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Ecological Resilience of Mediterranean Forests to Climate Change and Wildfires

Consiglio Nazionale delle Ricerche
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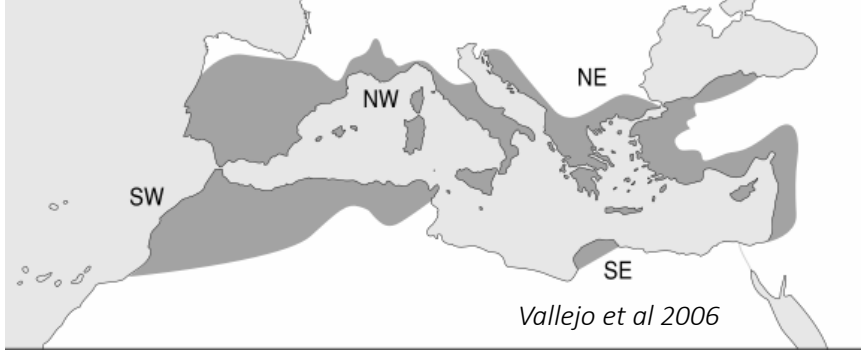
Ministero dell'Università e della Ricerca
Italiadomani PIANO NAZIONALE DI RIPRESA E RESILIENZA
NATIONAL BIODIVERSITY FUTURE CENTER

Plant traits and fire

- **Climatic factors** (wind, temperature, dryness..) are the most commonly studied
- Role of **plant species characteristics**: **ecosystem flammability** and **fuel load** are the most evident and well-studied aspects of plant influence on fire regime.
- Not much attention has been devoted to the effects of plant traits associated with **fire adaptation and post-fire response** on fire and ecosystems

Photograph taken by Prof. Eelco Rohling



Vallejo et al 2006

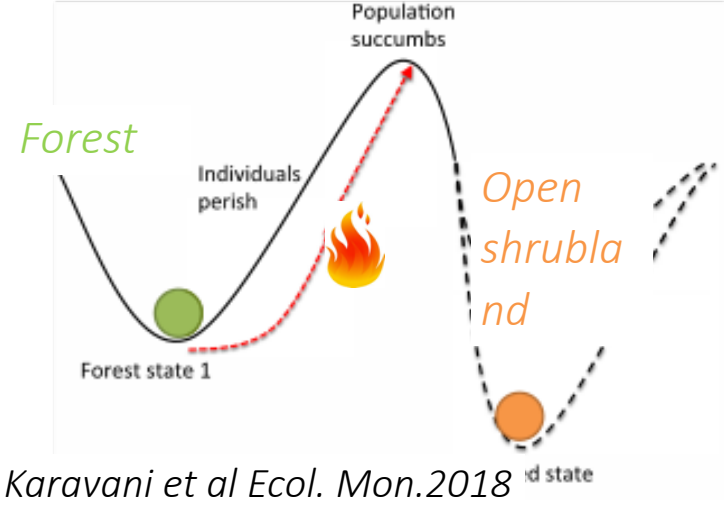
Resilience of Mediterranean Forest: fires and land abandonment

Agricultural land abandonment

Pines,shrubs and grasses

?

Oak forests (broad leaved, sclerophyllous forest)

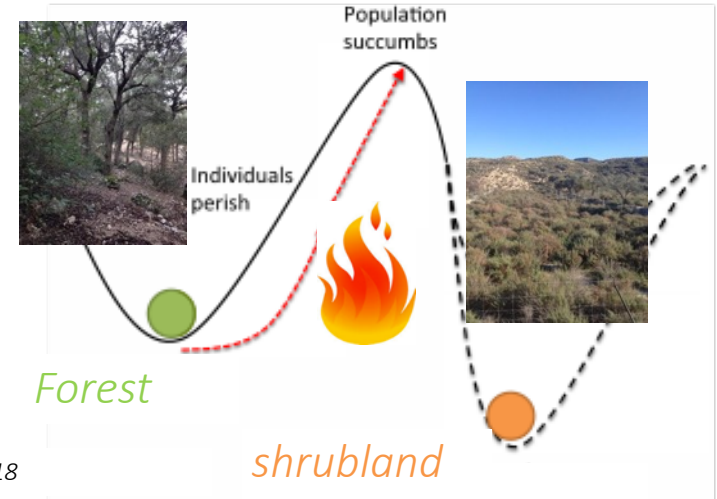


Karavani et al Ecol. Mon.2018

Open shrubland (degraded)

Catastrophic shifts in Mediterranean forests?

Can fires and aridity maintain the open shrubland as an alternative state to the oak forest?



Karavani, et al.2018

A modeling approach: ingredients

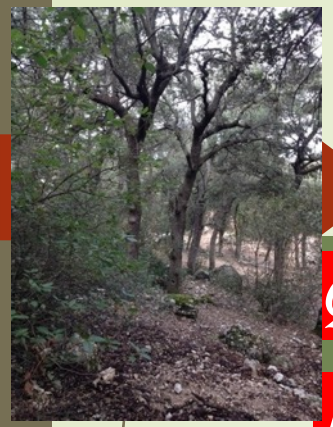
1- A classical model for competition and succession (Tilman 1994)

2-Fire:

- *different functional types (seeders/resprouters; flammability)*
- *stochastic fire occurrence (with vegetation-fire feedback)*

Calibration with data from: old-fields (no fire) or from sites with repeated fires

Baudena et al, 2020, New Phytologist



2-

Fire

RESPROUTERS

Quercus

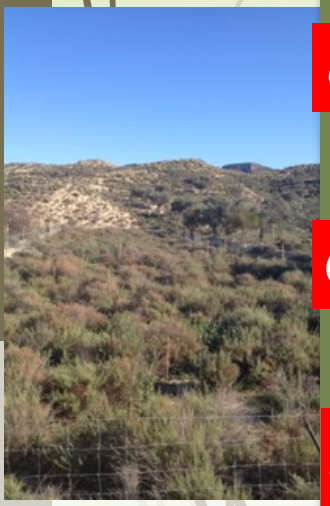
$$\frac{db_1}{dt} = c_1 b_1 (1 - b_1) - m_1 b_1$$

Pinus halepensis

$$\frac{db_2}{dt} = c_2 b_2 (1 - b_1 - b_2) - m_2 b_2 - c_1 b_1 b_2 + \alpha_2 (1 - \sum_{i=1}^{6} b_i)$$

Rosmar.

$$\frac{db_3}{dt} = c_3 b_3 (1 - \sum_{i=1}^{3} b_i) - m_3 b_3 - (c_1 b_1 + c_2 b_2) b_3 + \alpha_3 (1 - \sum_{i=1}^{6} b_i)$$



Ulex

$$\frac{db_4}{dt} = c_4 b_4 (1 - \sum_{i=1}^{4} b_i) - m_4 b_4 - (\sum_{i=1}^{3} c_i b_i) b_4 + \alpha_4 (1 - \sum_{i=1}^{6} b_i)$$

Cystus

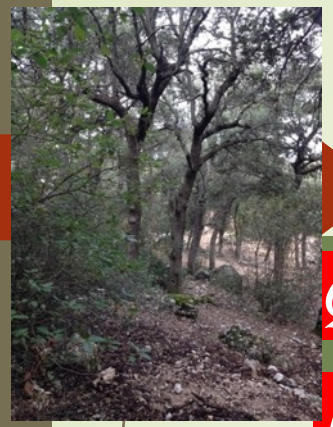
$$\frac{db_5}{dt} = c_5 b_5 (1 - \sum_{i=1}^{5} b_i) - m_5 b_5 - (\sum_{i=1}^{4} c_i b_i) b_5 + \alpha_5 (1 - \sum_{i=1}^{6} b_i)$$

Brachipod. retusum

$$\frac{db_6}{dt} = c_6 b_6 (1 - \sum_{i=1}^{6} b_i) - m_6 b_6 - (\sum_{i=1}^{5} c_i b_i) b_6$$

SEEDERS

Baudena et al, 2020



2-

Fire

RESPROUTERS

Quercus

Pinus halepensis

Rosmar.

Ulex

Cystus

Brachipoa. retusum

$$\frac{db_1}{dt} = c_1 b_1 (1 - b_1) - m_1 b_1$$

$$\frac{db_2}{dt} = c_2 b_2 (1 - b_1 - b_2) - m_2 b_2 - c_1 b_1 b_2 + \alpha_2 (1 - \sum_{i=1}^{6} b_i)$$

$$\sum_{i=1}^{6} b_i)$$

$$b_i)$$

$$b_i)$$

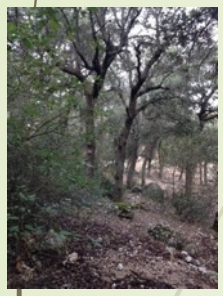
$$\frac{db_6}{dt} = c_6 b_6 (1 - \sum_{i=1} b_i) - m_6 b_6 - (\sum_{i=1} c_i b_i) b_6$$

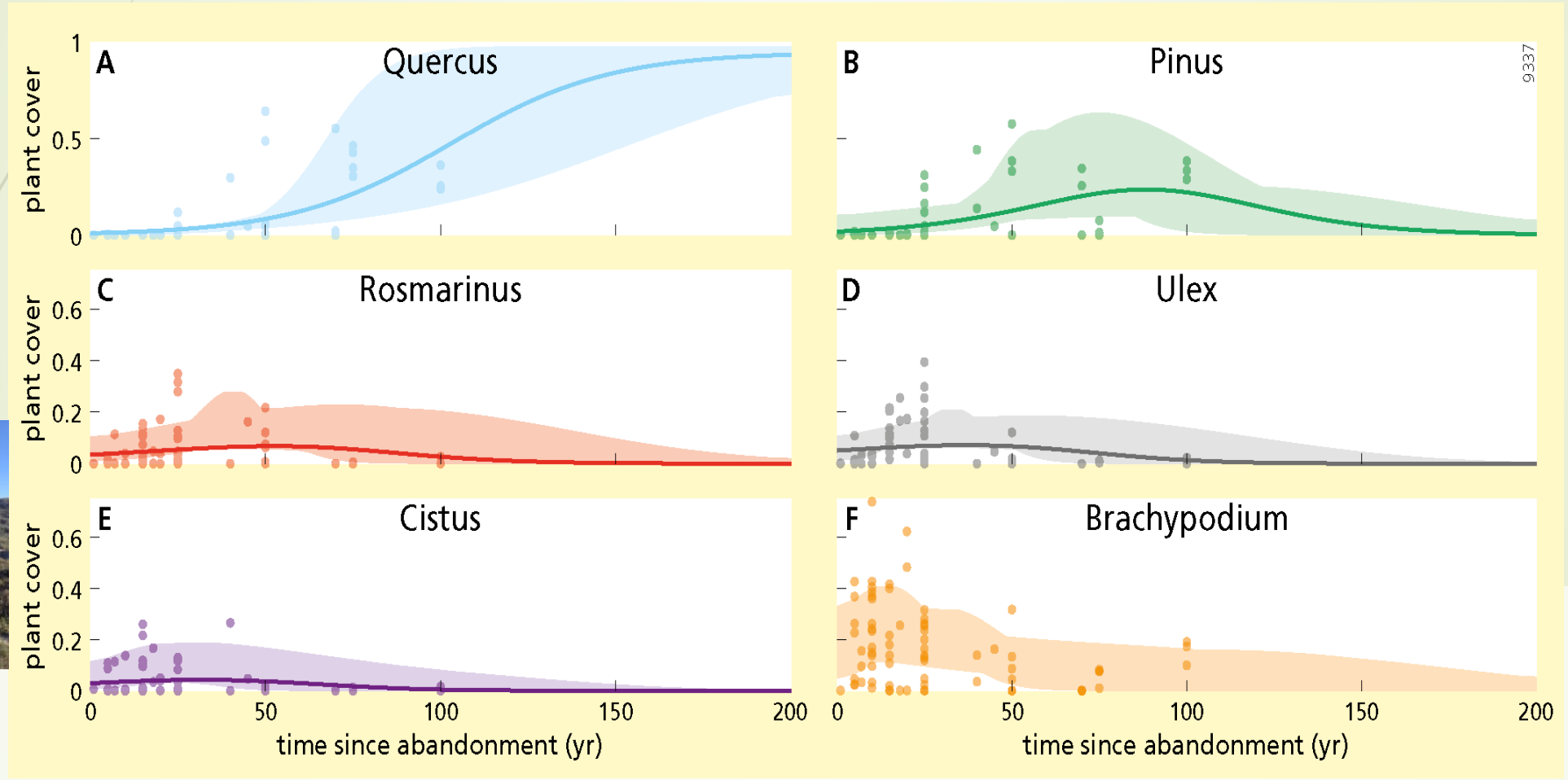
Stochastic fire:
Exponential distribution of frequencies, whose average is determined by plant composition:
Vegetation-fire feedback

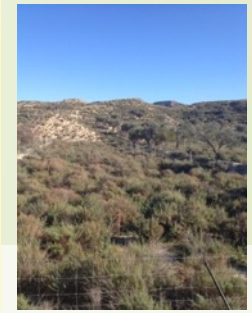
SEEDERS

Baudena et al, 2020

Oak forest if no fire…





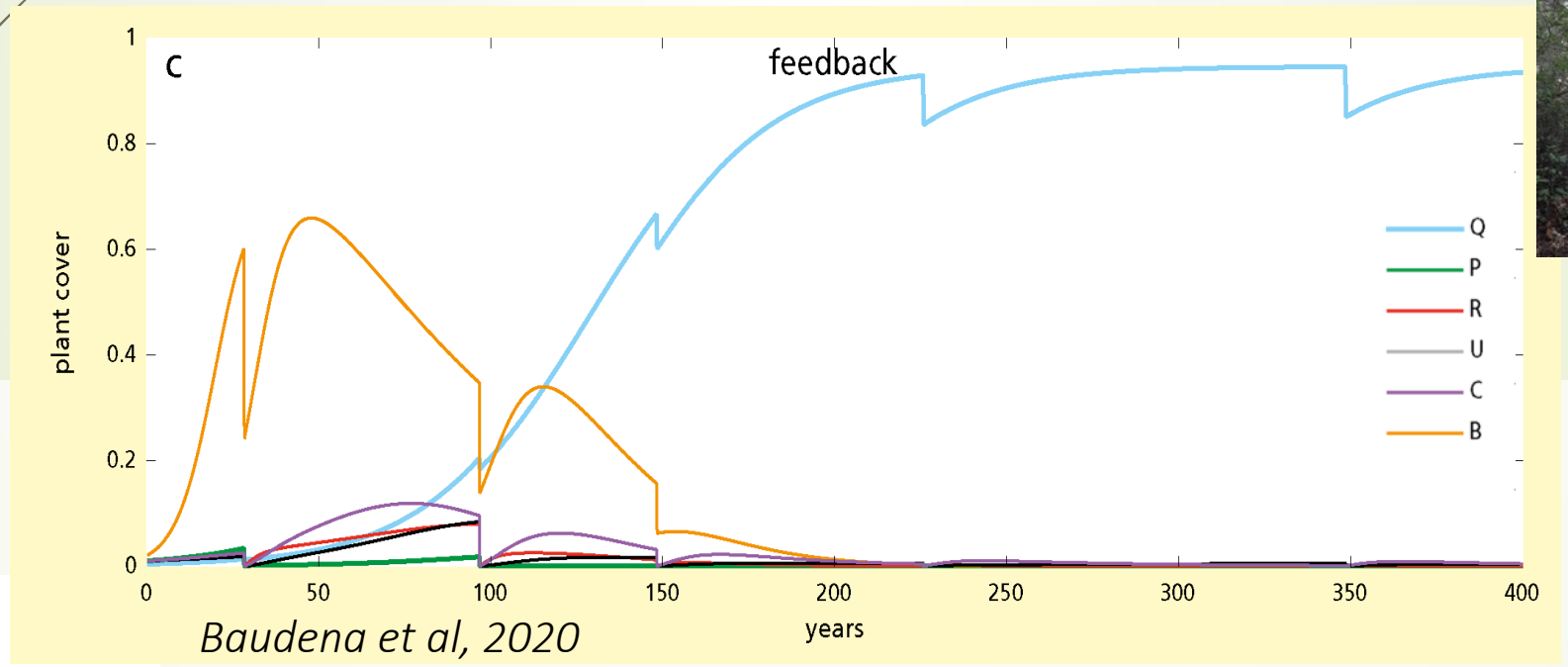


Baudena et al, 2020

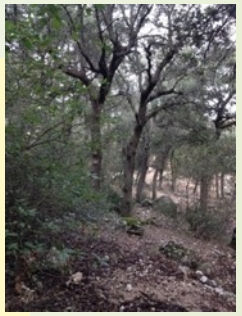
Results

Can fire lead to a state shift?

In the long run: it seems it can't..
oak forest recovers and dominates



Baudena et al, 2020



What about climate change?

Fire

Aridity increase affects growth and flammability

In the model (and in reality):

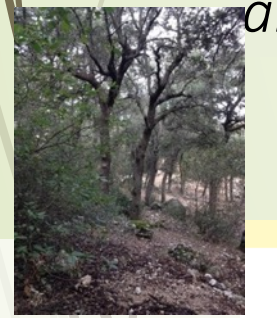
- Directly:
  - Decreases germination and establishment (competitive ability) especially of late successional species;
  - Diminishes resprouting ability
- Indirect effect: increases the chance of fire

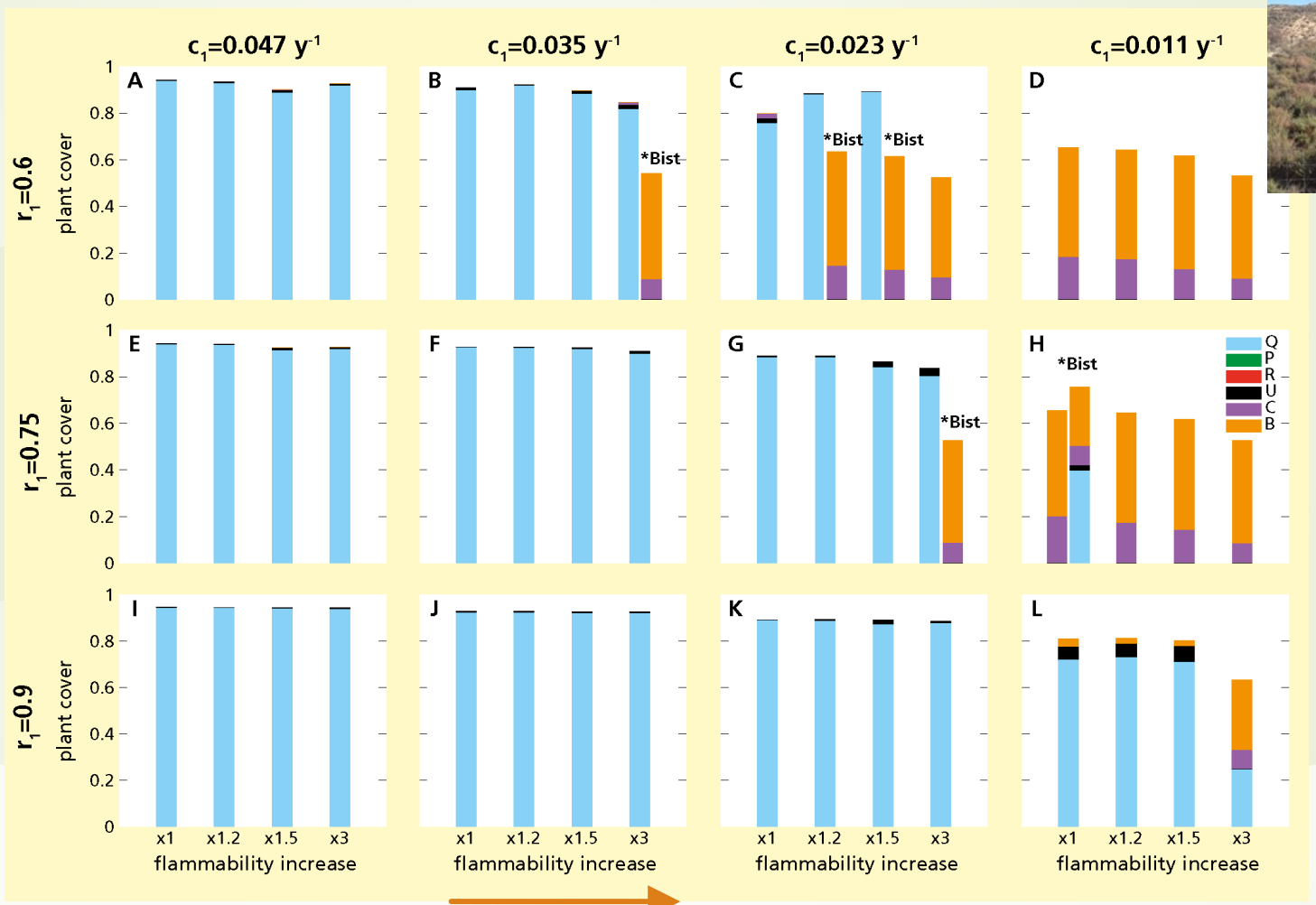
Baudena et al, 2020

Fire

Aridity-1: decreasing oak colonization ability

Aridity-2 decreasing oak resprouting ability





Aridity-3: increasing flammability

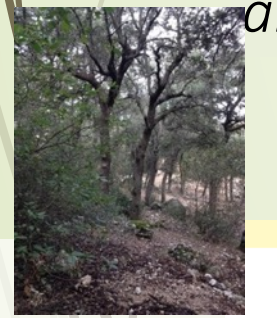
Average plant cover

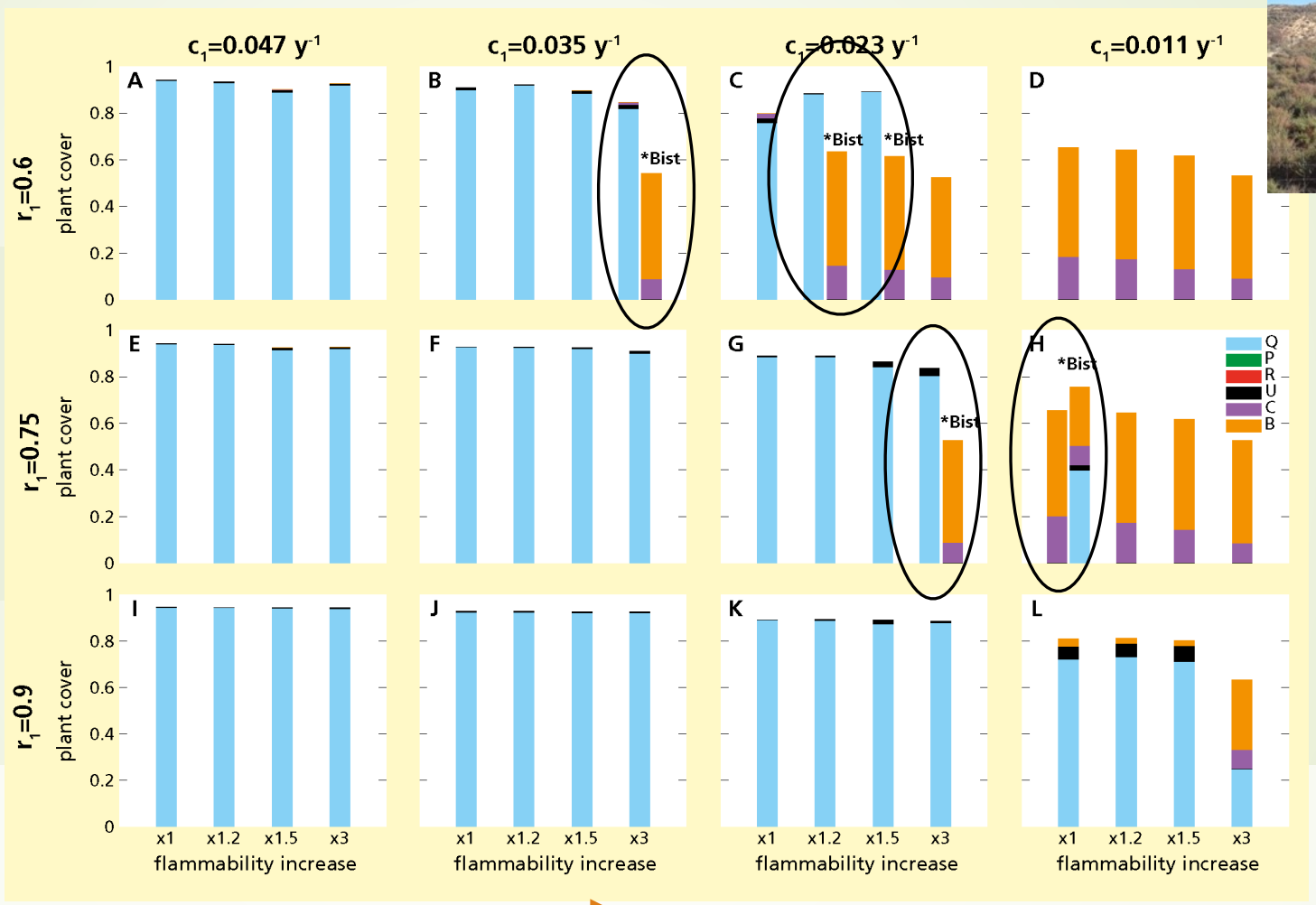
Baudena et al, 2020

Fire

Aridity-1: decreasing oak colonization ability

Aridity-2 decreasing oak resprouting ability





Aridity-3: increasing flammability

Average plant cover

Baudena et al, 2020

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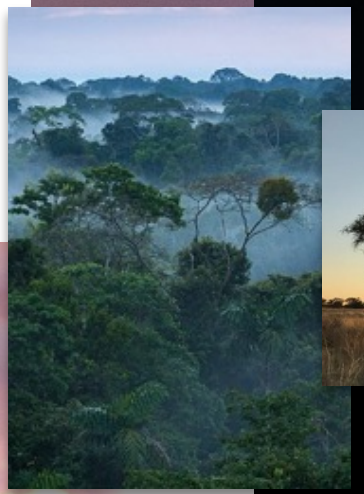
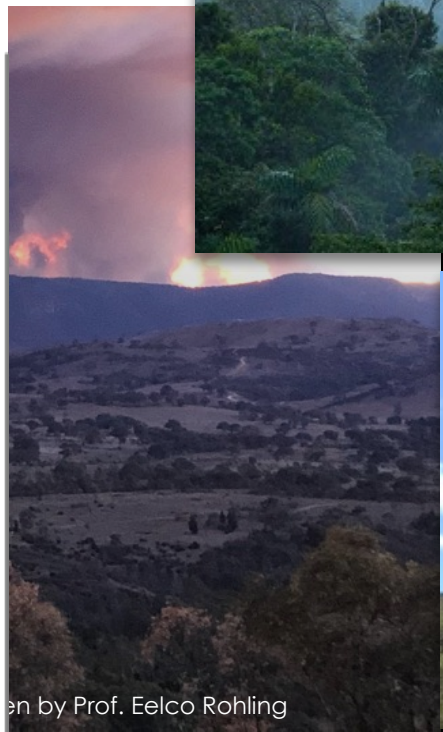
E-ARTICLE

Fire Responses Shape Plant Communities in a Minimal Model for Fire Ecosystems across the World

Marta Magnani,[1,2,3,4,*] Rubén Díaz-Sierra,[5,6] Luke Sweeney,[7] Antonello Provenzale,[1,4] and Mara Baudena[3,4,5,8]





Post-fire management: Promoting resilient landscapes

Integrated and adaptive management

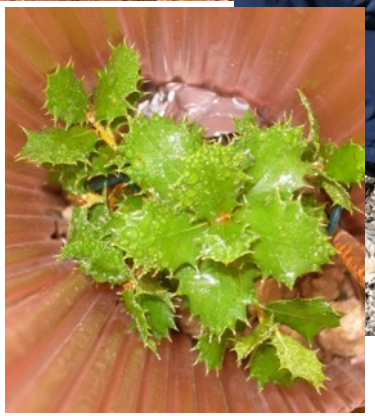
Fuel control + *Ecosystem restoration*

Future scenarios

Santana et al, in prep

Modelling

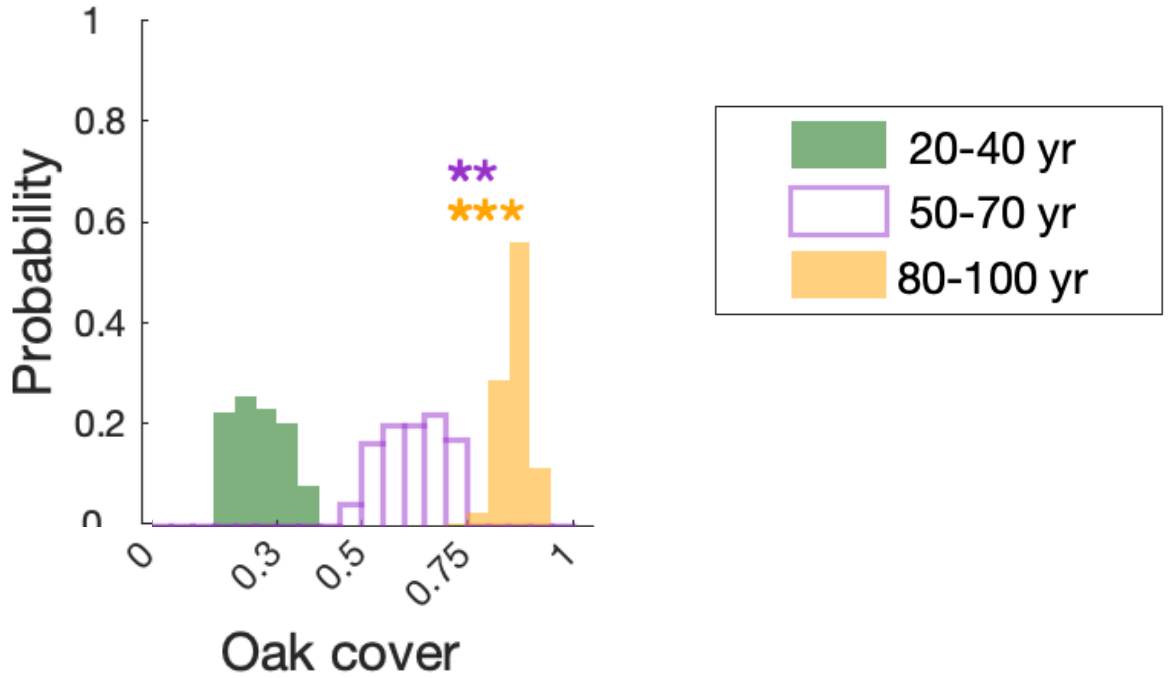
- *7 Treatments: management combinations of*
- *Clearings for reducing seeder species*
  -> Can be repeated every 10 yr
- *planting resprouting species*



- *3 climate scenarios*
- *Historical climate* *(calibrated with past data)*
- *Intermediate aridity increase*
- *Extreme aridity increase*

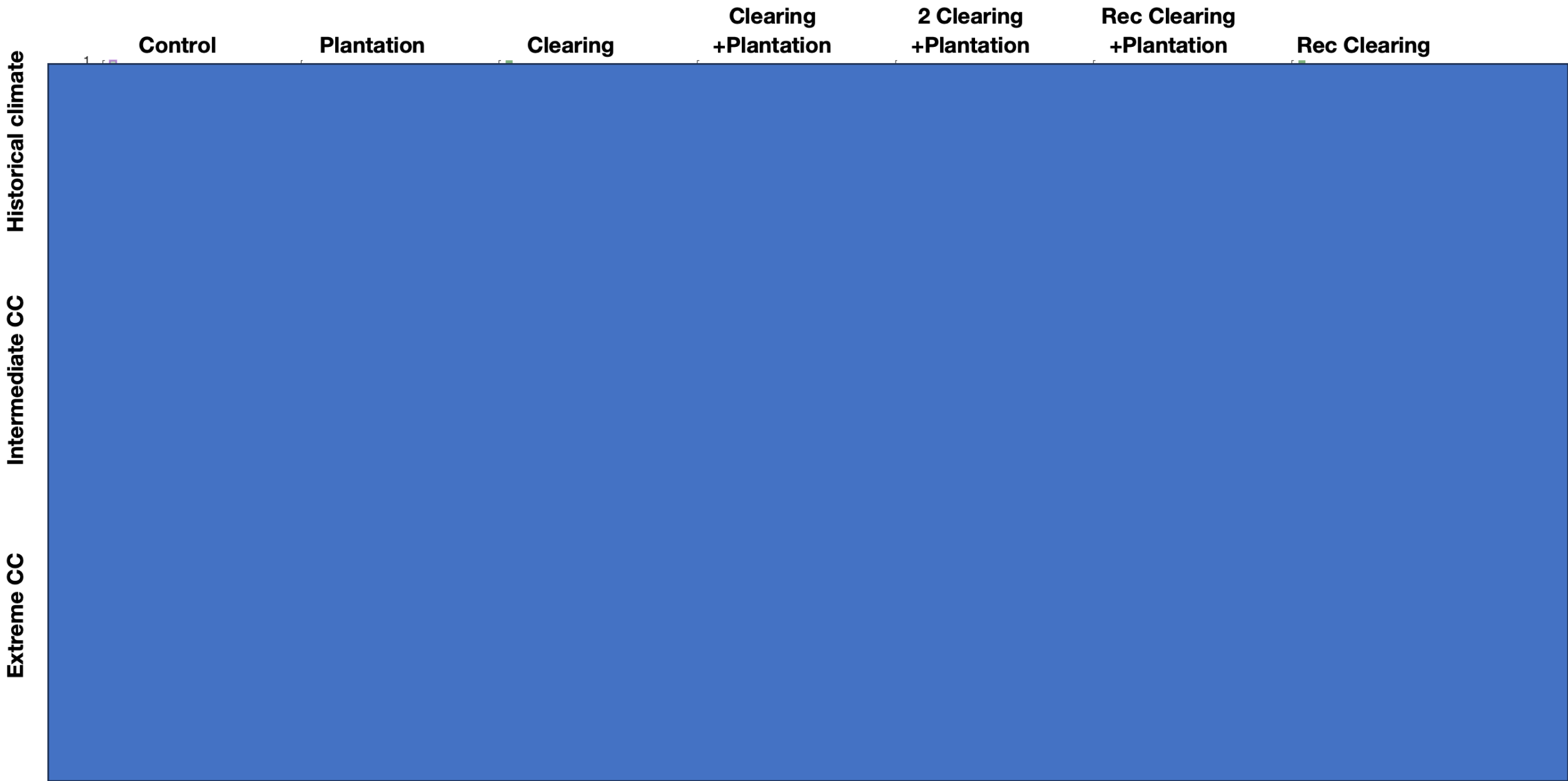
Aridity effects: decreases competitive ability and resprouting, increases flammability

Santana et al, in prep



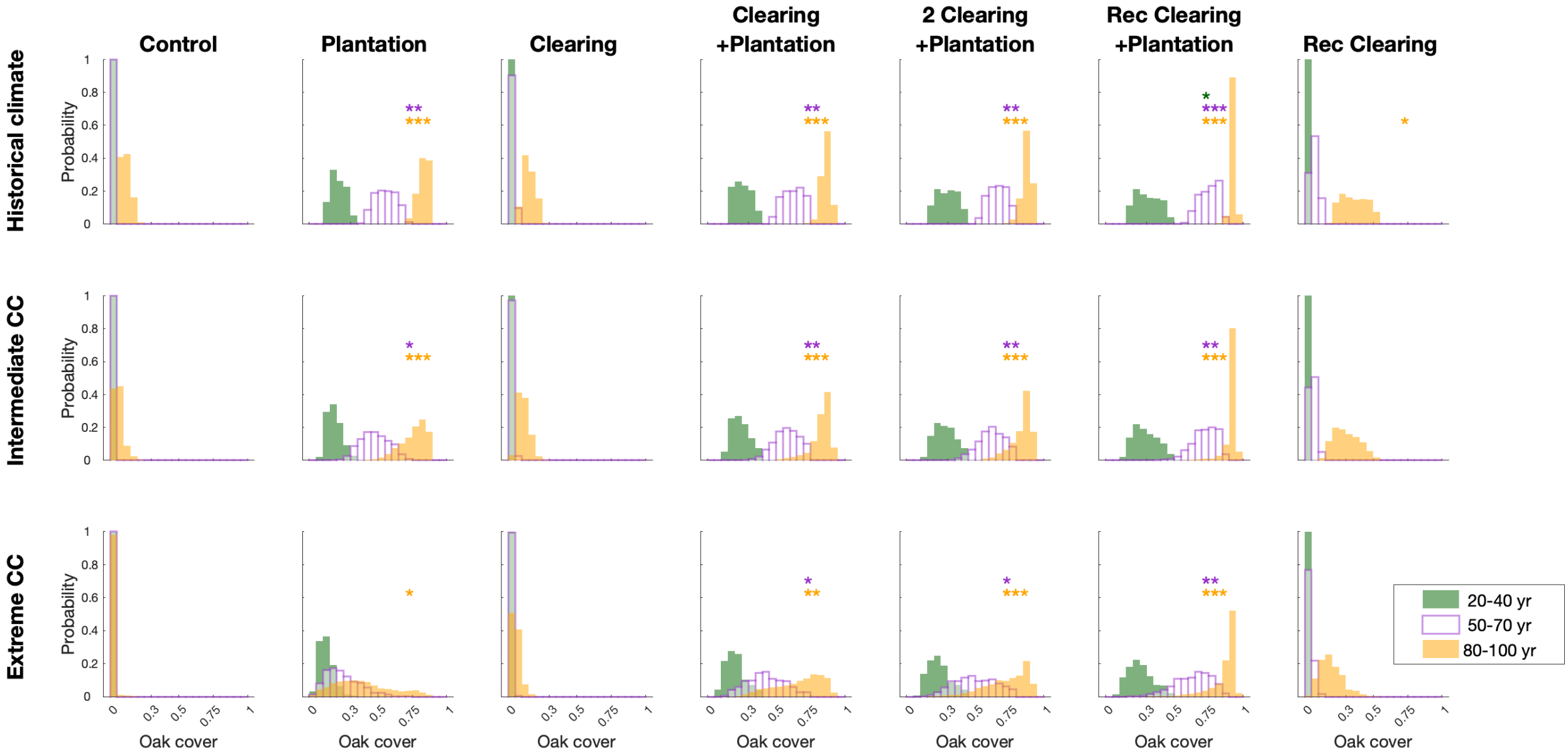
Santana et al, in prep

Results


Control
Plantation
Clearing
Clearing +Plantation
2 Clearing +Plantation
Rec Clearing +Plantation
Rec Clearing
Historical climate
Intermediate CC
Extreme CC

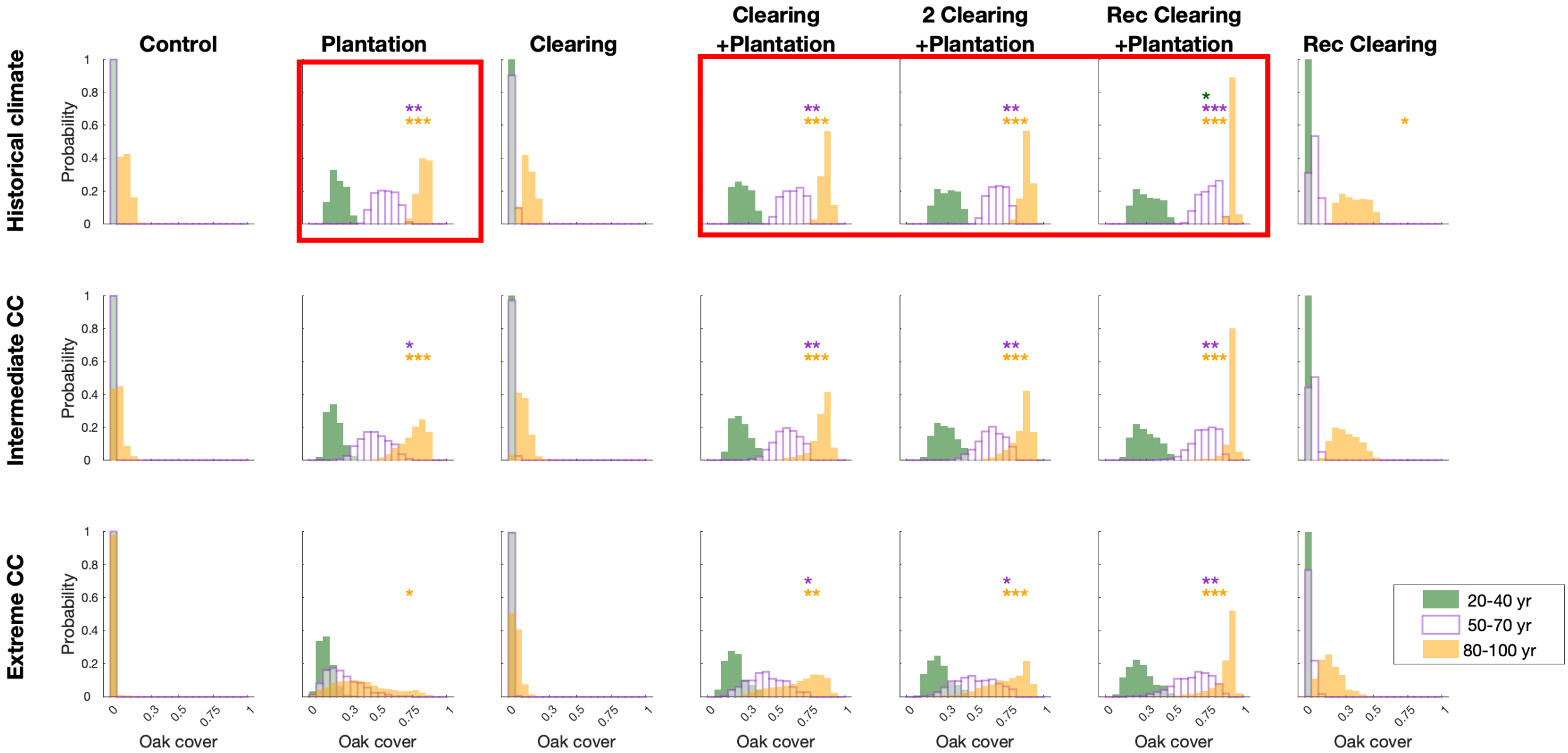
Results

Santana et al, in prep



Results

Santana et al, in prep



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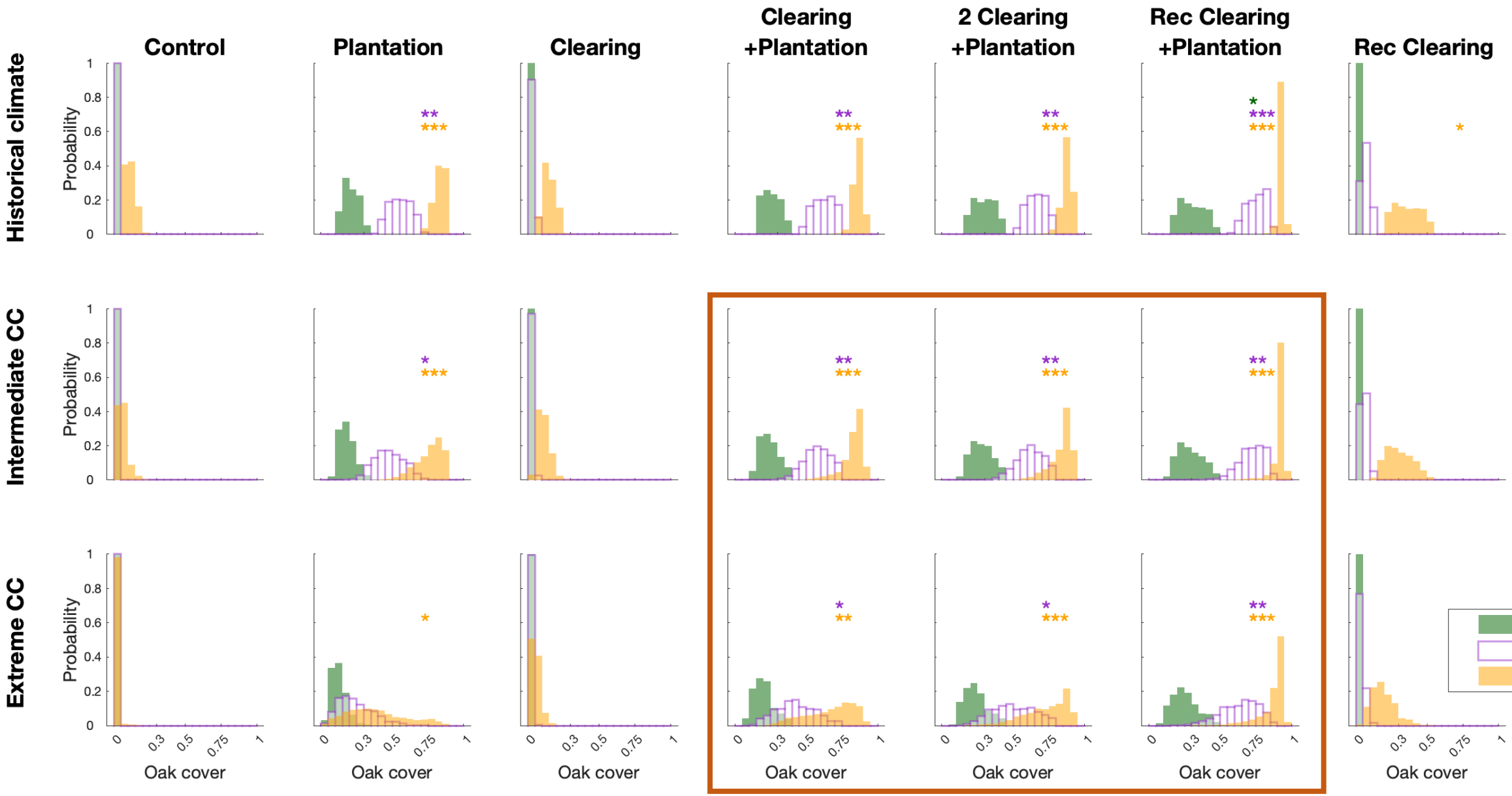
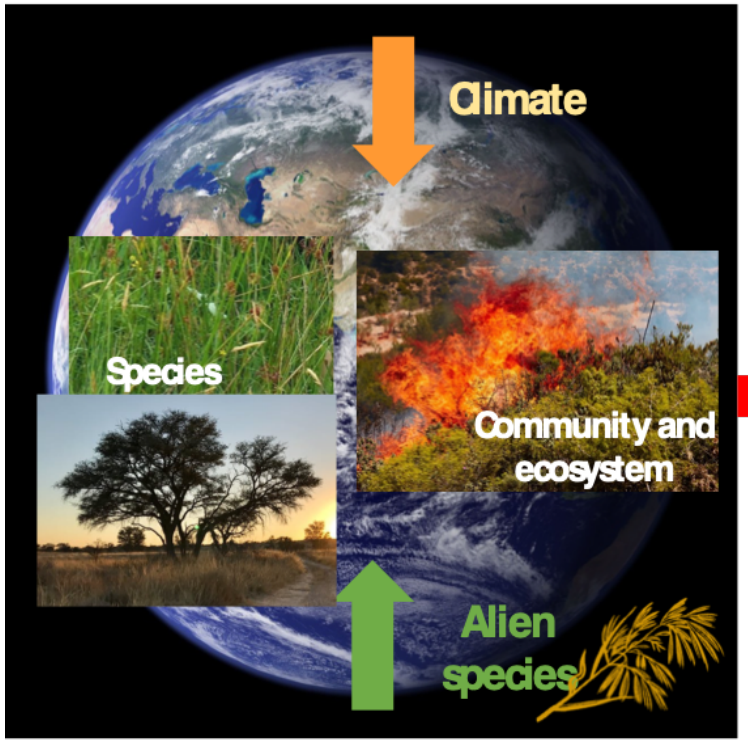
Santana et al, in prep

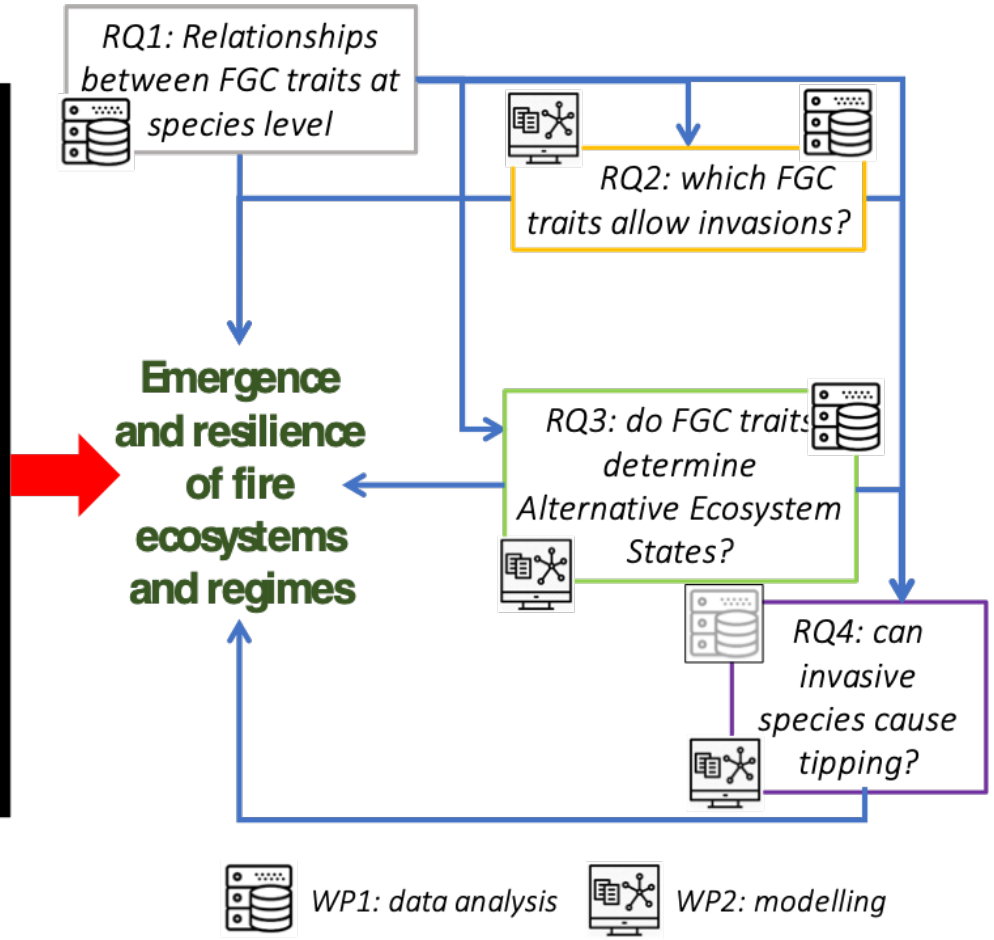


Summary and conclusions

- **Climate change** can lead Mediterranean forest to shift to shrublands by reducing the post-fire response (not only on increasing fire conditions and flammability)
- Importance of including plant fire-responses when modelling fire ecosystems under climate-change scenarios.
- **Adaptive management** combining fuel reduction and restoration can promote resprouter-dominated ecosystems
- In the long term, combination of planting resprouting species with recurrent clearings is the most effective strategy
- Future scenarios of climate change will reduce management effectiveness, and more efforts will be needed to achieve targets

"WiFin": Plant traits of native and invasive species in fire ecosystems across the world





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Marta Magnani, Rubén Diaz-Sierra, Antonello Provenzale, Luke Sweeney

Donatella D'Onofrio, Jost von Hardenberg

LifeWatch ERIC 2024 Thematic Service Workshop Series

Thank you for your attention!

Any questions?

Taxonomy | Brussels, Belgium, 30 January 2024

Climate Change Impact on Biodiversity Patterns | Lecce, Italy, 21-22 February 2024

Animal Movement and Biologging | Ostend, Belgium, 22 March 2024

Biogeography | Bologna, Italy, 4-5 April 2024

Biodiversity Observatory Automation | Ljubljana, Slovenia, 11 April 2024

Habitat Mapping | Aveiro, Portugal, 3 May 2024