

Pasture taxonomic and functional response to climate in Mediterranean drylands

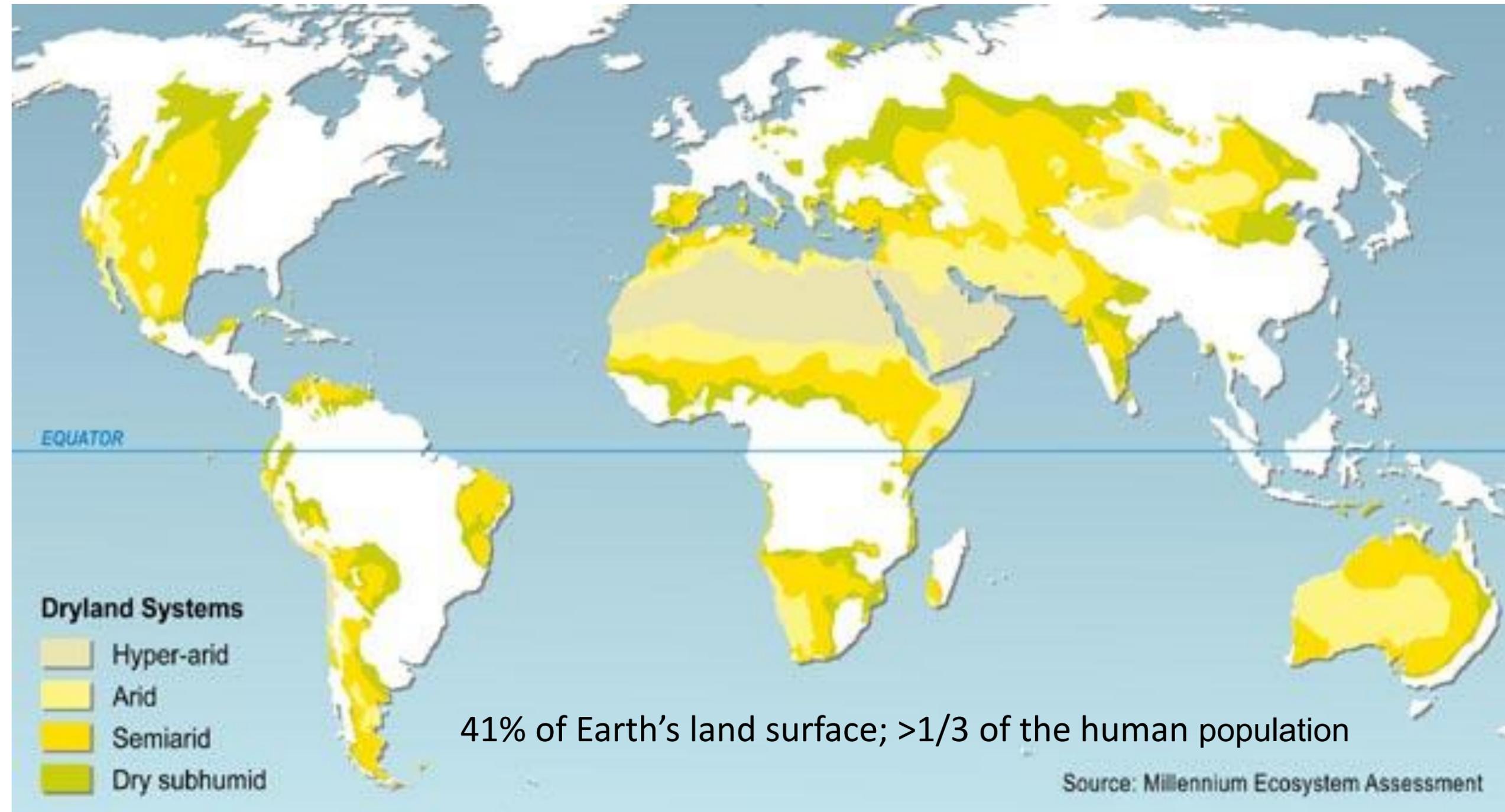
A resposta taxonómica e funcional das pastagens ao clima em zonas semiáridas Mediterrânicas

Alice Nunes, M. Köbel, I. Domingues, A. Príncipe, B.P. Reis, H. Serrano, M.A. Oliveira, C. Branquinho

CE3C - Centre for Ecology, Evolution and Environmental Changes
& CHANGE – Global Change and Sustainability Institute,
Faculdade de Ciências, Universidade de Lisboa

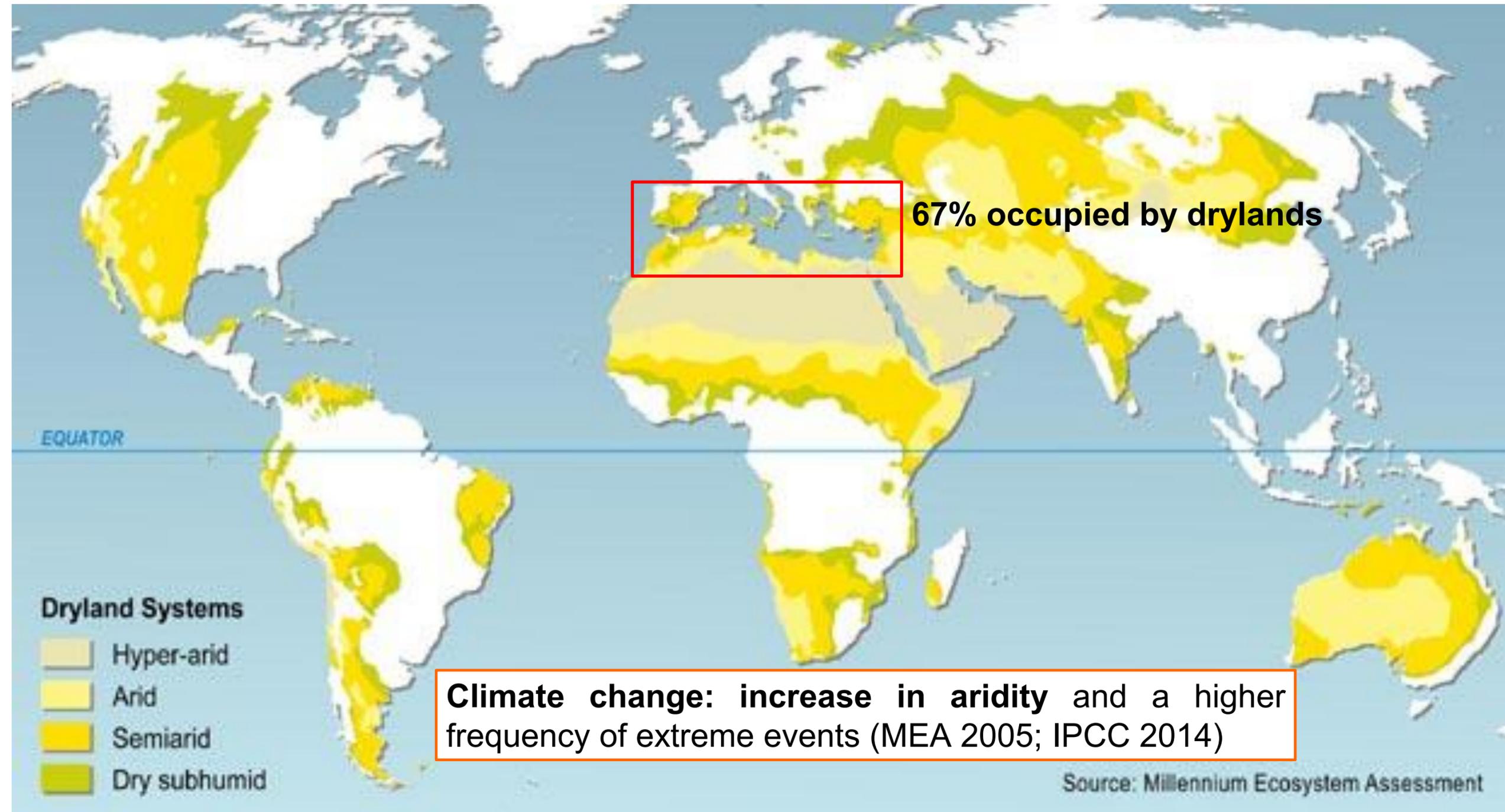


Drylands susceptibility to climate change



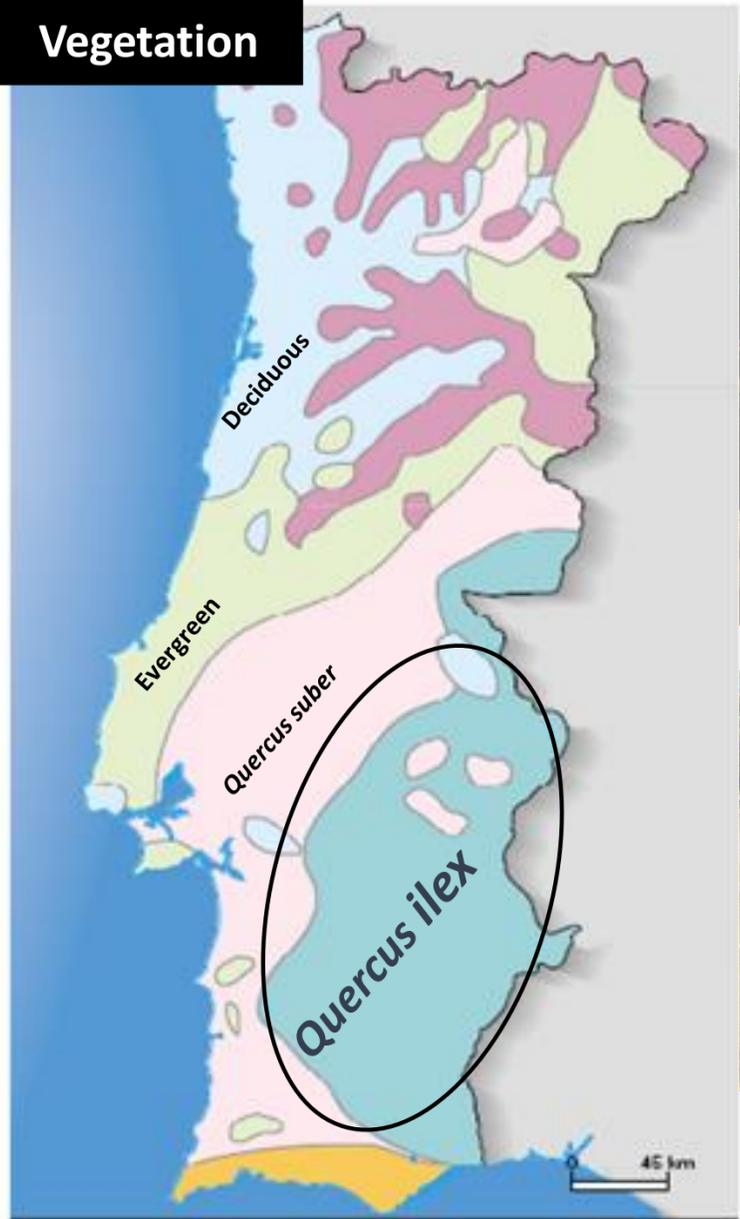
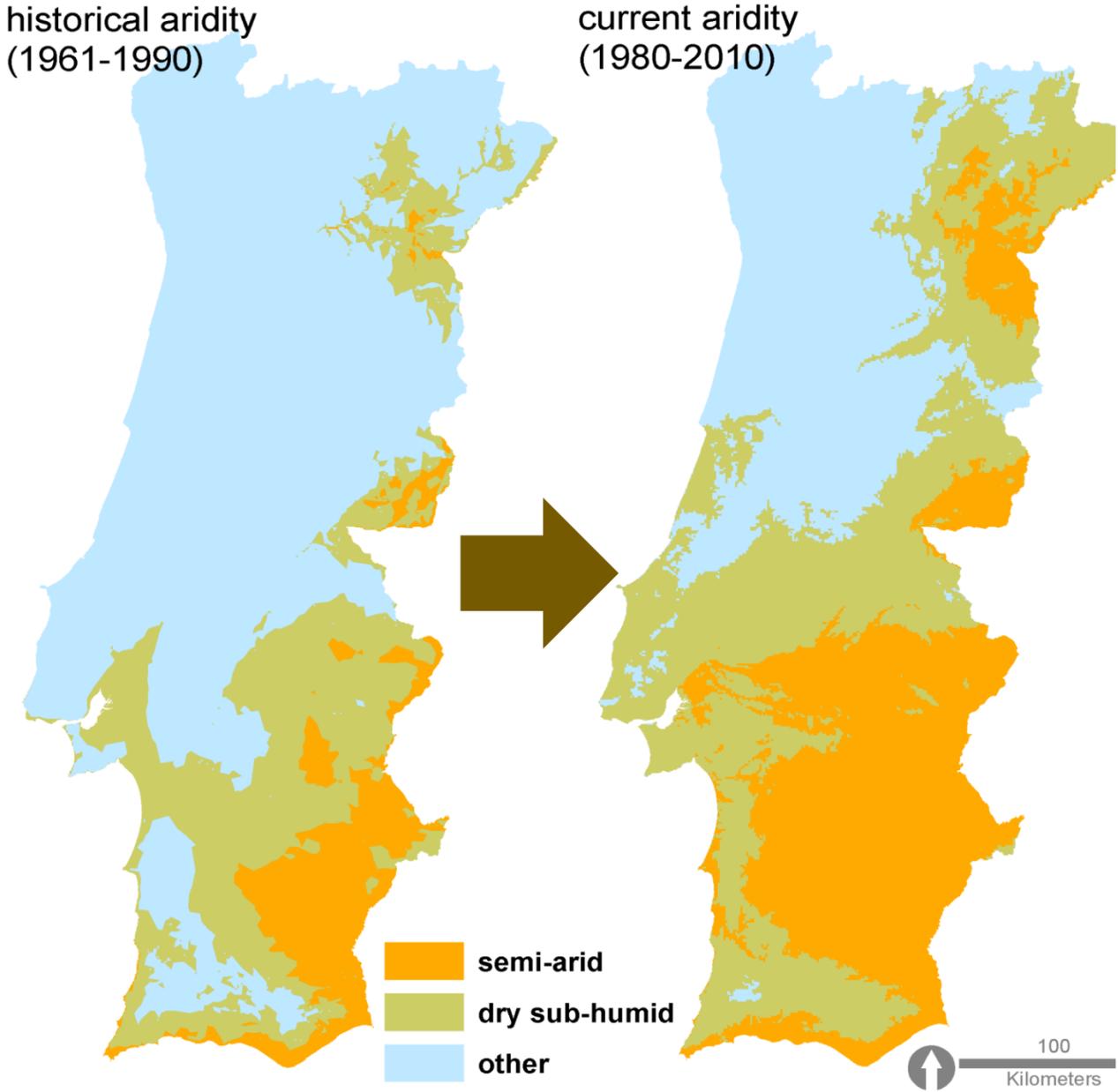
Drylands susceptibility to climate change

Desertification: land degradation (loss of biological or economic productivity) due to climate and human activities

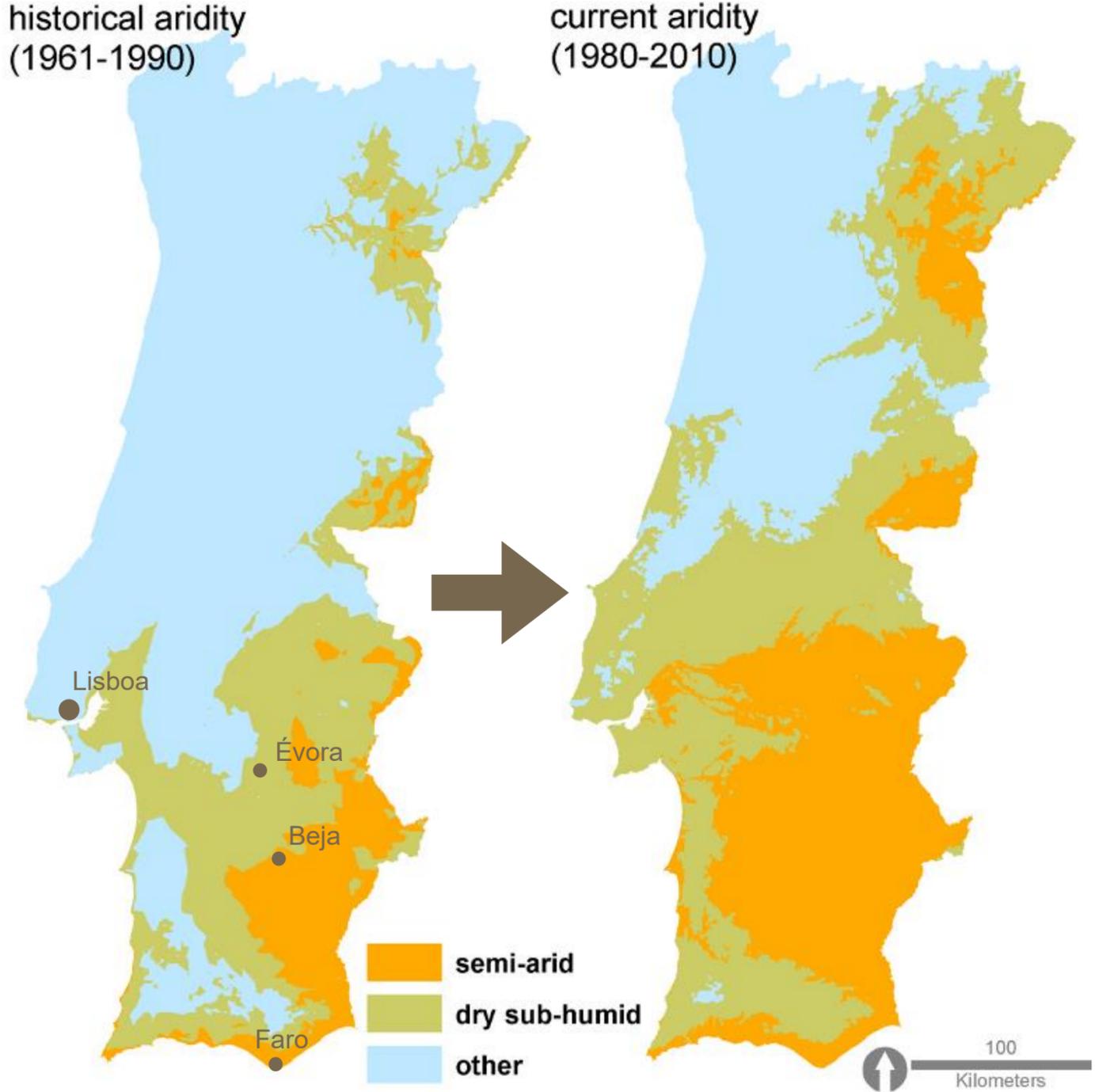


Drylands in Portugal and climate change

Cork-oak and Holm-oak woodlands (montado)



Drylands in Portugal and climate change



Cork-oak and Holm-oak woodlands (montado)

Importance: Ecosystem Services



REGULATING

Soil conservation; climate regulation; pest control; cleaning water and air; polinization, etc.



PROVISIONING

Cork; wood; livestock production; habitat; food; genetic resources, etc.



CULTURAL

Heritage and identity; landscape; education; gastronomy, etc.



SUPPORTING

High biodiversity; nutrient cycling; primary productivity; soil formation



Threats:

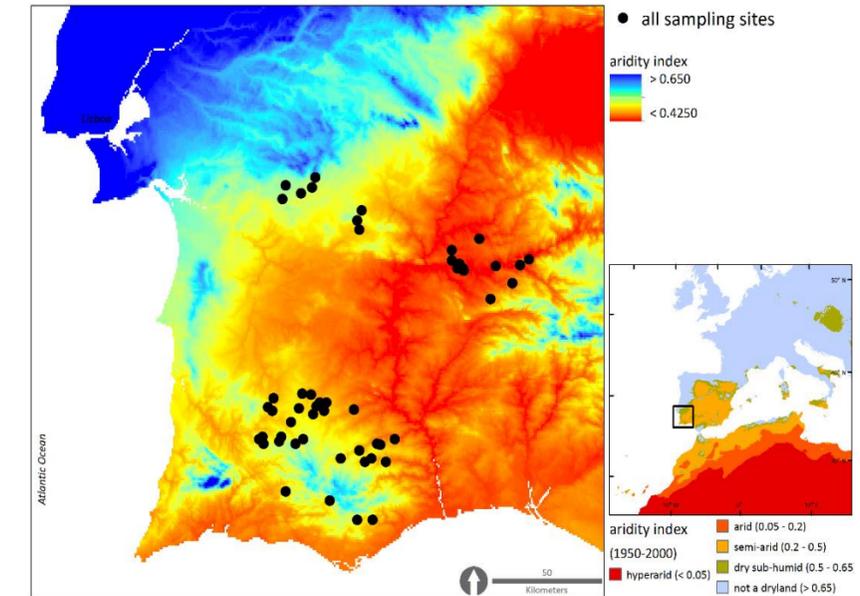
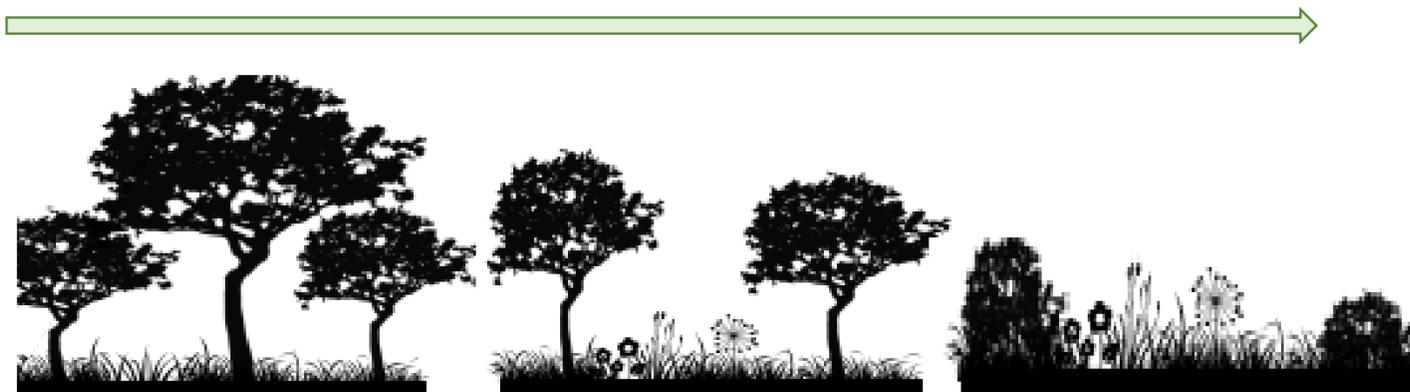
- Low natural regeneration
- High tree mortality
- Low reforestation success
- Biodiversity loss
- Low productivity

Millenium Ecosystem Assessment, 2004

Methods to study climate change effects on ecosystems

Empirical/observational

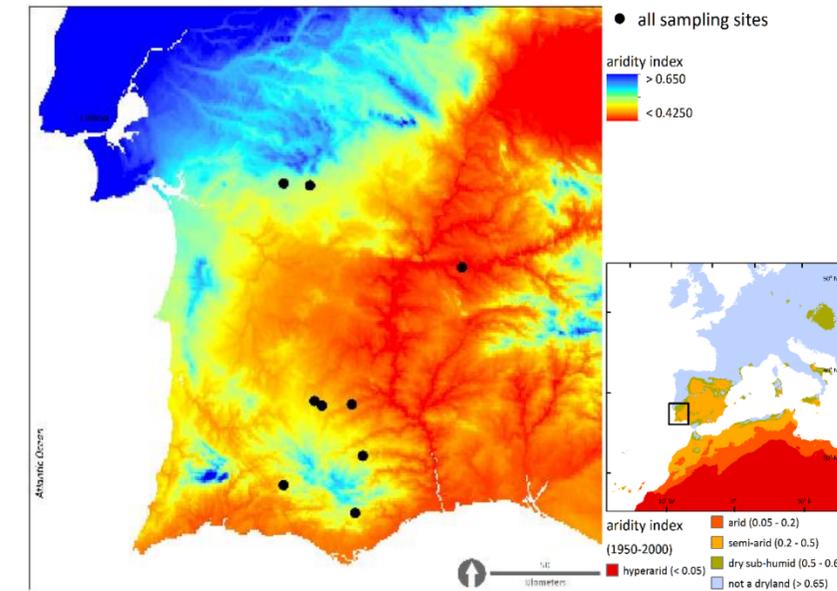
1. Along spatial climate gradients



Methods to study climate change effects on ecosystems

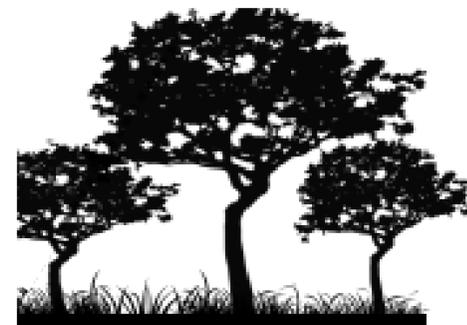
Empirical/observational

1. Along spatial climate gradients



2. Changing climate over time

Year 0



Year 5



Year 10



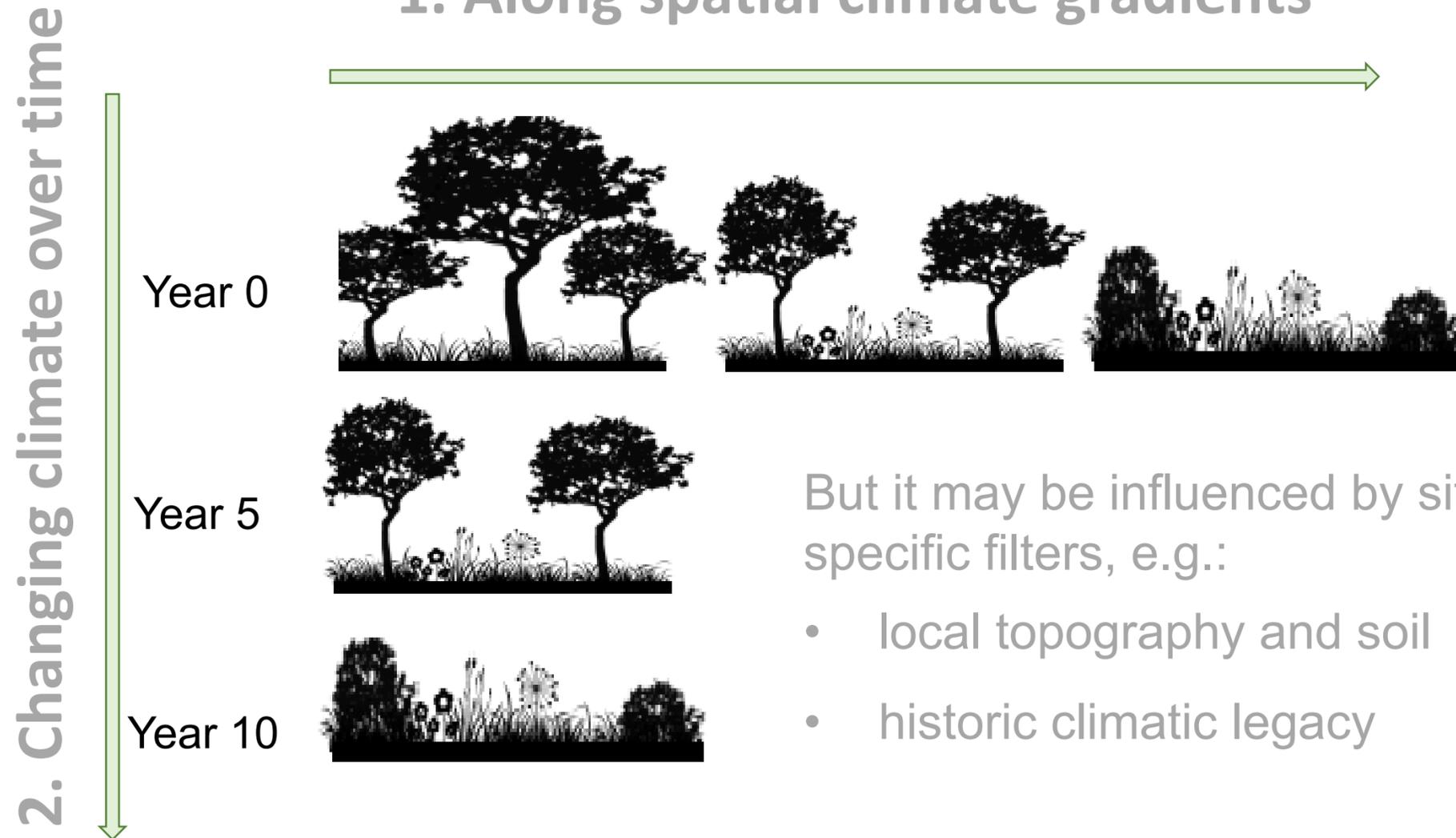
But it may be influenced by site-specific filters, e.g.:

- local topography and soil
- historic climatic legacy

Methods to study climate change effects on ecosystems

Empirical/observational

1. Along spatial climate gradients



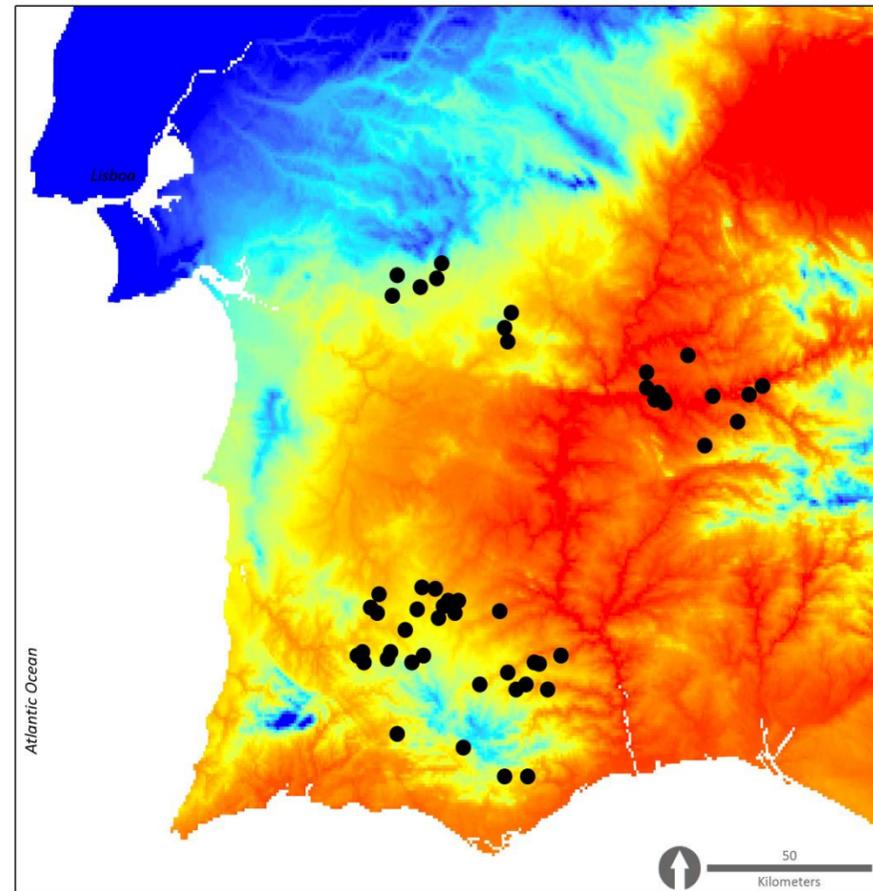
But it may be influenced by site-specific filters, e.g.:

- local topography and soil
- historic climatic legacy

3. Manipulative (cause-effect)



1. Studies along spatial climate gradients: response to aridity



Homogeneization of confounding variables:

- Holm-oak woodlands
- Altitude (150-300m)
- Slope (0-25°)
- No fire
- Soil characteristics
- Moderate grazing intensity

Stratification by the aridity index

$$AI_{\text{UNEP}} = \frac{\text{Potential Evapotranpiration}}{\text{Average annual precipitation}}$$

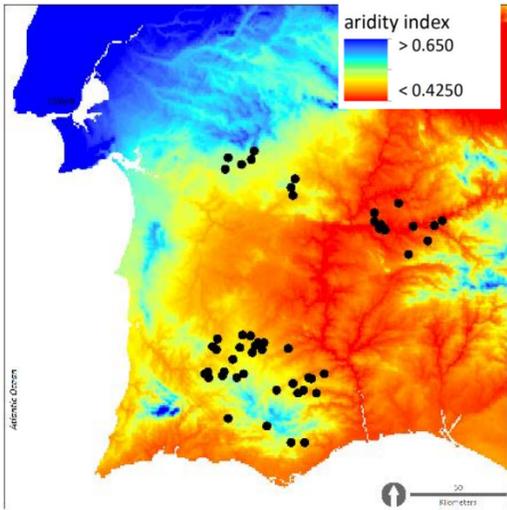
Plant community sampling in 2012;
new sampling in 2022



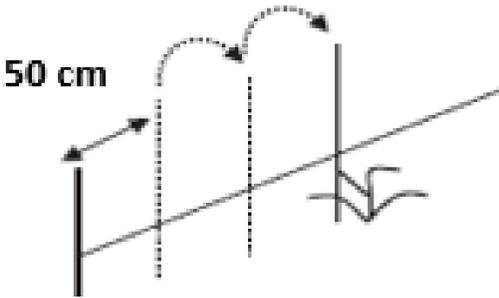
1. Studies along spatial climate gradients: response to aridity



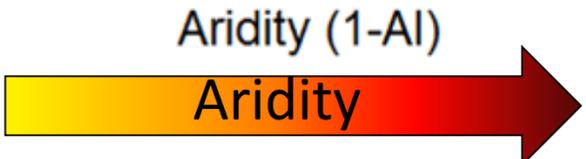
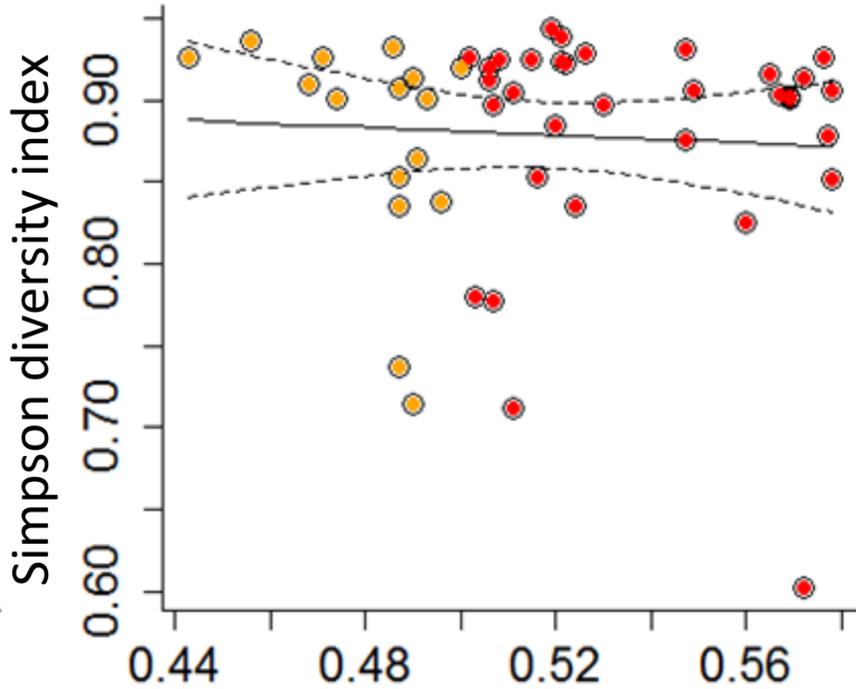
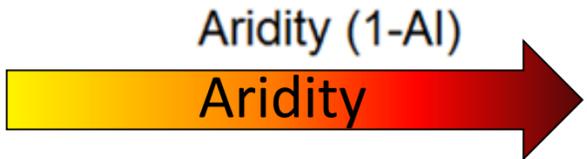
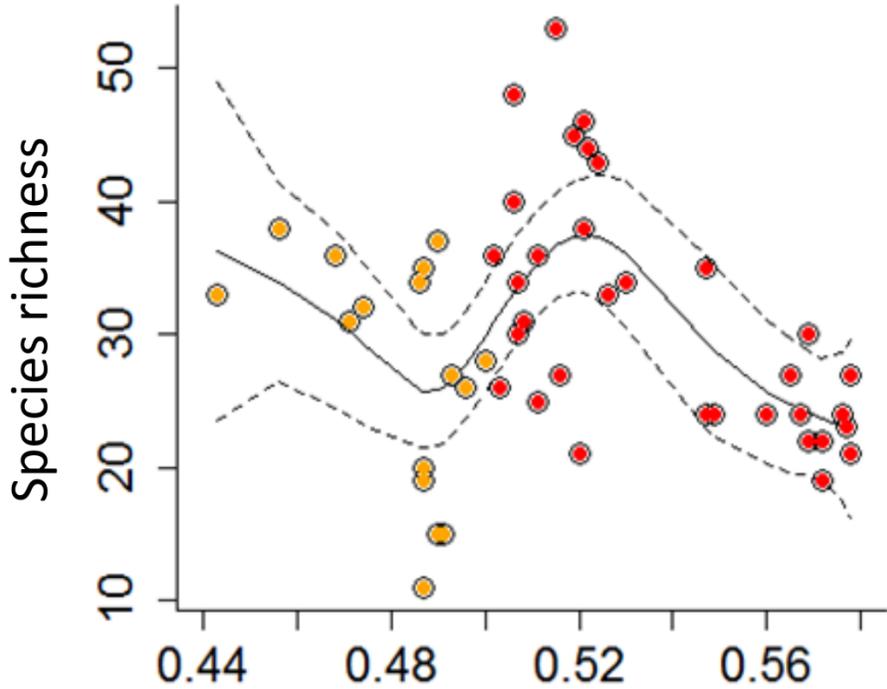
Sampling sites (54)



Point-intercept method



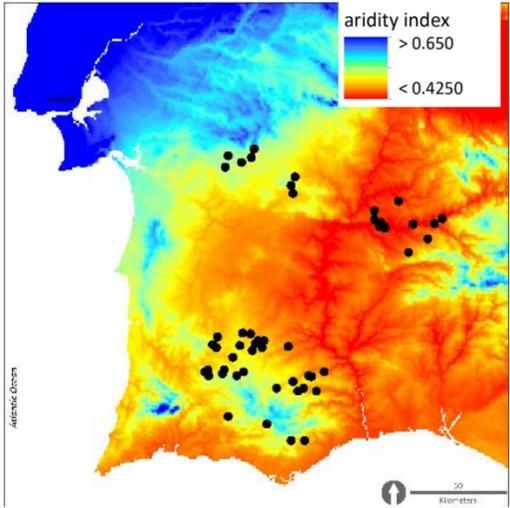
● dry_subhumid ● semi-arid



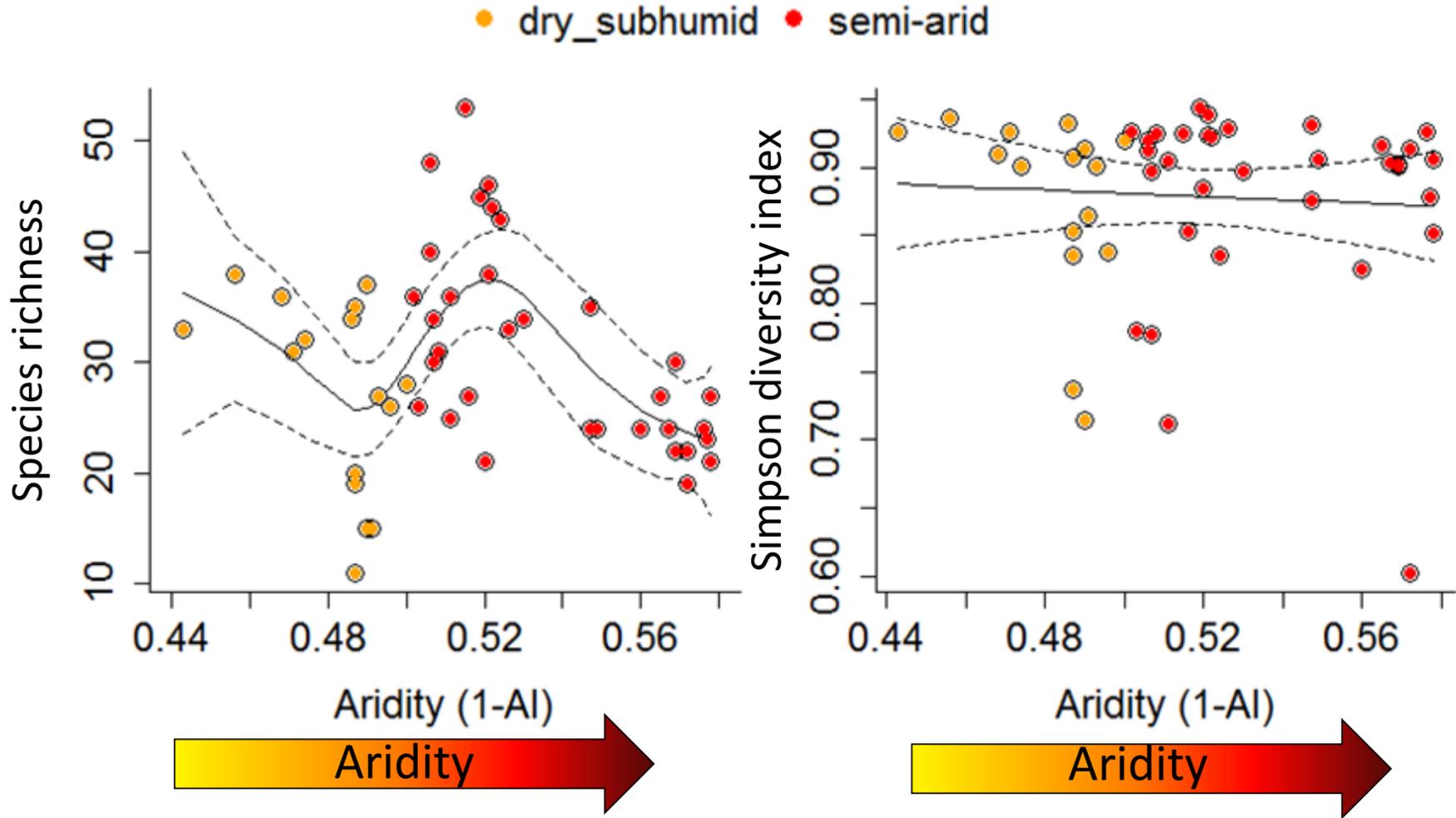
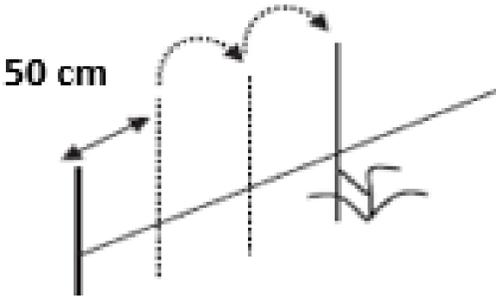
1. Studies along spatial climate gradients: response to aridity



Sampling sites (54)

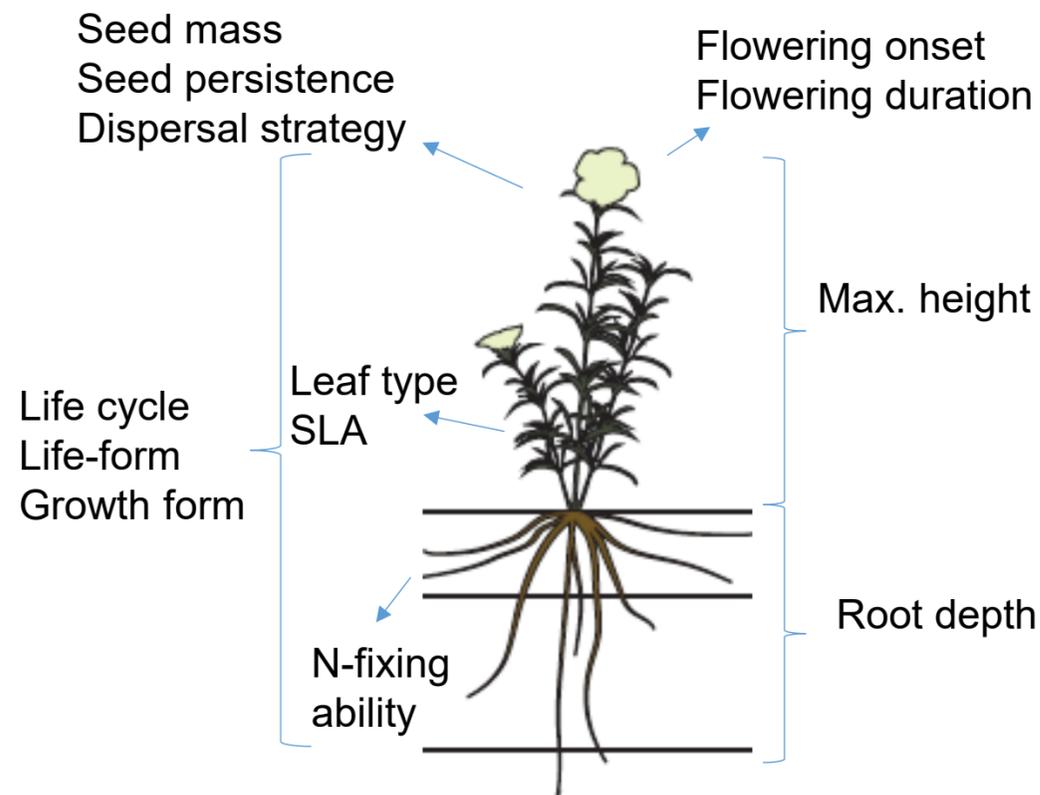


Point-intercept method



No clear trend in species diversity with aridity

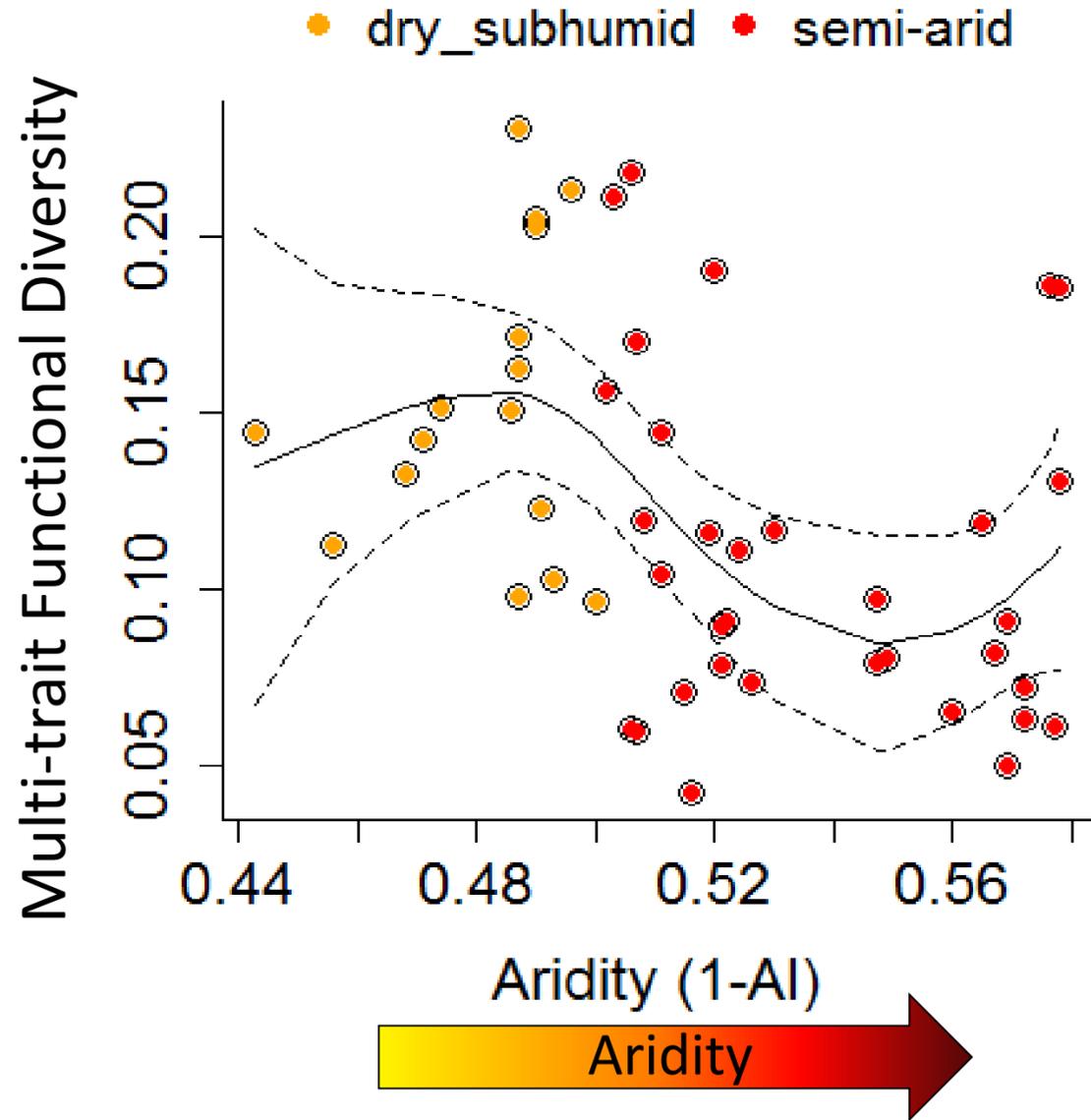
Functional response of the plant community to aridity



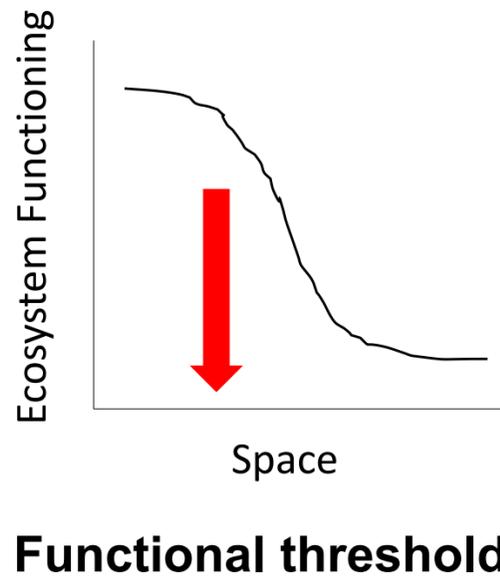
		Increasing aridity		
Trait	Categories	CWM	FD	
<i>Vegetative</i>	Life cycle	↓***	↓**	
	Life-form	↑**	n.s.	
	Growth-form	Phanerophyte	↓*	n.s.
		Rosette	↑*	n.s.
	Shrub	↓*	n.s.	
	Max. height	↓**	n.s.	
<i>Leaf</i>	Specific leaf area	n.s.	↓**	
<i>Reproductive</i>	Onset flowering	n.s.	↓*	
	Duration flowering	↓**	n.s.	
<i>Regenerative</i>	Dispersal strategy	Anemochory	↑**	
		Barochory	↓***	
	Seed persistence	n.s.	↓*	

Nunes et al. (2017) Agr. & Forest Meteo.

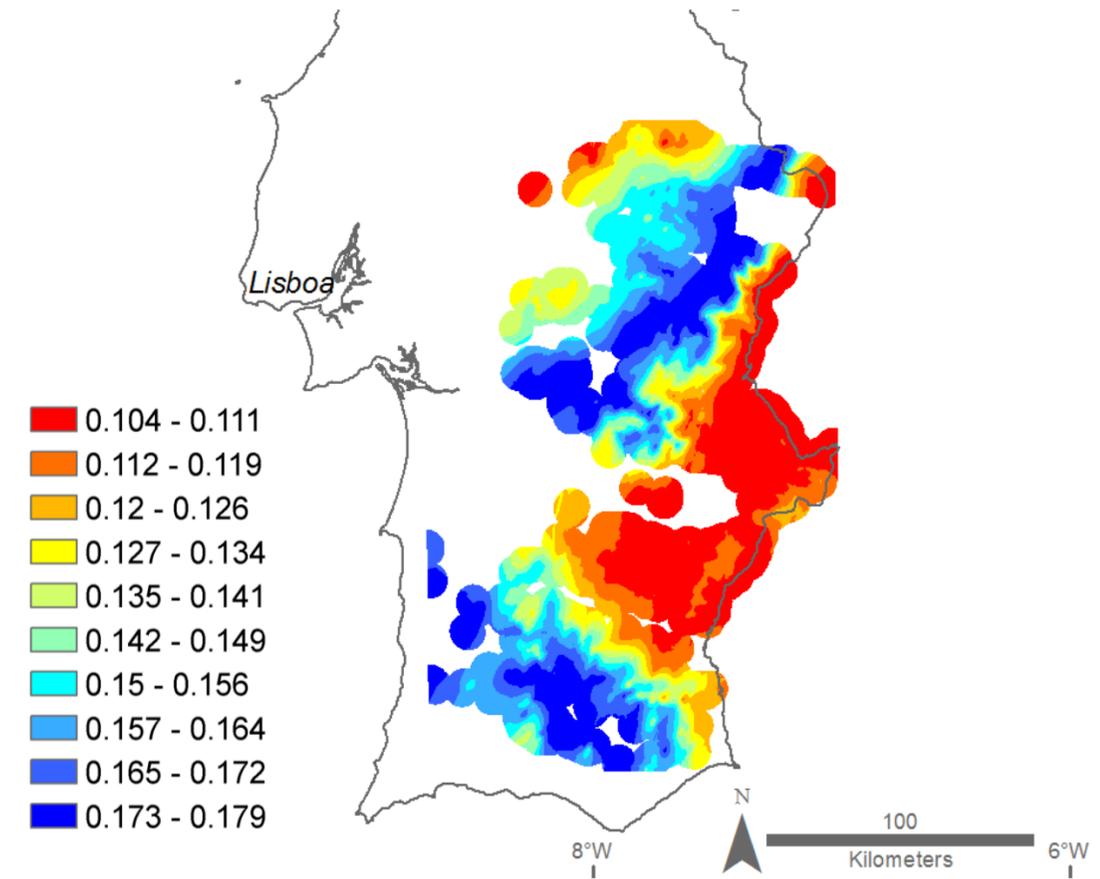
Functional indicator to track climate change effects



Monotonic non-linear decrease with increasing aridity

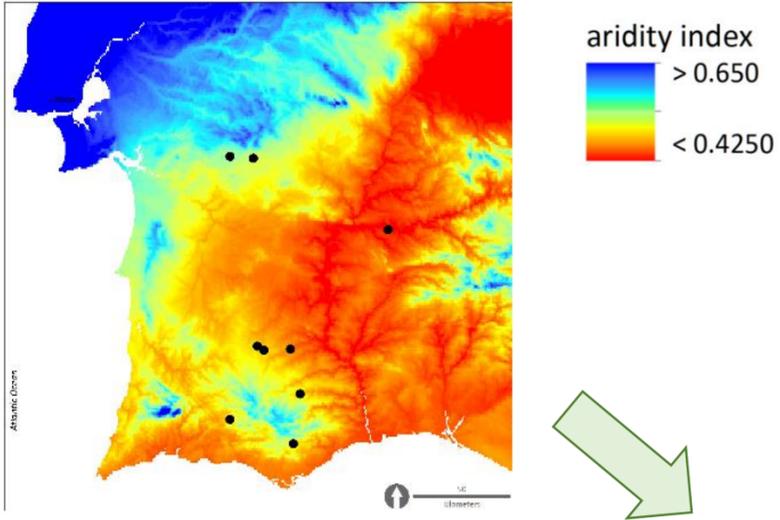


Map areas at risk of desertification and the loss of ecosystem services



2. Studies over time: response to dry and wet years

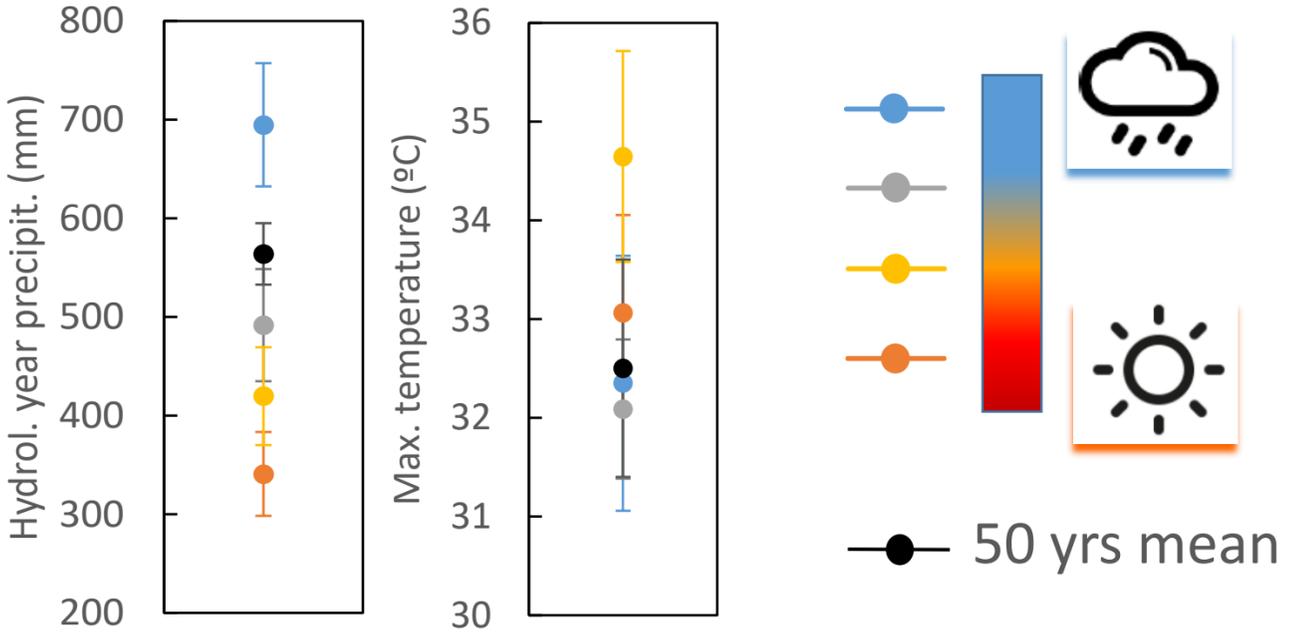
Sampling sites (13)



Resilience of the plant community to climatic fluctuations, particularly under climate change, and propose adaptation measures

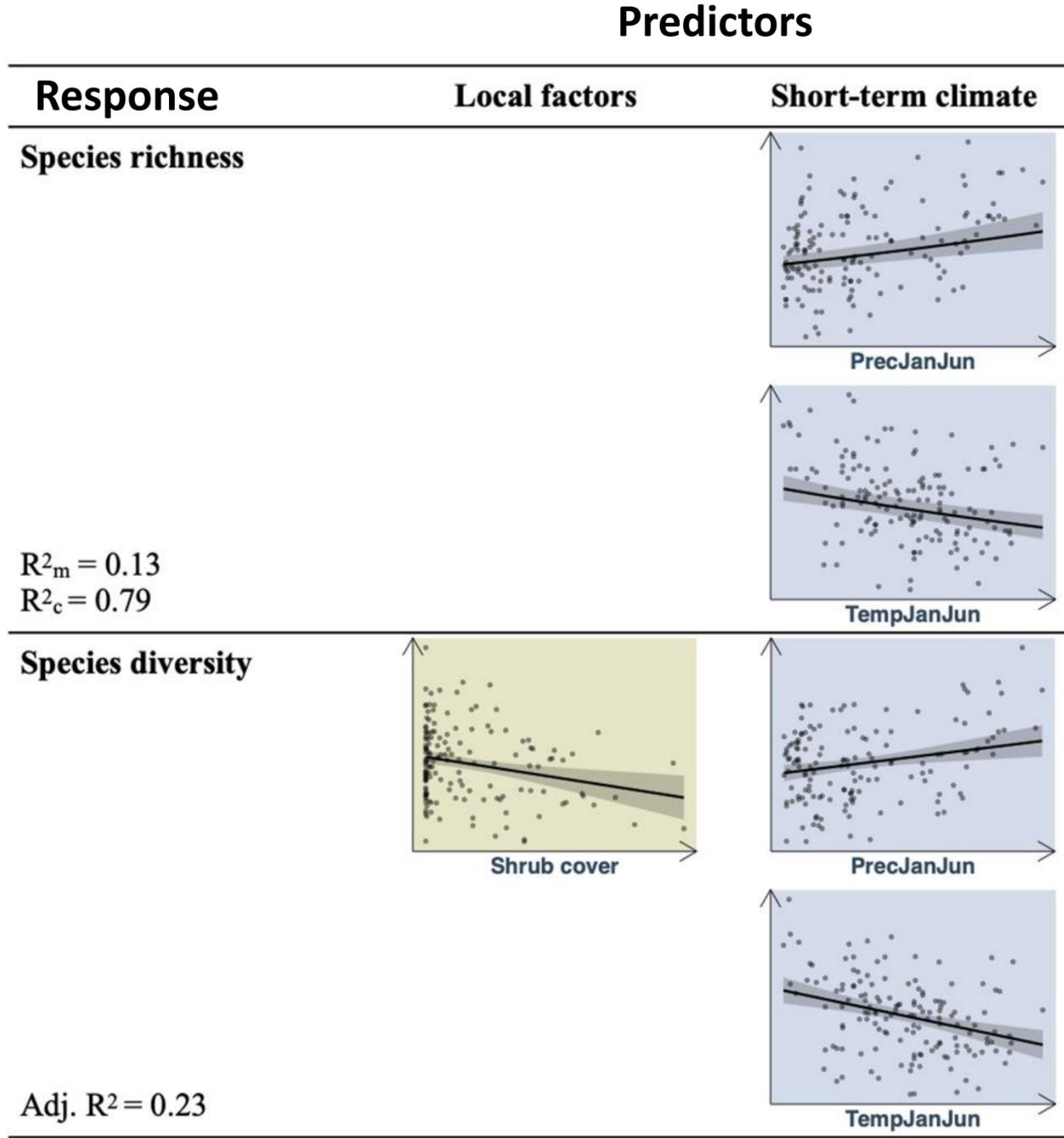
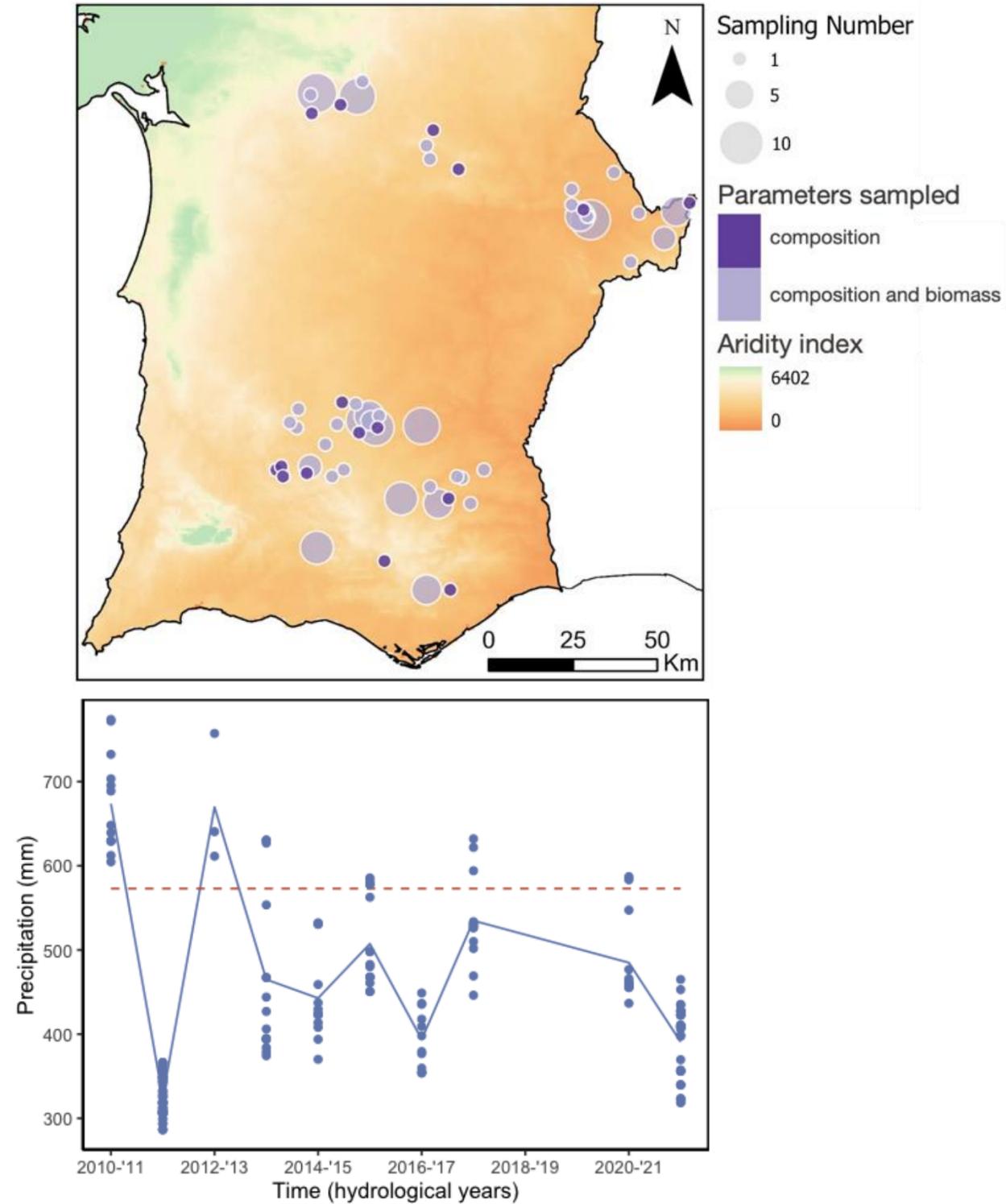


Each site sampled in four climatically contrasting years



2. Studies over time: response to dry and wet years

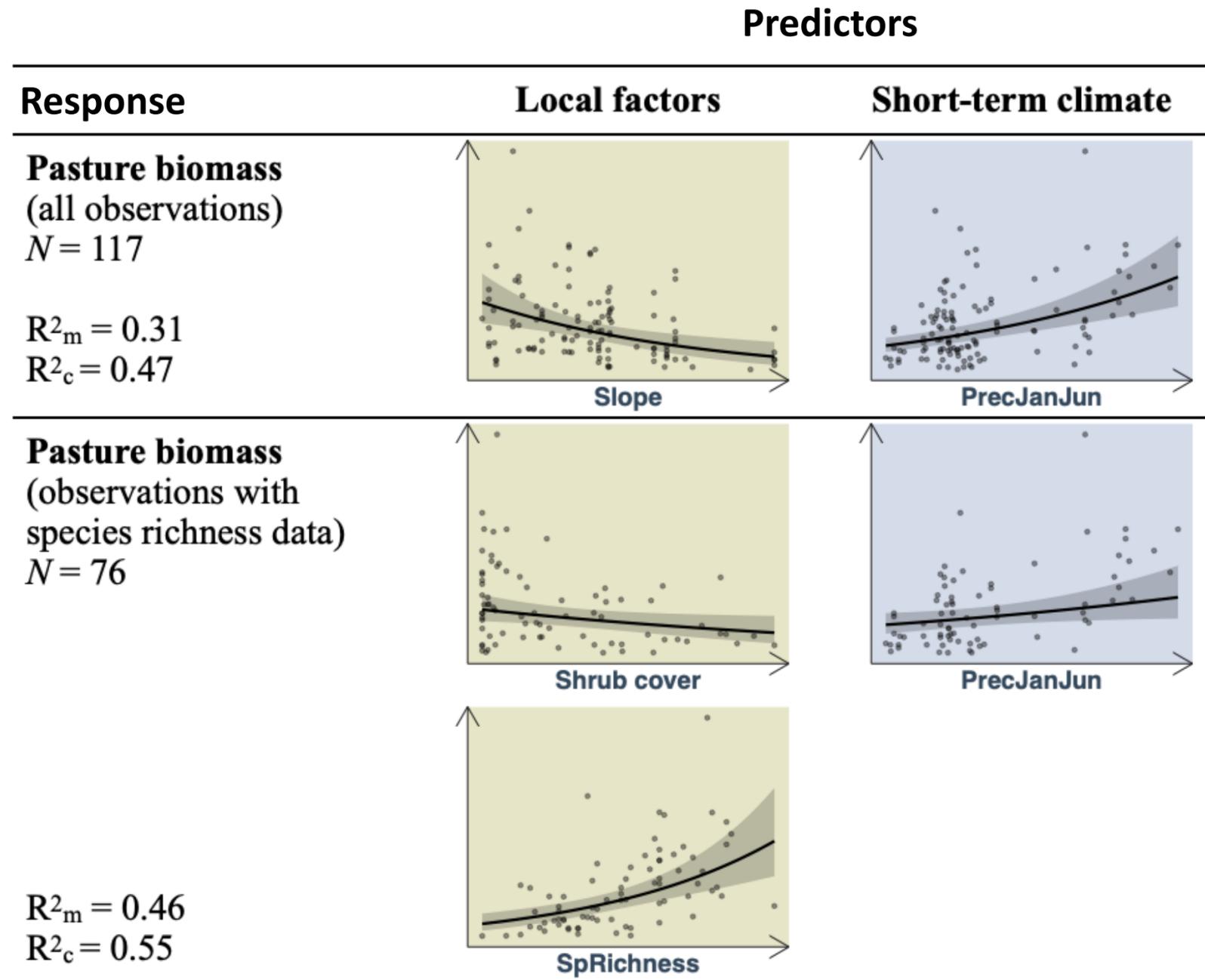
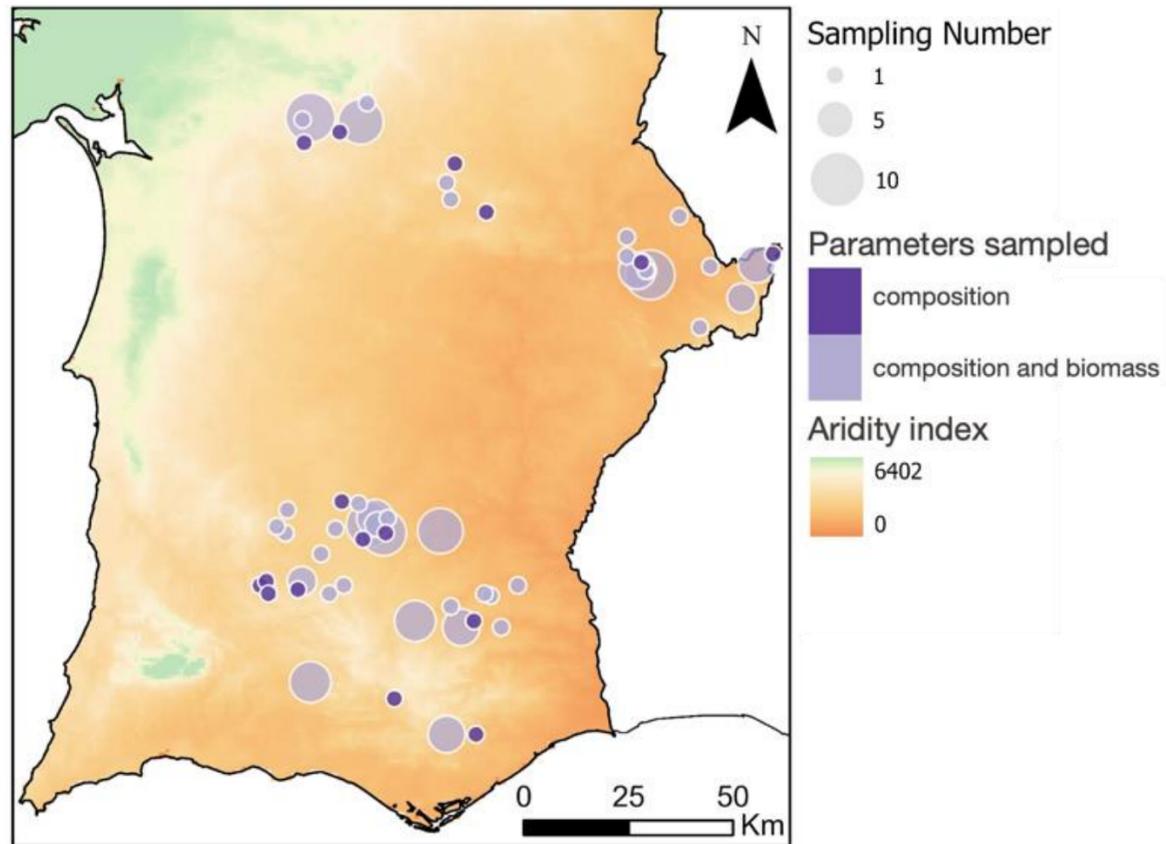
Sites were sampled 1-9 times between 2011 and 2022



Melanie Köbel et al. 2025 (in preparation)

2. Studies over time: response to dry and wet years

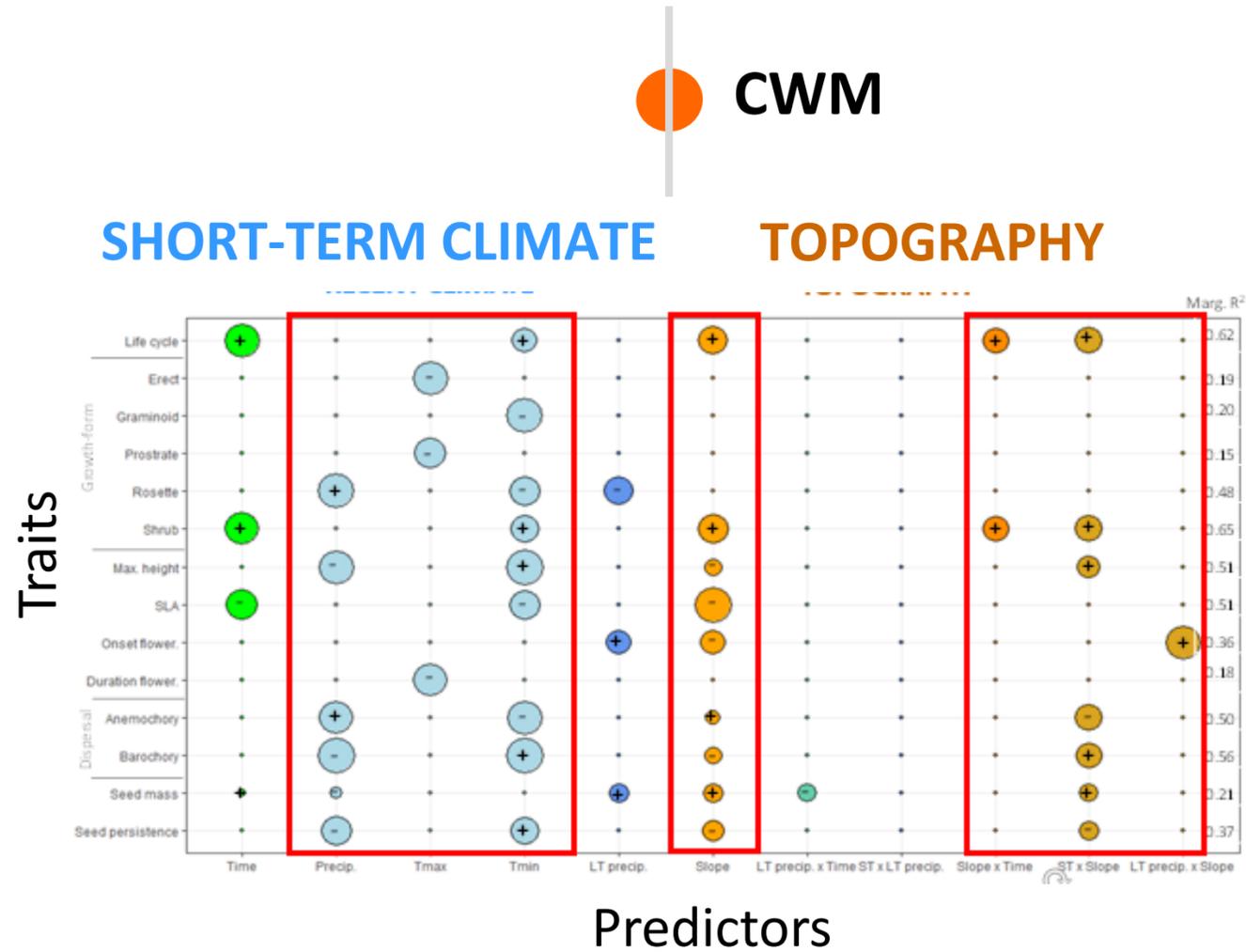
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Melanie Köbel et al. 2025 (in preparation)

2. Studies over time: response to dry and wet years

Plant Functional Traits: Relative importance of predictors



Nunes et al. (2017)



Predictors

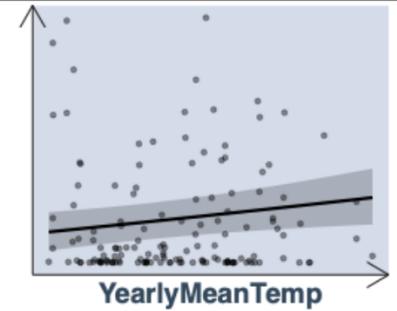
Response

Local factors

Short-term climate

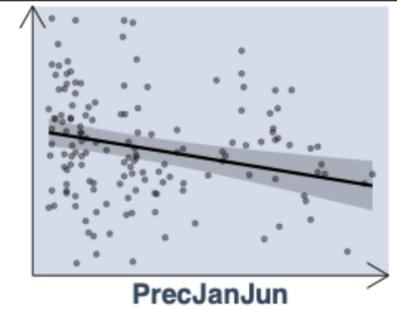
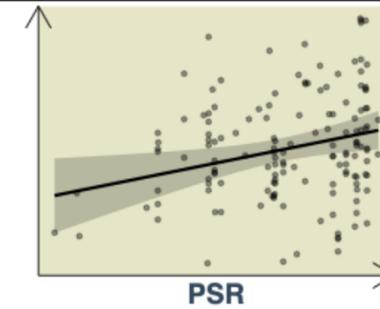
CWM woody

$R^2_m = 0.41$
 $R^2_c = 0.77$



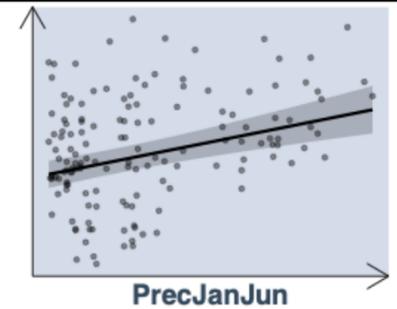
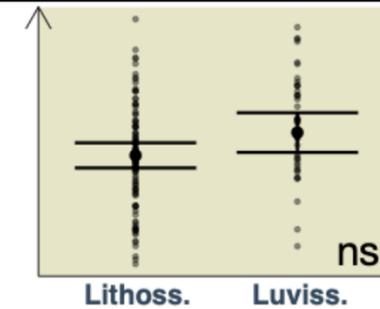
CWM grass

$R^2_m = 0.19$
 $R^2_c = 0.47$



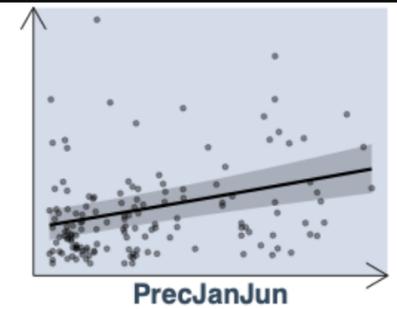
CWM forb

$R^2_m = 0.33$
 $R^2_c = 0.53$



CWM legume

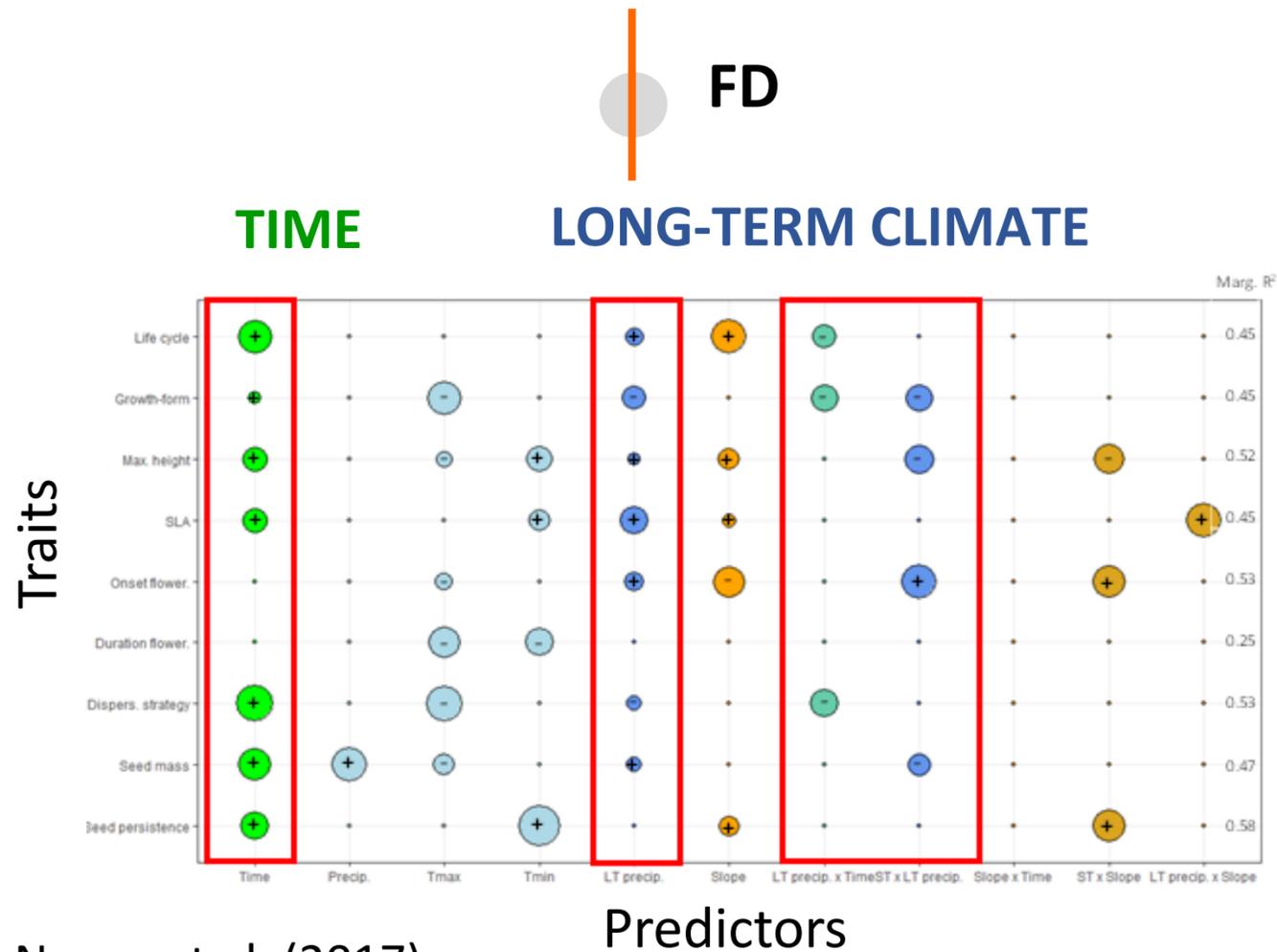
$R^2_m = 0.10$
 $R^2_c = 0.53$



Melanie Köbel et al. 2025 (in preparation)

2. Studies over time: response to dry and wet years

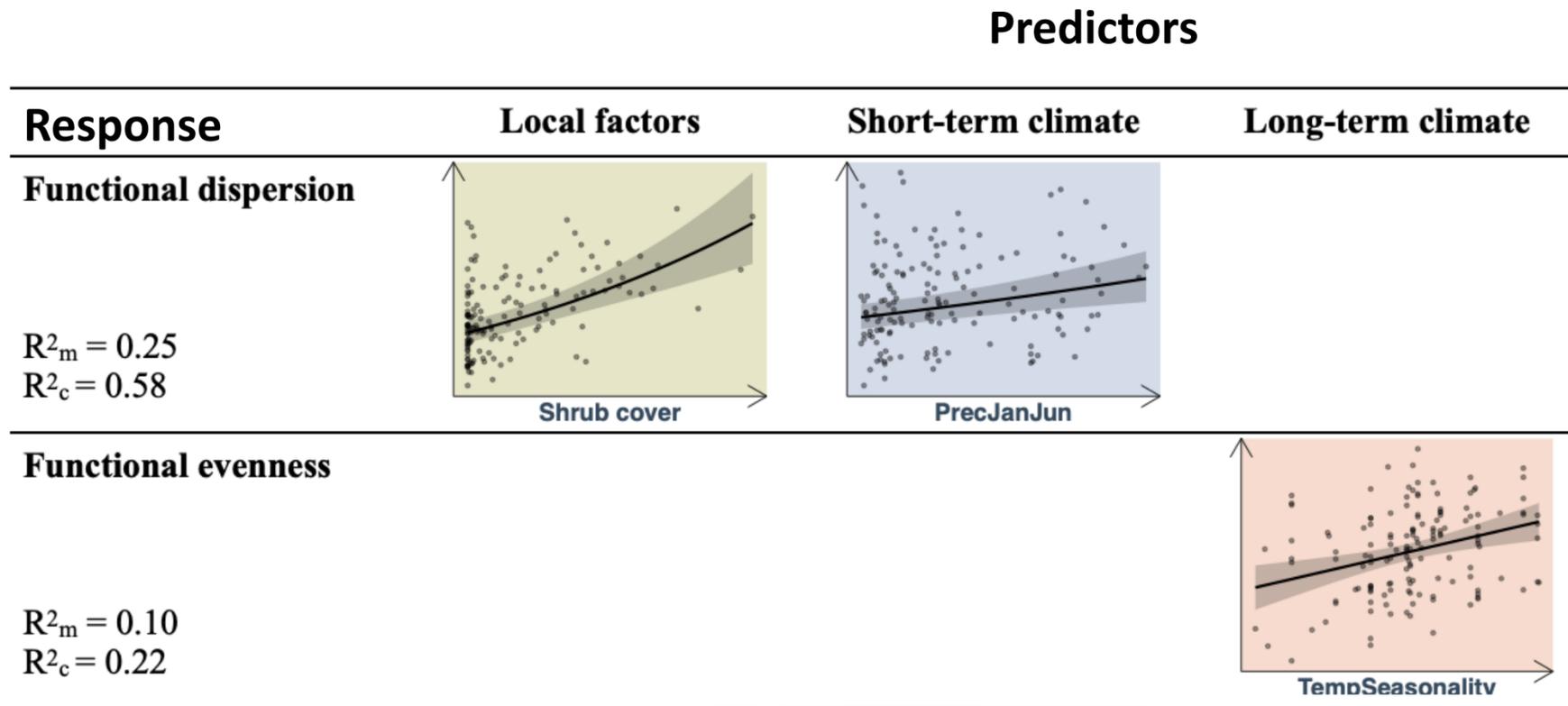
Plant Functional Traits: Relative importance of predictors



Nunes et al. (2017)

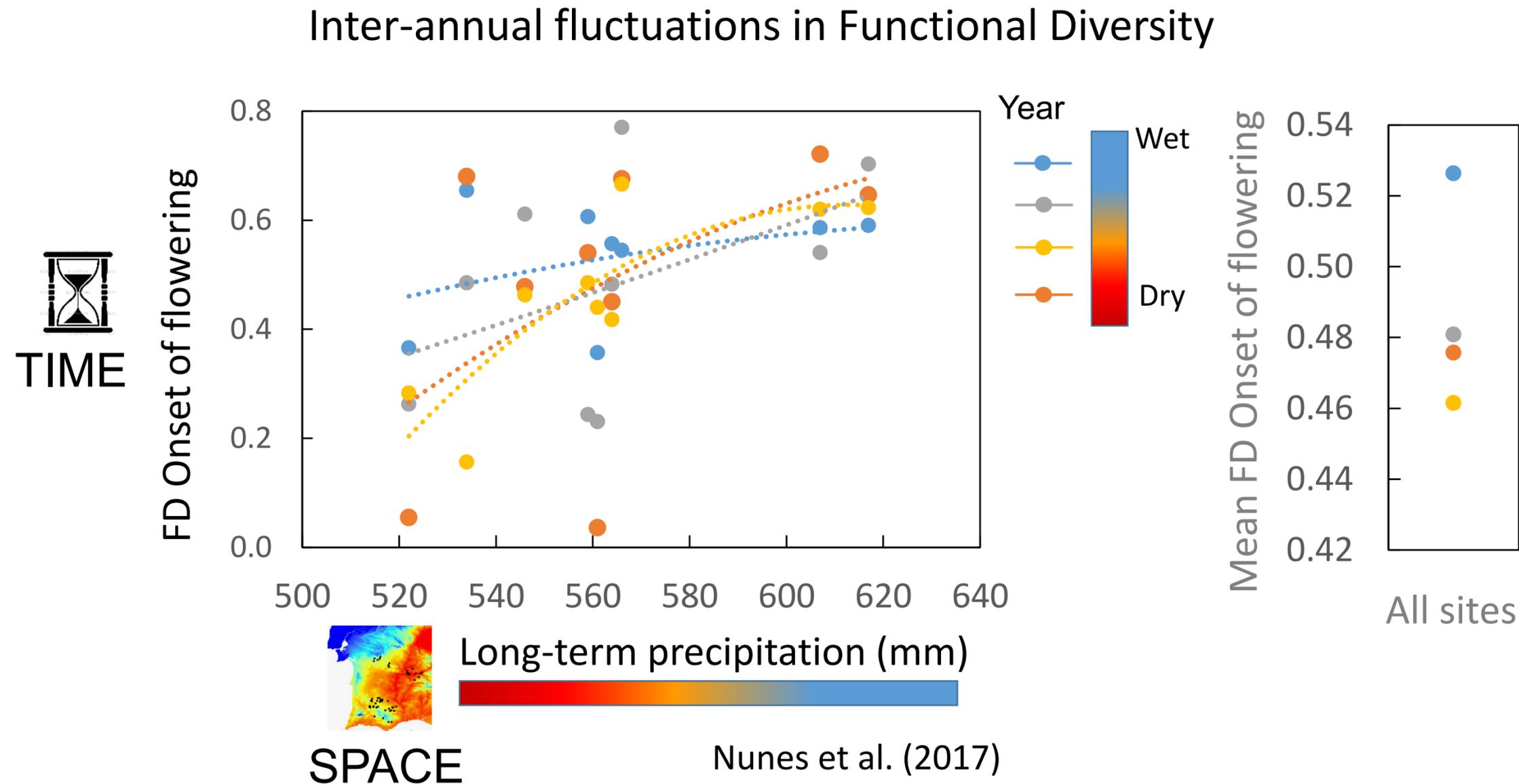


Legacy effect of climate on FD: climatic filtering acting at trait regional pool over the long-term



Melanie Köbel et al. 2025 (in preparation)

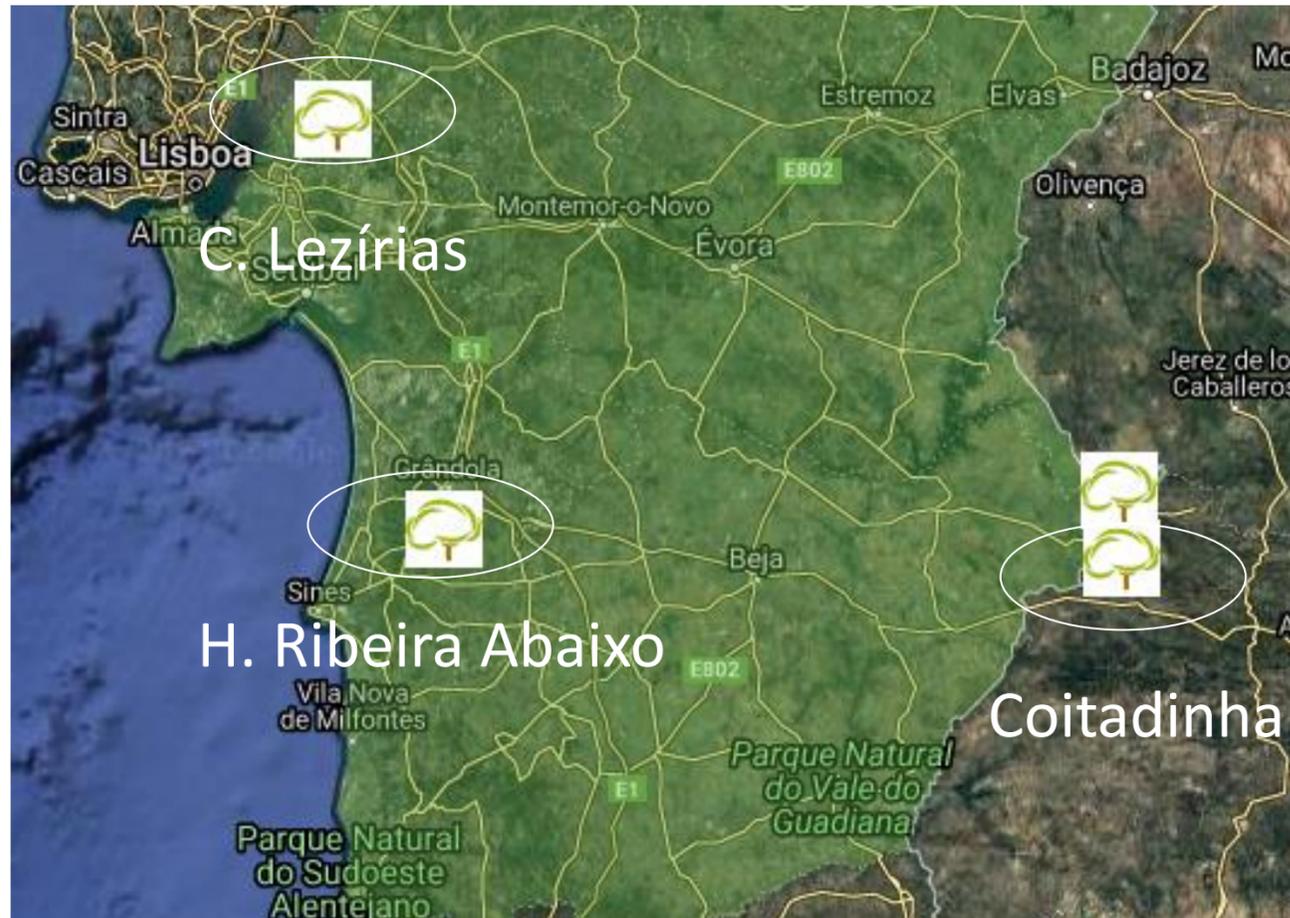
2. Studies over time: response to dry and wet years



- Historically drier sites show lower values and higher variation in FD, but also high resilience
- Despite inter-annual variation in FD, if climatic conditions persist, temporal trends are expected to converge to spatial patterns

3. Validating empirical observation through experimental manipulation

LTsER montado - Long Term Ecological Research sites (<http://www.ltsermontado.pt/>), with different aridity levels



Experiments with Rainout Shelters, following Droughtnet protocol (<https://drought-net.colostate.edu/>) International drought experiment

3 Treatments:

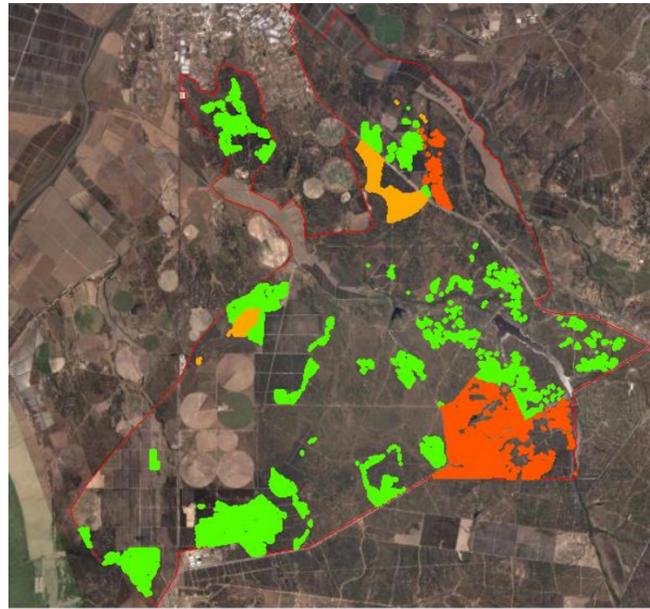
- Control
- Moderate-drought (moderate precipitation reduction)
- Extreme-drought (based on 1st percentile of long-term precipitation record at each site)

3 aridity levels (space); sampling over 4 years (time)

5 replicates in each of the 3 LTsER montado sites

3. Validating empirical observation through experimental manipulation

Selection of sampling sites



Baseline sampling pre-instalation



Rainout-shelters instalation

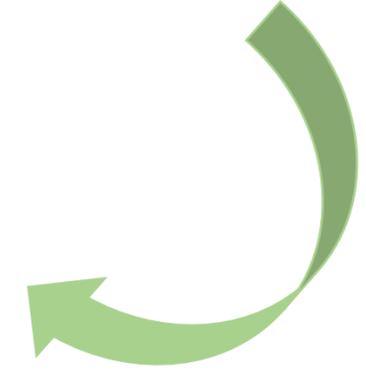
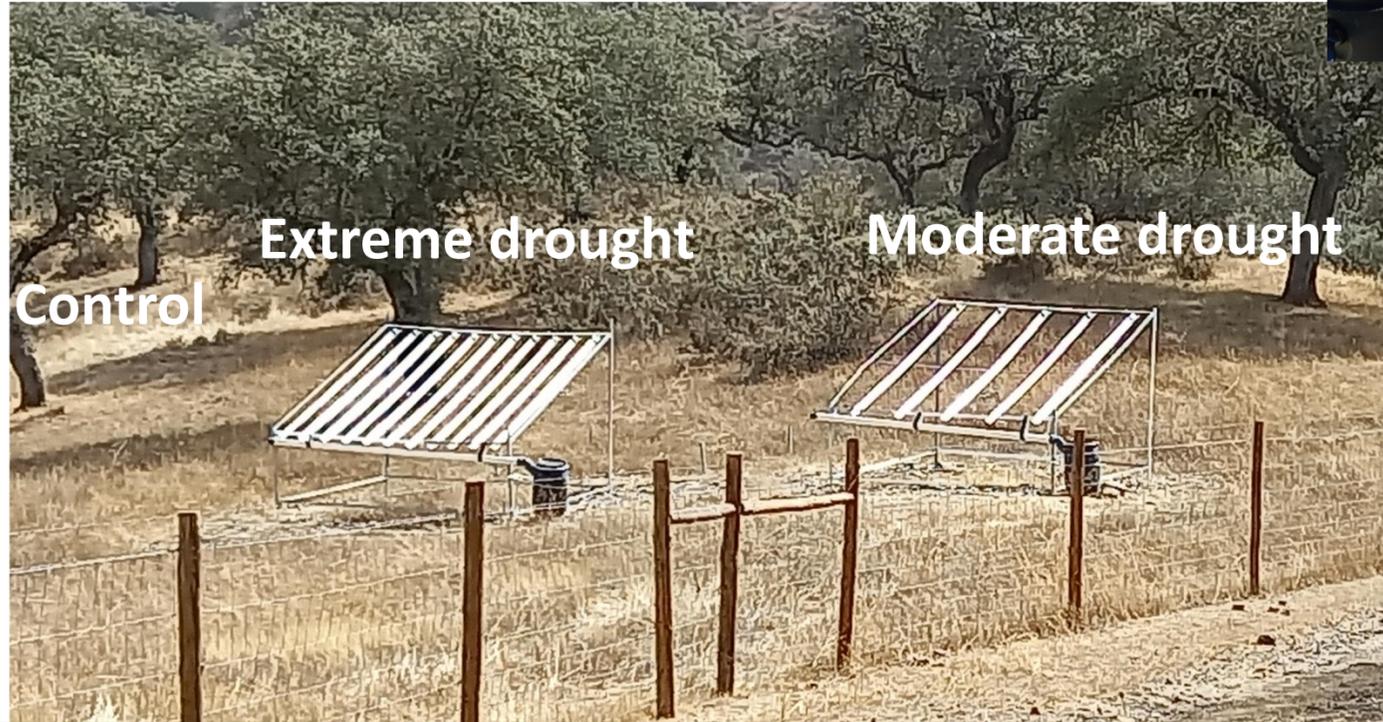


Continuous long-term monitoring

Sensors

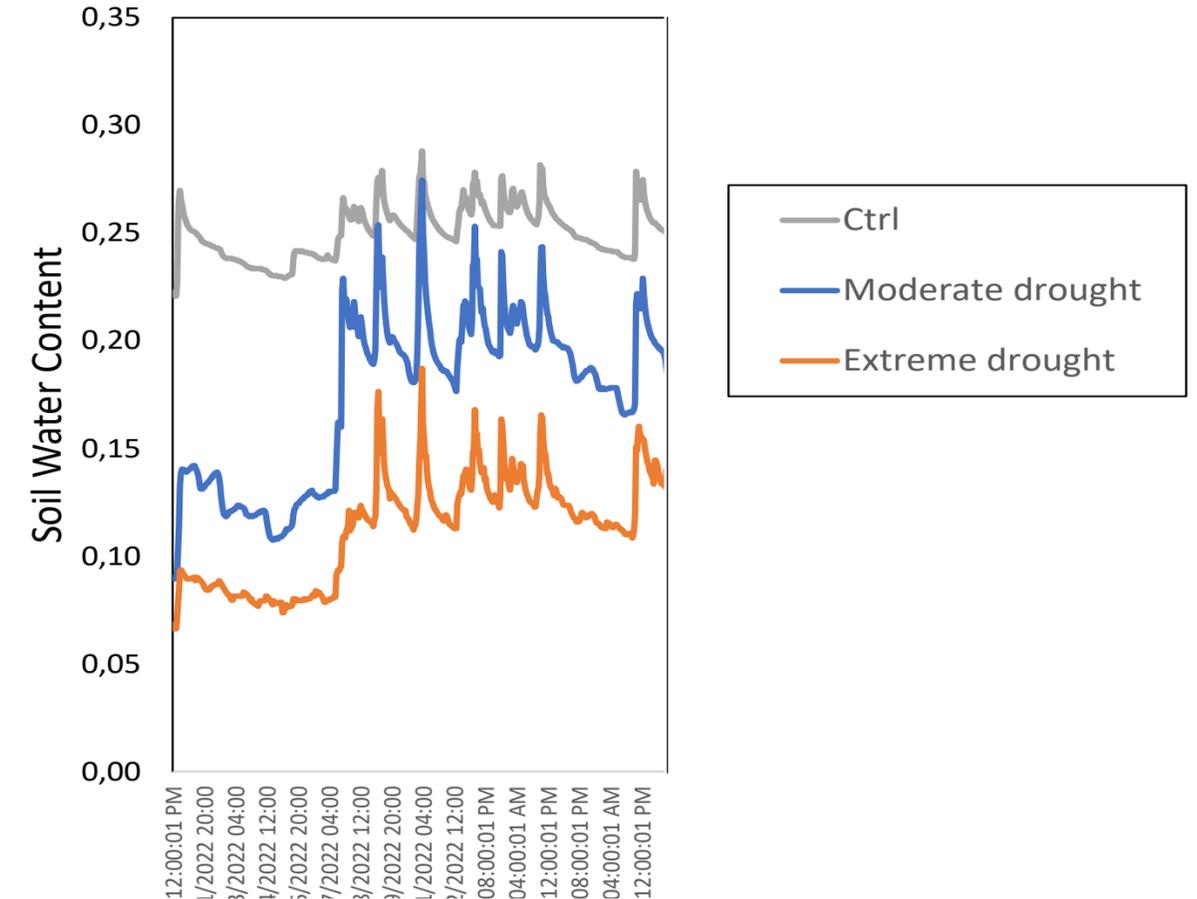
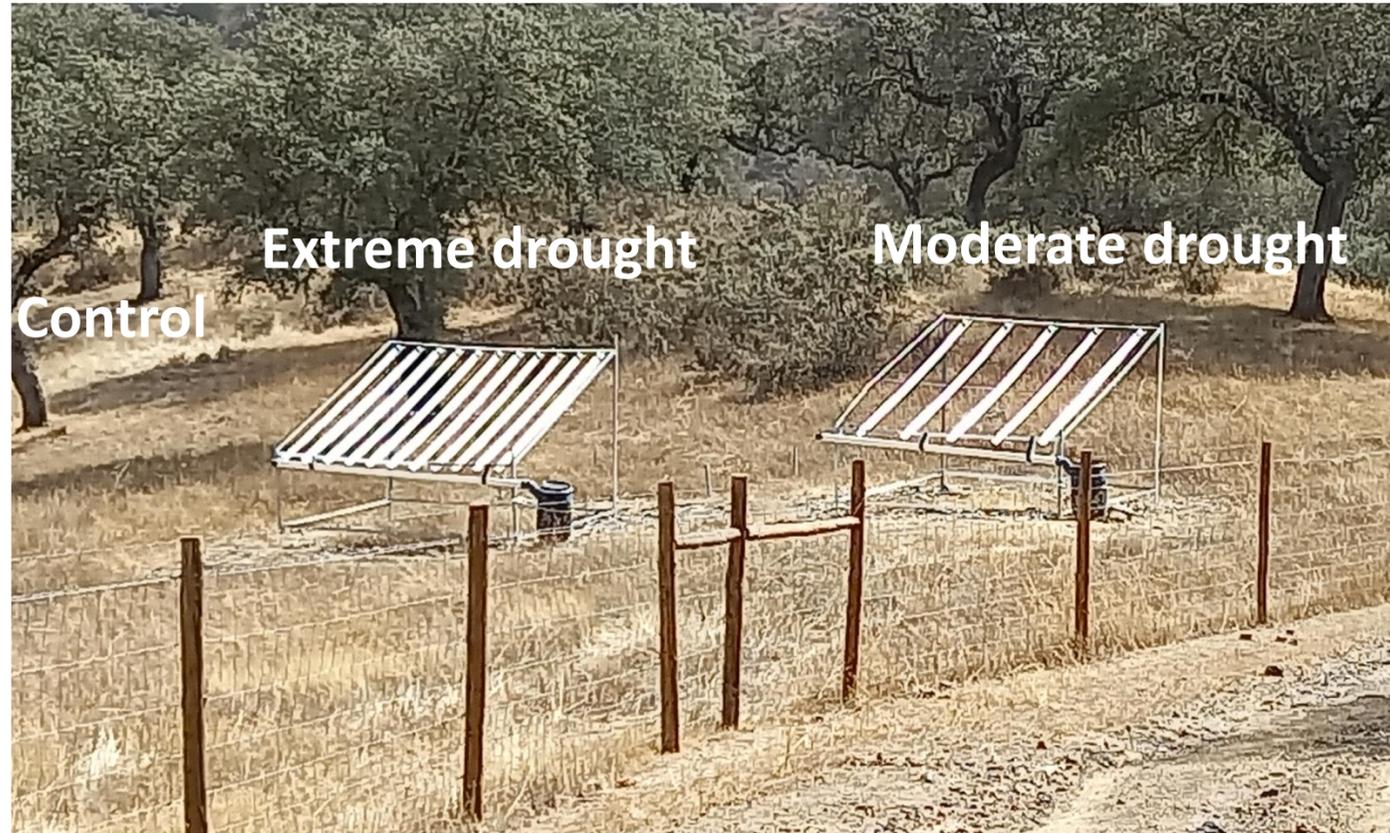


- Air and soil temp & RH
- Radiation
- Rain gauge



Project: PTDC/ASP-SIL/7743/2020

3. Validating empirical observation through experimental manipulation

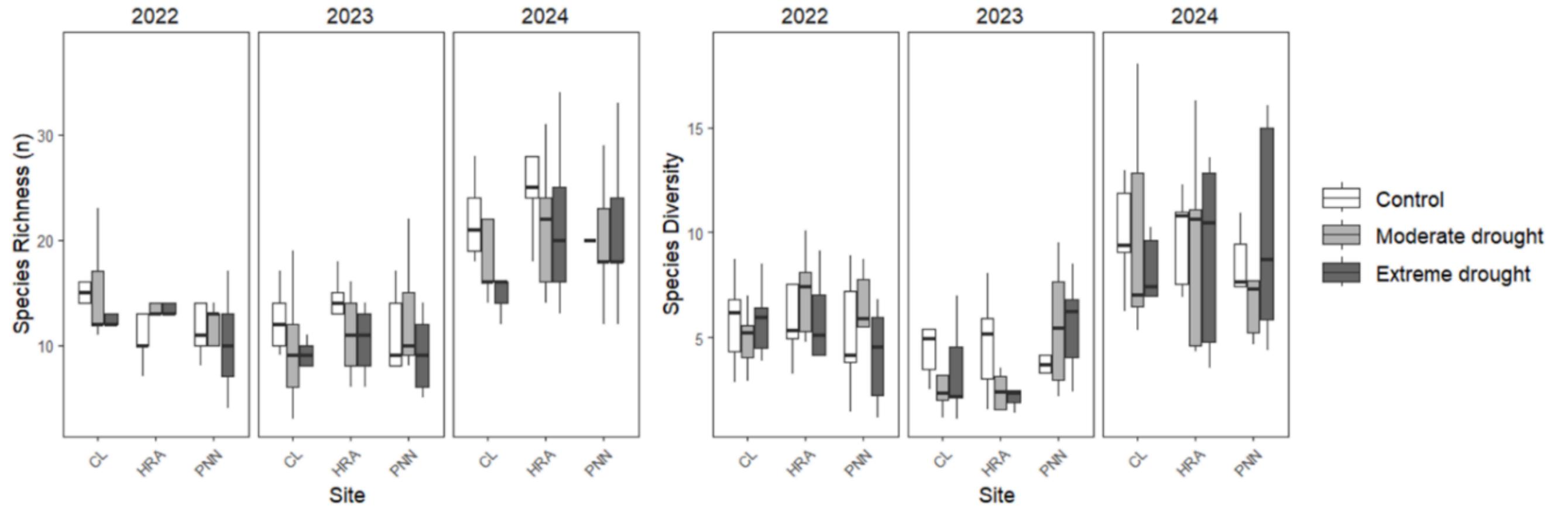
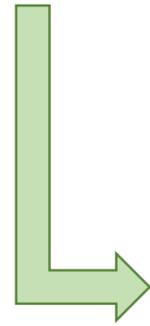


Site name (abbrev.) (coordinates)	Soil texture	M.A.P. short-term			M.A.P. long-term	A.I.
		2022	2023	2024		
<i>Companhia das Lezírias (CL)</i>	Sandy	554	359	505	691	0.63
<i>Herdade da Ribeira Abaixo (HRA)</i>	Sandy clay loam	456	274	477	636	0.55
<i>Herdade da Coitadinha (PNN)</i>	Sandy loam to Clay loam	378	321	453	545	0.43

Preliminary results from sampling 2 years after the implementation of drought treatments (2023 and 2024) on grassland diversity:

Inês Domingues et al. 2025 (in preparation)

3. Validating empirical observation through experimental manipulation



	CL			HRA			PNN		
	Df	<i>P</i>	Effect	Df	<i>P</i>	Effect	Df	<i>P</i>	Effect
<i>Richness</i>									
Year	1	0.000	+	1	0.000	+	1	0.000	+
Treatment	2	0.065	=	2	0.006	-			
<i>Species diversity</i>									
Year	1	0.000	+	1	0.000	+	1	0.000	+
Treatment	2	0.053	=	2	0.063	=	2	0.034	+(extreme drought)

Grassland plant diversity is **strongly influenced by interannual climatic variability**, varying in response to drought across sites with different aridity

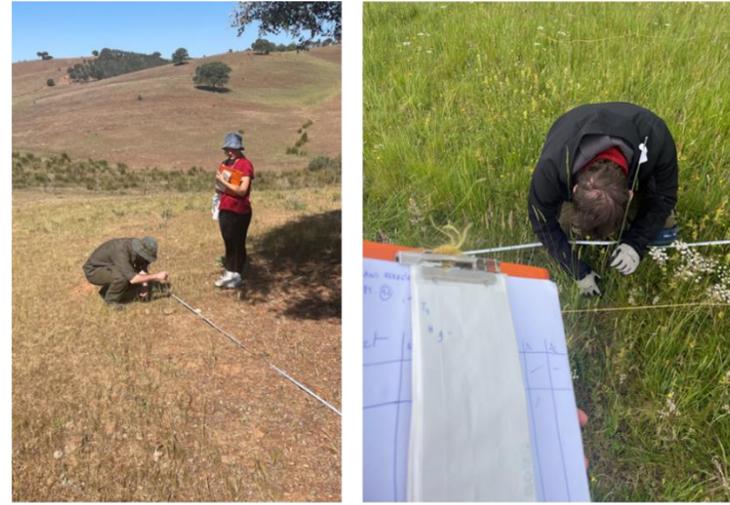
Complexity of drought impacts and the **need to consider additional biodiversity metrics** (e.g. functional trait metrics)

Inês Domingues et al. 2025 (in preparation)

How to adapt pastures to the future climate



Locais amostrados na campanha de 2023



PONTO 11 - Codeseiro, Guarda, local 2, 18/05/2023
PONTO 12 - Soutelinho, Vila Real, 23/05/2023

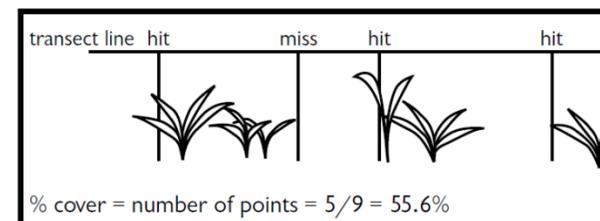


FIGURE 8.10. Point intercept method of measuring cover.



Example of results from Indicator Species Analysis (13 locations, Alentejo)

+ arid

Group 115	#sps.	13	stat	p.value
planLago	1.000	0.001	***	
bracDist	0.999	0.001	***	
bromHord	0.950	0.003	**	
stipCape	0.943	0.001	***	
trifCher	0.939	0.002	**	
cistLada	0.882	0.003	**	
planBell	0.868	0.004	**	
cistMons	0.816	0.012	*	
lavaPedu	0.816	0.013	*	
gastVent	0.816	0.008	**	
hymeLoto	0.801	0.024	*	
avenBarb	0.770	0.032	*	

+ arid

Group 4476	#sps.	17	stat	p.value
rumeBuce	1.000	0.001	***	
chamMixt	0.977	0.001	***	
chaeFasc	0.943	0.001	***	
moliLaev	0.943	0.001	***	
polyTetr	0.942	0.002	**	
agroPour	0.920	0.007	**	
illeVert	0.882	0.003	**	
juncBufo	0.871	0.010	**	
orniPinn	0.868	0.007	**	
ceraGlom	0.865	0.009	**	
trifSubt	0.834	0.049	*	
trifCern	0.816	0.008	**	

Need to consider climatic “clusters”, as well as inter-annual variability in species composition and diversity, and biomass

How to adapt pastures to the future climate

Estimation of **forage quality** through **plant functional traits** and abundance

- **Leaf N**: used to estimate protein content and as an indicator of forage nutritional value
- **SLA and LDMC** - leaves with higher SLA and lower LDMC are more palatable than those with low SLA and high LDMC

Estimation of **forage nutritional value** through measurement (fiber, energy, and protein) in composite vegetation samples along the climate gradient

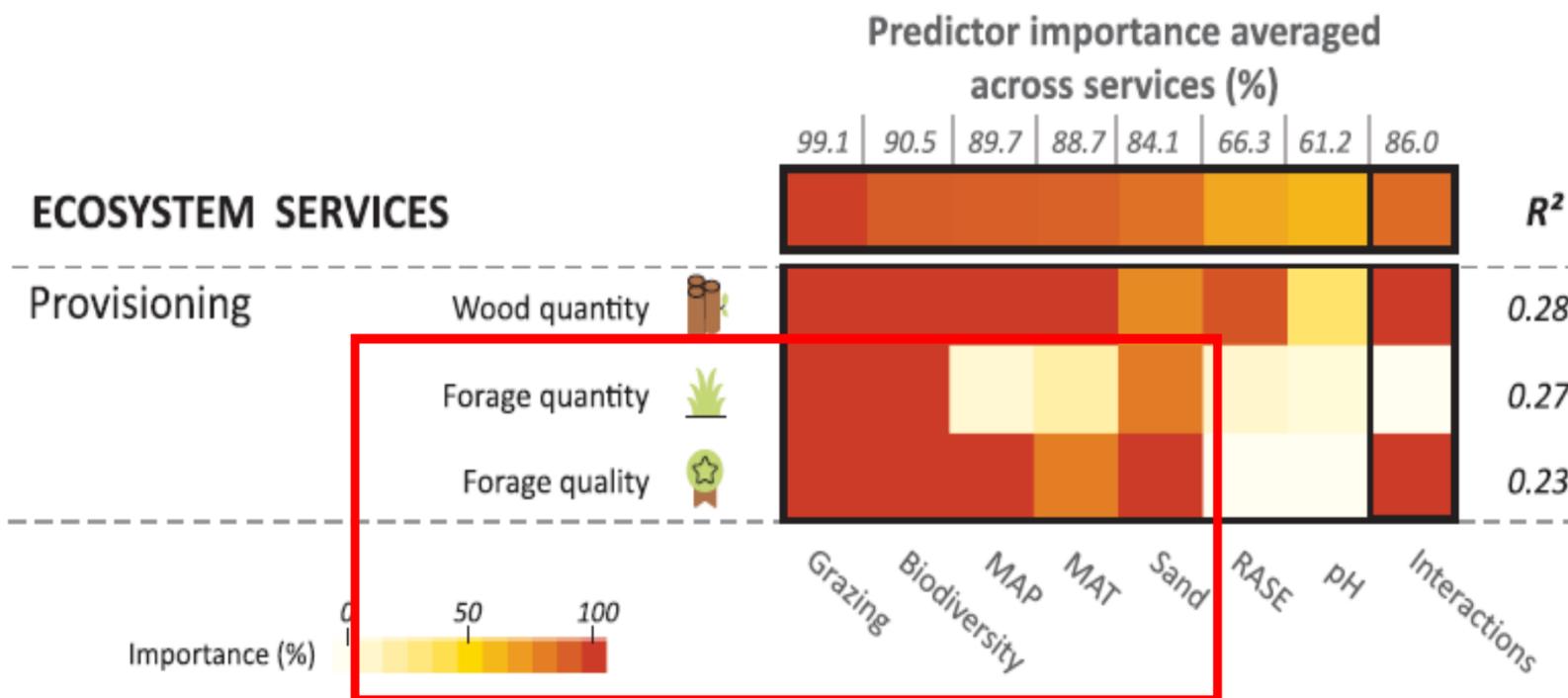


Fig. 2. Relative importance of predictors of ecosystem services selected in the best-fitting models.

Maestre et al. (2022) *Science*

- Plant functional traits are often not considered in species selection or monitoring...
- Need to foster the use of **trait-based indicators** in pasture adaptation and restoration planning and monitoring

Nunes et al. (2016) STOTEN

OBRIGADA

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Email: amanunes@fc.ul.pt

Website: [ECOR – Restoration Ecology group \(CE3C\)](#)



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