WHAT WILL BE THE IMPACT OF CLIMATE CHANGE ON MARITIME PINE FOREST DISTRIBUTION AND PRODUCTIVITY IN PORTUGAL?

GLOBAL CHANGE, VULNERABILITY AND ADAPTIVE MANAGEMENT OF FORESTED LANDSCAPES – HOW TO MANAGE INCREASING PRESSURES AND THREATS ABOVE THE CURRENT RESILIENCE TIPPING POINTS

Cristina Alegria

TOPICS

1. INTRODUCTION
2. METHODS
3. RESULTS & DISCUSSION
4. CONCLUSION

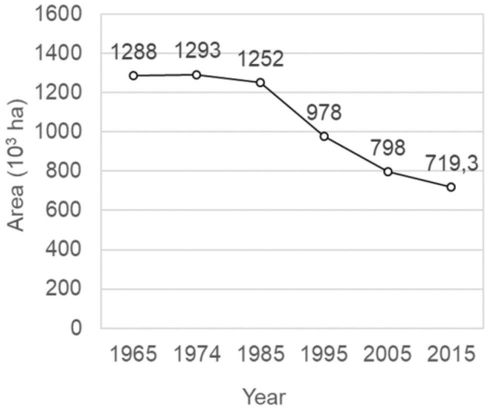
1. INTRODUCTION

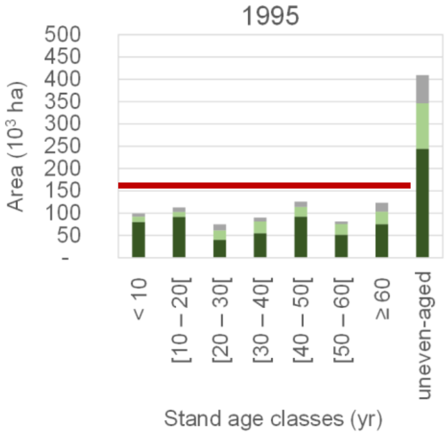
Maritime pine

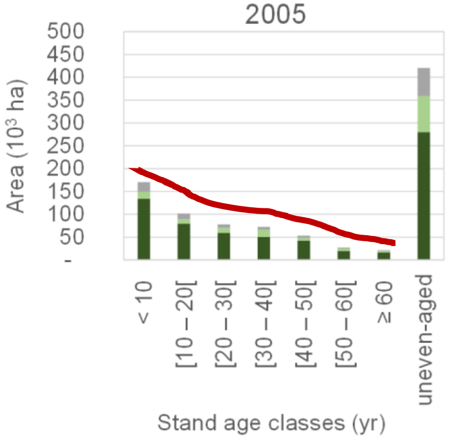
Context

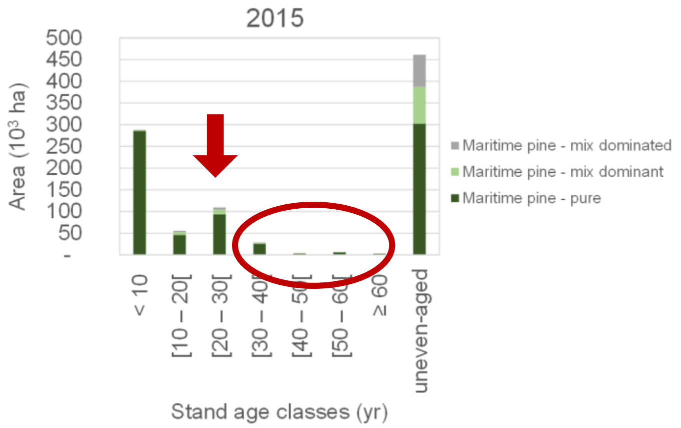
The wildfires impact on Maritime pine forest:

- **Species' area decrease and**
- **Species' regeneration capacity loss**









Aims

- **Modelling species' current distribution and productivity; and**
- **Modelling species' distribution for projected future climate change scenarios.**

Provide key tools for decision support – species afforestation planning for the present and for the future under climate change scenarios

2. METHODS

Data

Sample points

- Land Cover COS 1995
- NFI 1995

Grid 1 km n=88455
Species presence n= 23752
NFI plots n=739

Environmental variables

- Temperature
- Precipitation
- Elevation
- Soil

WorldClim 1.4 (1960-1990) (≈1 km)

Shuttle Radar Topography Mission (≈30 m)

Raster ESDBv2 (≈1 km)

Type	Variable	Units	Description
Temperature	T max	°C 10^{-1}	Monthly average maximum temperature
	T min	°C 10^{-1}	Monthly average minimum temperature
	BIO1	°C 10^{-1}	Annual mean temperature
	BIO2	°C 10^{-1}	Mean diurnal range (mean of monthly (max temp–min temp))
	BIO3	%	Isothermality $BIO3 = 100.BIO2.BIO7^{-1}$
	BIO4	%	Temperature seasonality (standard deviation ×100)
	BIO5	°C 10^{-1}	Maximum temperature of the warmest month
	T max Aug	°C 10^{-1}	Maximum temperature in August
	BIO6	°C 10^{-1}	Minimum temperature of the coldest month (i.e., winter frost)
	T min Jan	°C 10^{-1}	Minimum temperature in January
	BIO7	°C 10^{-1}	Temperature annual range $BIO7 = BIO5 - BIO6$
	BIO8	°C 10^{-1}	Mean temperature of the wettest quarter
	BIO9	°C 10^{-1}	Mean temperature of the driest quarter
	BIO10	°C 10^{-1}	Mean temperature of the warmest quarter
	BIO11	°C 10^{-1}	Mean temperature of the coldest quarter
Precipitation	*BIO12*	mm	Annual precipitation
	BIO13	mm	Precipitation of the wettest month
	BIO14	mm	Precipitation of the driest month
	BIO15	%	Precipitation seasonality (coefficient of variation)
	BIO16	mm	Precipitation of the wettest quarter
	BIO17	mm	Precipitation of the driest quarter
	BIO18	mm	Precipitation of the warmest quarter
	BIO19	mm	Precipitation of the coldest quarter
Topography	*E*	m	Elevation—The vertical distance measured between a point and a datum (a reference surface) which is usually the mean sea level (MSL)
	S	%	Slope—The rate of change of elevation for each digital elevation model (DEM) cell (i.e., the first derivative of a DEM)
	A	°	Aspect—The orientation of slope measured clockwise in degrees from 0 to 360, where 0 is north-facing, 90 is east-facing, 180 is south-facing, and 270 is west-facing.
Soil	*WRBFU*		Soil codes from the international soil classification system for naming soils and creating legends for soil maps.

1st step - Bayesian Machine Learning (ML) analysis

Species distribution most influential environmental variables for the present

Sample points
- Land cover COS 1995
- NFI 1995

Environmental variables
- Temperature
- Precipitation

Grid 1 km n=88455
Species presence n= 23752
NFI plots n=739

2nd step - Modelling - Machine Learning (ML) and Kriging approaches

Species distribution and productivity modelling for the present and for the future under climate change scenarios

Sample points

COS 1995
NFI 1995

Grid 1 km n=88455
Species presence n= 23752
NFI plots n=739

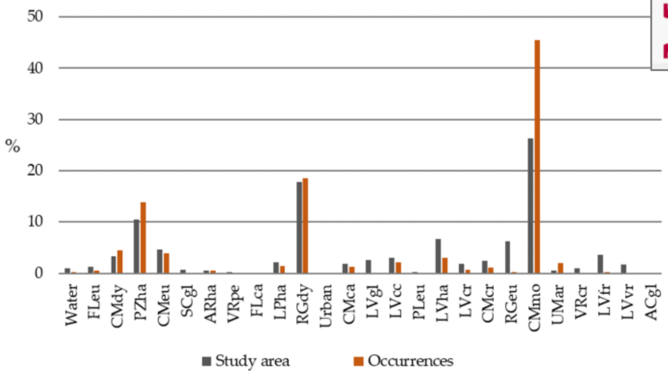
Environmental variables

Temperature
Precipitation

Elevation

Soil

WRFBU	Group	Qualifier
Water	-	-
FLeu	Fluvisol	Eutric
CMdy	Cambisol	Dystric
PZha	Podzol	Haplic
CMeu	Cambisol	Eutric
SCgl	Solonchak	Gleyic
ARha	Arenosol	Haplic
VRpe	Vertisol	Pellic
FLca	Fluvisol	Calcaric
LPha	Leptosol	Haplic
RGdy	Regosol	Dystric
Urban	-	-
CMca	Cambisol	Calcaric
LVgl	Luvisol	Gleyic
LVcc	Luvisol	Calcic
PLeu	Planosol	Eutric
LVha	Luvisol	Haplic
LVcr	Luvisol	Chromic
CMcr	Cambisol	Chromic
RGeu	Regosol	Eutric
CMmo	Cambisol	Mollic
UMar	Umbrisol	Arenic
VRcr	Vertisol	Chromic
LVfr	Luvisol	Ferric
LVvr	Luvisol	Fluvic
ACgl	Acrisol	Gleyic



ML Random Forest algorithm

ML Maximum Entropy algorithm

Simulations

Present distribution – variables select
Present productivity - site index

Present distribution
Future distribution 2070
- RCP 4.5 (less severe)
- RCP 8.5 (most severe)

Stochastic Sequential Gaussian Simulation approach

Greenhouse gas emission scenarios – "Representative Concentration Pathways" (RCPs)

3rd step - Ecological envelope approach

Species potential distribution for the present and for the future under climate change scenarios

Environmental variables

- BIO5
- BIO6
- BIO7
- BIO12
- E
- WRBFU

Scenarios

- Present
- Future 2070
  - RCP 4.5
  - RCP 8.5

Binary maps algebra

ArcGIS

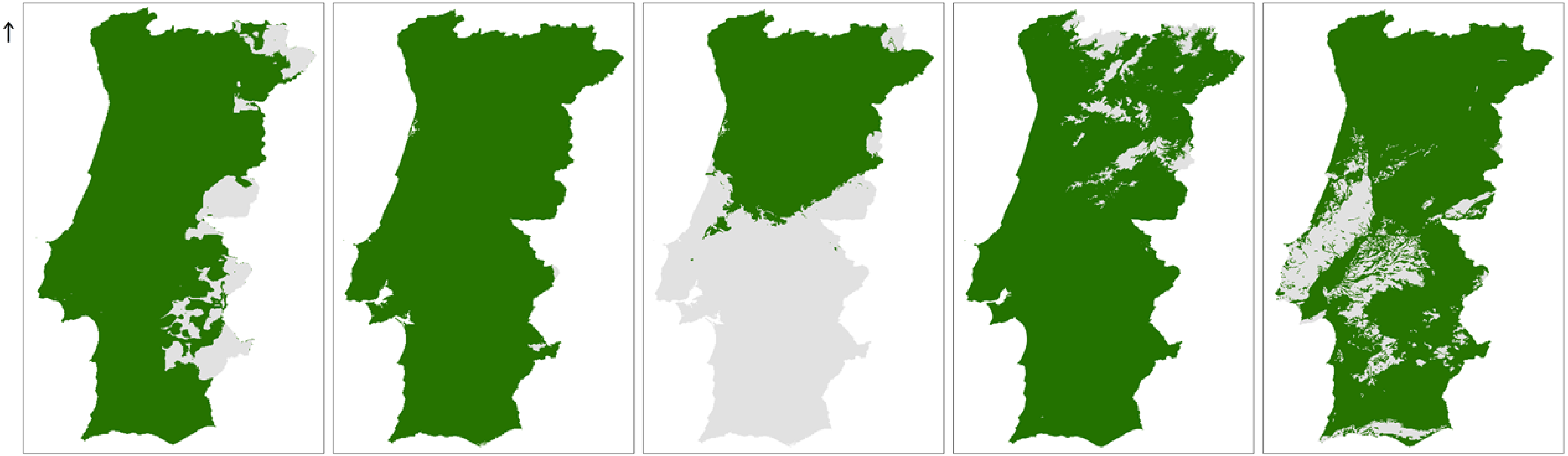
$$(BIO5 \times BIO6) + BIO7 + BIO12 + E + WRBFU$$

Variables selection and thresholds - ML Classification and Regression Trees (CART) and empirical knowledge

Temperature Limits (°C)	Temperature Range (°C)	Precipitation (mm)	Elevation (m)	Soil
BIO5 < 29.8 *BIO6* > 2.6	*BIO7* ≤ 25.1	*BIO12* > 821	*E* < 731	Soils different of Limestone (LVcc, CMca, and FLca)

Binary maps

Temperature Limits (°C)	Temperature Range (°C)	Precipitation (mm)	Elevation (m)	Soil
$BIO5 < 29.8$ $BIO6 > 2.6$	$BIO7 \leq 25.1$	$BIO12 > 821$	$E < 731$	Soils different of Limestone (LVcc, CMca, and FLca)

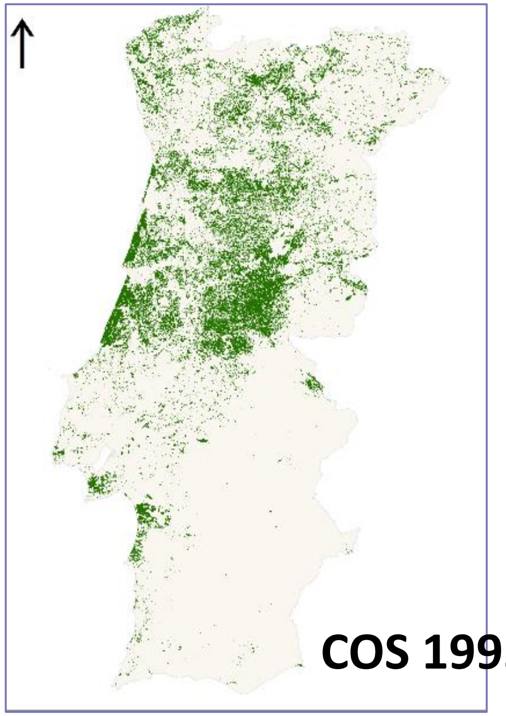


3. RESULTS & DISCUSSION

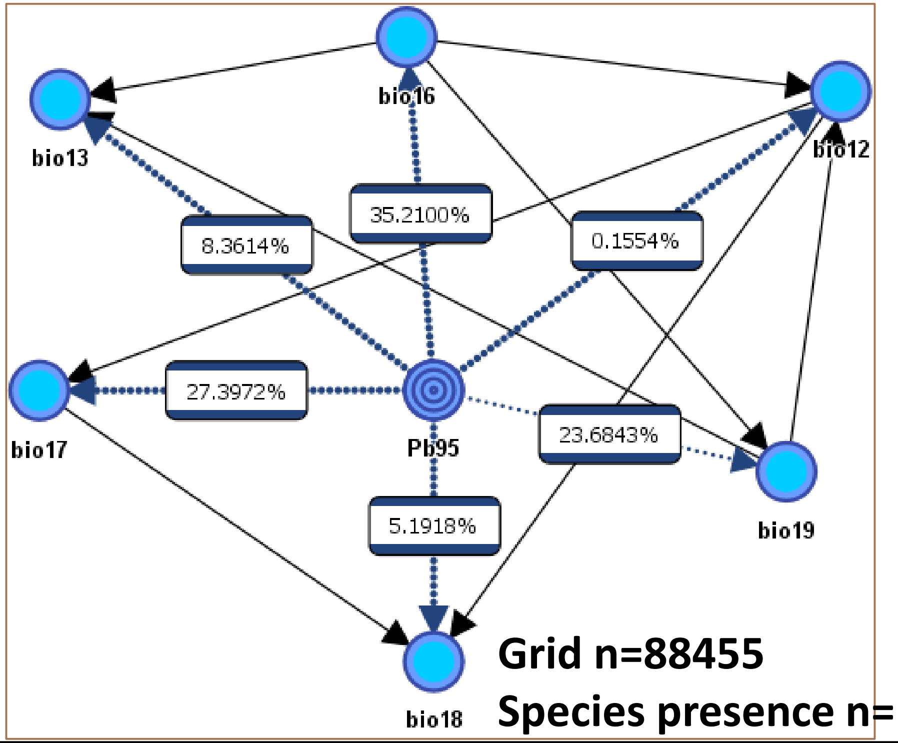
Bayesian Machine Learning (ML) analysis

Most influential variables for species distribution - mainly determined by **precipitation-related variables,** but **elevation and temperature-related variables** were very important to **differentiate species productivity.**

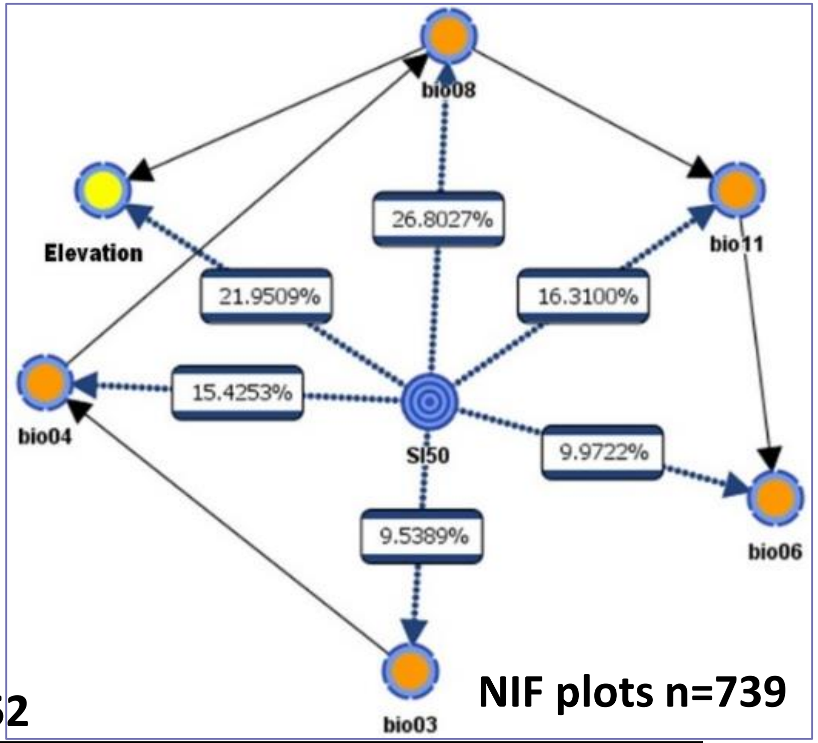
Maritime pine



COS 1995



Grid n=88455
Species presence n= 23752



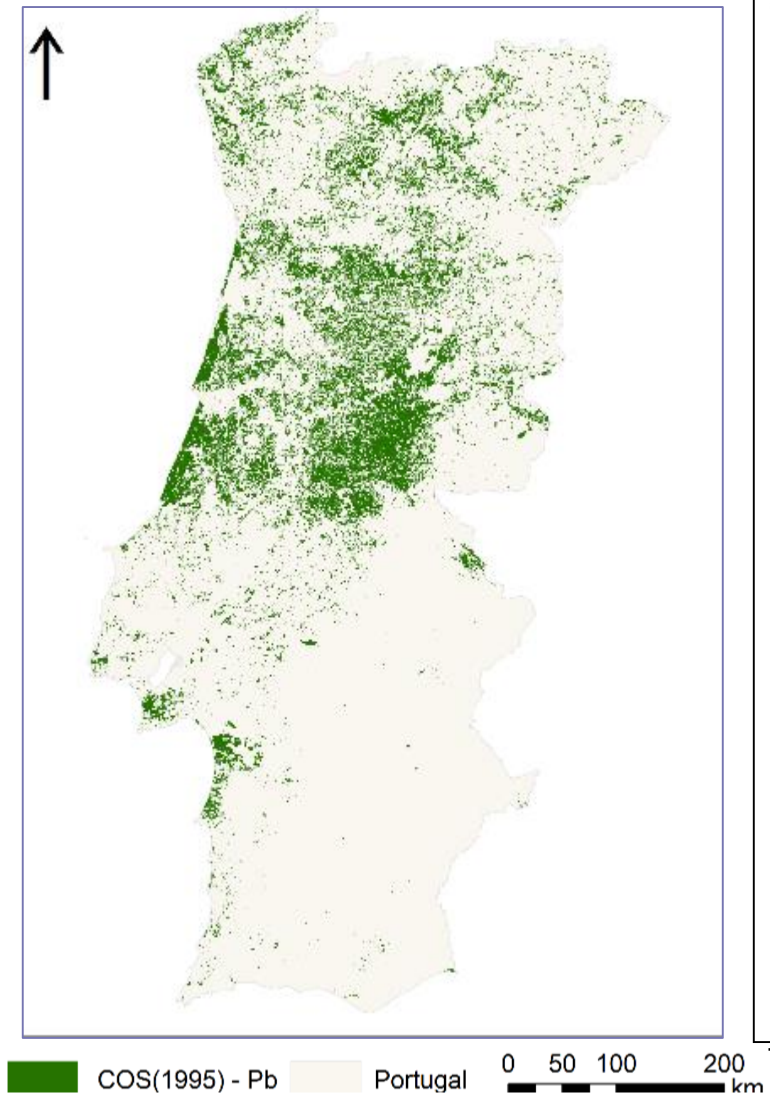
NIF plots n=739

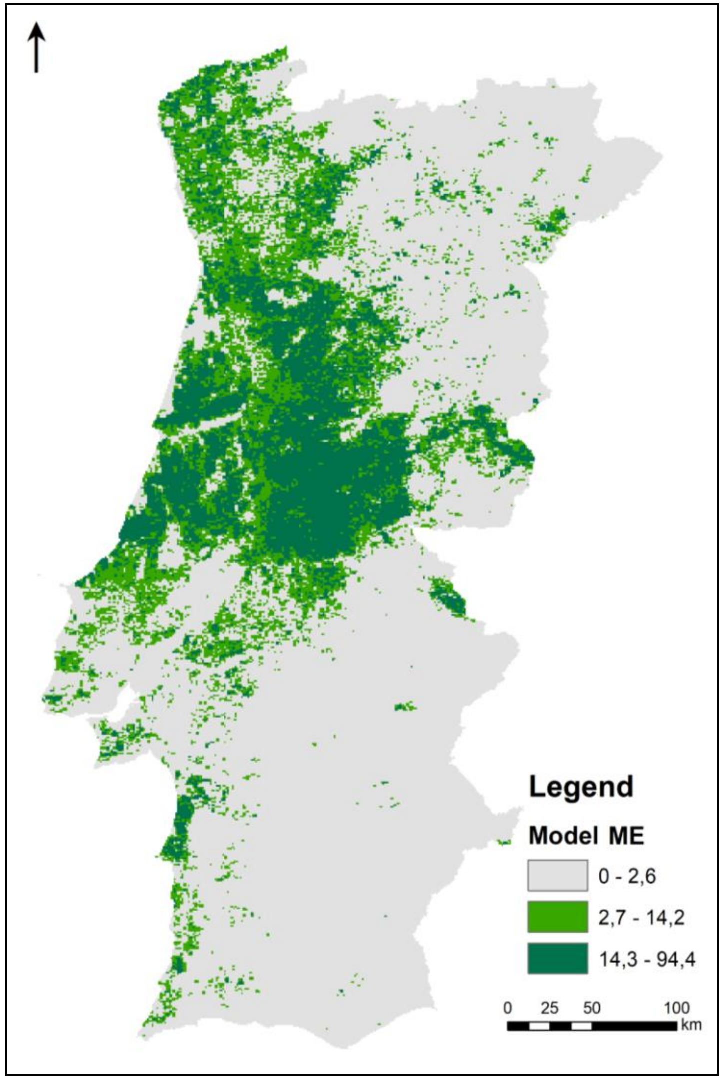
Species distribution modelling for the present

COS 1995

ML modelling - Regression Tree algorithm "Random Forest"

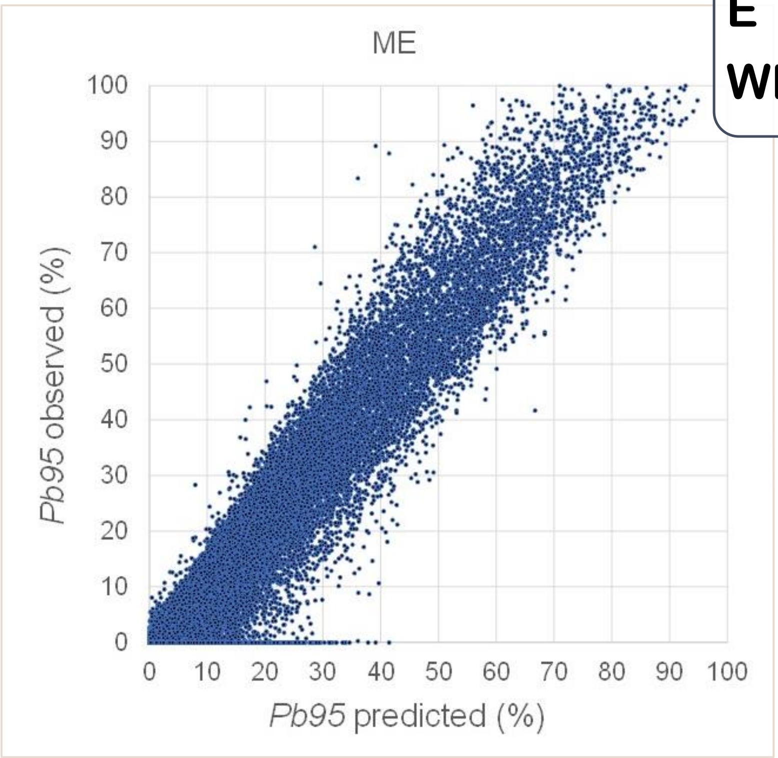
Maritime pine





Efficiency R^2=0.69
Precision MAE=5.5
n=88455

BIO5
BIO6
BIO7
BIO12
E
WRBFU



What will be the impact of climate change on maritime pine forest distribution and productivity in Portugal?

Species productivity modelling for the present

Maritime pine

NFI plots n=739

IQE50 – stand dominant height (m) at 50 years

≥ 21,16	High
19,47 - 21,15	Medium-High
18,13 - 19,46	Medium
16,71 - 18,12	Low-Medium
< 16,7	Low

Productivity (35-45 years)

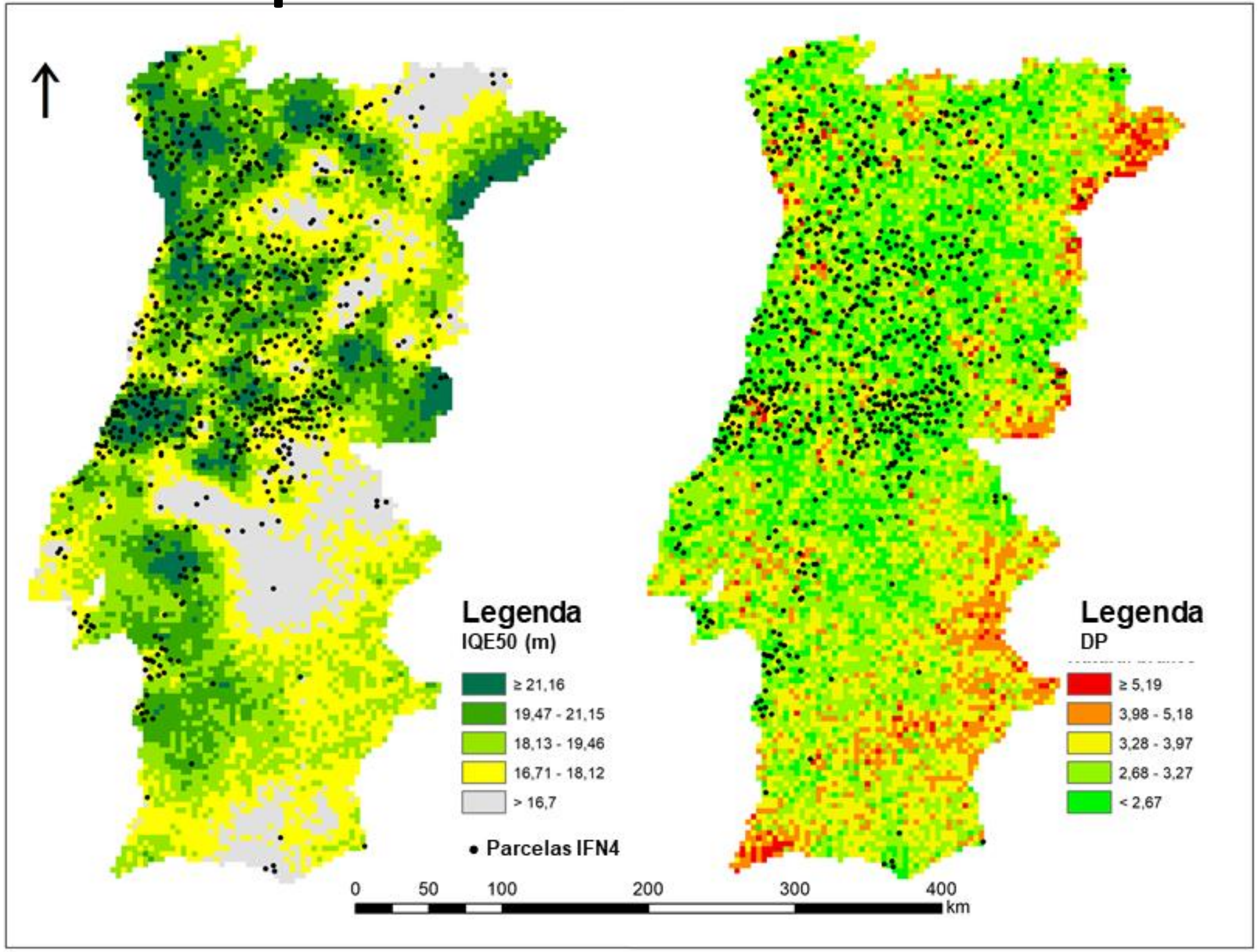
- **0.7–3.4 $m^3ha^{-1}y^{-1}$** dunes
- **4 $m^3ha^{-1}y^{-1}$** south rio Tejo
- **5–10 $m^3ha^{-1}y^{-1}$** north Rio Tejo
- **10.3 $m^3ha^{-1}y^{-1}$** north and centre regions (submontane and montane)
- **13.3 $m^3ha^{-1}y^{-1}$** costal centre

Empirical

Maritime pine occupation

- Optimum – elevation and continentality limitations
- Optimum – basal region
- Regular – soil limitations
- Optimum – wind and moisture limitations

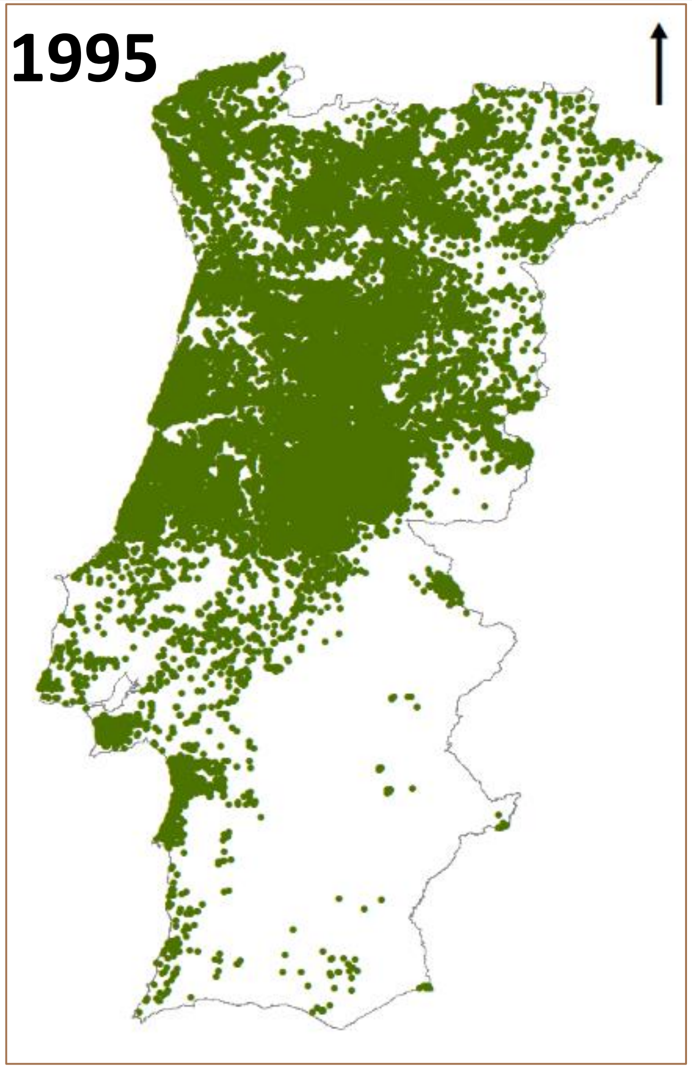
Sequential Gaussian Simulation

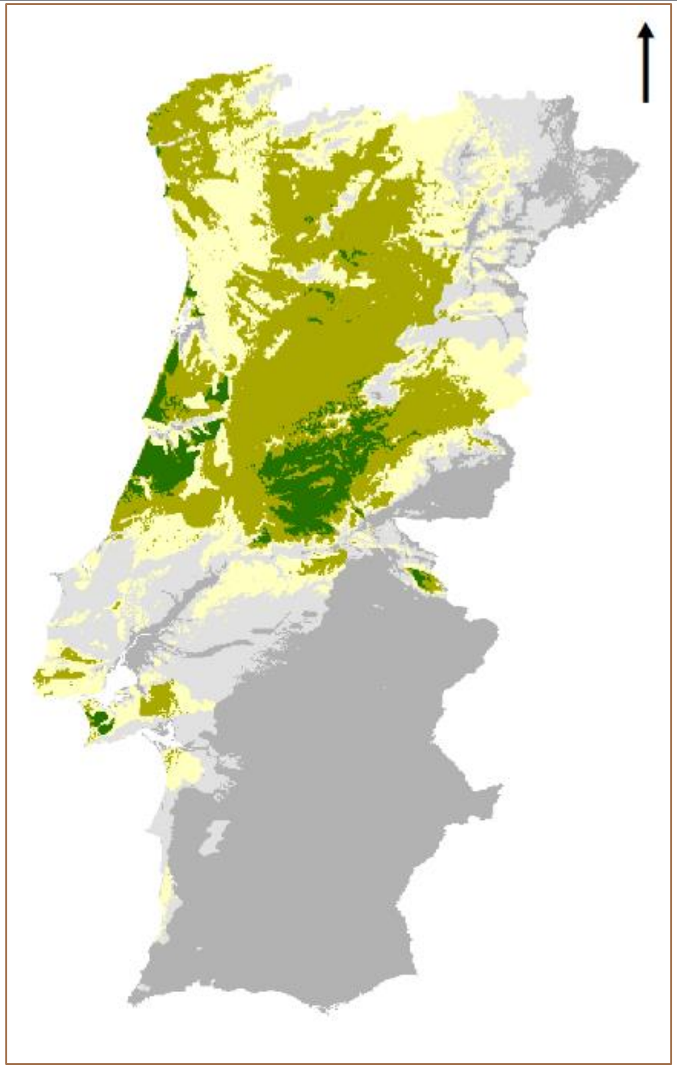


MaxEnt - Species distribution for the present

Maritime pine

COS 1995





ML simulation - Classification Tree algorithm "Maximum Entropy"

BIO5
BIO6
BIO7
BIO12
E
WRBFU

Modelling efficiency
AUC=0.74
n=88455

Regular-medium-high suitability classes

[0.4 - 0.6[[0.6 - 0.8[[0.8 - 1.0]

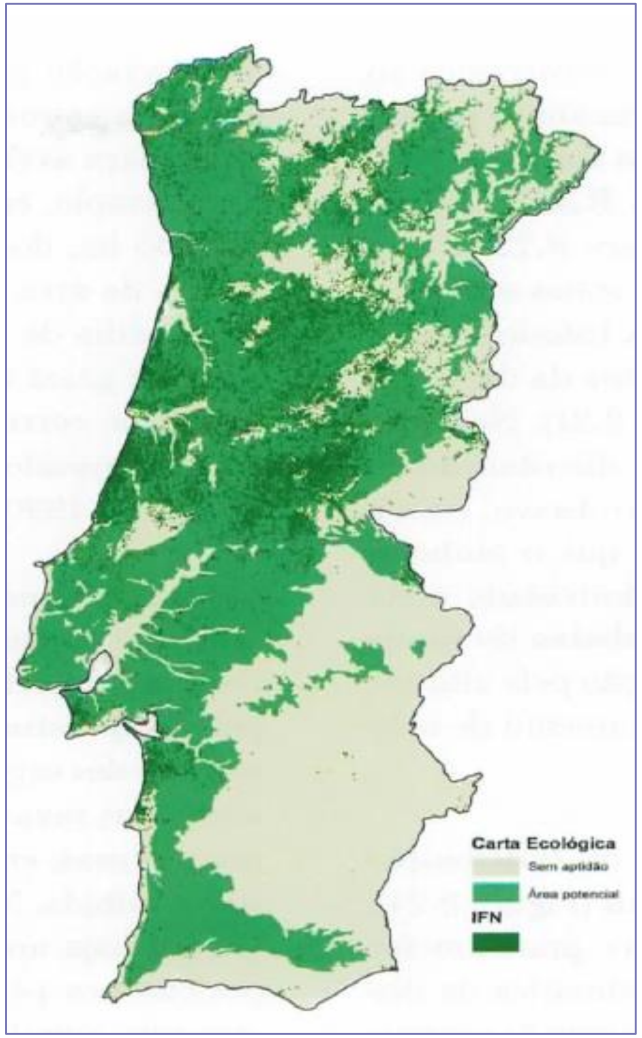
47.3%

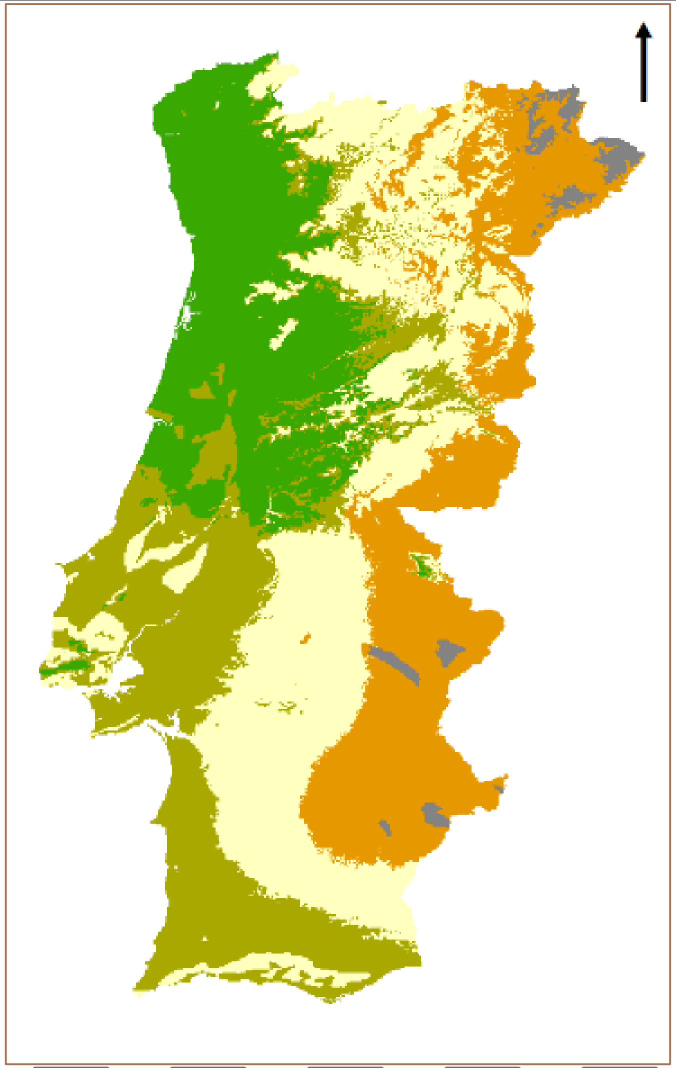
Suitability [0.0 - 0.2[[0.2 - 0.4[[0.4 - 0.6[[0.6 - 0.8[[0.8 - 1.0]

(1) non-suitable area [0–0.2[, (2) low-suitability area [0.2–0.4[, (3) regular-suitability area [0.4–0.6[, (4) medium-suitability area [0.6–0.8[, and (5) high-suitability area [0.8–1.0]

Ecological envelope - Species distribution for the present

Maritime pine





1 2 3 4 5

(1) unsuitable, (2) marginal, (3) regular, (4) favourable, and (5) optimum

Regular-favourable-optimum suitability classes

3 4 5

76.5%

MaxEnt - Species distribution for the future 2070

Scenarios 2070

Maritime pine

Regular-medium-high suitability classes

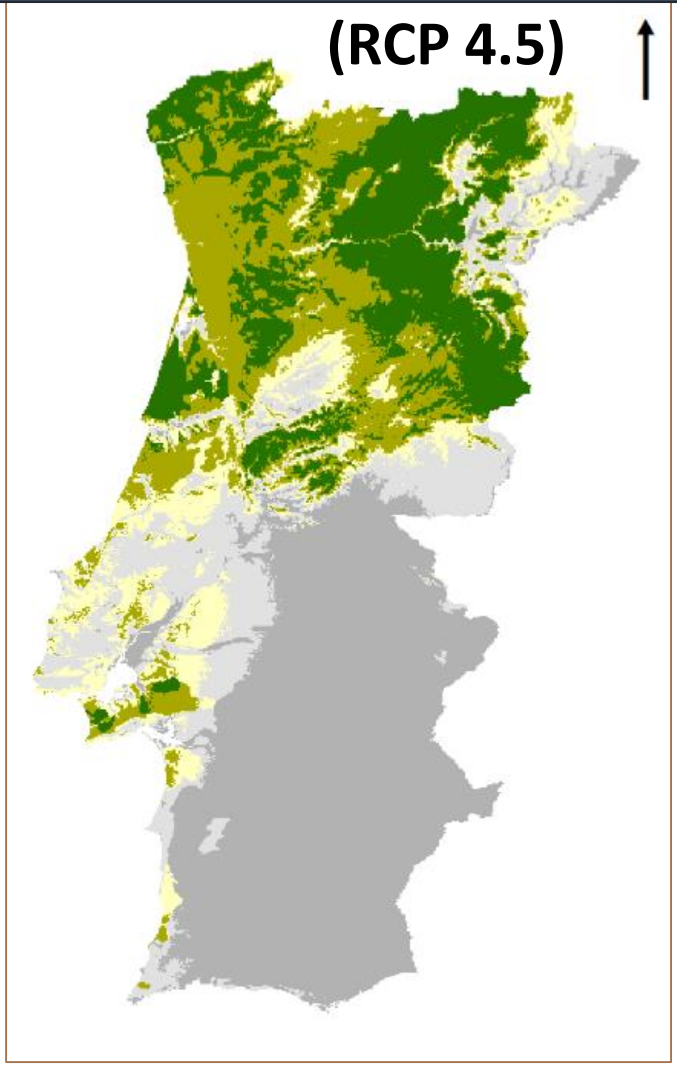
[0.4 - 0.6[[0.6 - 0.8[[0.8 - 1.0]

47.3%

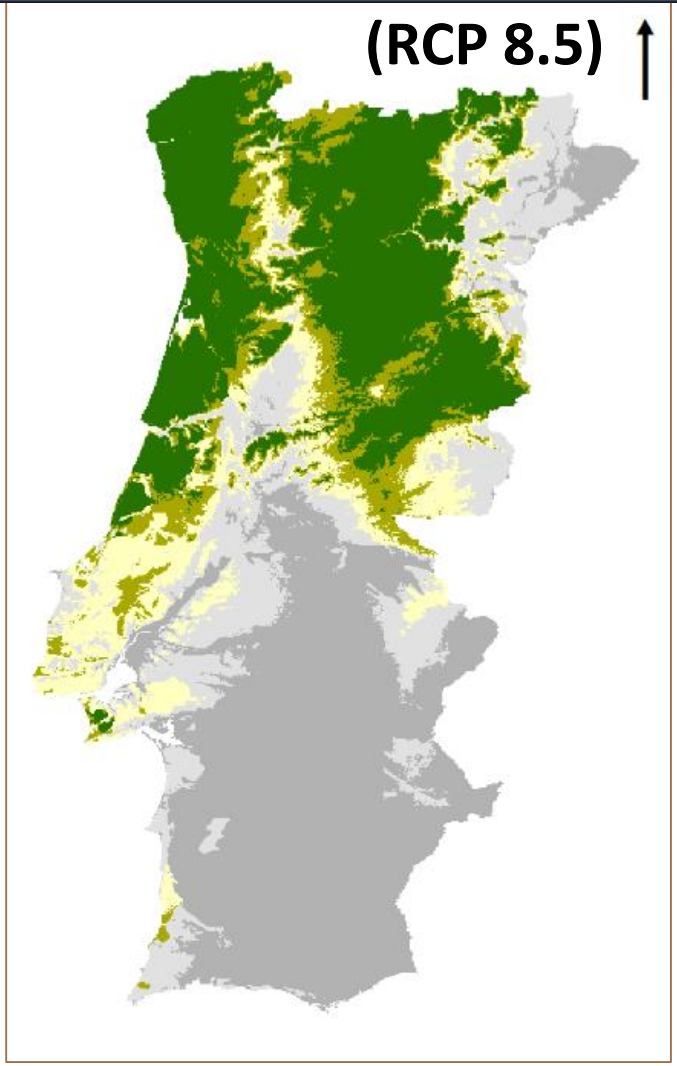
40.0%–40.1% Loss

Relocation

(RCP 4.5)



(RCP 8.5)



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Ecological envelope - Species distribution for the future 2070

Scenarios 2070

Regular-favourable-optimum suitability classes

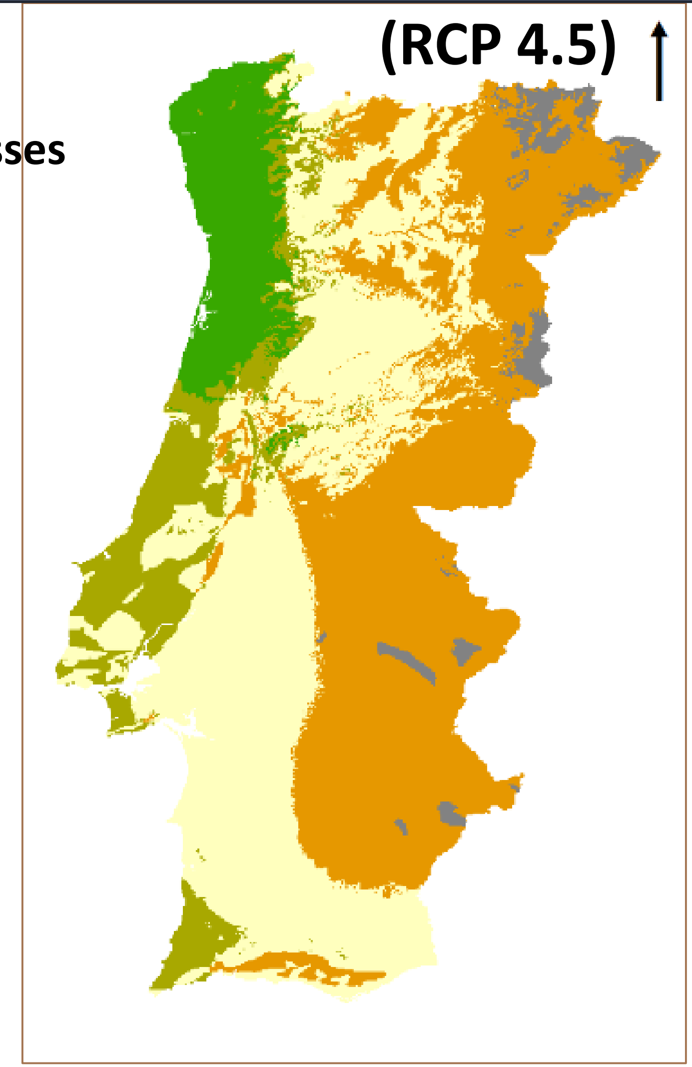
3 4 5

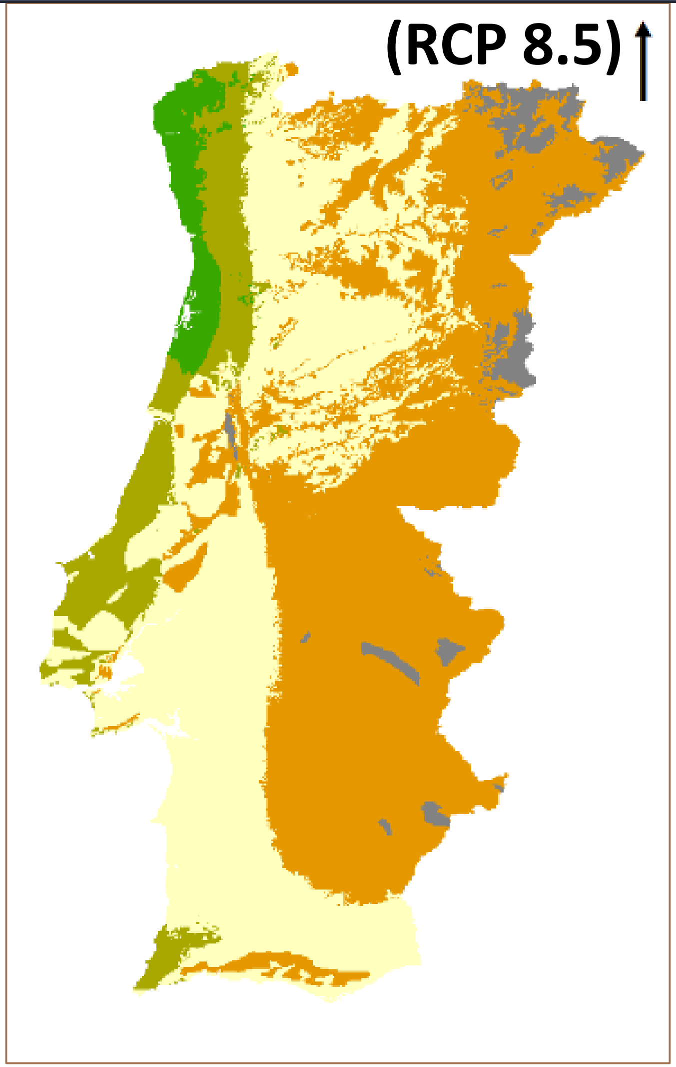
Maritime pine

76.5%

58.1%–51.7% Loss

North and Coast





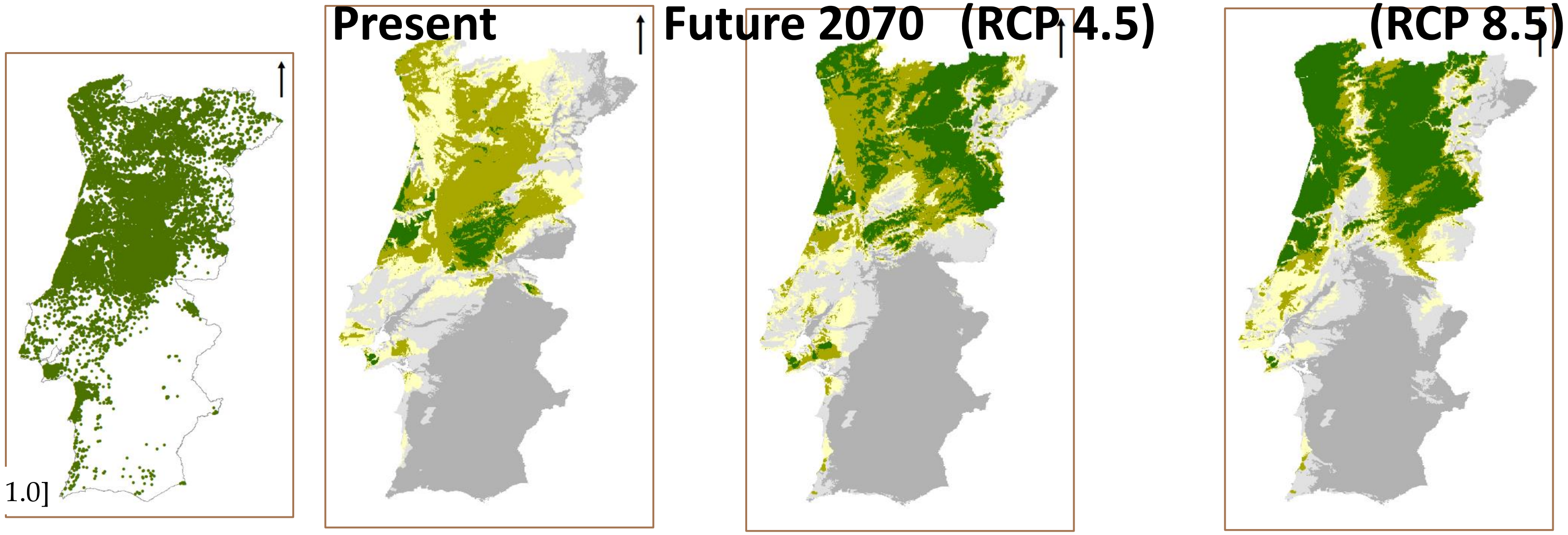
1 2 3 4 5

(1) unsuitable, (2) marginal, (3) regular, (4) favourable, and (5) optimum

Species distribution – MaxEnt and Ecological envelope

Maritime pine

- **MaxEnt – Current**



[0.0 - 0.2[[0.2 - 0.4[[0.4 - 0.6[[0.6 - 0.8[[0.8 - 1.0]

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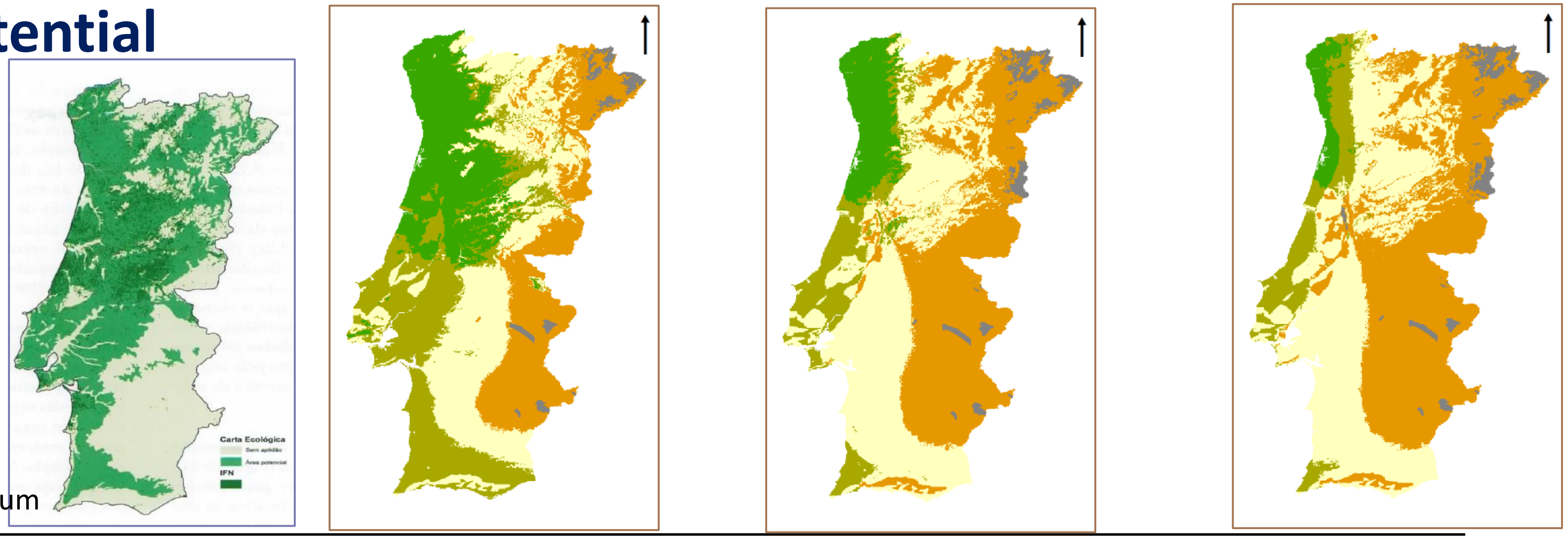
- **Ecological envelope – Potential**



1 2 3 4 5

(1) unsuitable, (2) marginal, (3) regular, (4) favourable, and (5) optimum

4. CONCLUSION

- **Species distribution** is mainly determined by **precipitation-related variables,** but **elevation and temperature-related variables** were very important to **differentiate species productivity.**

- **Species' distribution for the present** using the **ML modelling** provided fitting **efficiencies of around 70%** and matched well the **species' current distribution.**

- **The species ecological envelope map for the present** was closer to the **species' empiric potential distribution.**

- In sum, these two set of maps are **complementary** being **key tools for decision support** to set **recommendations in planning this species future afforestation** in the **best suitability areas** having in mind the **impact of climate change.**

REFERENCES

Alegria, C.; Almeida, A.M.; Roque, N.; Fernandez, P.;Ribeiro, M.M. Species Distribution Modelling under Climate Change Scenarios for Maritime Pine (Pinus pinaster Aiton) in Portugal. Forests 2023, 14, 591. https://doi.org/10.3390/f14030591

Alegria, C.; Roque, N.; Albuquerque, T.; Gerassis, S.; Fernandez, P.; Ribeiro, M.M. Species ecological envelopes under climate change scenarios: A case study for the main two wood-production forest species in Portugal. Forests. 2020, 11, https://doi:10.3390/F11080880 .

Alegria, C., Roque, N., Albuquerque, T., Fernandez, P., Ribeiro, M.M. 2021. Modelling Maritime Pine (*Pinus pinaster* Aiton) Spatial Distribution and Productivity in Portugal: Tools for Forest Management. Forests, 12, 368. https://doi.org/10.3390/f12030368

Forests

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