aeet
ASOCIACIÓN ESPAÑOLA DE ECOLOGÍA TERRESTRE

ReDeC
RED SEGUIMIENTO DECAIMIENTO FORESTAL

Diversidad genética y capacidad adaptativa en pinsapares y cedrales con decaimiento

UNIVERSIDAD PABLO DE OLAVIDE SEVILLA

DENDROLAVIDE

Juan Carlos Linares

Nothing in Biology Makes Sense Except in the Light of Evolution

(Theodosius Dobzhansky, 1972)

Estrés climático → Presión selectiva → Crecimiento, producción semillas, reclutamiento

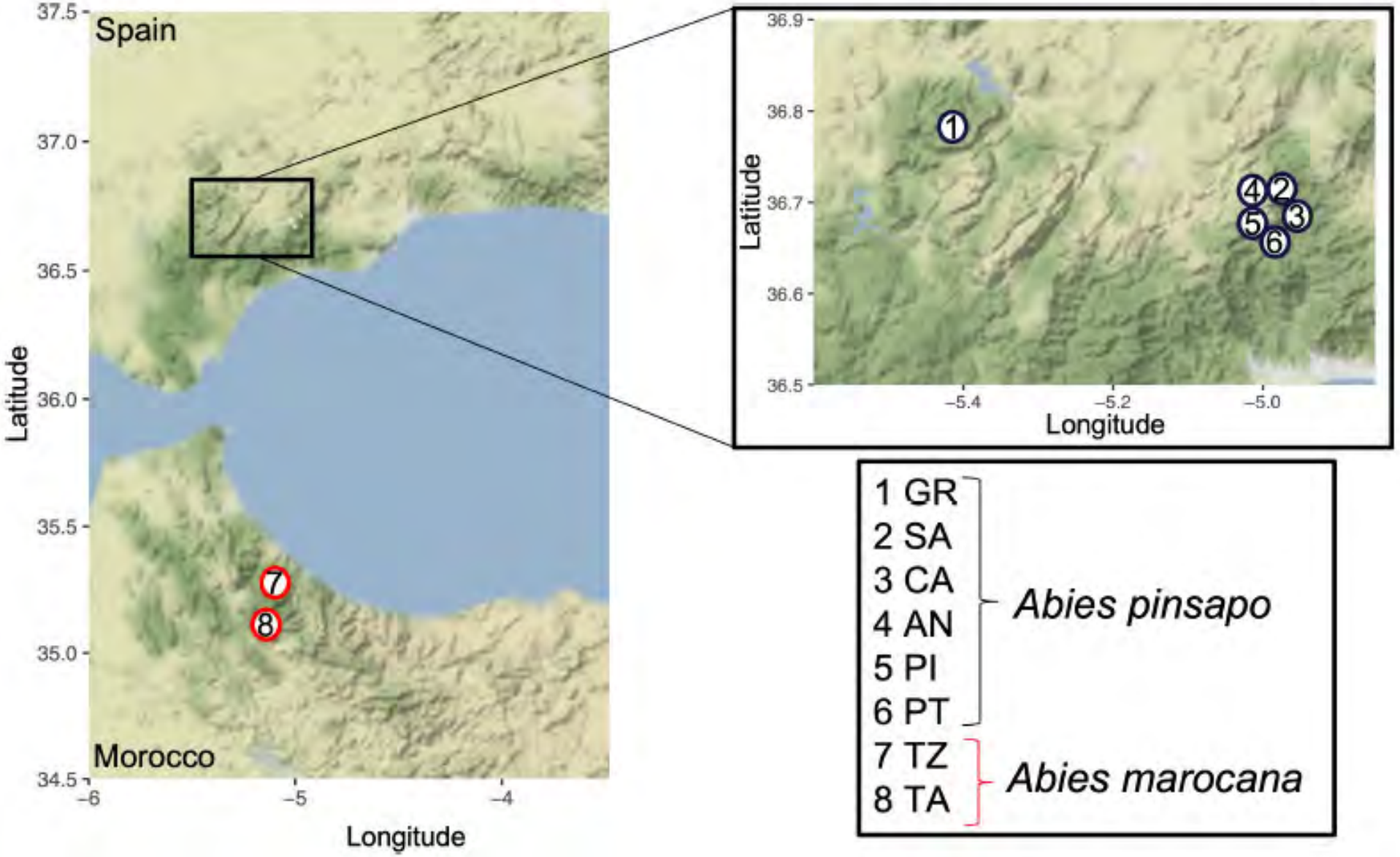
Estrés climático → Decaimiento y mortalidad → Declive poblacional, erosión genética

-> Posibles tendencias evolutivas en los límites de distribución del pinsapo y el cedro del Atlas

-> Estimaciones del riesgo de inadaptabilidad al cambio climático basadas en relaciones genotipo-ambiente

-> Comparar las estimaciones de vulnerabilidad genética con patrones de crecimiento y sensibilidad dendroclimática


SPAIN
5°W
40 km
Grazalema
Torreón
1654m
Sierra de
las Nieves
Torrecilla
1919m
36°N
Strait of
Gibraltar
Mediterranean
Sea
North Atlantic
Ocean
Talassemtane
Jbel Tazaout
1725m
Jbel Lâkraa
2159m
MOROCCO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Morocco
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Longitude
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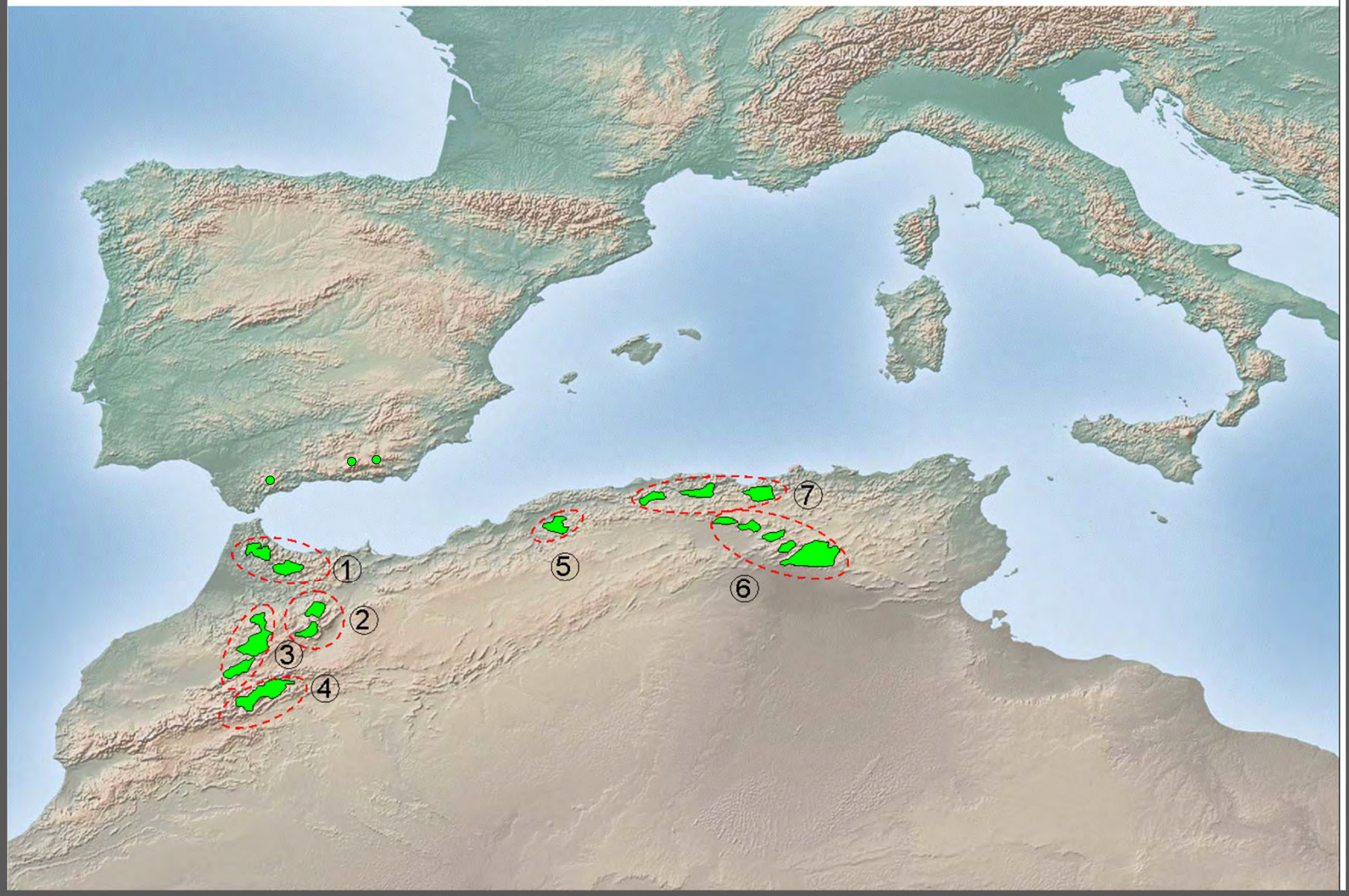
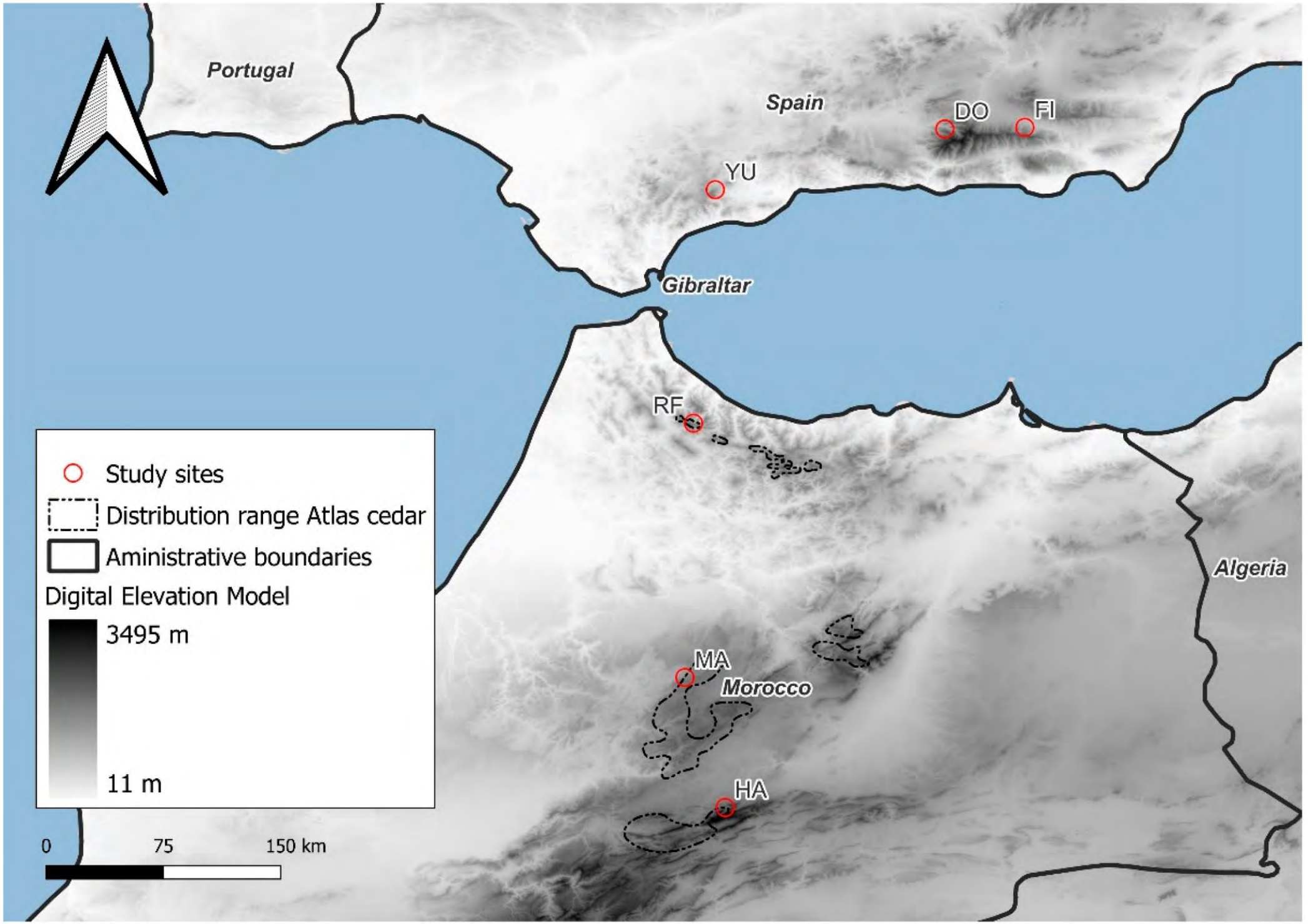
4 AN
5 PI
6 PT
Abies pinsapo
7 TZ
8 TA
Abies marocana

Marruecos
1. Rif
2. Medio Atlas Oriental
3. Medio Atlas Central
4. Alto Atlas Oriental

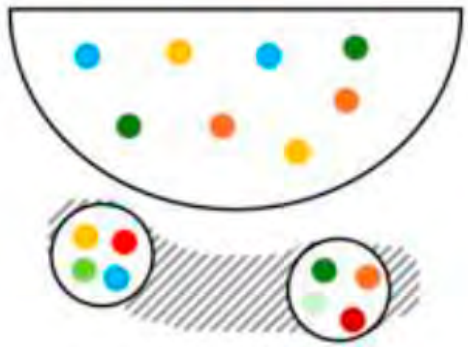
Argelia
5. Ouarsenis
6. Aurès
7. Djurdjura



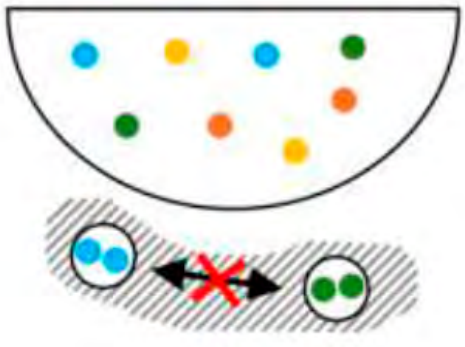

Portugal
Spain
DO
FI
YU
Gibraltar
RF
Algeria
MA
Morocco
HA
Study sites
Distribution range Atlas cedar
Aministrative boundaries
Digital Elevation Model
3495 m
11 m
0
75
150 km

Posibles tendencias evolutivas en los límites de distribución determinados por sequía/calor

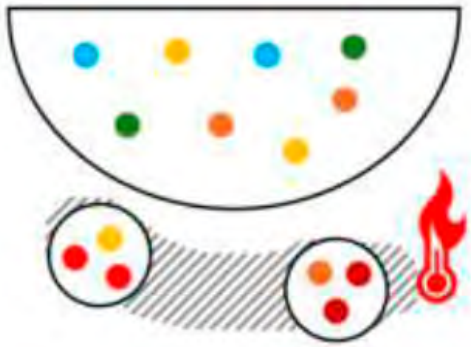
Límites de distribución (latitudinales/ altitudinales)



Alta Diversidad

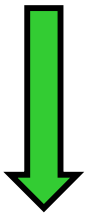


Deriva Genética

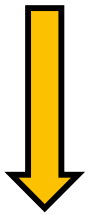


Adaptación Local

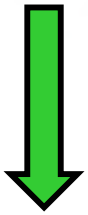
¿Dónde?



Reservorios de diversidad Intra- e inter-poblacional Larga persistencia (ej. refugios glaciares)



Declive debido a cambios climáticos pasados (ej. poblaciones muy pequeñas)



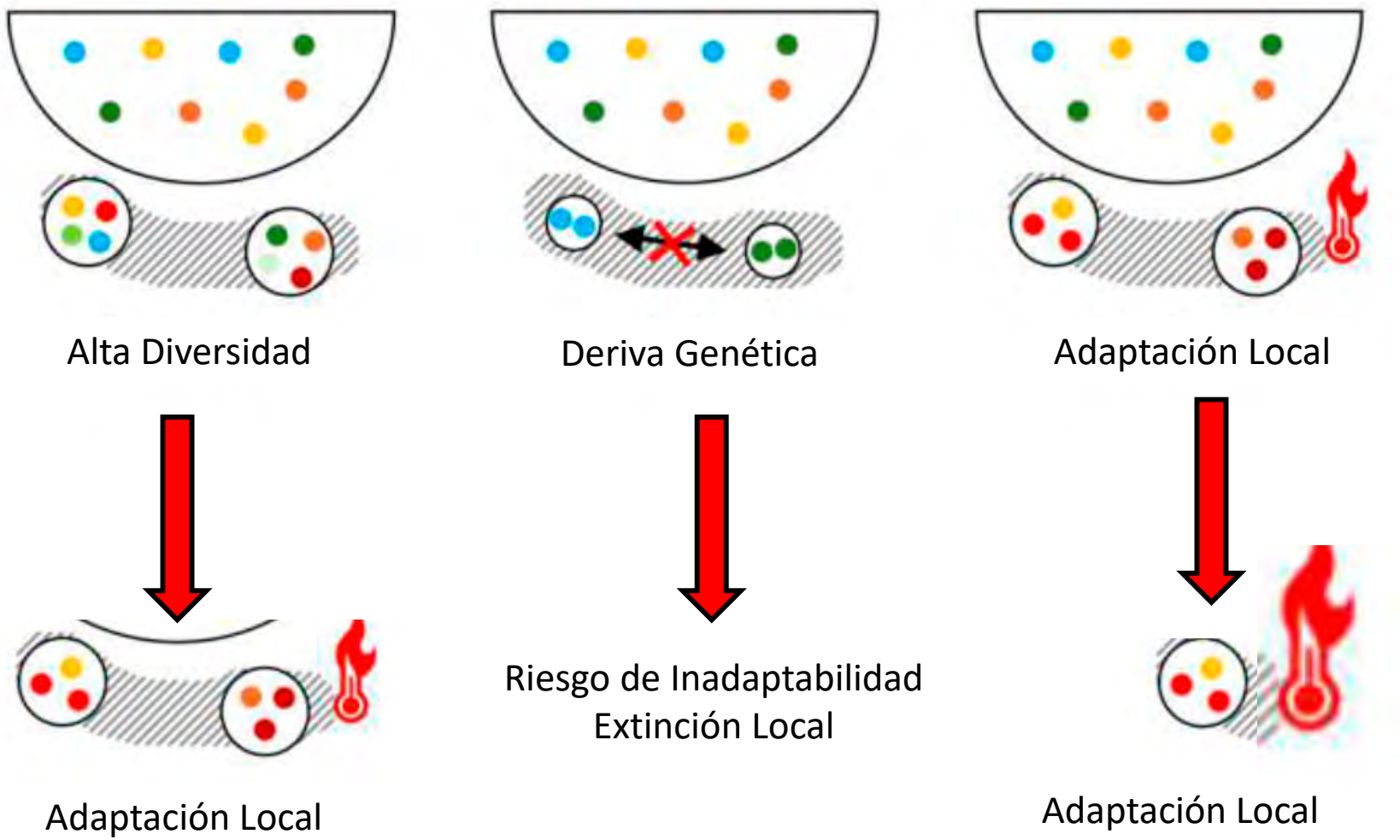
Caracteres adaptativos debido a la presión selectiva de cambios climáticos pasados

Perrier, A. Keenan, O. J. Galloway L. F. (2025) Revisiting evolution at the rear edge. Trends in Ecology and Evolution. *In Press*.

Posibles tendencias evolutivas esperadas en límites de distribución determinados por sequía

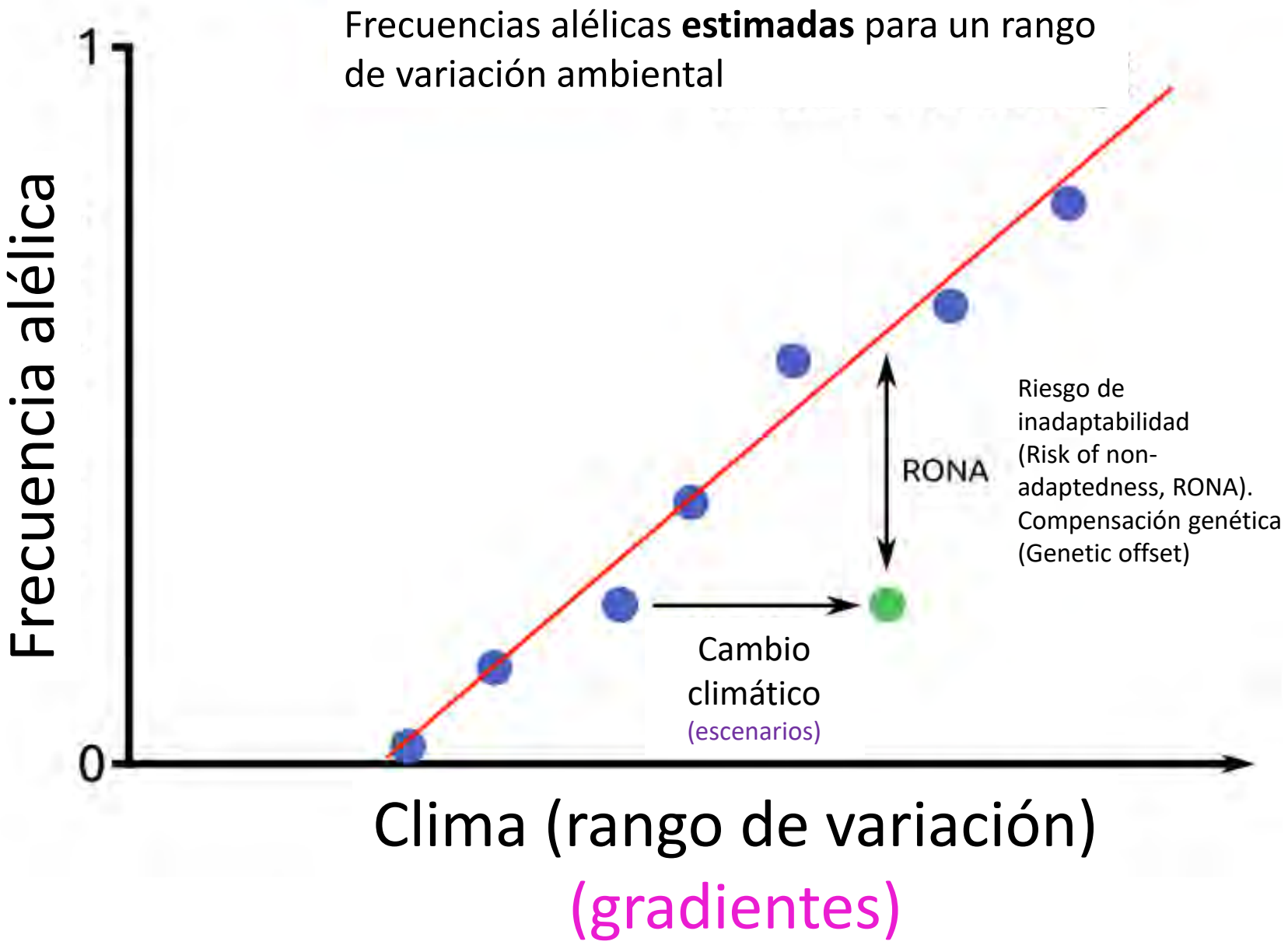
Límites de distribución (latitudinales/ altitudinales)

Escenarios climáticos futuros



Perrier, A. Keenan, O. J. Galloway L. F. (2025) Revisiting evolution at the rear edge. Trends in Ecology and Evolution. *In Press*.

Riesgo de inadaptabilidad (Risk of non-adaptedness, RONA)



Identifica polimorfismos genéticos correlacionados con variables ambientales.
Estima frecuencias alélicas para un rango de variación ambiental.

Frichot et al., 2013. Mol Biol Evol.
Rellstab et al., 2016. Mol Ecol.

WordClim Bioclimatic variables

- BIO1 = Annual Mean Temperature
- BIO2 = Mean Diurnal Range (Mean of monthly (max temp - min temp))
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- BIO4 = Temperature Seasonality (standard deviation ×100)
- BIO5 = Max Temperature of Warmest Month
- BIO6 = Min Temperature of Coldest Month
- BIO7 = Temperature Annual Range (BIO5-BIO6)
- BIO8 = Mean Temperature of Wettest Quarter
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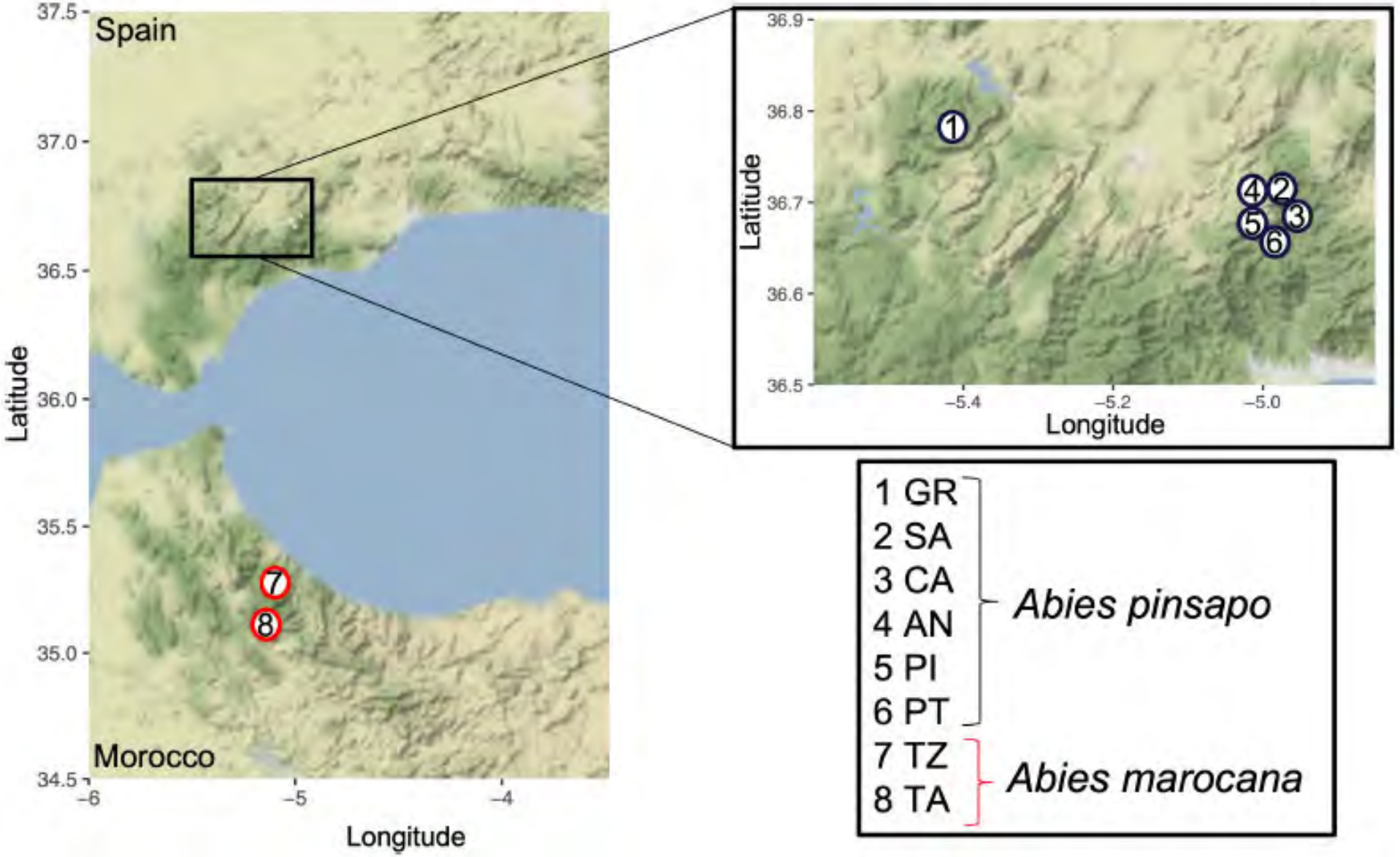
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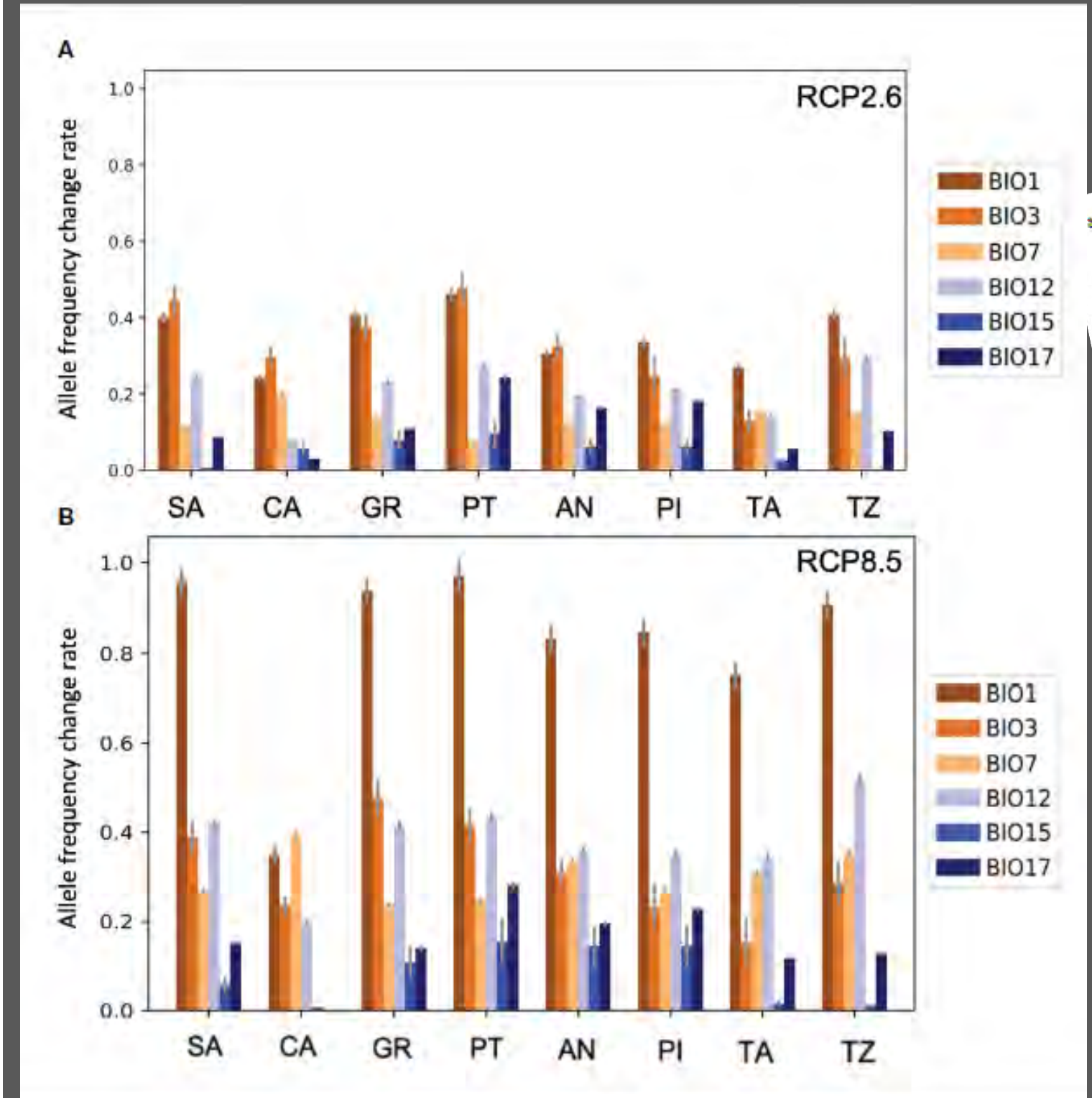

frontiers | Frontiers in Plant Science

Warming appears as the main risk of non-adaptedness for western Mediterranean relict fir forests under expected climate change scenarios

Belén Méndez-Cea[1], Isabel García-García[1], Juan Carlos Linares[1]* and Francisco Javier Gallego[1]*

Méndez-Cea B, García-García I, Linares JC and Gallego FJ (2023) Warming appears as the main risk of non-adaptedness for western Mediterranean relict fir forests under expected climate change scenarios. Front. Plant Sci. 14:1156448. doi: 10.3389/fpls.2023.1156448

Méndez-Cea *et al.*, 2023. Front. Plant Sci.

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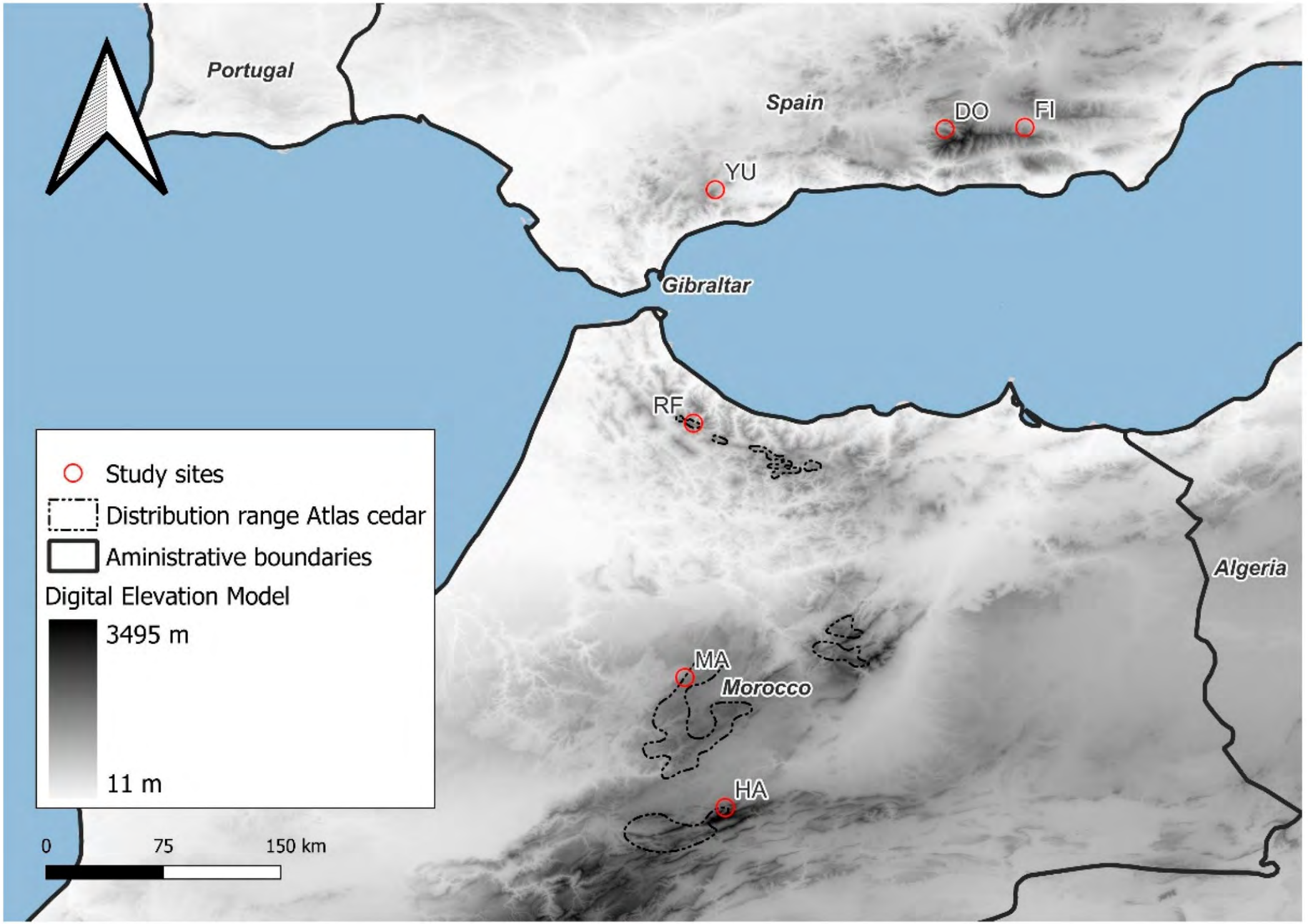
Portugal
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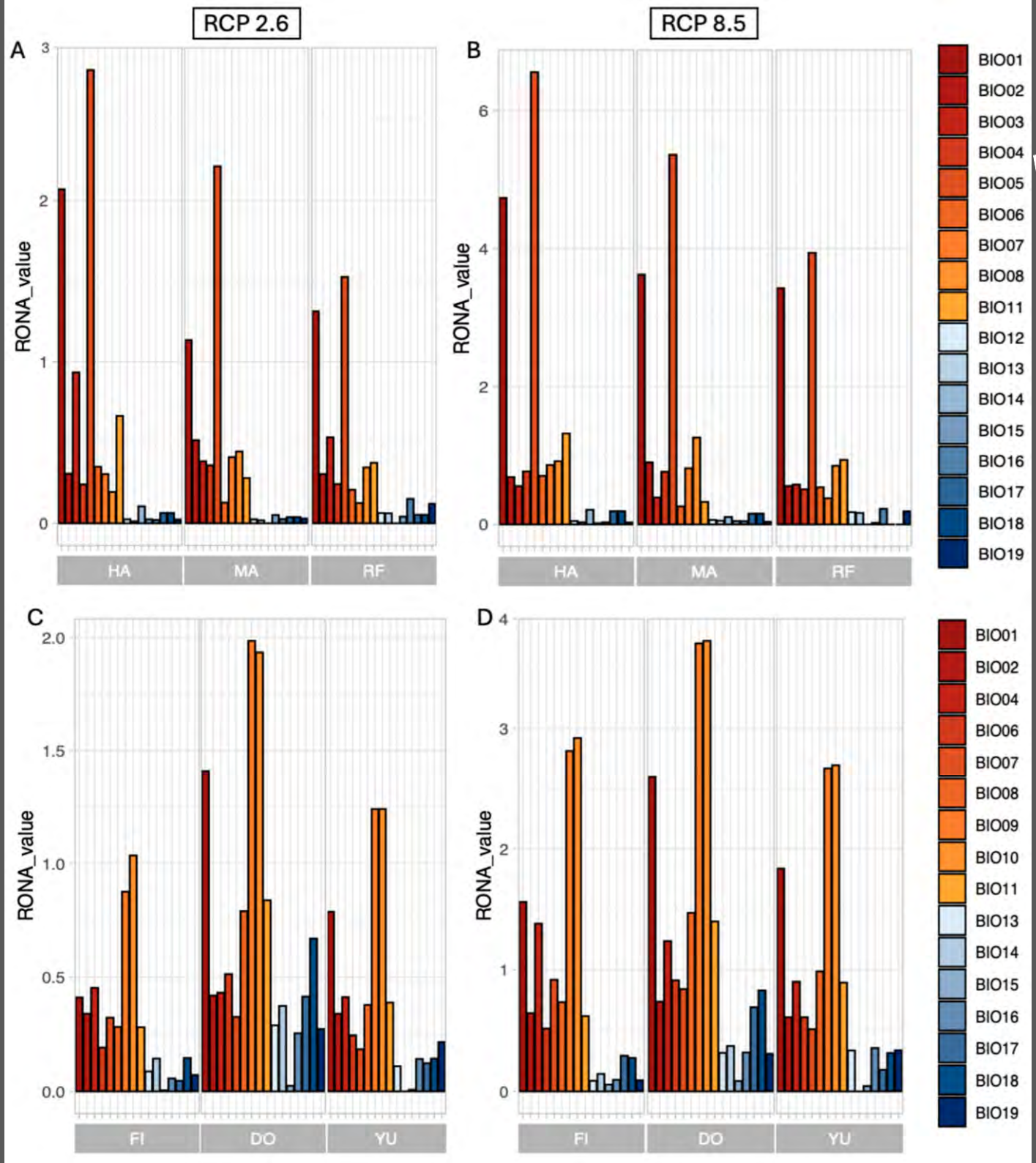

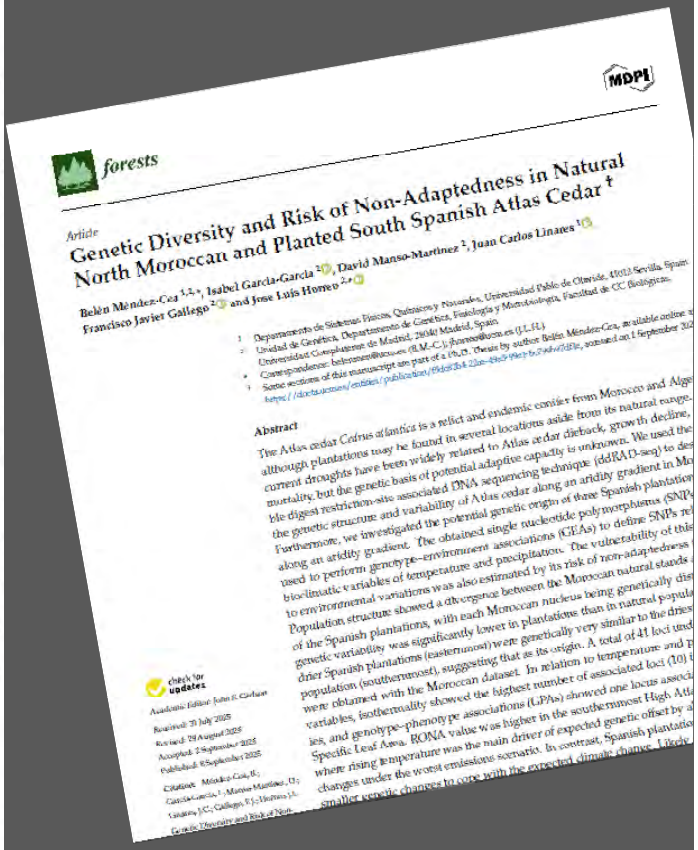

forests

Article

Genetic Diversity and Risk of Non-Adaptedness in Natural North Moroccan and Planted South Spanish Atlas Cedar †

Belén Méndez-Cea [1,2,*], Isabel García-García [2], David Manso-Martínez [2], Juan Carlos Linares [1], Francisco Javier Gallego [2] and José Luis Horreo [2,*]

Abstract

The Atlas cedar Cedrus atlantica is a relict and endemic conifer from Morocco and Alge... although plantations may be found in several locations aside from its natural range... current droughts have been widely related to Atlas cedar dieback, growth decline, ... mortality, but the genetic basis of potential adaptive capacity is unknown. We used the ... ble digest restriction-site associated DNA sequencing technique (ddRAD-seq) to des... the genetic structure and variability of Atlas cedar along an aridity gradient in Mo... Furthermore, we investigated the potential genetic origin of three Spanish plantation... along an aridity gradient. The obtained single nucleotide polymorphisms (SNPs... used to perform genotype–environment associations (GEAs) to define SNPs re... bioclimatic variables of temperature and precipitation. The vulnerability of this ... to environmental variations was also estimated by its risk of non-adaptedness. ... Population structure showed a divergence between the Moroccan natural stands ... of the Spanish plantations, with each Moroccan nucleus being genetically dis... genetic variability was significantly lower in plantations than in natural popula... drier Spanish plantations (easternmost) were genetically very similar to the dries... population (southernmost), suggesting that as its origin. A total of 41 loci und... were obtained with the Moroccan dataset. In relation to temperature and p... variables, isothermality showed the highest number of associated loci (10) ... ies, and genotype–phenotype associations (GPAs) showed one locus associ... Specific Leaf Area). RONA value was higher in the southernmost High Atla... where rising temperature was the main driver of expected genetic offset by ... changes under the worst emissions scenario. In contrast, Spanish plantatio... smaller genetic changes to cope with the expected climatic change. Likely ...

Méndez-Cea *et al.*, 2025. Forests

WordClim Bioclimatic variables

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- BIO2 = Mean Diurnal Range (Mean of monthly (max temp - min temp))
- **BIO3 = Isothermality (BIO2/BIO7) (×100)**
- BIO4 = Temperature Seasonality (standard deviation ×100)
- **BIO5 = Max Temperature of Warmest Month** ⬅ Poblaciones naturales de cedro muy sensibles a altas temperaturas
- BIO6 = Min Temperature of Coldest Month
- BIO7 = Temperature Annual Range (BIO5-BIO6)
- BIO8 = Mean Temperature of Wettest Quarter ⬅ Plantaciones: Sensibles a la temperatura cuando hay humedad
- BIO9 = Mean Temperature of Driest Quarter
- BIO10 = Mean Temperature of Warmest Quarter
- BIO11 = Mean Temperature of Coldest Quarter
- BIO12 = Annual Precipitation
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- BIO18 = Precipitation of Warmest Quarter
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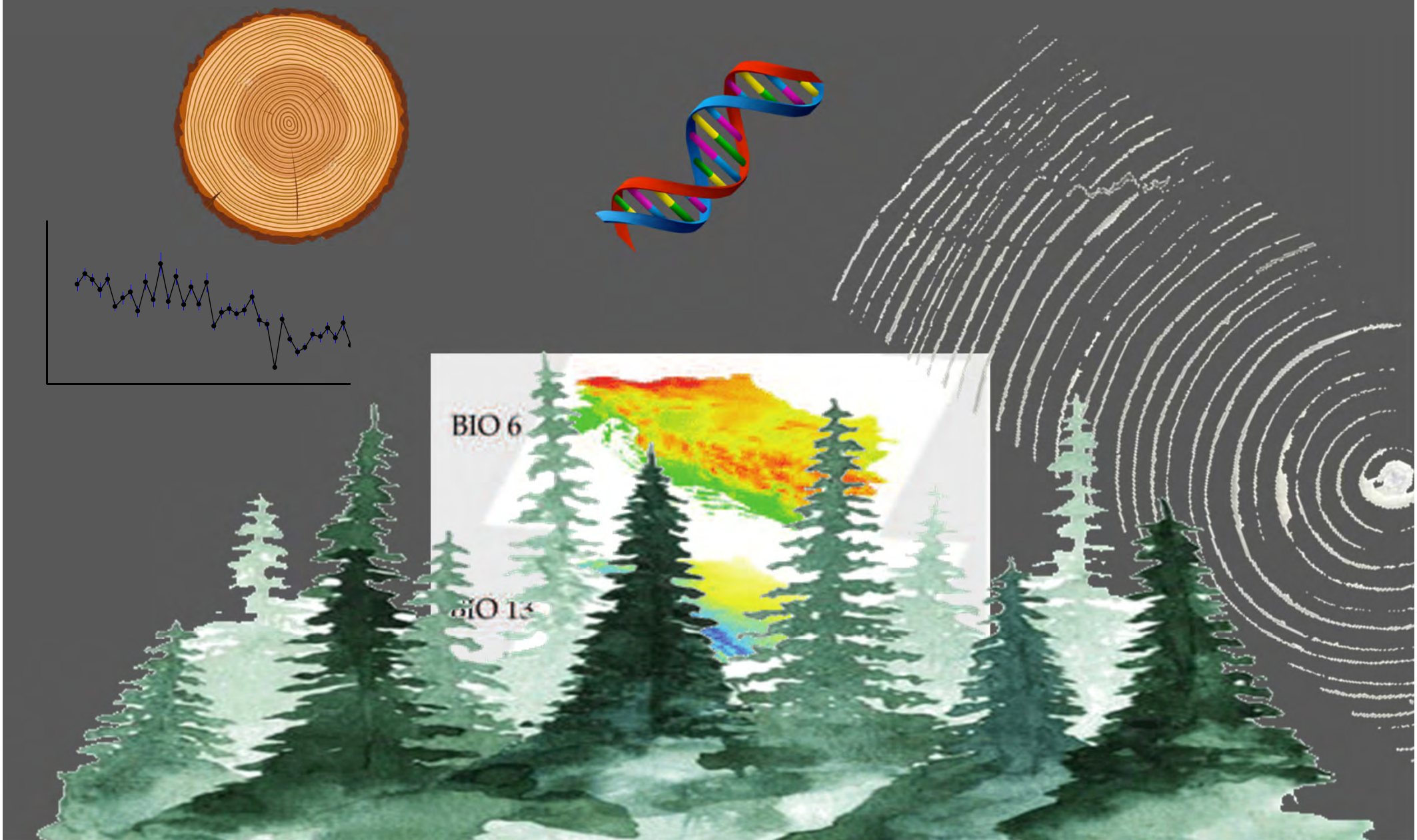
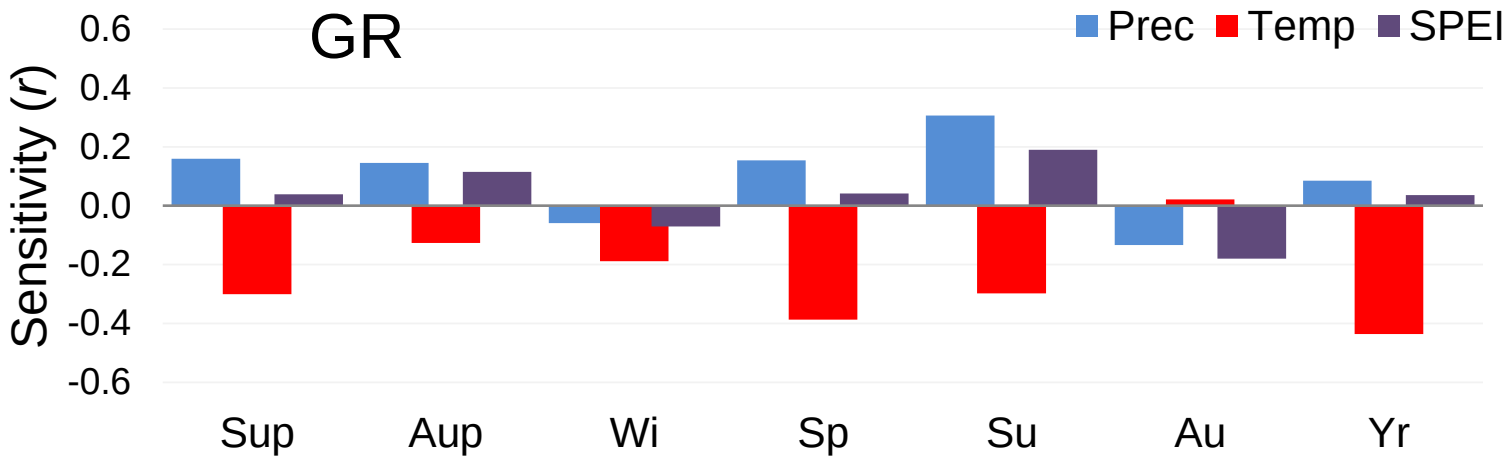
Identifica polimorfismos genéticos correlacionados con variables ambientales.
Estima frecuencias alélicas estimadas para un rango de variación ambiental.

¿Coinciden las estimaciones de vulnerabilidad genética con los patrones de crecimiento y sensibilidad dendroclimática?



Grazalema. Límite altitudinal. Sensibilidad negativa a la temperatura

Abies pinsapo



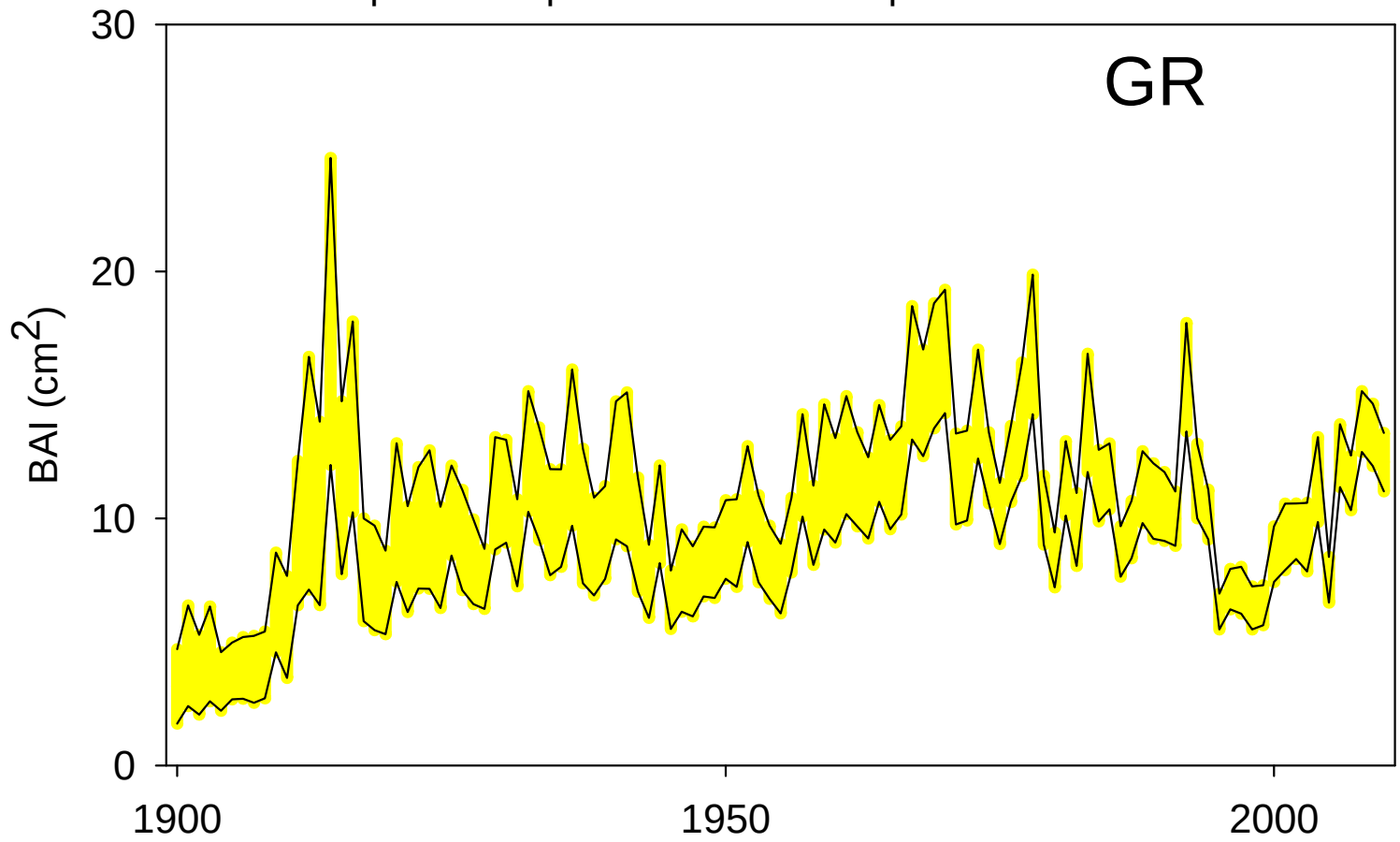
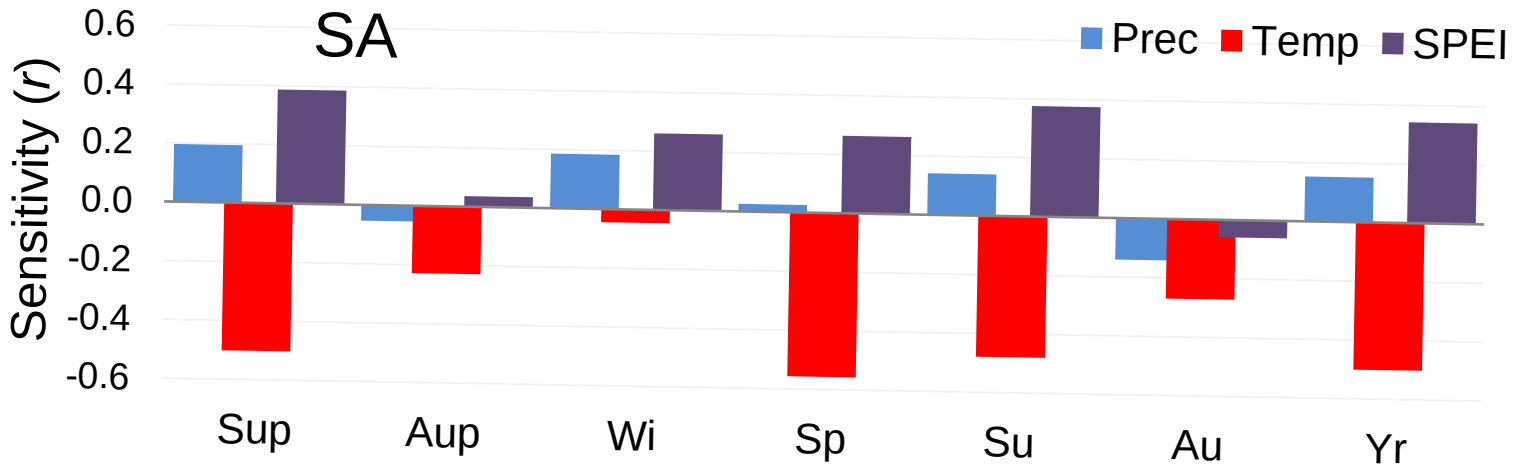


Foto: Juan Carlos Linares

Abies pinsapo

Saucillo (Sierra de las Nieves). Límite altitudinal. Sensibilidad negativa a la temperatura



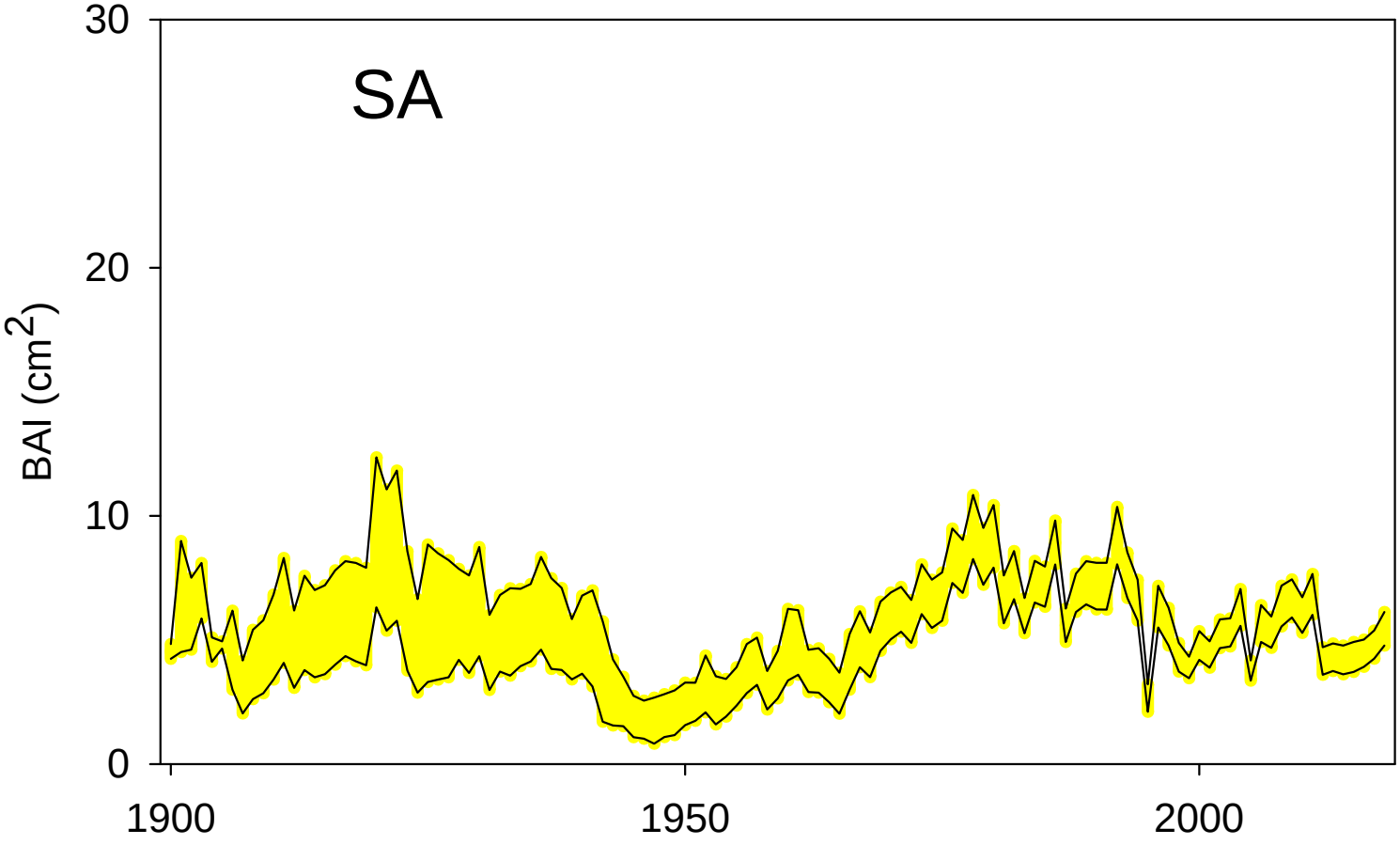
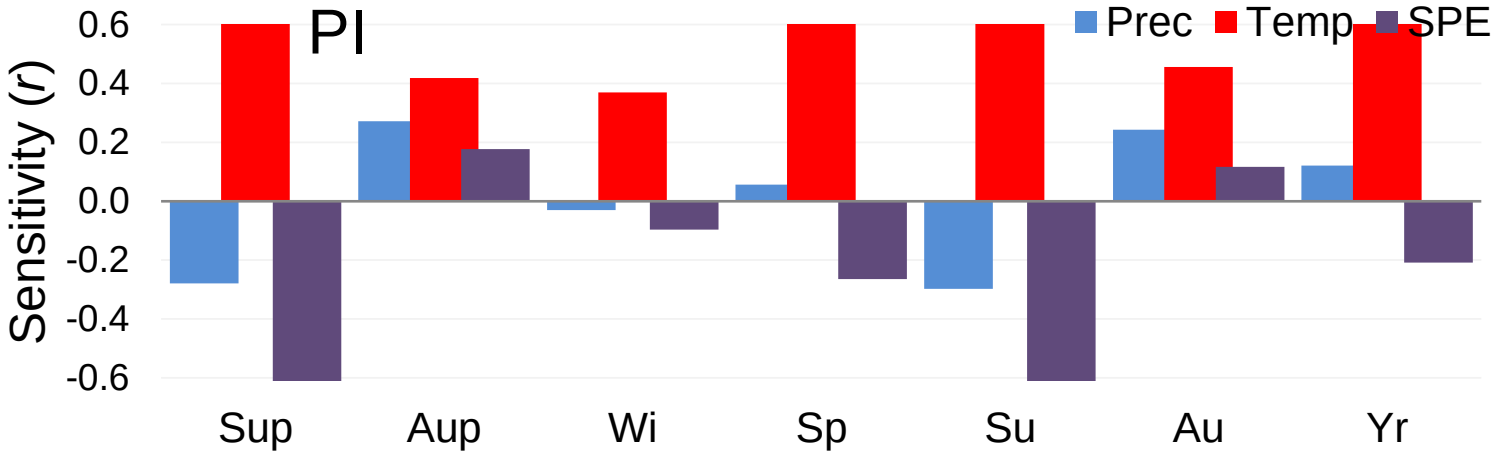
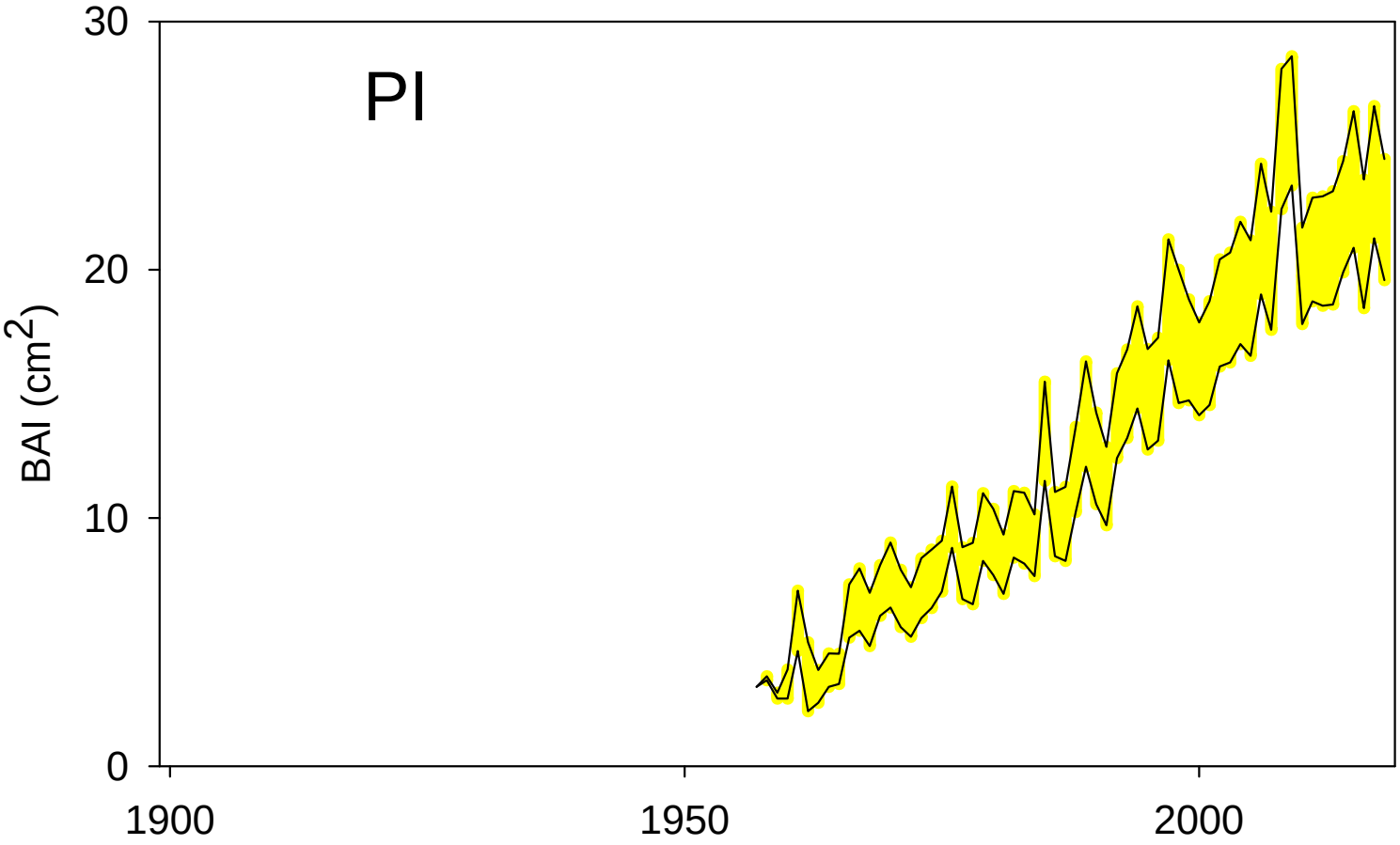


Foto: Juan Carlos Linares

Abies pinsapo

Pilones (Sierra de las Nieves). Límite altitudinal. Sensibilidad positiva a la temperatura






2011
Foto: Víctor Lechuga


2011
Foto: Víctor Lechuga


2015
Foto: Víctor Lechuga

2019

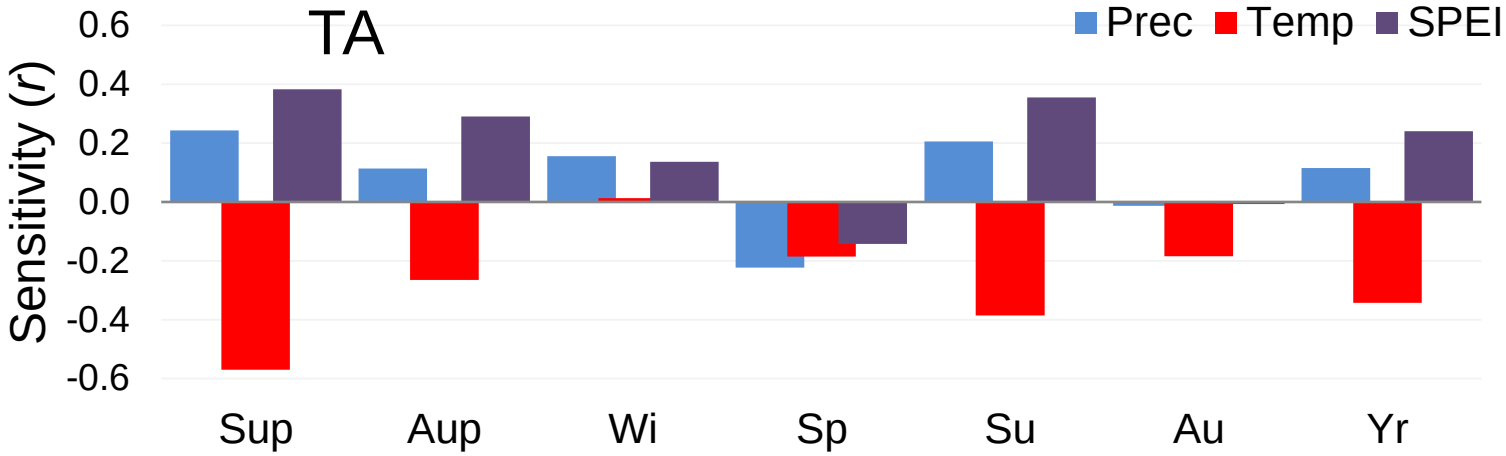
Foto: Víctor Lechuga

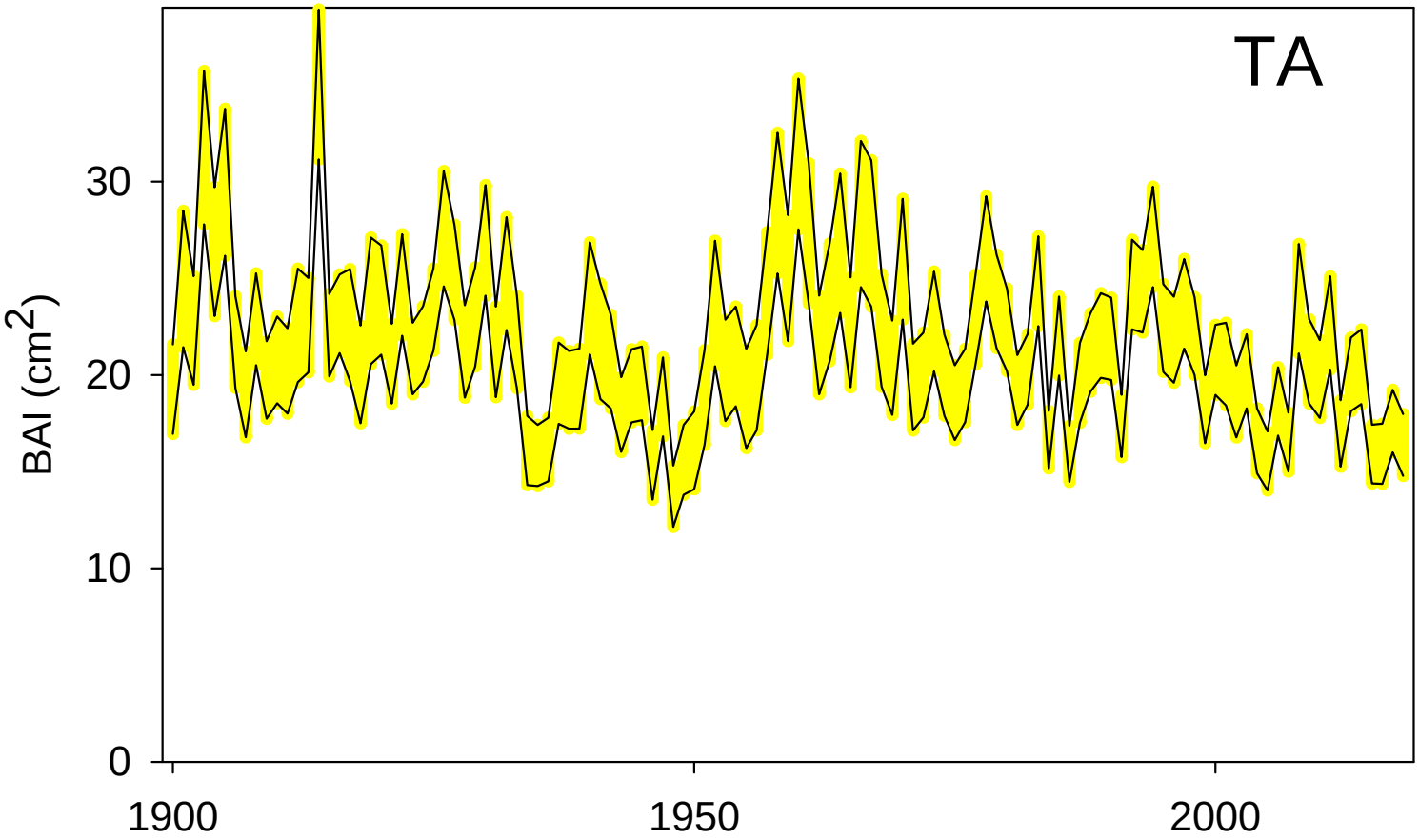
2022

Foto: Víctor Lechuga

TA. Talasemtanne (Marruecos). Sensibilidad negativa a la temperatura

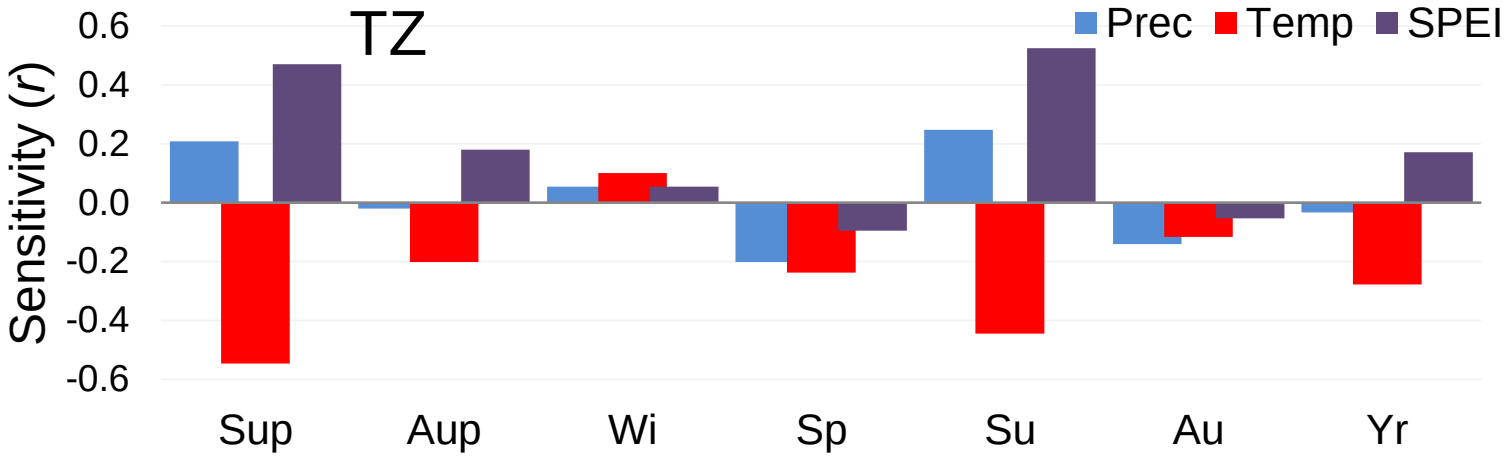
Abies marocana

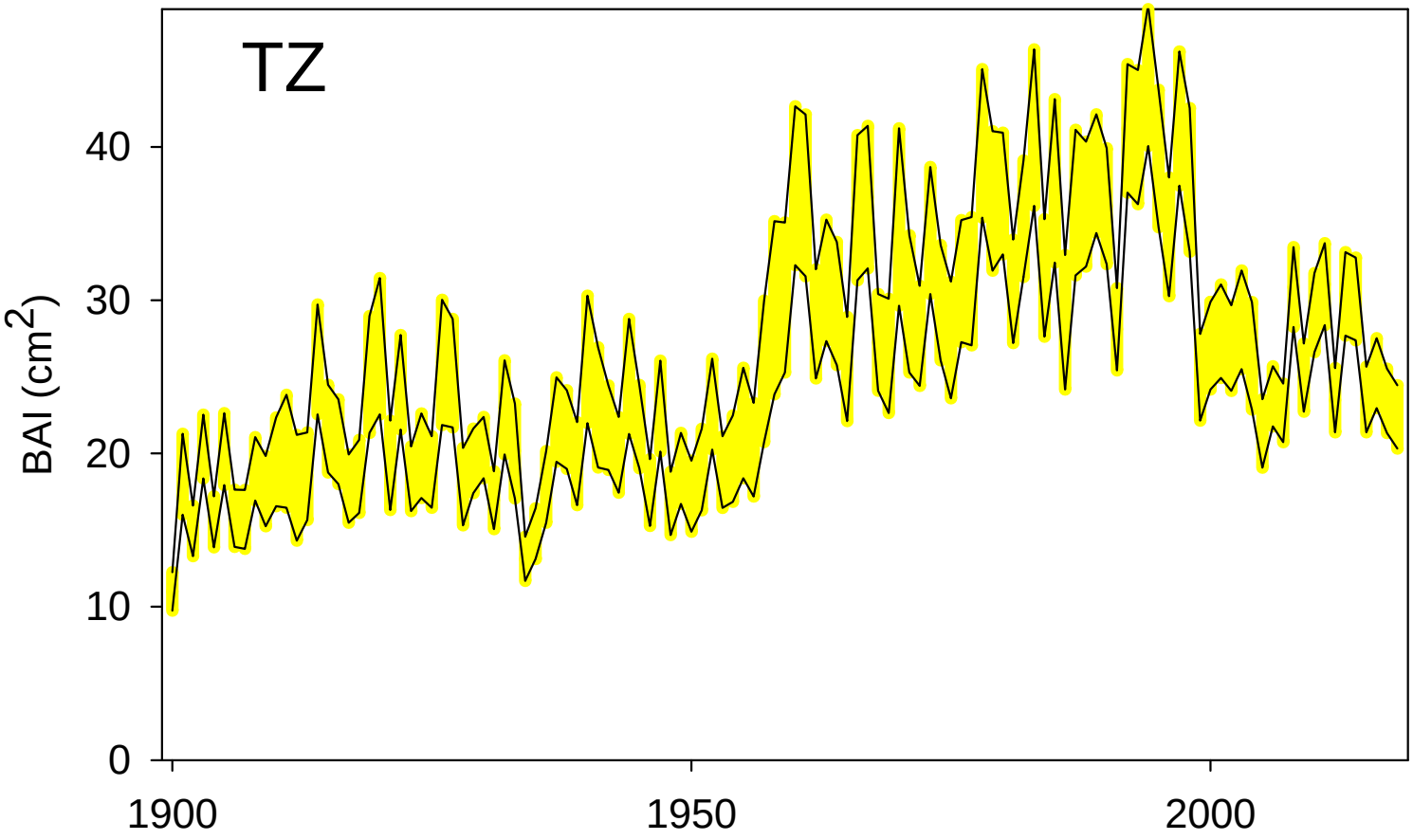




TZ. Tazaot (Marruecos). Sensibilidad negativa a la temperatura

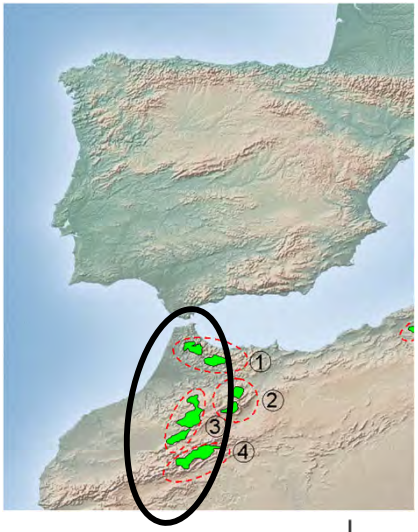
Abies marocana





Abies marocana

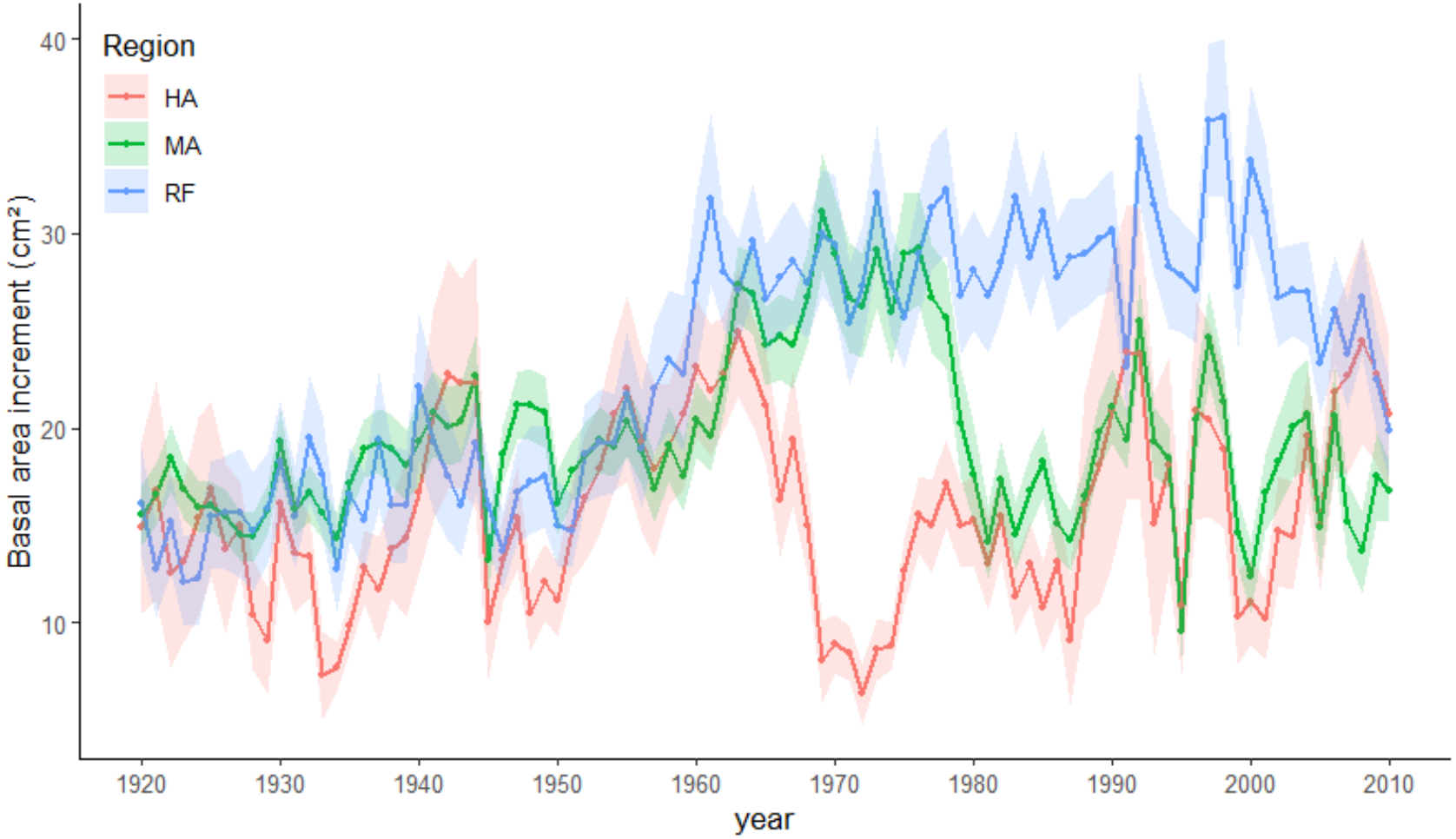

Foto: Juan Carlos Linares

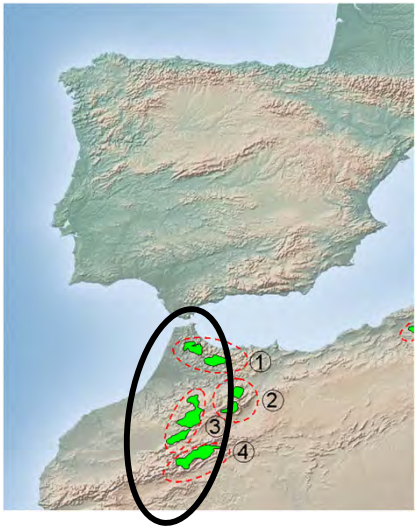


Alto Atlas, Medio Atlas y Rif (Marruecos)

Cedrus atlantica

Descensos de crecimiento en el gradiente latitudinal:
Alto Atlas \ **(1960s)** , Medio Atlas \ **(1970s)** , y Rif \ **(2000s)**

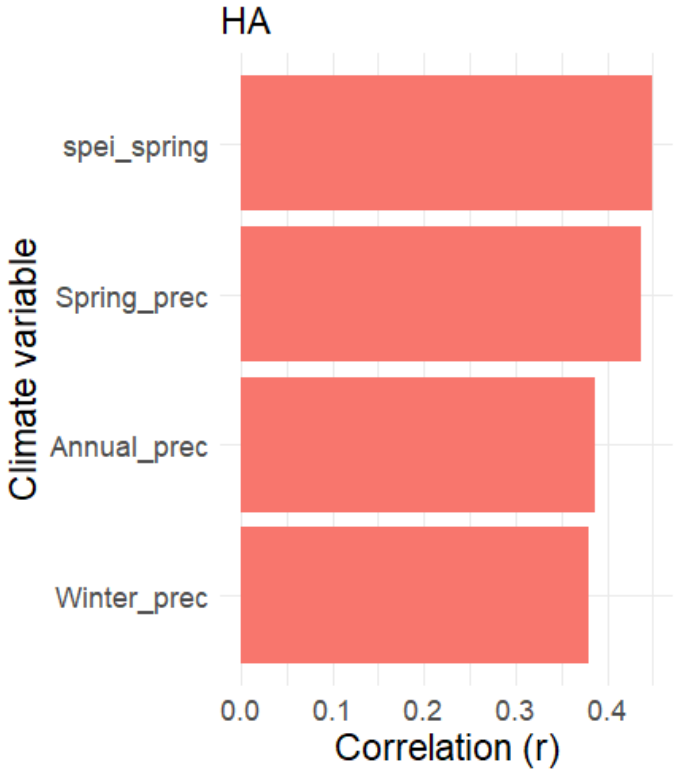


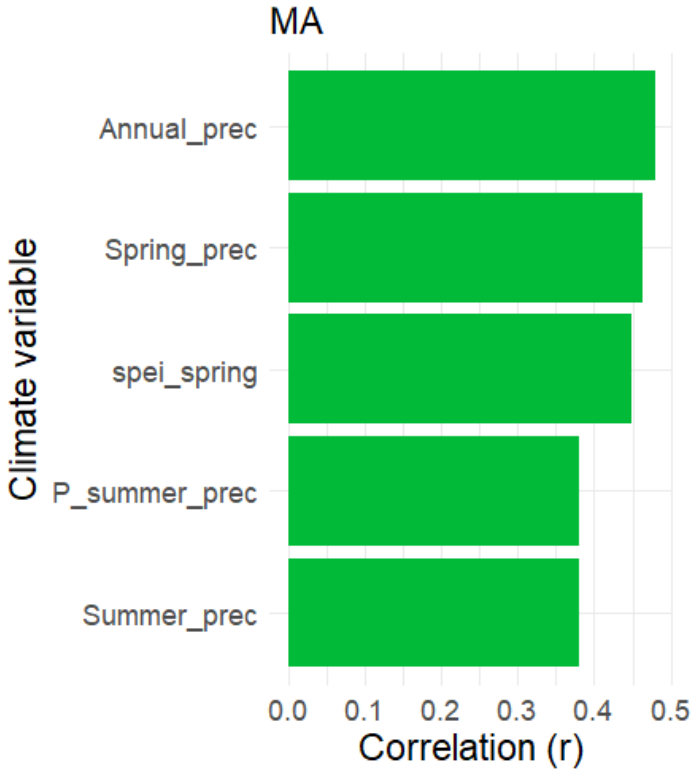


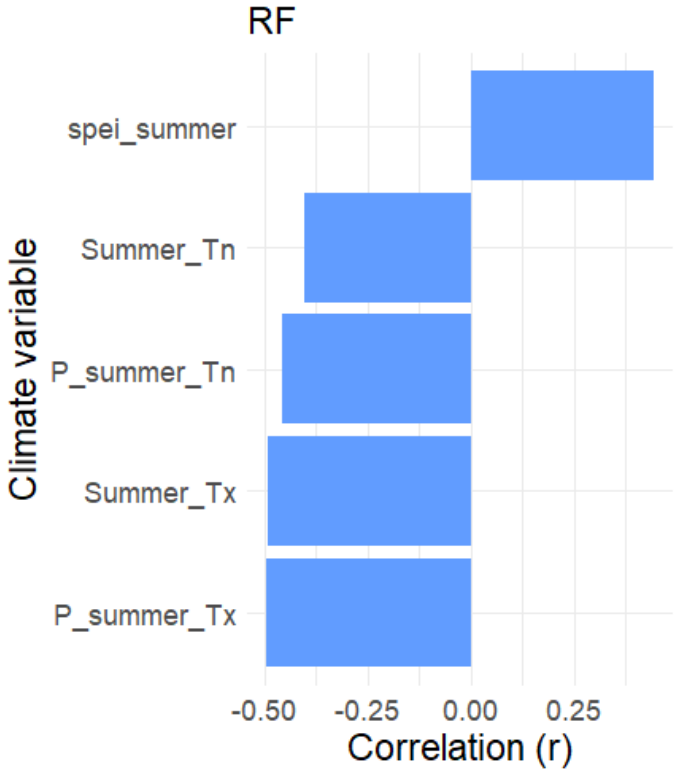
Alto Atlas, Medio Atlas y Rif (Marruecos)

Cedrus atlantica

Alta sensibilidad a la sequía en Alto Atlas y Medio Atlas; y a la temperatura de verano en el Rif.







Alto Atlas (Marruecos)

Cedrus atlantica

Foto: Pepe Carreira

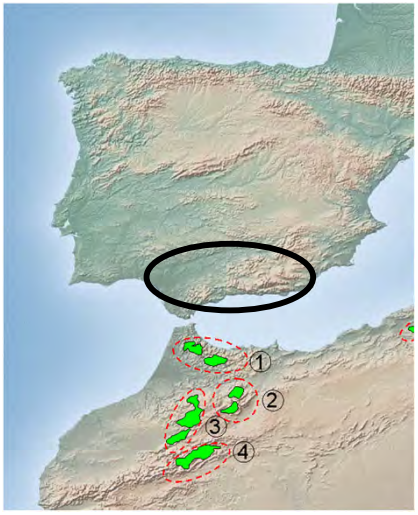
Alto Atlas (Marruecos)

Foto: Juan Carlos Linares


Alto Atlas (Marruecos)
Foto: Juan Carlos Linares

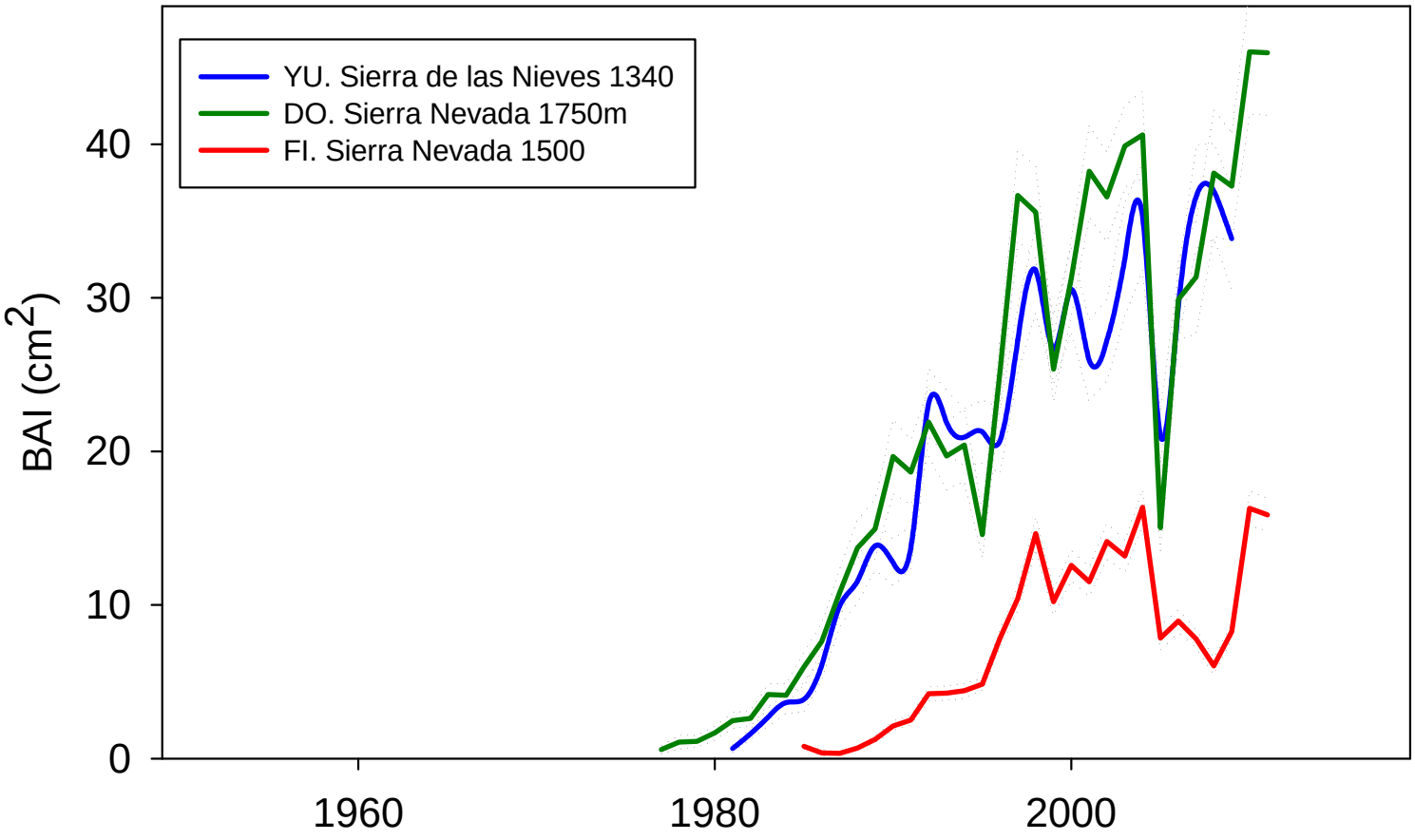
Medio Atlas (Marruecos)

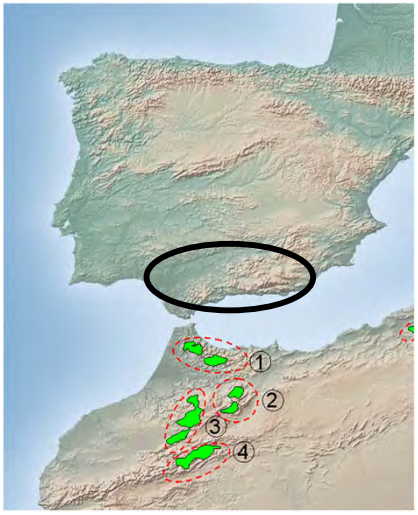
Cedrus atlantica



Plantaciones de cedro del Atlas, España.
Yunquera (Clima similar al Rif), Dornajo (clima similar al Medio Atlas) y Fiñana (Clima similar al Alto Atlas).

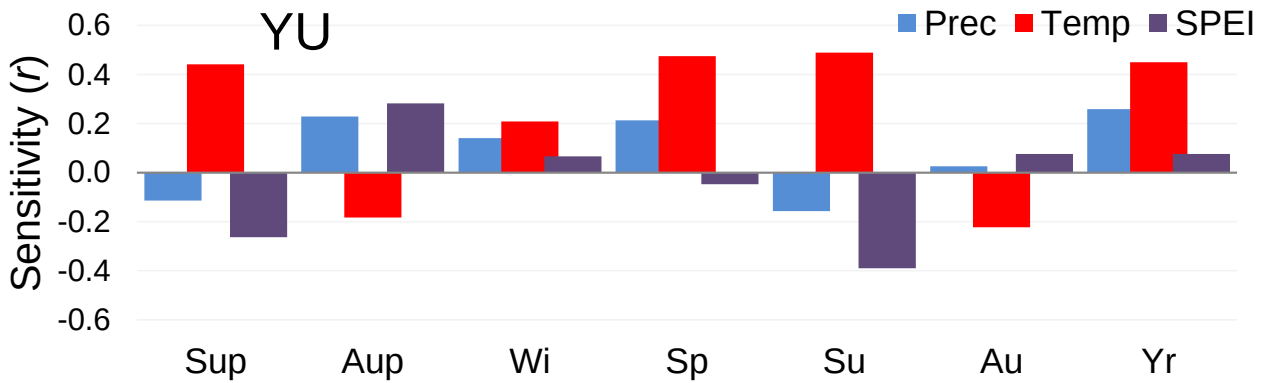
Fuerte descenso en sequía 2005, pero con recuperación.

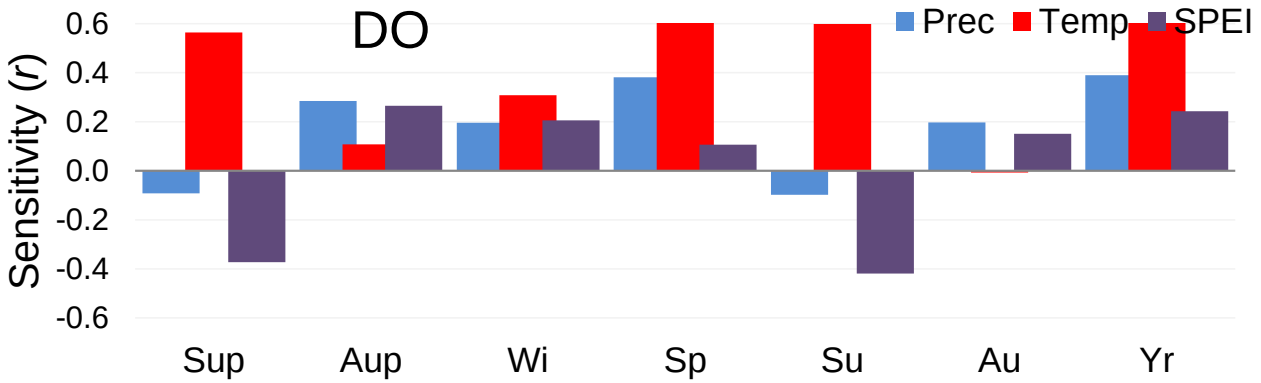


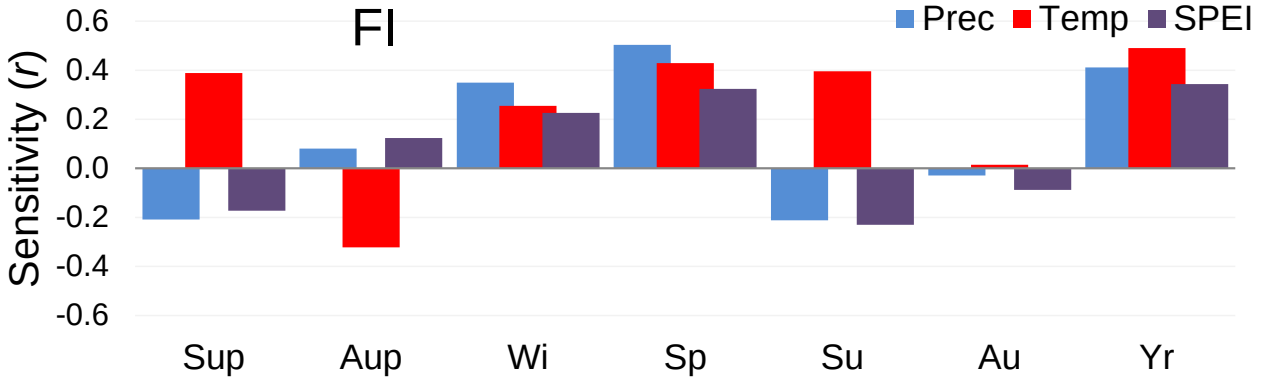


Gradiente longitudinal de aridez

Plantaciones de cedro del Atlas.
Sensibilidad positiva a la temperatura







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LETTER TO THE EDITOR | Free Access

Plantations Do Not Necessarily Lack Resilience

This article relates to:

Jitang Li (李继唐) ✉, Jesús Julio Camarero, Antonio Gazol

First published: 25 September 2025 | https://doi.org/10.1111/gcb.70509 | Citations: 1

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Graphical Abstract

Climate change has intensified the frequency and severity of droughts, posing significant challenges to both natural and planted forests. Ma et al. (2025) explored the drought risk of planted vs. natural forests in China. They reported lower resistance and resilience in planted forests compared to natural forests. However, assessing drought risk in plantations is complex and requires consideration of various key factors, including tree species, stand age, management, resilience, and, importantly, evaluation methods. Only by taking these factors into account can the drought risk of planted forests be accurately assessed so as to develop effective management strategies to ensure their long-term sustainability (comment to Ma et al., *Global Change Biology*, 31, e70055, 2025). The photograph shows our views on the different drought responses of planted and natural forests in northern China.

Recommended

Planted Forests in China Have Higher Drought Risk Than Natural Forests

Longlong Ma, Jun Ma, Pu Yan, Feng Tian, Josep Peñuelas, Mukund Palat Rao, Yongshuo Fu, Zhenhong Hu

Global Change Biology

Optimistic growth of marginal region plantations under climate warming: Assessing divergent drought resilience

Jitang Li, Yuyang Xie, Jesús Julio Camarero, Antonio Gazol, Ester González de Andrés, Lingxiao Ying, Zehao Shen

Conclusiones:

En el campo todo dice menos de lo que de ello se espera

Conclusiones:

La temperatura está muy relacionada con polimorfismos genéticos (adaptación local) y es la variable ambiental más determinante del riesgo de inadaptabilidad

Conclusiones:

Indicadores genéticos y dendroclimáticos coinciden en la vulnerabilidad de los límites de distribución a diferentes escalas

GRACIAS

Juan Carlos Linares

Deseos:

Incorporar bases de datos climáticos de mayor resolución.

Testar diferentes escalas temporales en los modelos genotipo-ambiente.

Deseos:

Analizar amplios gradientes ambientales, incluyendo plantaciones y límites de distribución