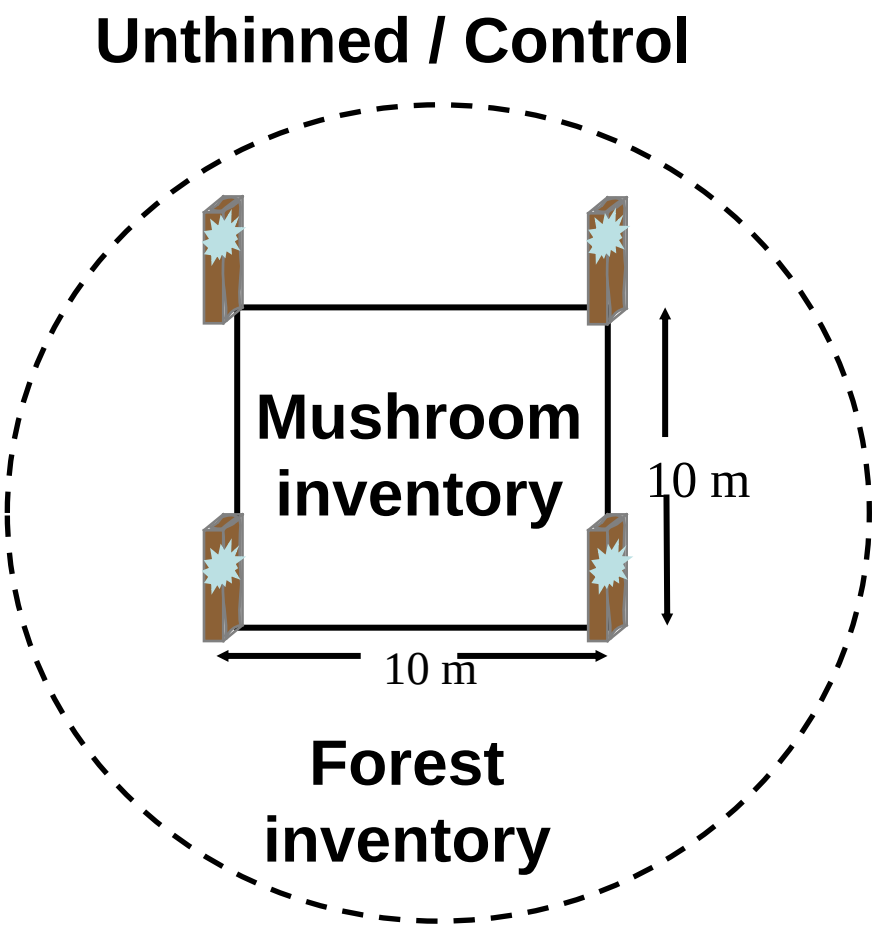
Pinus pinaster: 28 experimental plots (paired-plot design)

Pinus uncinata: 18 experimental plots (paired-plot design)

Thinning intensity gradient: 0 to 90% in stand basal area

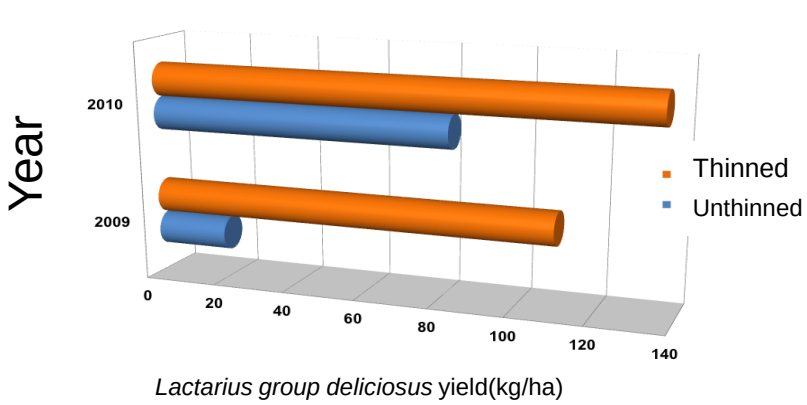




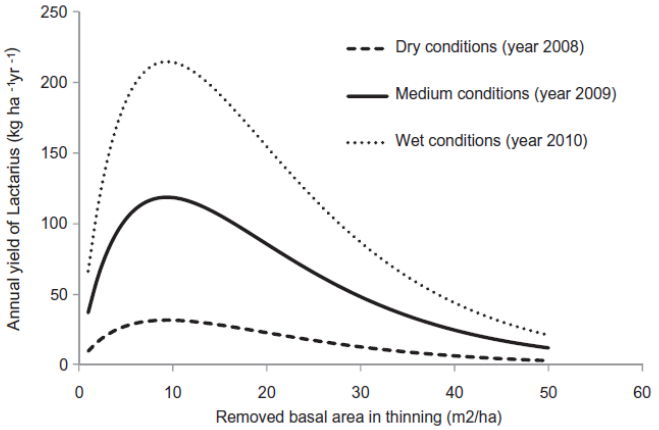
Silvicultural & forest management practices

Thinning

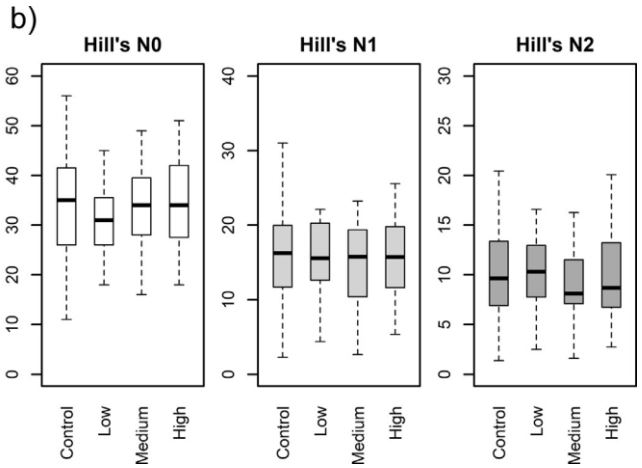
Bonet et al. (2012)



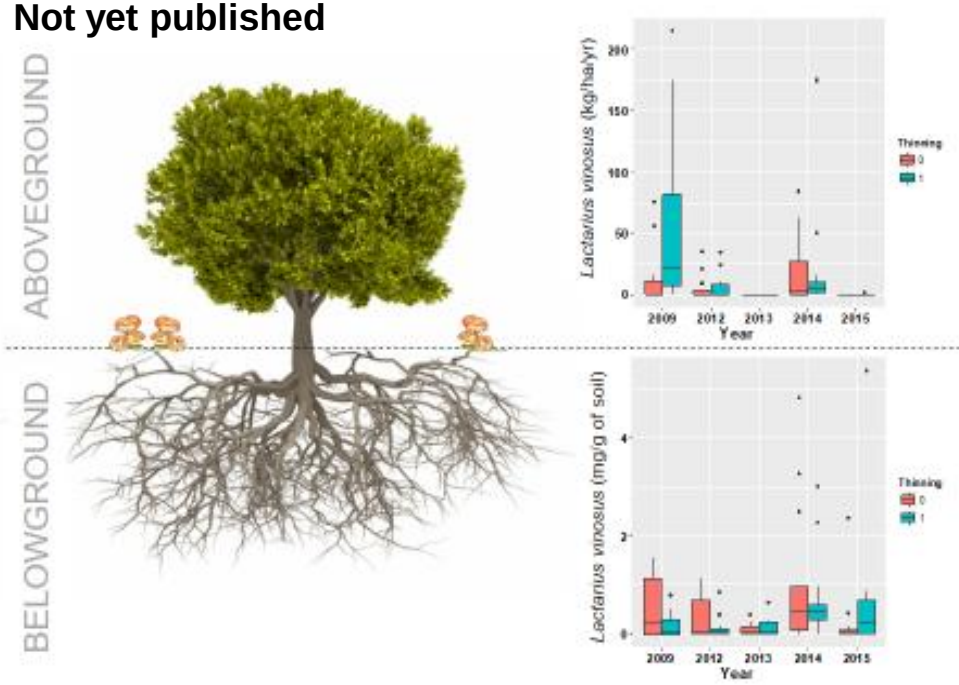
Lactarius group deliciosus yield(kg/ha)



Castaño et al. (2018)

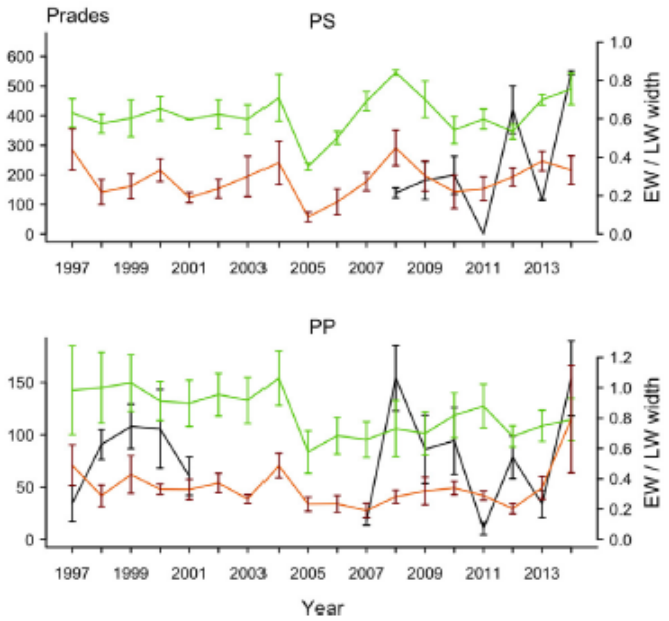


Not yet published

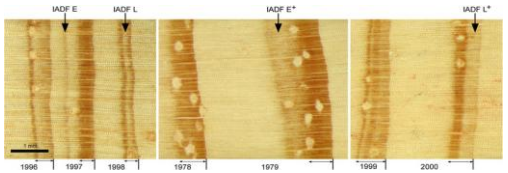


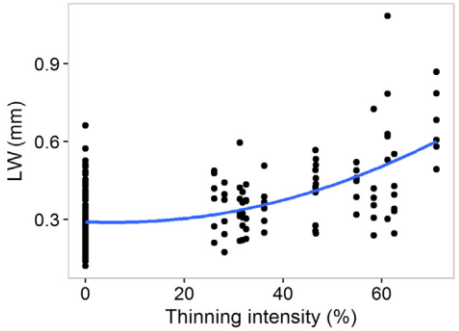
… link with enhanced tree growth

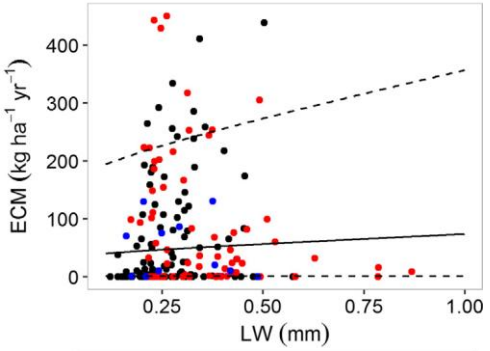
Some **positive relationships** found between mycorrhizal fungal yields, tree growth and thinning intensity (Primicia et al. 2016, Collado et al. 2018).

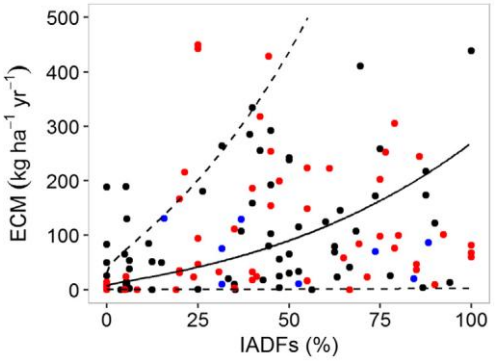


Intra-annual density fluctuations





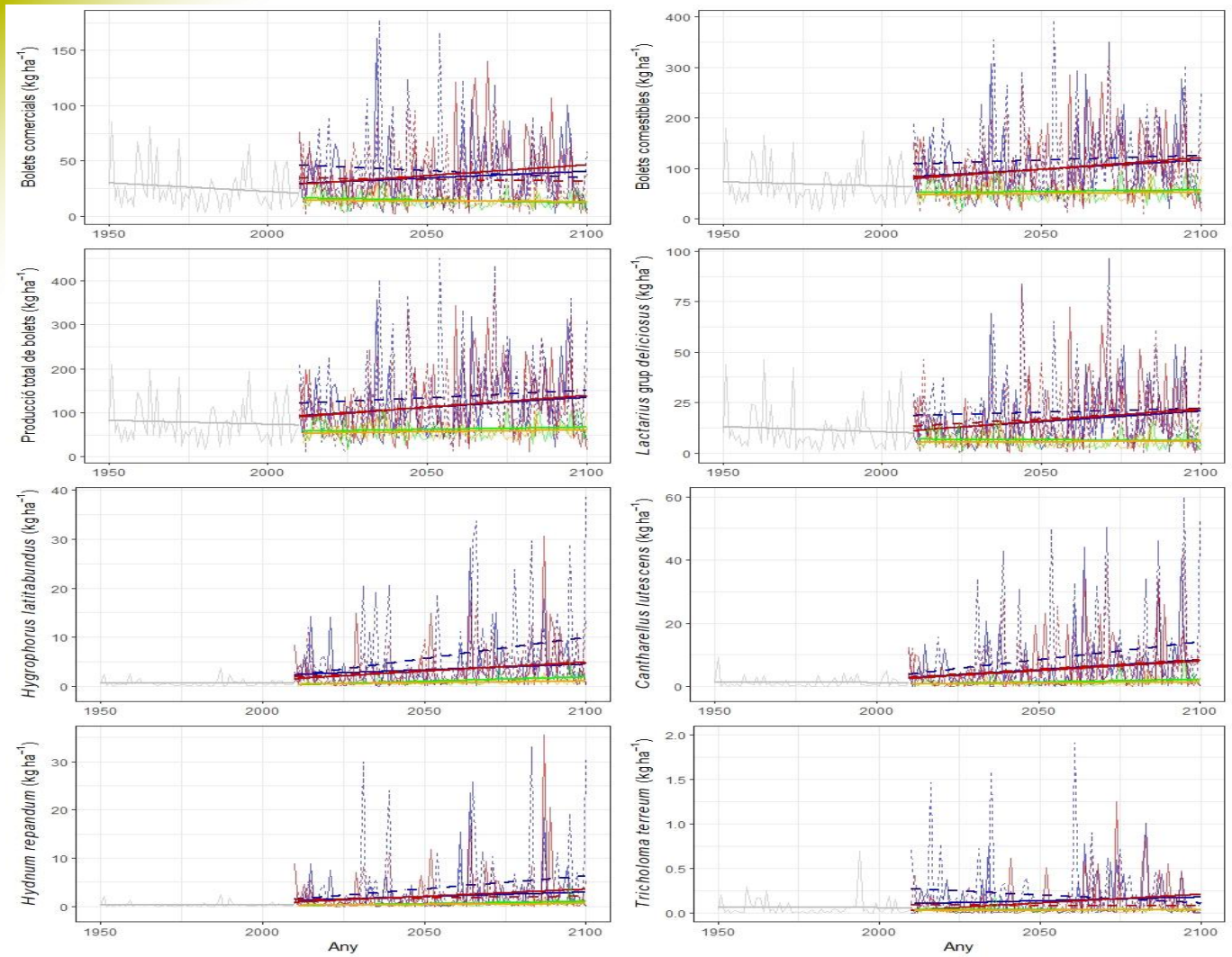




- Saprobic fungi less correlated with tree growth than mycorrhizal fungi

- Lagged effects? Saprobic (similar to Egli et al. 2010)

Current research on the relationship with climate change – Preliminary results



Downscaled Climate Change Scenarios:

- RCP4.5 (solid line)
- RCP8.5 (dashed line)
- A2 (green)
- B2 (orange)

Regional Climate Models:

- RCA4 (blue)
- CCLM4-8-17 (red)

Climate change

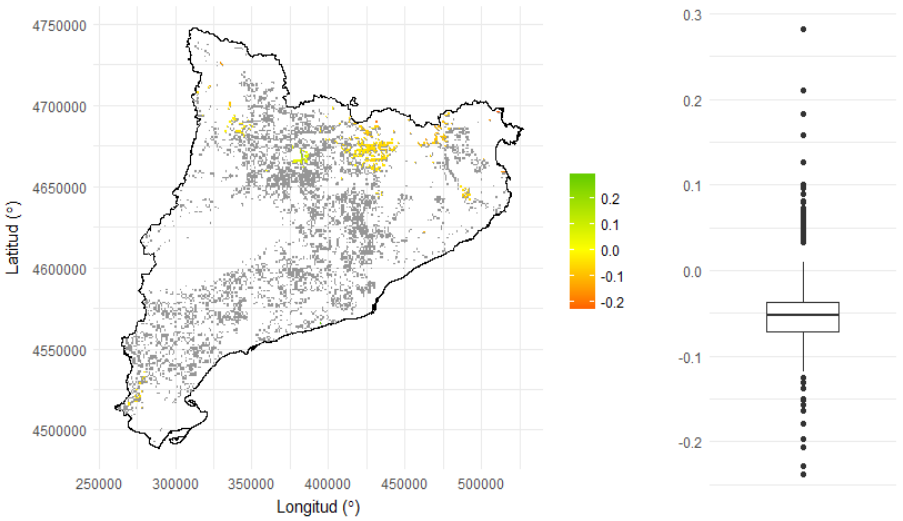


Figura 3 Evolució futura de la producció de *Lactarius* grup *deliciosus* a nivell regional. En el mapa es mostren les variacions significatives (avaluades mitjançant el test de Mann-Kendall) del pendent de la línia de tendència (determinat a partir de la aproximació de Theil-Sen). El diagrama de caixa descriu la distribució de la superfície amb variacions significatives.

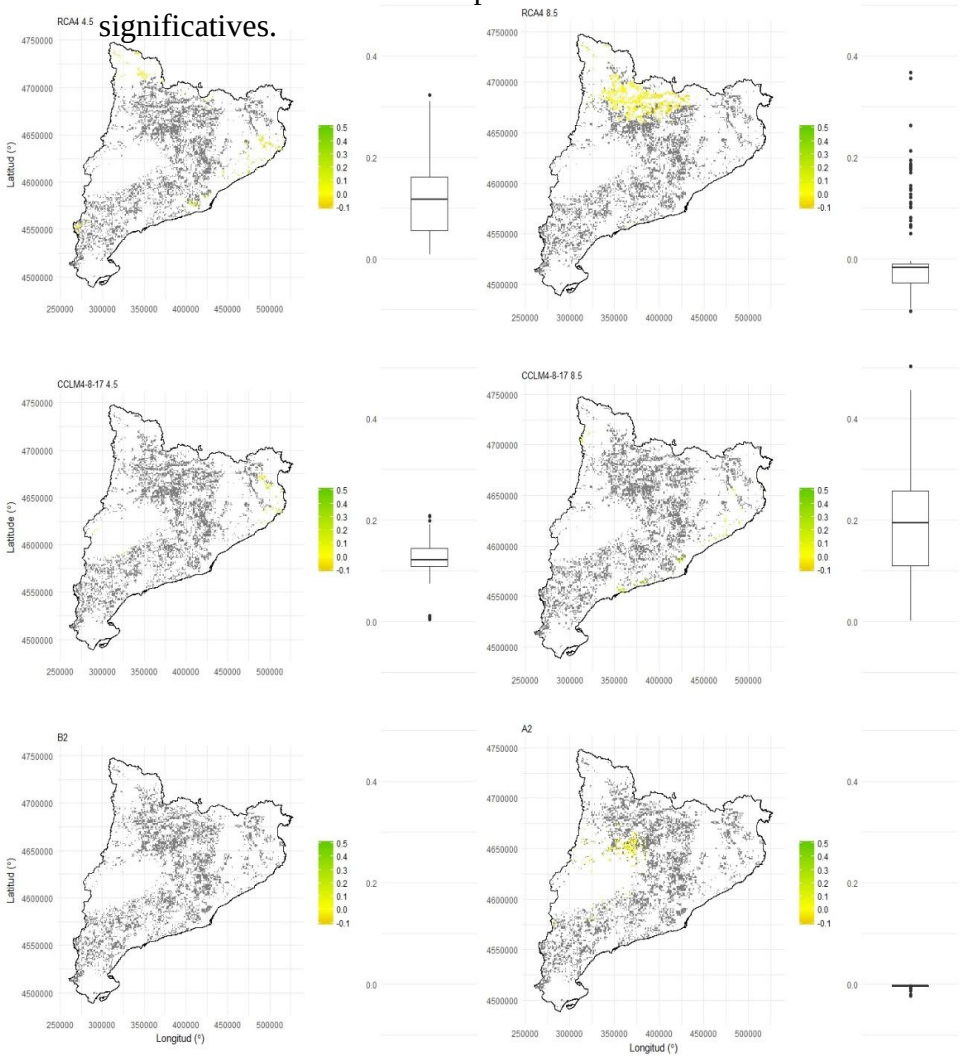


Figura 3 Evolució històrica de la producció de *Lactarius* grup *deliciosus*. Es mostren les variacions significatives (avaluades mitjançant el test de Mann-Kendall) del pendent de la línia de tendència (determinat a partir de la aproximació de Theil-Sen). El diagrama de caixa descriu la distribució de la superfície amb variacions significatives.

Climate change & forest management schedules - preliminary

BAU

Pinassa (Pn06)

Edad	Tipo	%N	%AB
20	Clareo	50	50
35	Clara	35	25
60	Clara	35	25
85	Clara	35	25
115	Prep.	45	45
125	Disem.	50	50
135	Final	100	100

CAR – Carbon sequestration

Pinassa (Pn06-t.llarg)

Edad	Tipo	%N	%AB
20	Clareo	50	50
35	Clara	35	25
60	Clara	35	25
85	Clara	35	25
115	Clara	35	25
150	Prep.	45	45
160	Disem.	50	50
170	Final	100	100

Pinassa (Pn10)

Edad	Tipo	%N	%AB
30	Clareo	55	55
90	Clara	45	35
270	Prep.	50	50
280	Disem.	60	60
290	Final	100	100

BIO – Biomass production

Pinassa (Pn06 modif.)

Edad	Tipo	%N	%AB
20	Clareo	60	60
35	Clara	45	35
55	Clara	45	35
70	Disem	50	50
80	Final	100	100

Pinassa (Pn09 modif.)

Edad	Tipo	%N	%AB
35	Clareo	55	55
55	Clara	50	35
70	Prep.	50	50
80	Disem.	50	50
90	Final	100	100

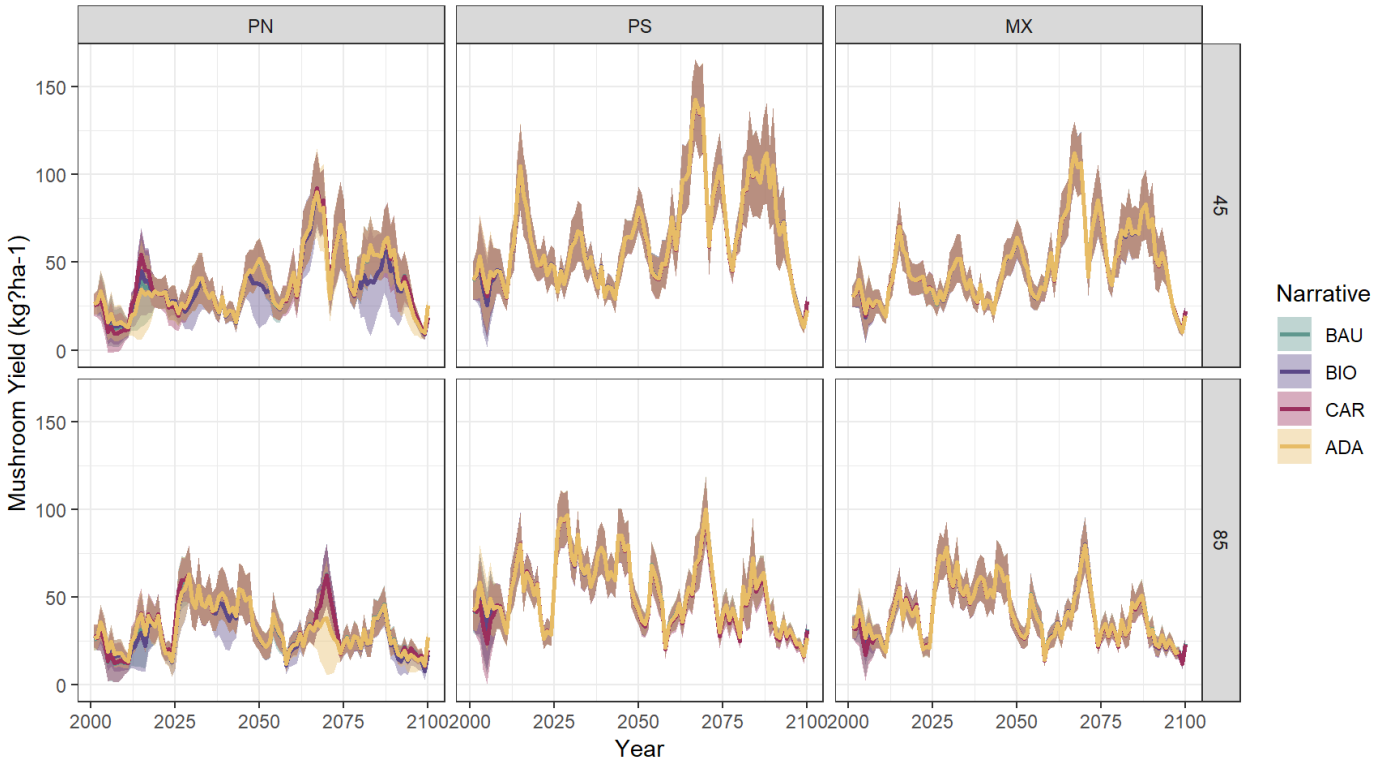
ADA – Adaptation

Pinassa (Pn06-mod)

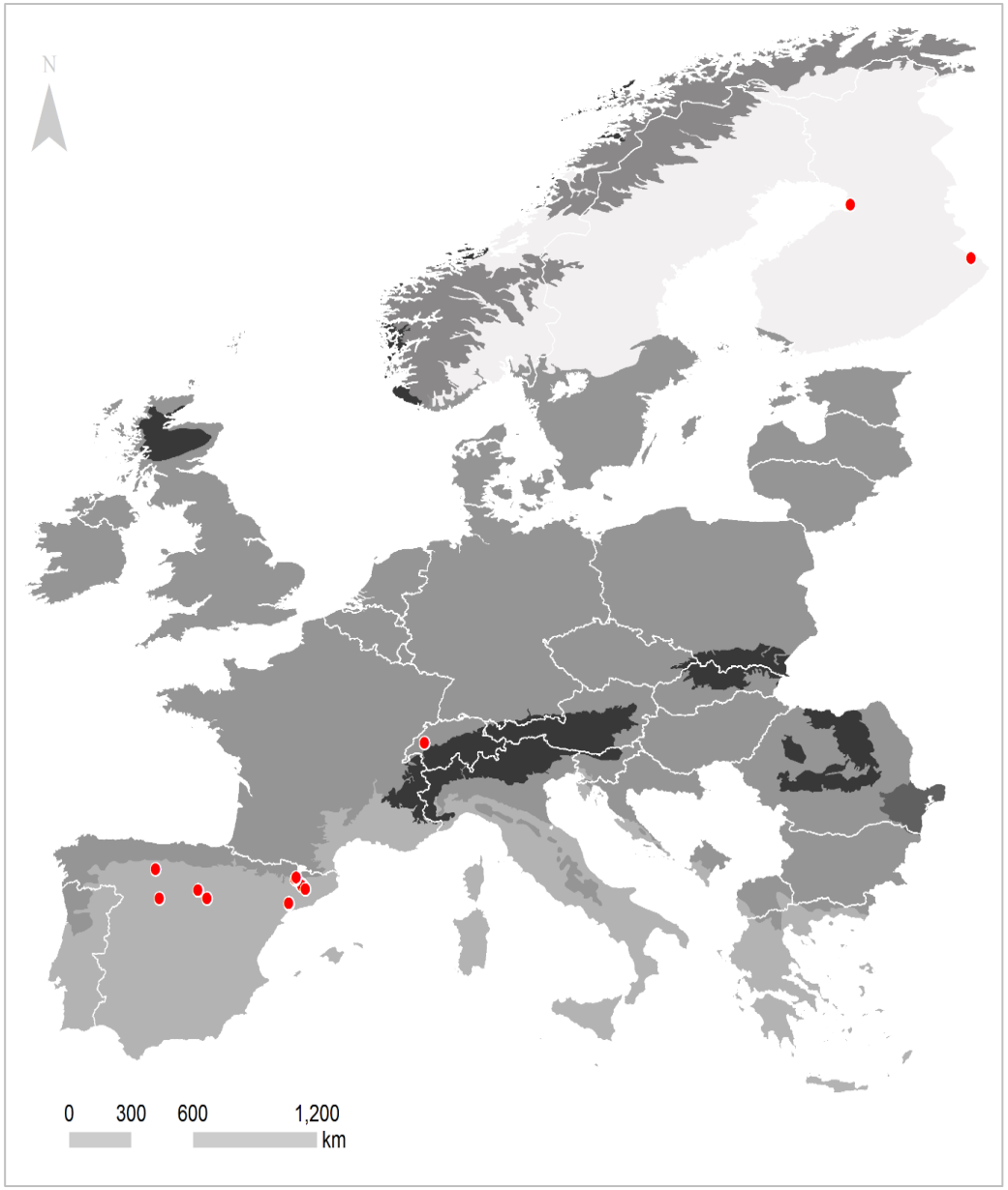
Edad	Tipo	%N	%AB
20	Clareo	50	50
40	Clara	45	35
60	Clara	45	35
115	Prep.	45	45
125	Disem.	50	50
135	Final	100	100

Pinassa (Pn06-mod)

Edad	Tipo	%N	%AB
20	Clareo	50	50
40	Clara	55	45
60	Clara	55	45
115	Prep.	45	45
125	Disem.	50	50
135	Final	100	100



Scaling up at the continental level – coming research



Conclusions

- Fungi is a highly diverse and **cryptic kingdom**: difficult/costly to study their dynamics and management (mainly under field conditions)
- At the end of the day, not much really known about fungal dynamics & forest management (**huge opportunities for ground-breaking research**)
- Still, we know a few things:
  - **Silviculture can enhance (or reduce)** the provision of fungal ecosystem services and biodiversity (sometimes conflicting objectives)
  - Different **fungal species may react differently** to silvicultural treatments
  - Therefore, **avoid general recommendations** about “mushrooms” or “fungi”, but rather need to **develop and rely on species- and ecosystem-specific guidelines**

Further research… a vast territory to be explored!

- Even-aged *vs.* uneven-aged forestry? Impact of **forest management alternatives**
- **Mixed versus pure** stands? Impact of tree diversity
- Improved knowledge on **aboveground & belowground** fungal dynamics & drivers
- **Species-specific** responses to disturbance and management
- **Mechanistic** approaches to further understand fungal dynamics and responses
- Impact of **global change**, etc., etc., etc.

Grazie mille!

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Universitat de Lleida