Topics 2023 WEBINARS

EO&GEO Series: UAV Remote Sensing for LULC, Landscape, Citizen Sciences

MDPI

Multicriteria Spatial Analysis applied to Agro-Environmental Planning

Luís Quinta-Nova
Agrarian Higher School, Castelo Branco Polytechnic
University Castelo Branco, Portugal

Instituto Politécnico de Castelo Branco Polytechnic University

QRural

CERNAS Centro de Estudos de Recursos Naturais, Ambiente e Sociedade

VALORIZA Centro de Investigação para a Valorização de Recursos Endógenos

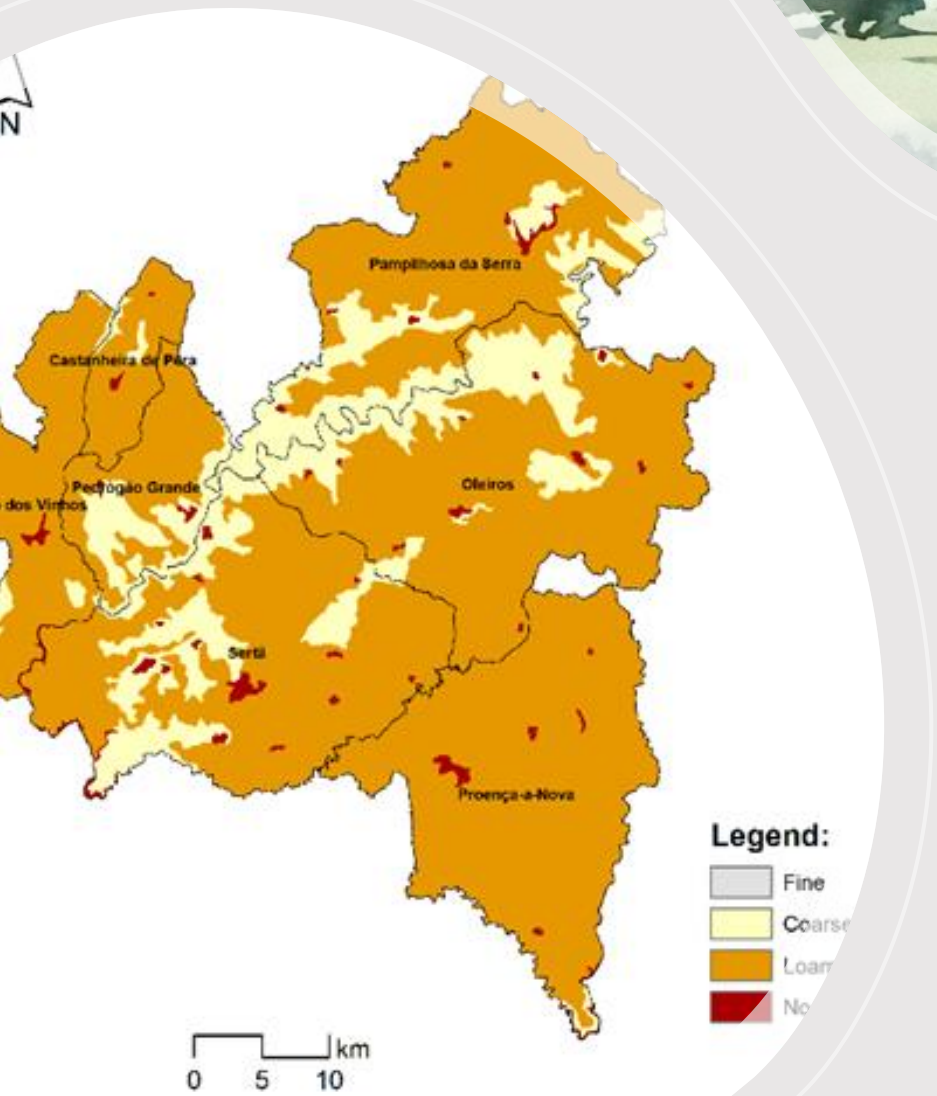
geobiotec Geobiociências, Geoengenharias e Geotecnologias

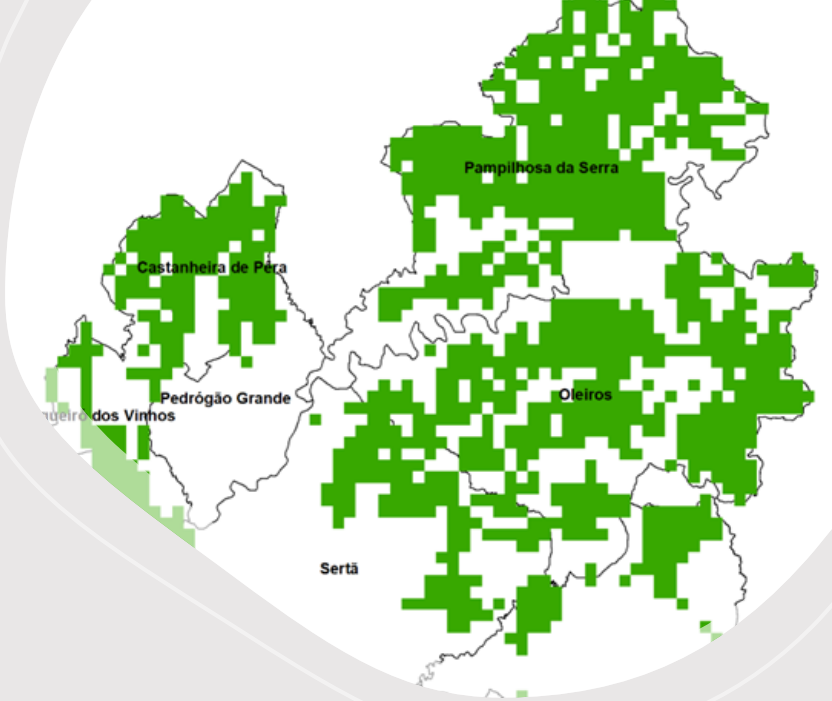
Topics 2023 WEBINARS

MDPI

Framework

- The **Analytic Hierarchy Process** (AHP) is one of the most widely used methods of **Multicriteria Decision Analysis** (MCDA); it was developed in the 1970s by Thomas L. Saaty and is considered to be relevant to nearly any ecosystem management application that requires the evaluation of multiple participants or involves complex decision-making processes.
- The AHP decomposes a problem in all the variables that constitute it, in a scheme of criteria and subcriteria, and then makes pairwise comparisons between them. The calculation of the weight of each factor allows the evaluation of each of the elements within the defined hierarchy. In the end, it is necessary to verify the consistency of the matrix after obtaining the weight values.
- Various techniques of MCDA have been used extensively in rural land-use suitability analysis (e.g., Alkimim, Sparovek & Clarke, 2015; Zhang et al., 2015; Mighty, 2015; Dedeoğlu & Dengiz, 2019; Quinta-Nova & Ferreira, 2020; Wotlolan et al., 2021; Quinta-Nova, 2022).





1

PRESENT AND FUTURE AGROFORESTRY LAND SUITABILITY ANALYSIS IN CENTRAL PORTUGAL

Objectives

This study aims to determine the suitability of species cultivated in an agroforestry mode in the **Pinhal Interior Sul region**, Portugal, as an alternative agrosystem, based on the analysis of the soil and climate limiting factors. For this purpose, the biophysical criteria determining the cultivation of common oak (*Quercus robur* L.), cork oak (*Quercus suber* L.), strawberry tree (*Arbutus unedo* L.), and sweet chestnut (*Castanea sativa* Mill.) were processed using a Geographic Information System for the present time and in the face of two future emission scenarios.

Cork oak

Common oak

Sweet chesnut

Strawberry tree

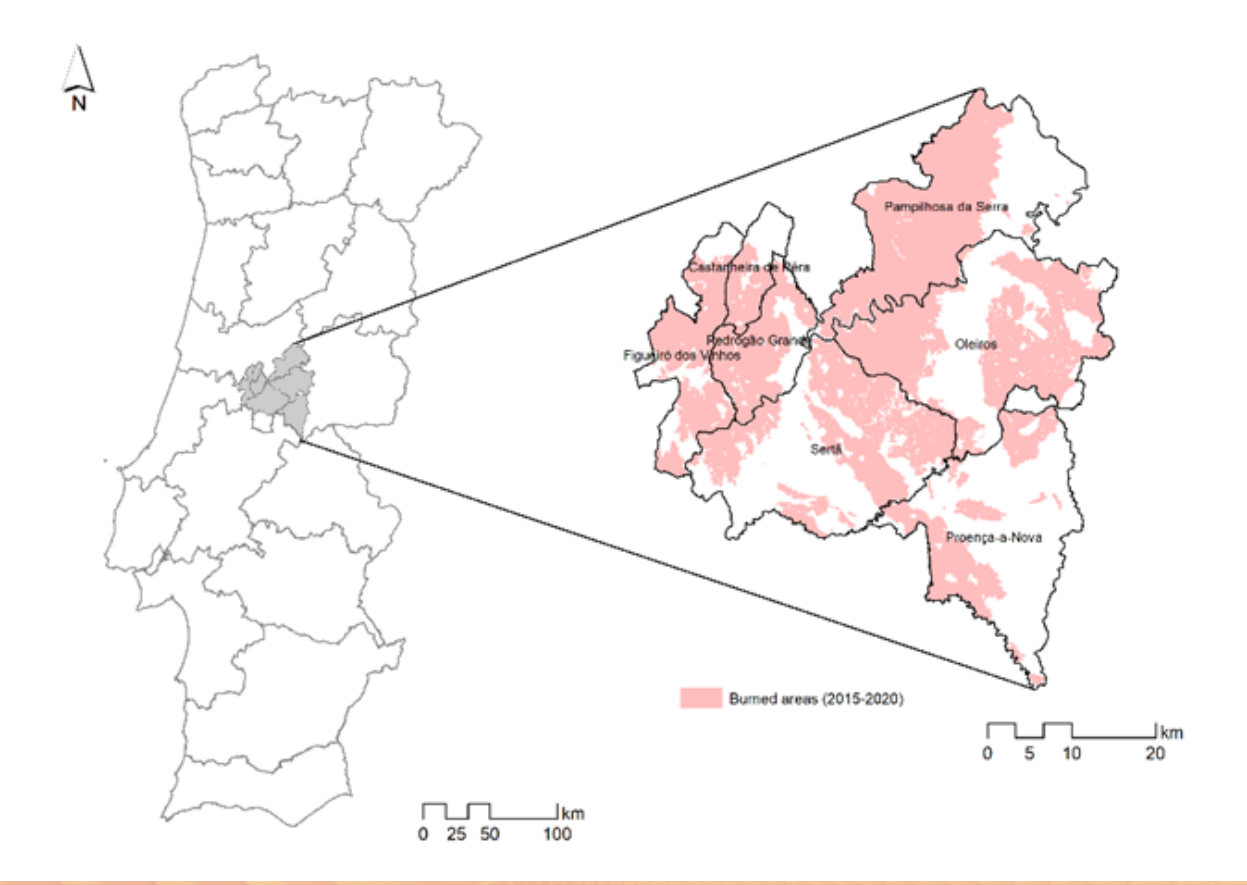
Study area

The study area is located in the Central Region of mainland Portugal.

The region covers an area of 2,079 km² and includes seven municipalities with a **very high risk of rural fire**.

During the period **between 2015 and 2020 the burnt area** in the region reached **1,145 km²**, corresponding to **55% of the area**.

This region is mainly occupied by **forest stands of pine trees and eucalyptus (69.4%)** and shrubland (15%), with only 11.5% corresponding to woodlands, agroforestry, and agriculture.



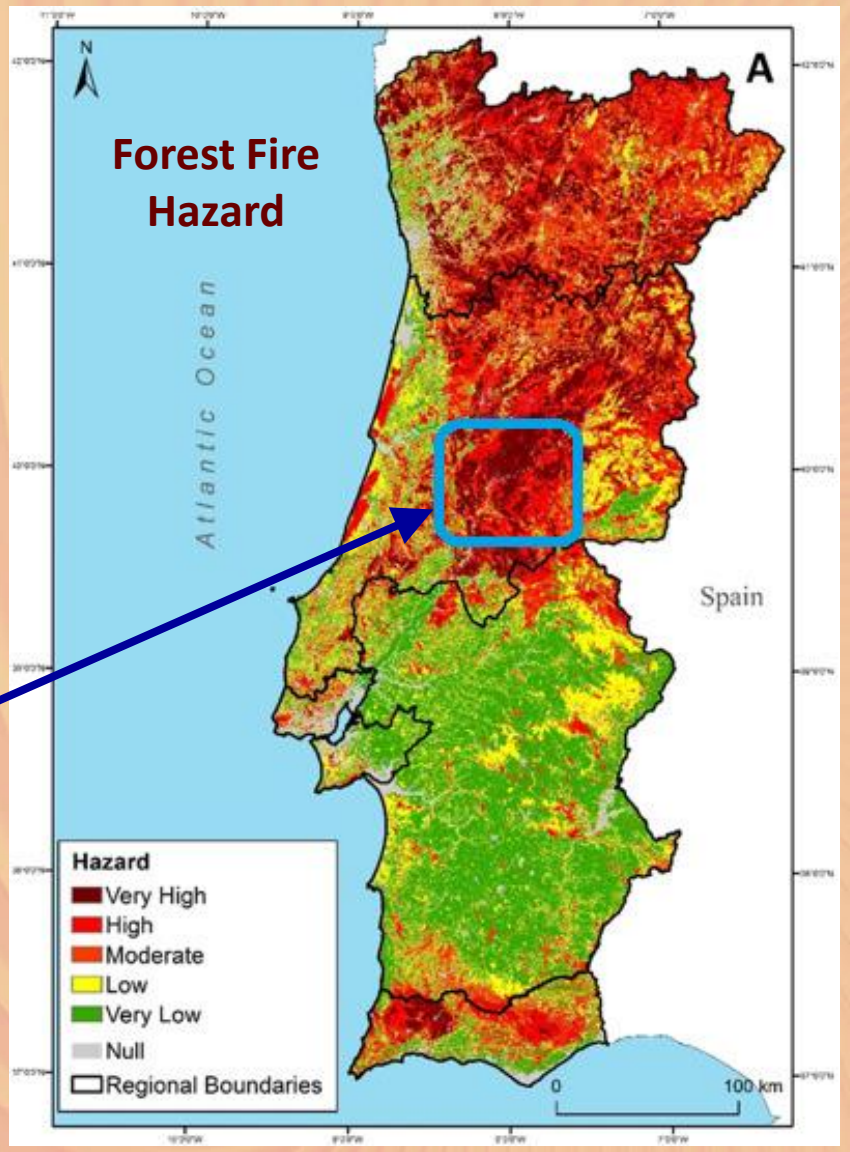
Topics 2023 WEBINARS

Study area

Mosaic of production forest and agricultural areas

Intensification

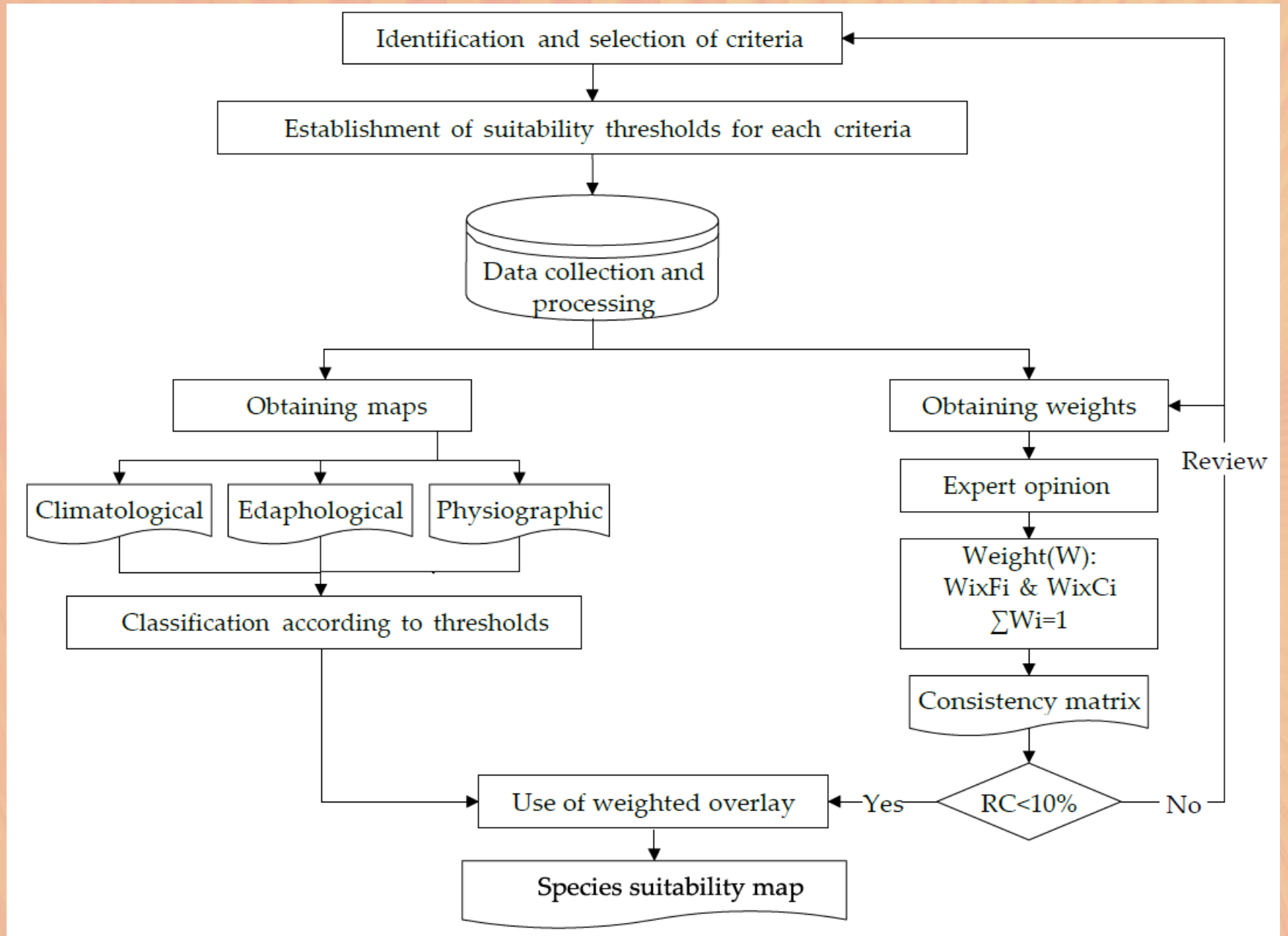
Eucalyptus tree and Pine tree plantations (intensive monoculture)



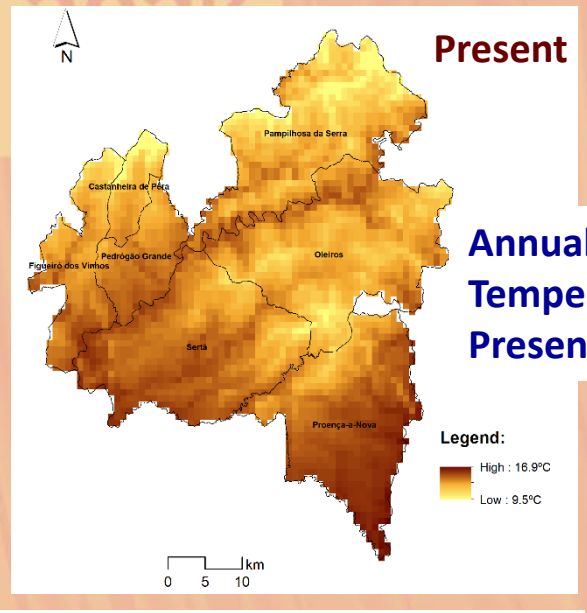
Methods

- The classification of the plant species suitability resulted from the integration of a set of biophysical criteria based on ecological requirements. Geoprocessing and spatial analysis were performed to geographic data, namely **climate** (annual mean temperature and annual precipitation), **soils** (texture, depth and pH), and **topography** (elevation and slope).
- In future conditions, we have considered two **Representative Concentration Pathways** (RCPs) scenarios (**RCP 4.5 - Stabilization scenario** and **RCP 8.5 - Worst-case scenario**) fitted for **2070**.
- The different layers corresponding to each criteria were classified into two suitability levels: low to medium suitability and high suitability. After creating layers resulting from the reclassification in suitability levels, the general suitability for each species was performed using a multicriteria decision analysis - the Analytic Hierarchy Process - AHP.

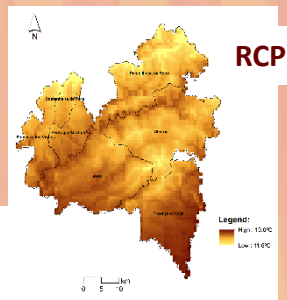
Methods

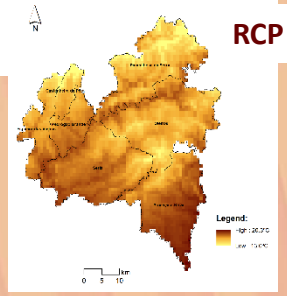

Identification and selection of criteria
Establishment of suitability thresholds for each criteria
Data collection and processing
Obtaining maps
Climatological
Edaphological
Physiographic
Classification according to thresholds
Obtaining weights
Expert opinion
Weight(W):
WixFi & WixCi
∑Wi=1
Consistency matrix
RC<10%
Yes
No
Review
Use of weighted overlay
Species suitability map

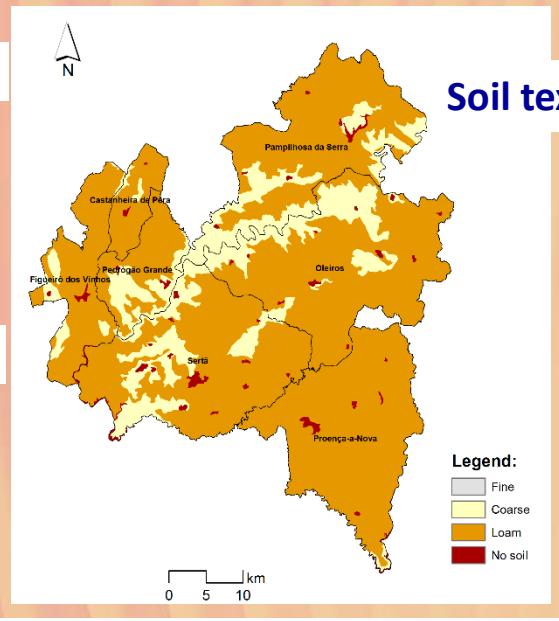
Criteria

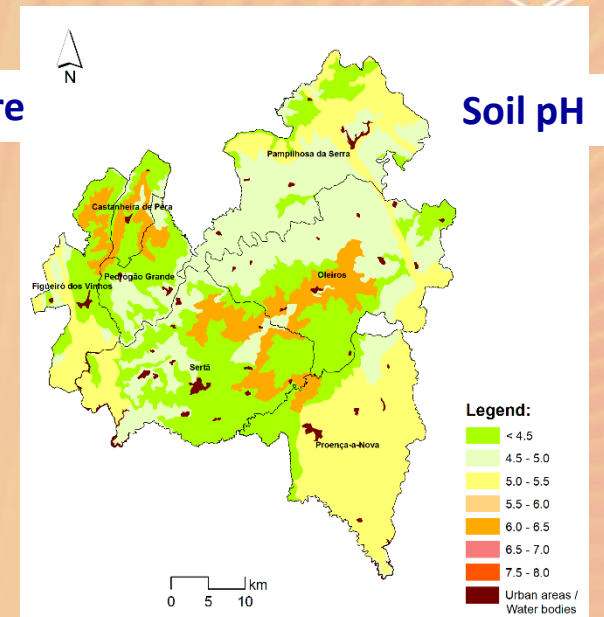


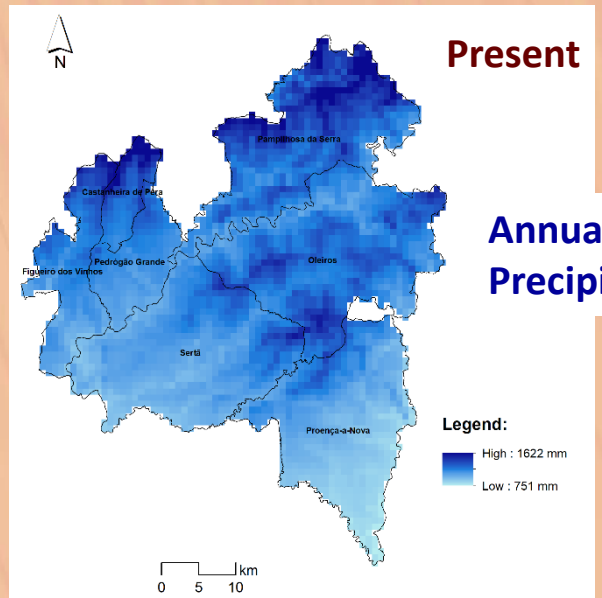
Annual Mean Temperature Present



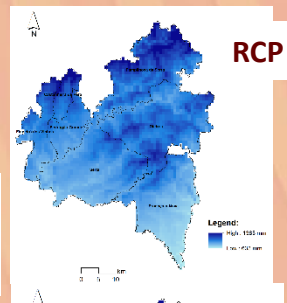


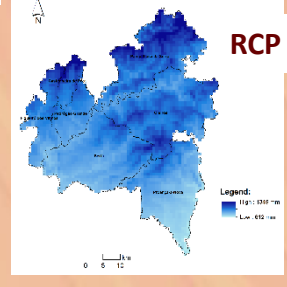


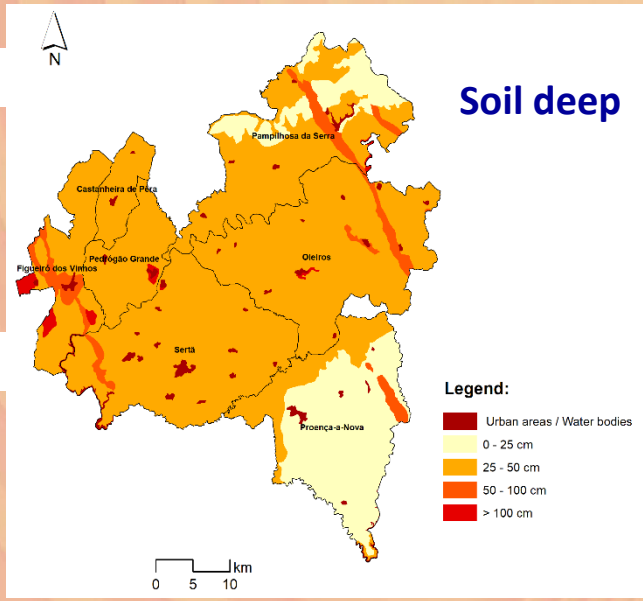


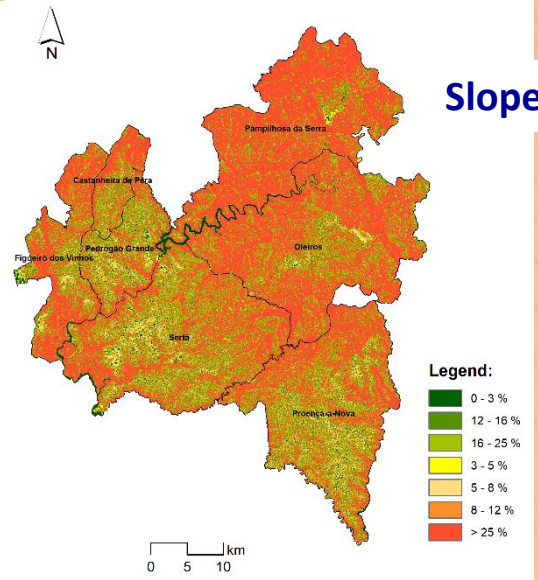


Annual Precipitation



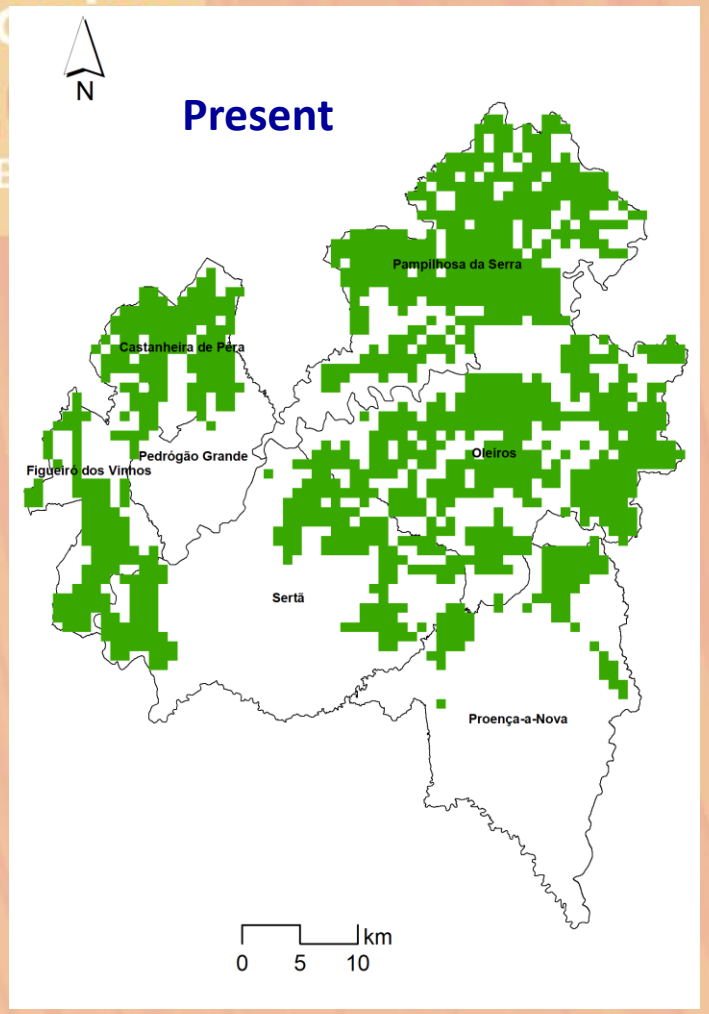


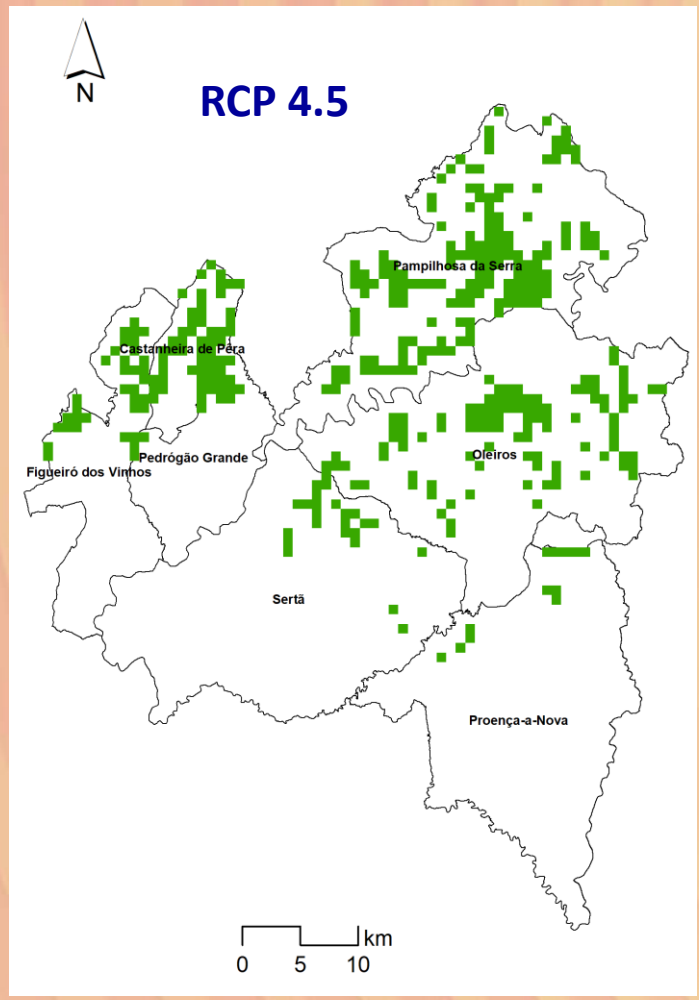


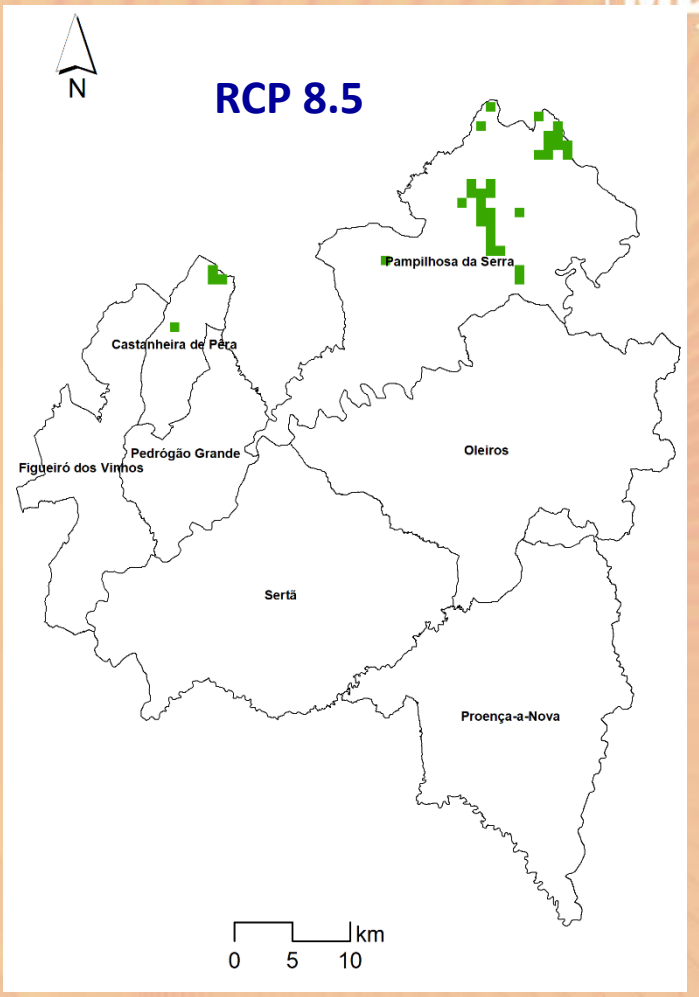


Suitability maps

Common oak - *Quercus robur*



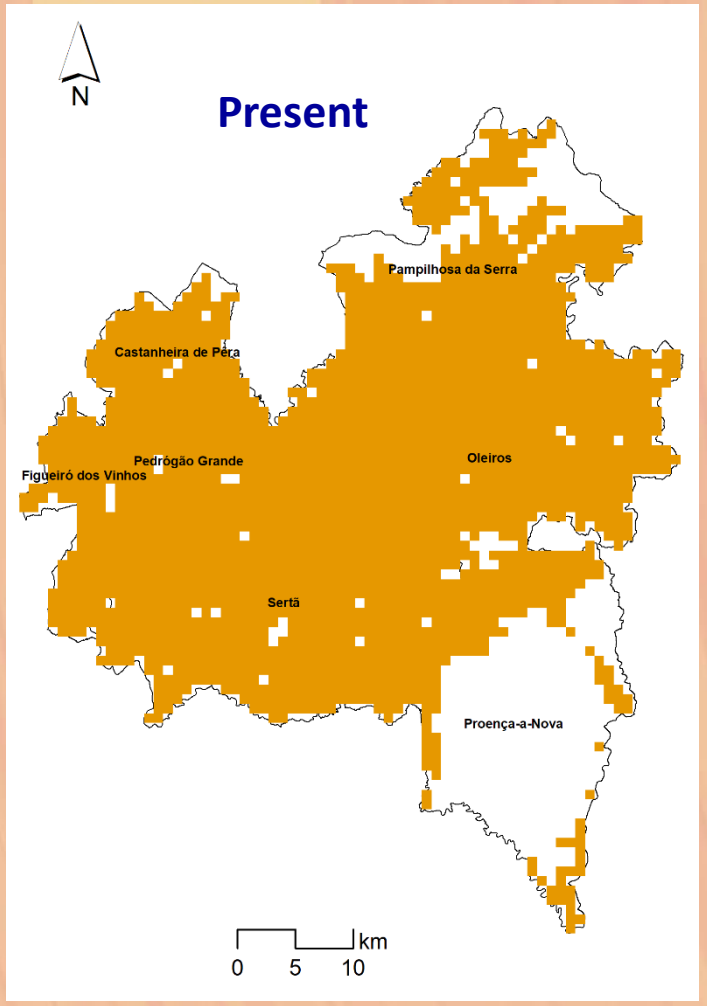


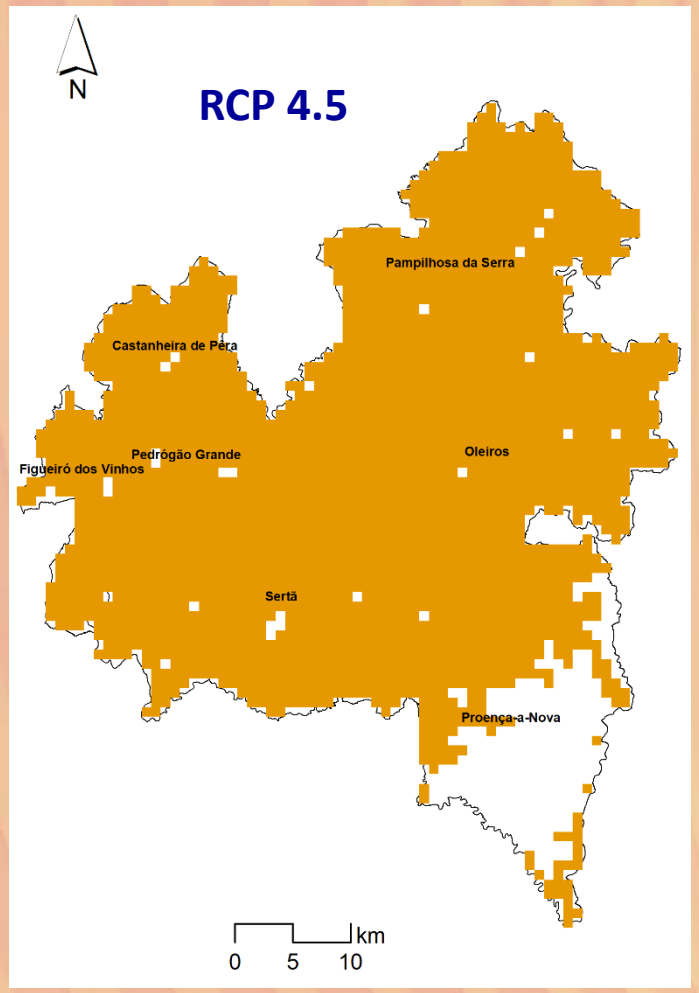


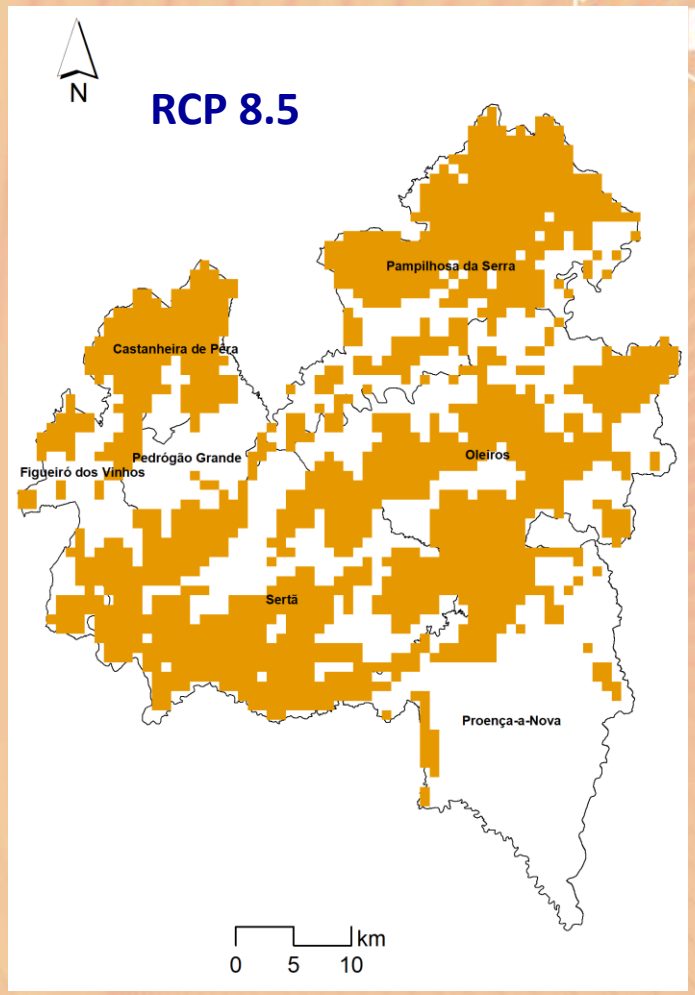
42.1% of the total area, is classified as highly suitable for common oak in the present situation. For the Intermediate future scenario output (RCP 4.5 - 2070), the total area with high suitability for common oak decrease to 272.8 km^2 (**13.3%**) and reduces even more for the worst-case climate change scenario (RCP 8.5 - 2070) with 24.1 km^2, corresponding to only **1.2%** of the total area.

Suitability maps

Cork oak - *Quercus suber*



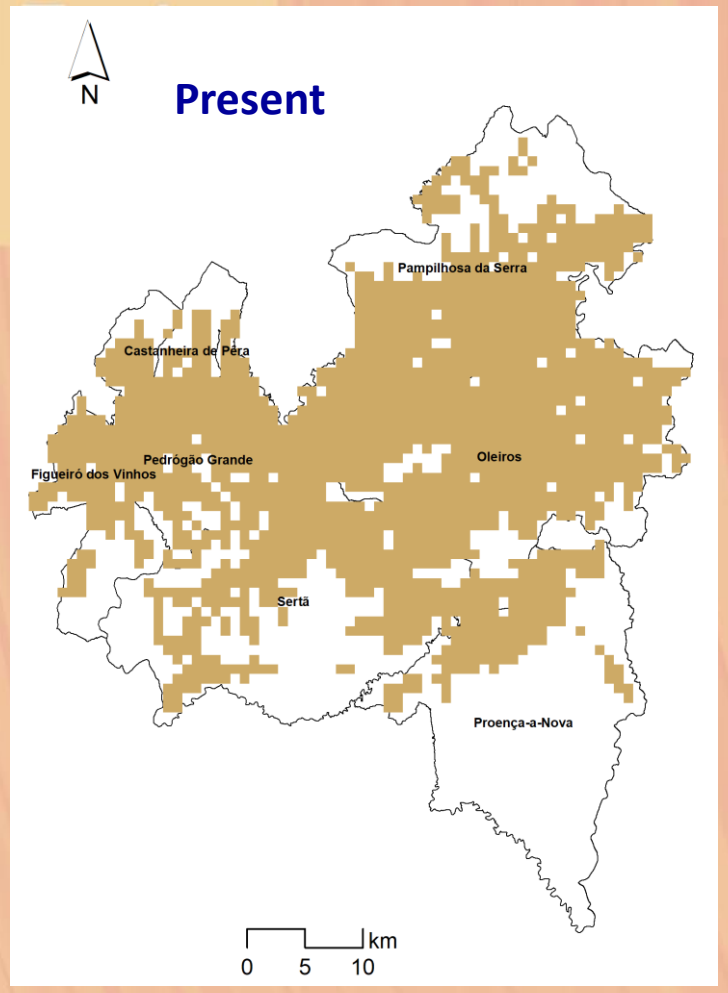


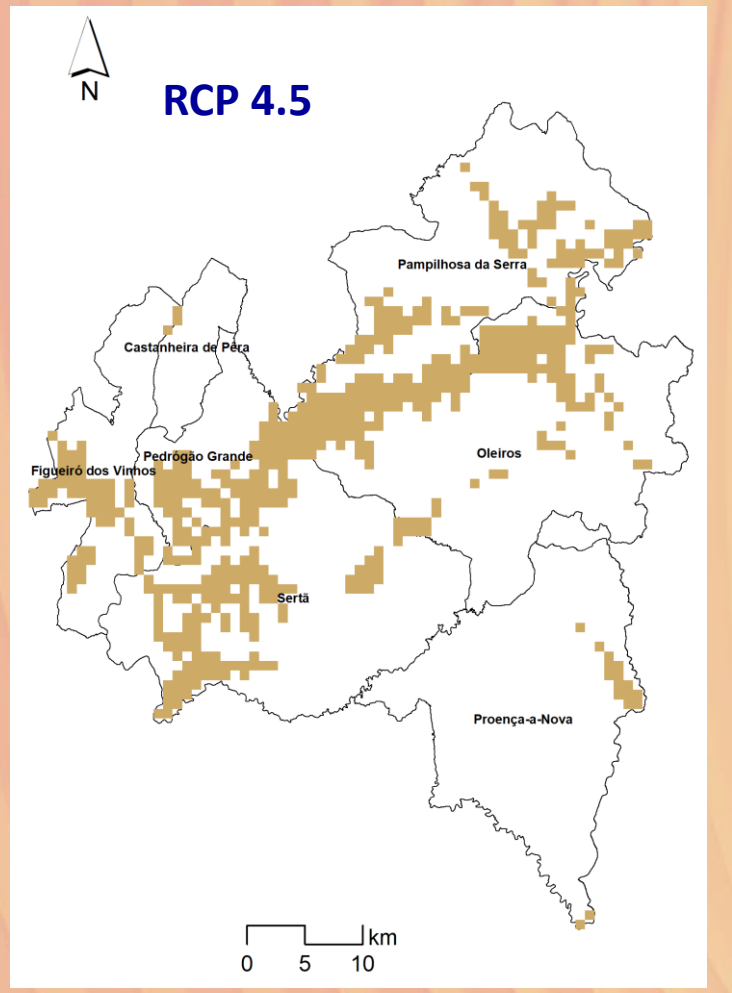


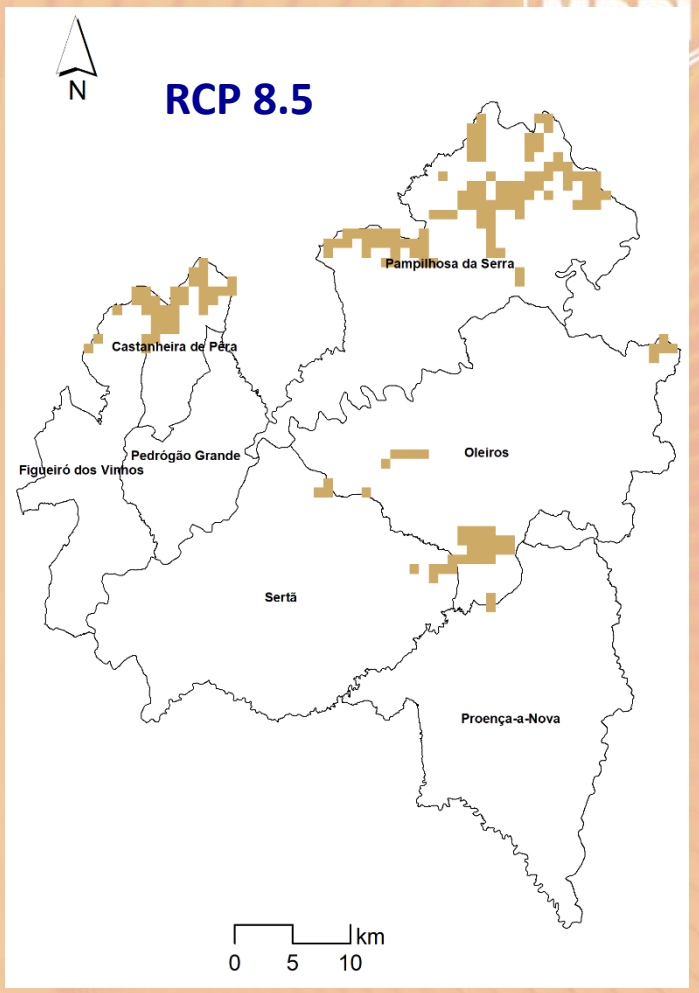
In the present situation, the study area presents high suitability in **80.1%** of the territory (1,639.6 km^2). However, for future scenarios, there are notable differences, with an increase of highly suitable area for the intermediate scenario (4.5 - 2070), with a total area of 1,812.5 km^2 (**88.6%**), while for the worst-case scenario the potential distribution of the species drops to 1,128.4 km^2 (**55.2%**) and becomes more fragmented.

Suitability maps

Sweet chestnut - *Castanea sativa*



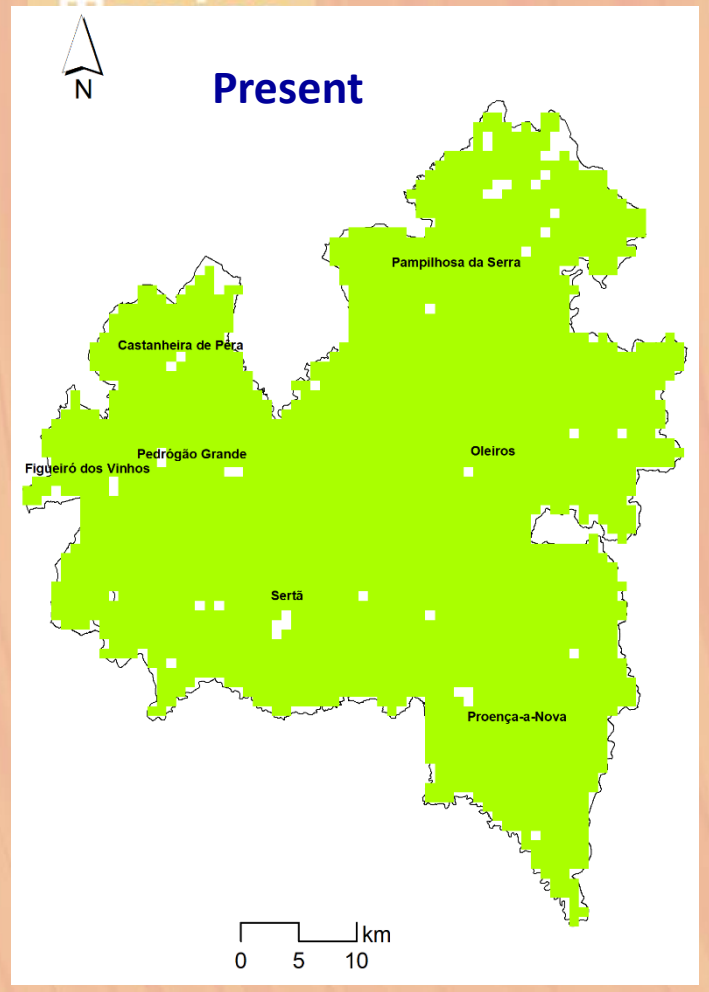


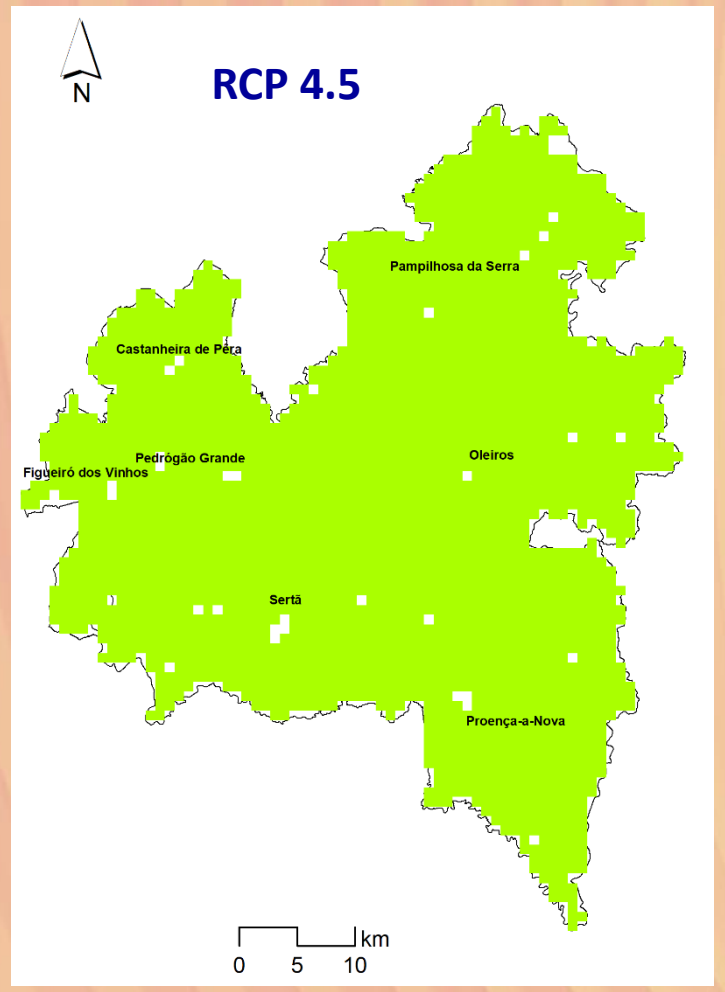


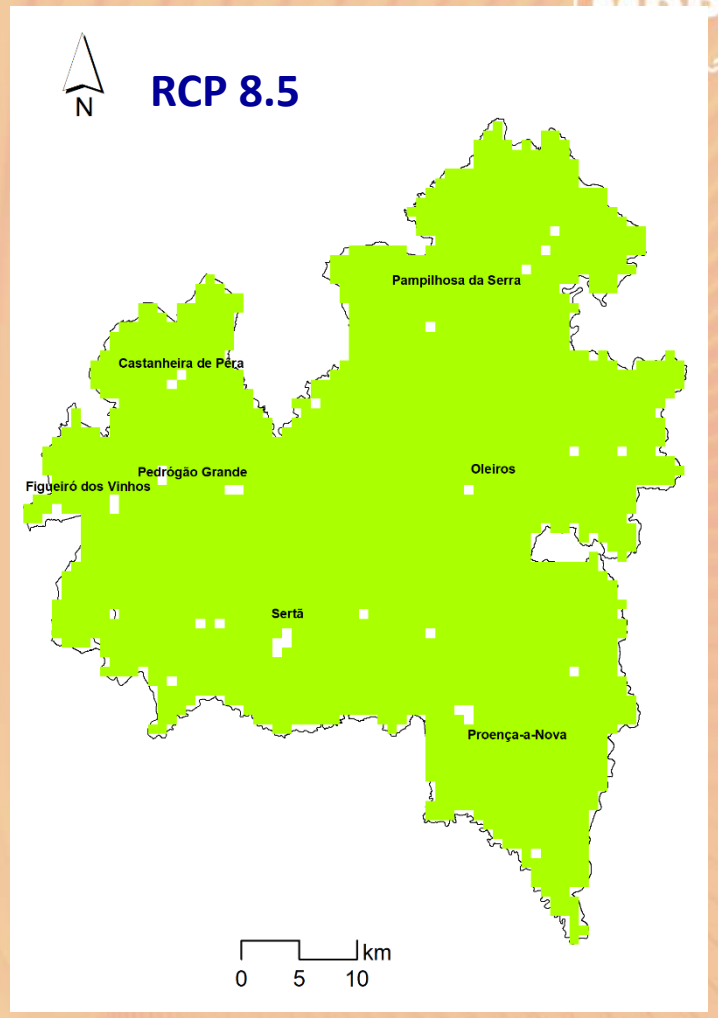
The high suitability area for the sweet chestnut in the present corresponds to 1,235.2 km^2 (**60.4%**). For both future climate scenarios, the potential high suitability area decreases, with 413.3 km^2 (**20.2%**) for the intermediate scenario, and 124.0 km^2 (**6.0%**) for the worst-case scenario.

Suitability maps

Strawberry tree - *Arbutus unedo*







The high suitability distribution for strawberry tree occupies practically all of the available arable land in the study area (2004 km^2; **97.9%**), and will practically not change over time, although there will be a slight increase in both future scenarios, with 2018.5 km^2 (**98.7%**) for the intermediate scenario, and 2021.9 km^2 (**98.8%**) for the worst-case scenario.

Topics 2023 WEBINARS

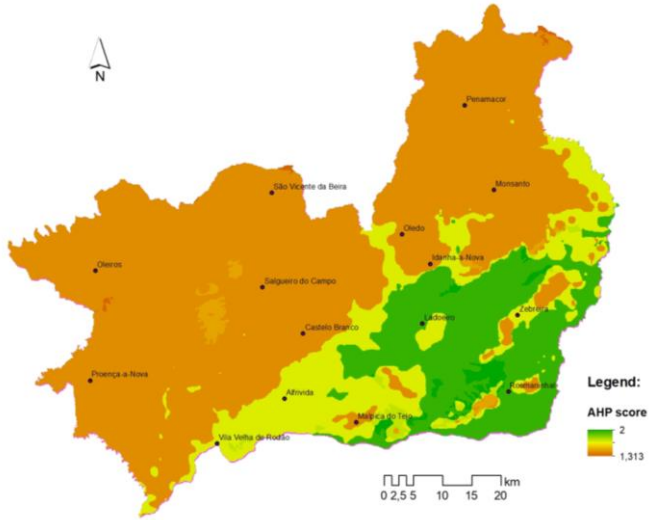
MDPI

Main conclusions

- **Species more adapted to Atlantic conditions like common oak and sweet chestnut will decrease**, it's urgent to promote species more adapted to future climate conditions. On the other hand, the strawberry tree has a high suitability in almost all the region in the present and future scenarios;
- **For further study is recommend selecting other native species (e.g., holm oak) more adapted to Mediterranean conditions** in order to adapt to the bioclimatic shifts towards higher latitudes and/or altitudes;
- It's important to privilege diverse landscapes in the studied region characterized by the mosaic of agrosilvopastoral systems serving as an alternative to the current extensive monoculture landscapes of even-aged stands of fast-growing species.

2

LAND SUITABILITY ANALYSIS FOR EMERGING FRUIT CROPS IN CENTRAL PORTUGAL



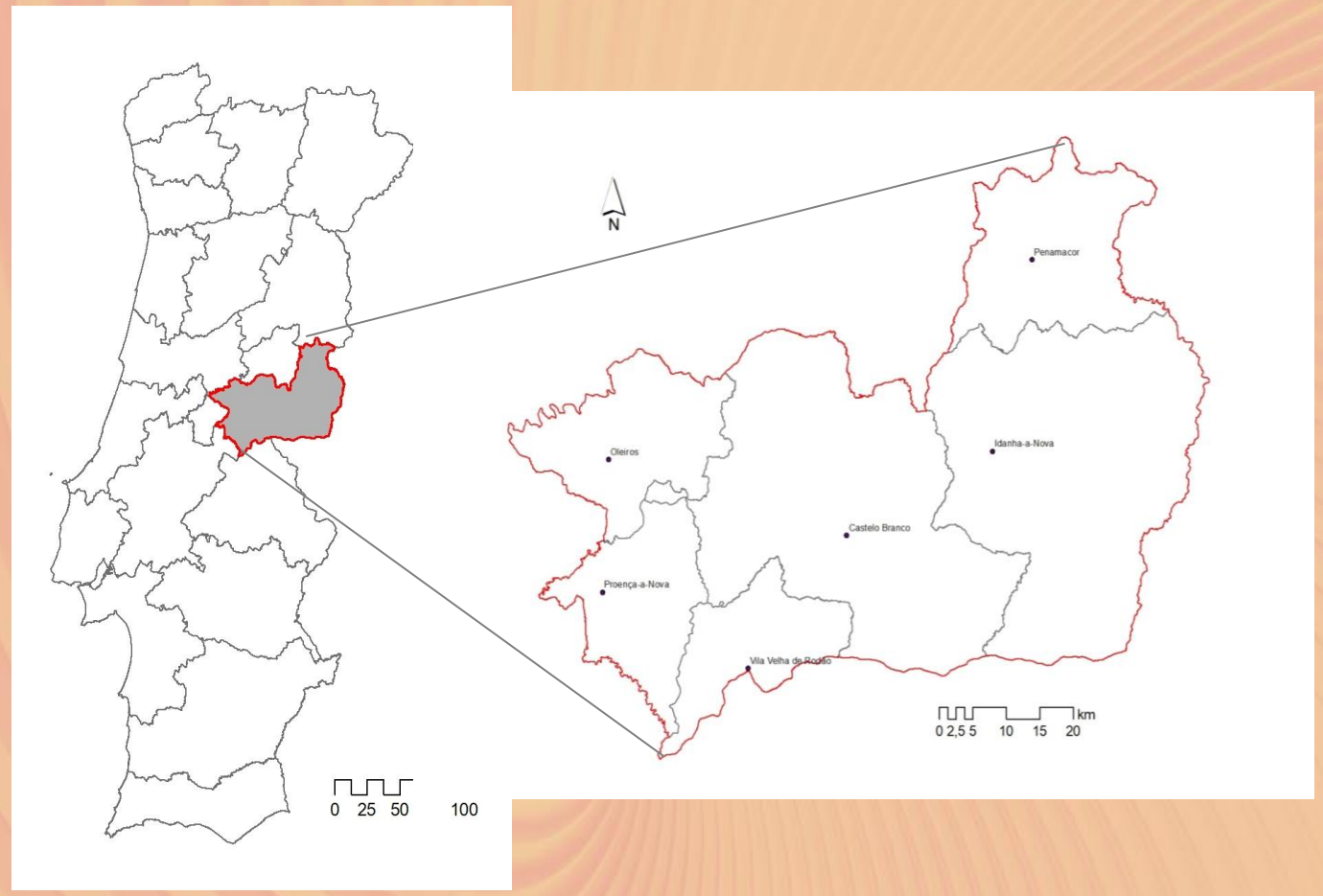
The objective of this study was to determine the suitability for the cultivation of emerging fruit crops in the Beira Baixa region, based on the analysis of the soil and climate limiting factors.

For this purpose, the biophysical criteria determining the cultivation of the **pistachio tree** (*Pistacia vera* L.), **strawberry tree** (*Arbutus unedo* L.), almond tree (*Prunus dulcis* (Mill.) DA Webb) and **walnut tree** (Juglans regia L.) were processed using a Geographic Information System.

Study area

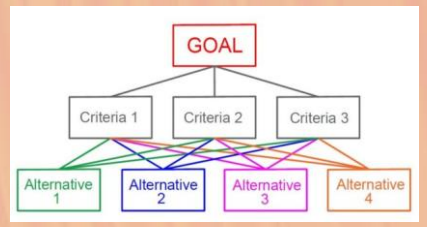
Beira Baixa region, Portugal

- The Beira Baixa region is an administrative division in eastern Portugal. The region covers an area of 4,614.6 km² and has a population of 80,775 inhabitants (17.5 inh./km²). The area includes seven municipalities: Idanha-a-Nova, Penamacor, Oleiros, Proença-a-Nova, Vila Velha de Ródão and Castelo Branco.
- Forest (51%), agriculture (17%), and pastures (11%) are the main land uses.
- The climate is mainly characterized by a warm temperate, Mediterranean climate with a distinct wet season in winter.

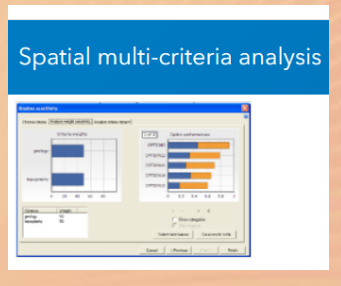


Methods

Multicriteria decision analysis to determine the suitability for each crop



Analytic Hierarchy Process (AHP)
(Saaty, 1970)



- The different layers corresponding to each criteria were classified in two suitability levels: low or medium suitability (1) and high suitability (2). After creating layers resulting from the reclassification in suitability levels, the general suitability for each crop was performed using the Analytic Hierarchy Process - AHP.

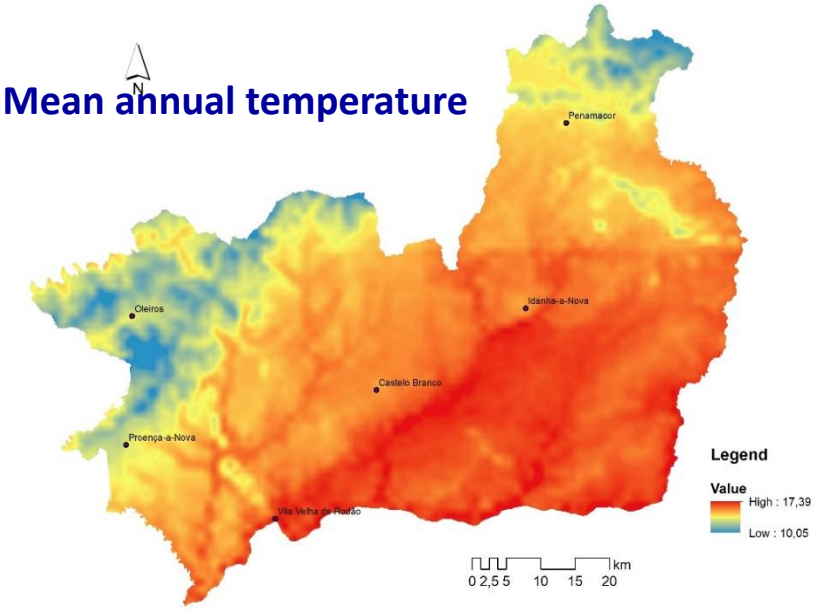
- Weights were calculated using the "*Spatial multi-criteria analysis*" tool, developed by Marinoni (2018).

Methods

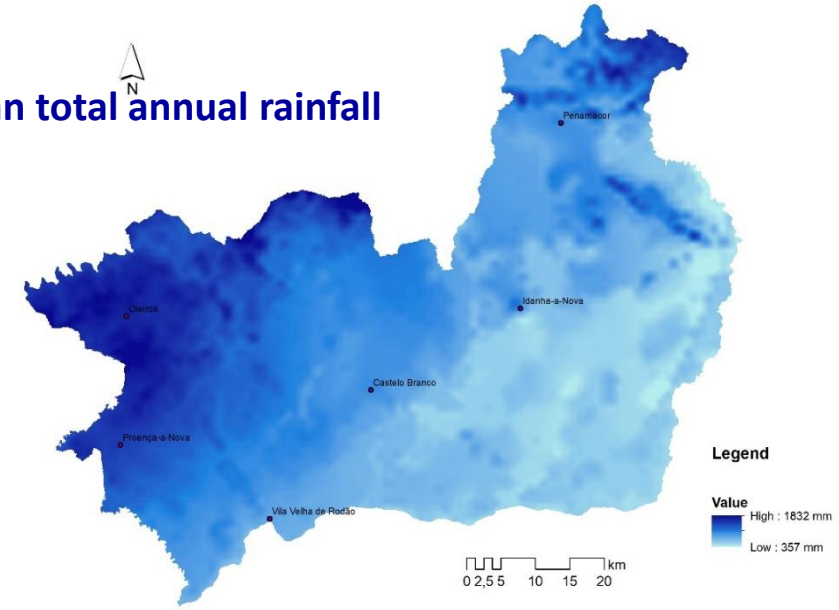
Criteria considered in determining crop suitability.

Criteria	Description
Mean annual temperature	Average of the 12 mean monthly temperatures (ºC)
Mean total annual rainfall	Total annual depth of precipitation from a given precipitation time series (mm)
Chilling hours	Sum of hours with temperature ≤ 7.2 °C (h)
Crop heat units	Influence of temperature on a crop's growth and development (h)
Mean relative humidity	Ratio of the actual amount of water vapour present in a volume of air at a given temperature to the maximum amount that the air could hold at that temperature (%)
Biogeography	Portugal biogeographic units and adapted species
Elevation	Height above the Earth's sea level (m)
Soil pH	Measure of the acidity or alkalinity of a soil
Soil Organic Matter	Fraction of the soil that consists of plant or animal tissue in various stages decomposition (%)

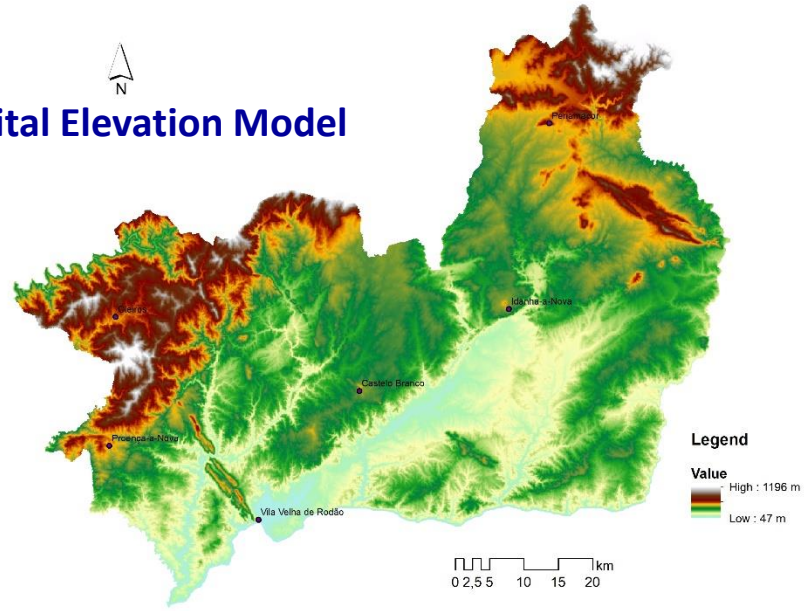
Mean annual temperature



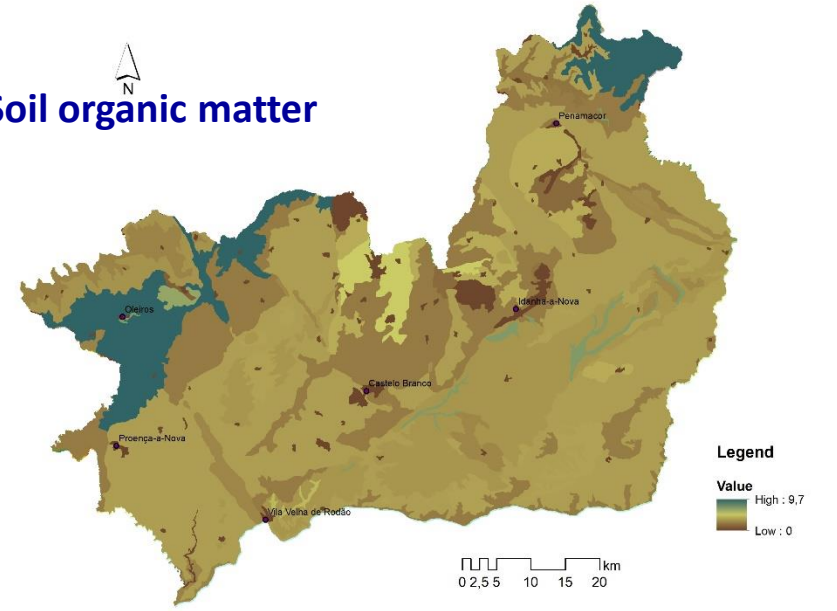
Mean total annual rainfall



Digital Elevation Model



Soil organic matter

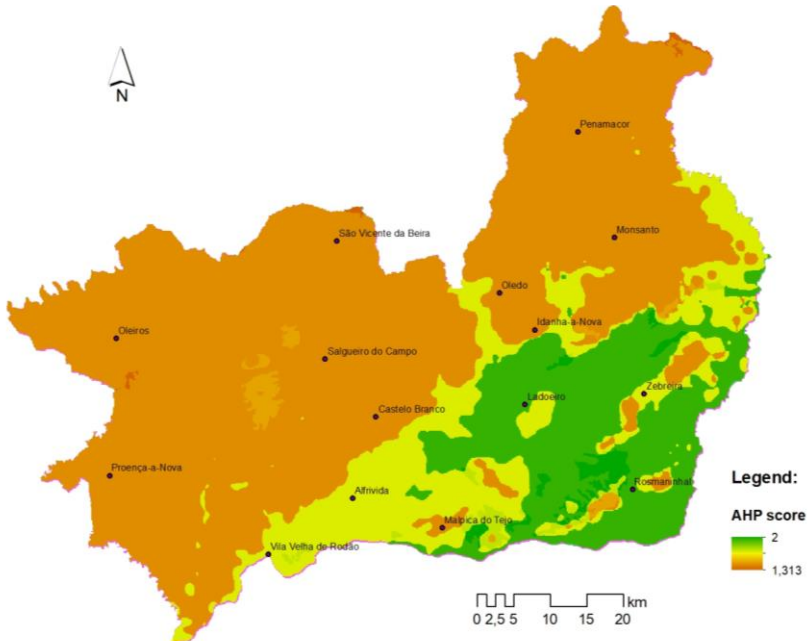


Topics 2023 WEBINARS

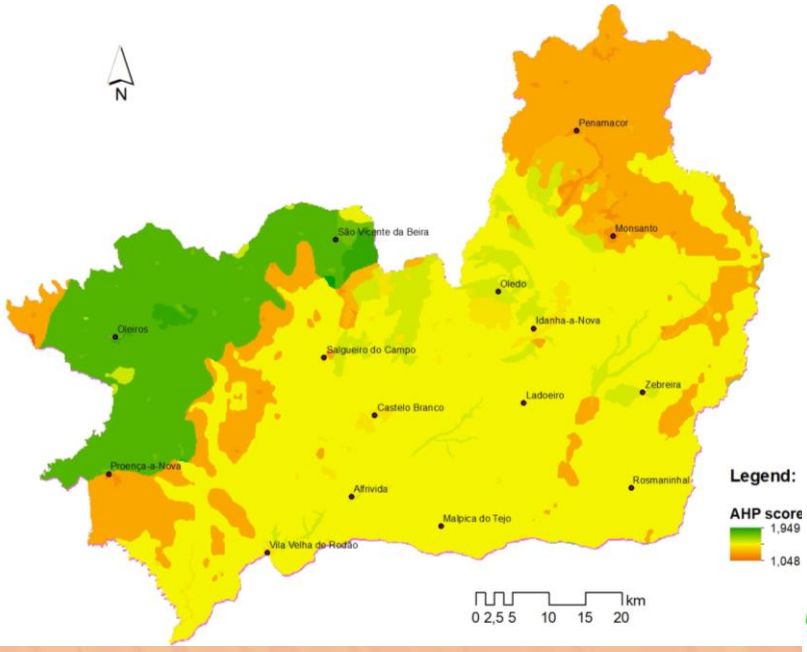
MDPI

Crop suitability maps

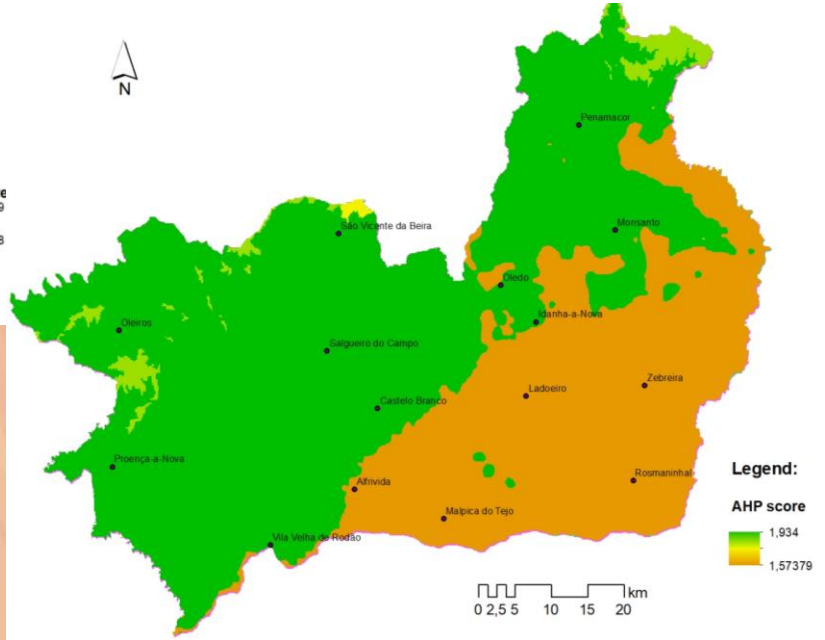
Almond tree - *Prunus dulcis*



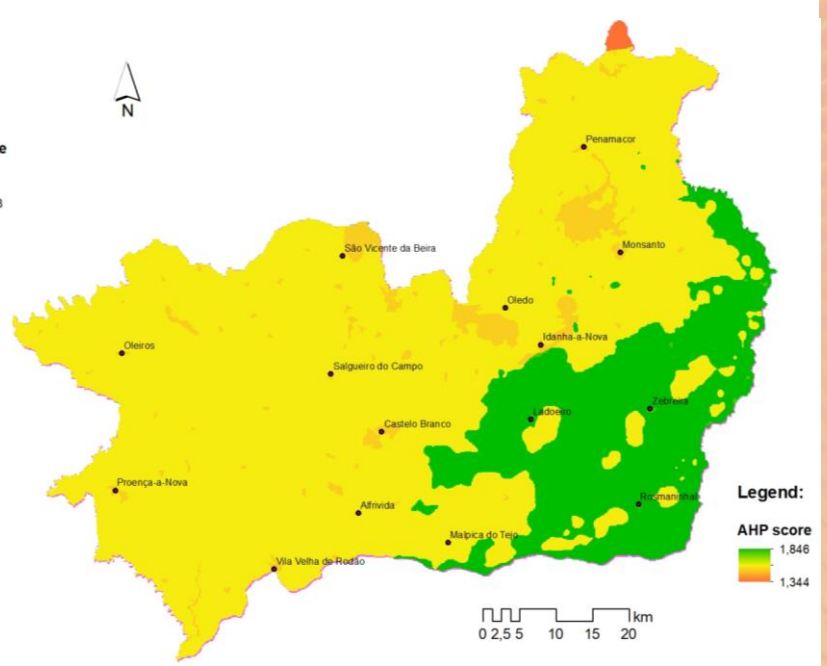
Strawberry tree - *Arbutus unedo*



Walnut tree - *Juglans regia*



Pistachio tree - *Pistacia vera*



Topics 2023 WEBINARS

MDPI

Main conclusions

Almond tree

- About 16.4% of the total area available are classified as highly suitable, especially in the south SE part of the region.
- Low winter and spring temperatures and very high summer temperatures inhibit growth and fruit set. On the other hand, very high summer temperatures when accompanied by low soil moisture can result in the shrinkage of almonds.

Strawberry tree

- The area with high suitability to strawberry tree crop corresponds to 15.8% of the total area available, corresponding to NW of the region, in an area with higher altitude (around 600-800 m) with more suitable climatic conditions and topographic adaptation.

Pistachio tree

- The area with higher potential to pistachio tree crop is 15.9% of the total area available and overlaps the potential almond tree crop area, resulting from natural conditions, especially the climatic influence.

Walnut tree

- The area with higher suitability corresponds to 63.2% of the total area available. Higher precipitation during the winter and the temperature are the main parameters that compromise this species.

3

An integrated agroforestal suitability model using a GIS-based multicriteria analysis method

The aim of the study was to integrate into the process of determining land suitability the risk factors that most directly influence rural territories, namely soil erosion and forest fire risk.

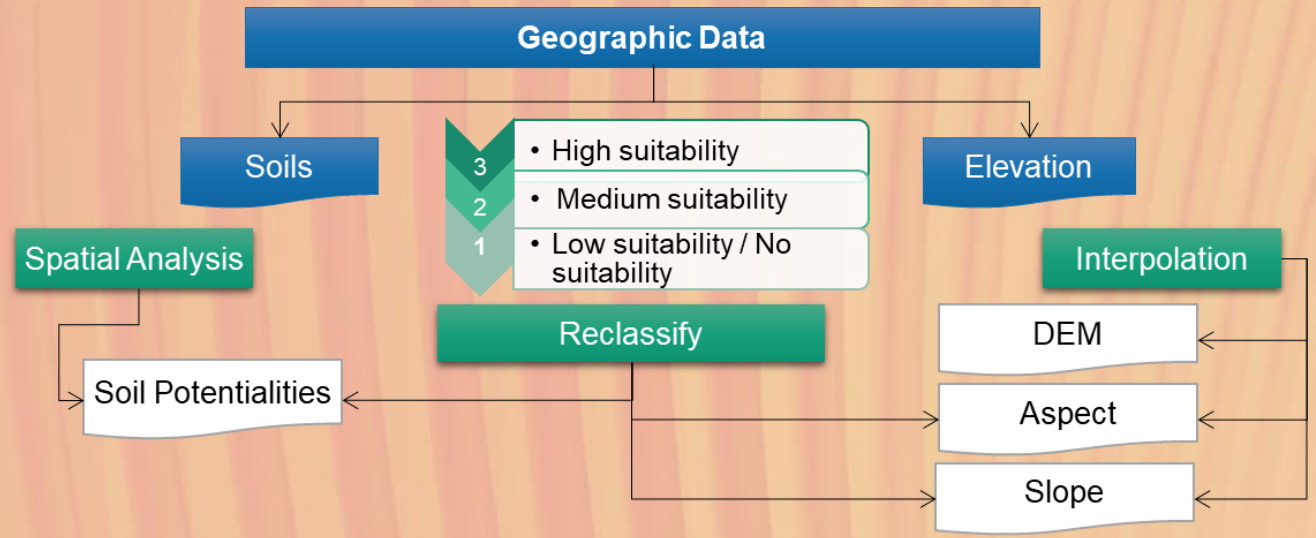
Study areas: Idanha-a-Nova & Beira Interior Sul region, Portugal

Topics 2023 WEBINARS

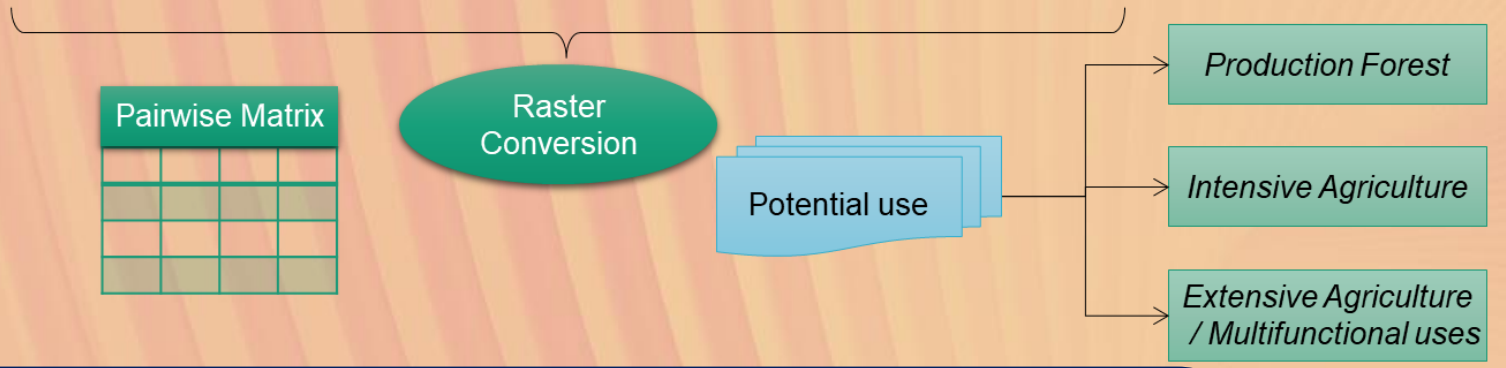
MDPI

Methods

Spatial Analysis and Geoprocessing

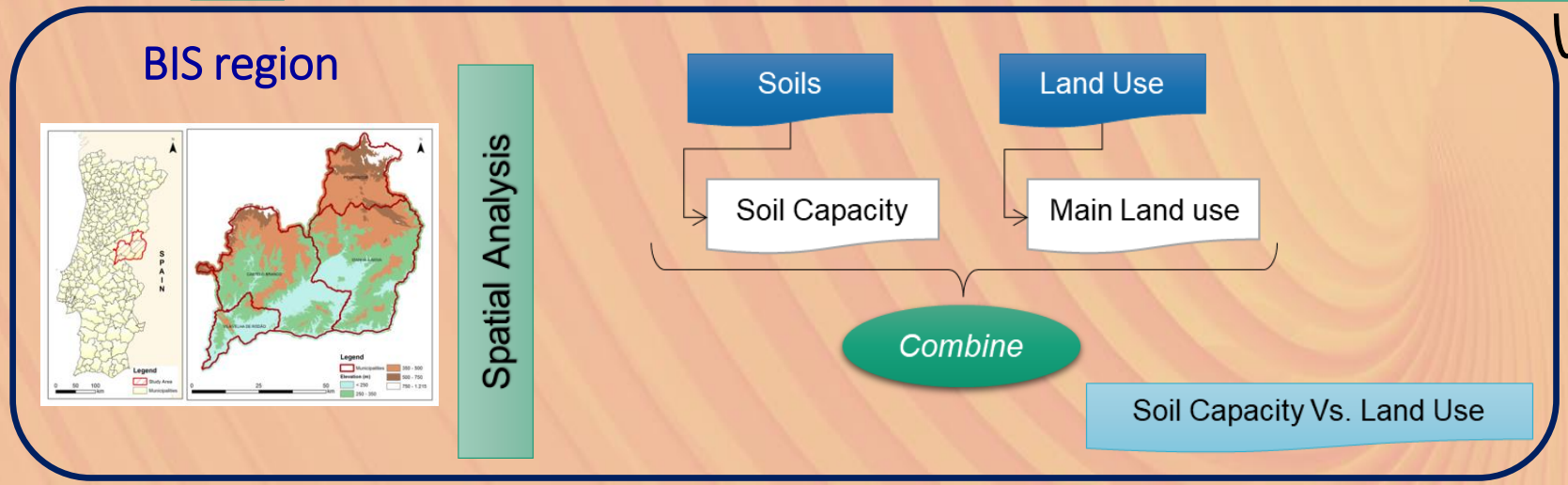


Analytical Hierarchy Process



Erosion Risk

Fire Risk

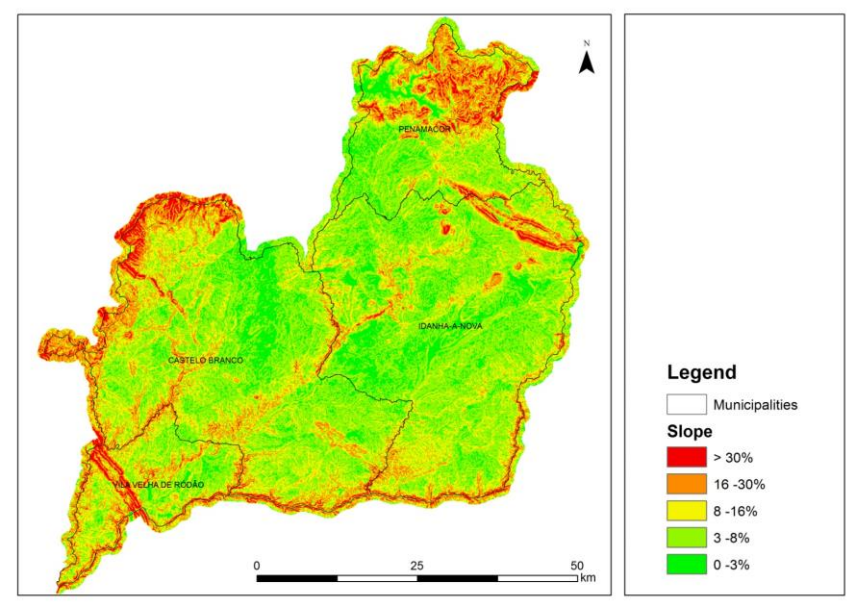


Idanha-a-Nova municipality

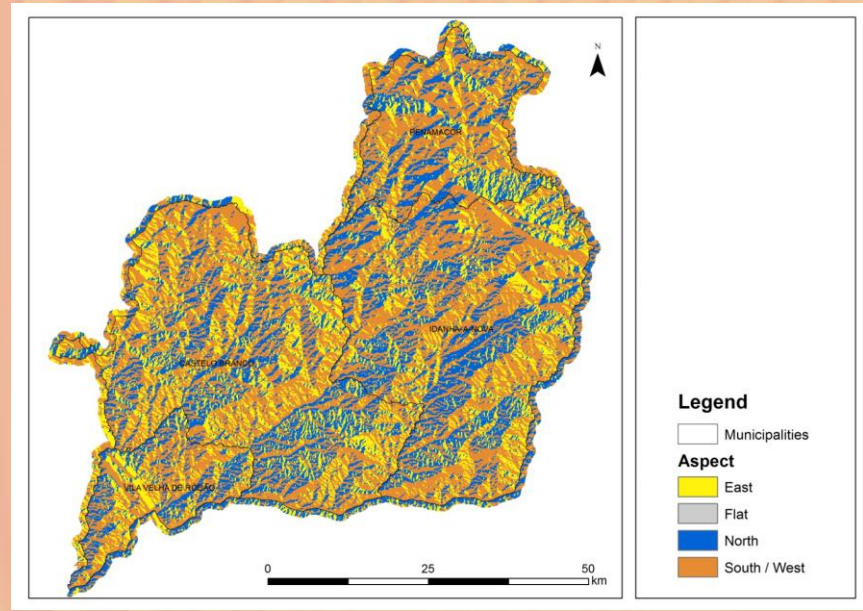
Soil Capacity Classification

Capacity class	Soil characteristics	Potential use
I	Different soil types that present high to very high constraints to production uses due to soil thickness, vulnerability to erosion or stoniness. With very low fertility.	Woodland and scrub with soil protection and recovery functions. In some cases, more favorable, pasture under a “montado” system.
II	Soils with coarse texture, without severe erosion problems, generally with low to very low fertility.	Forestry (pineyards and “montado” system), pastures, vineyards. In some cases, cereal crops and horticulture if water and organic matter is available.
III	Soils without severe erosion problems. With medium to low fertility.	Cereal crops, horticulture, orchards and improved pastures. Forestry.
IV	Soils without erosion problems. With medium o high fertility.	Cereal crops in intensive mode, orchards, improved pastures and forestry. Soils suitable for olive groves.
V	Soil with high fertility.	Good for different uses depending on drainage, soil texture, and availability of irrigation water: irrigations systems. Intensive forestry.
Rocky outcrops	–	Not suitable
Social areas	Urban areas and water bodies	Not suitable

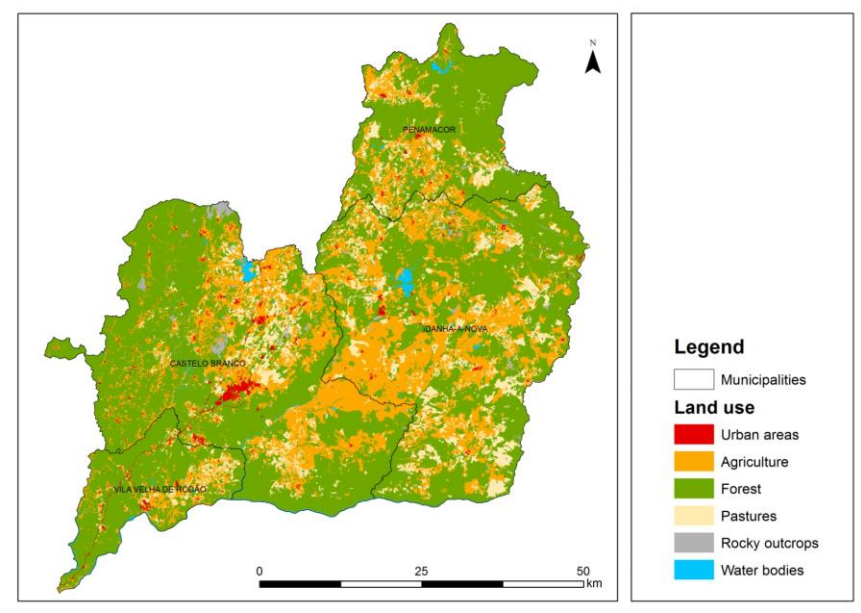
Topics 2023 WEBINARS



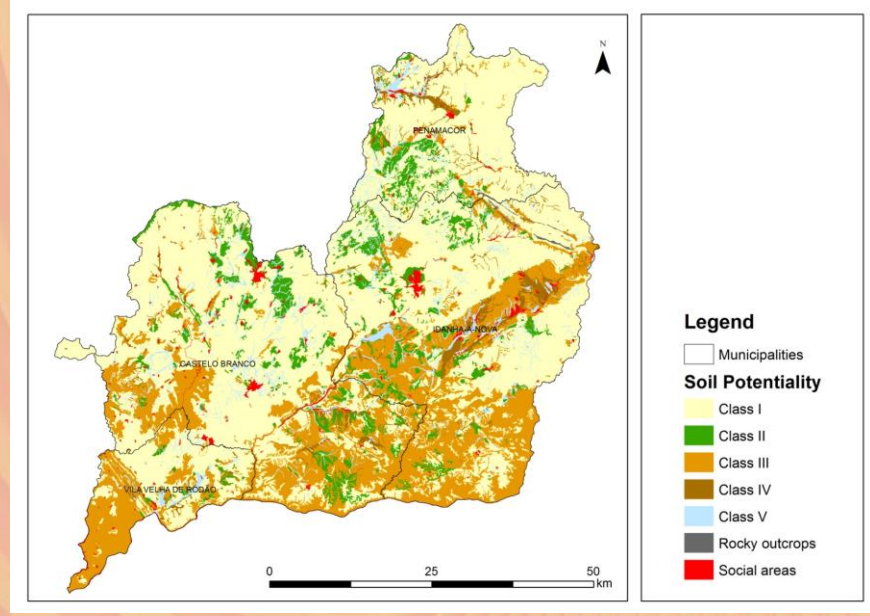
Slope



Aspect



Land use

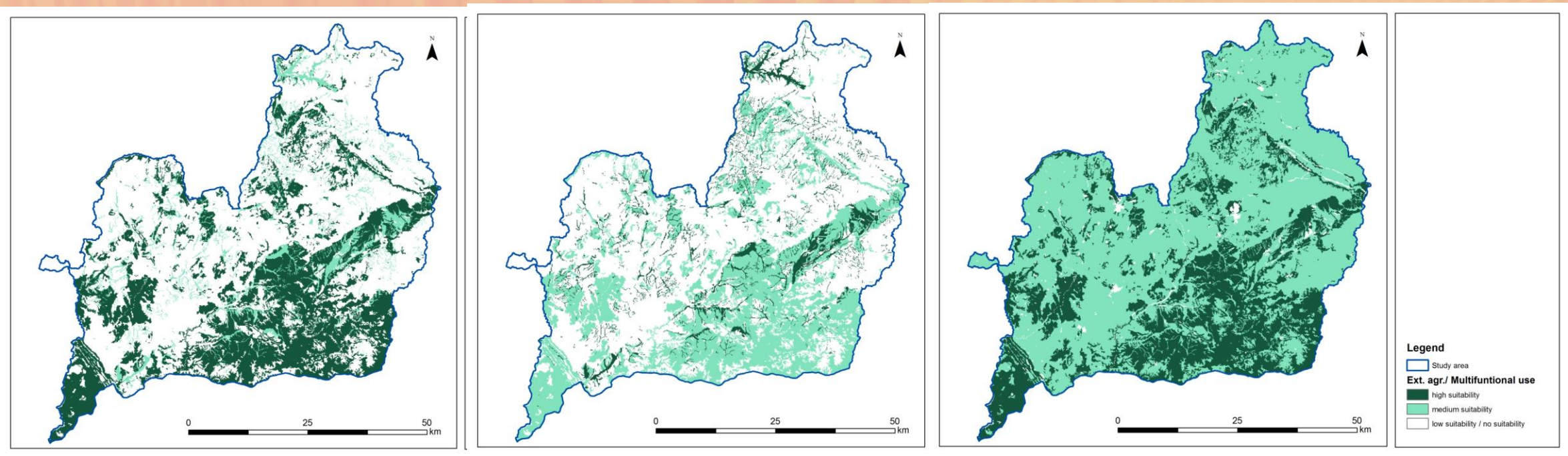


Soil capacity

Topics 2023 WEBINARS

MDPI

Suitability maps - Beira Interior Sul region



Production forest

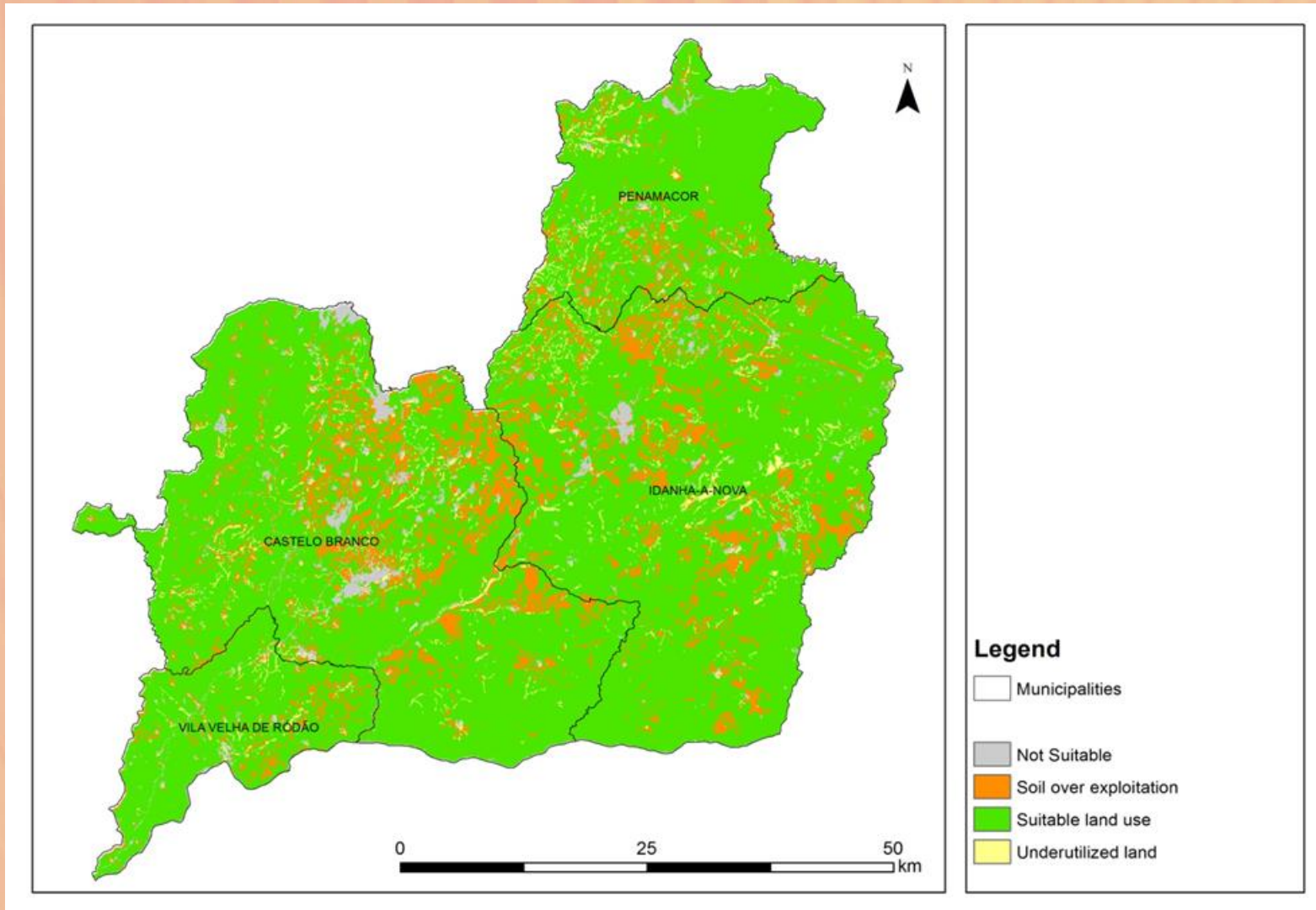
Intensive agriculture

Extensive agriculture/ Multifunctional use

Topics 2023 WEBINARS

Soil capacity vs. Land use - Beira Interior Sul region

MDPI

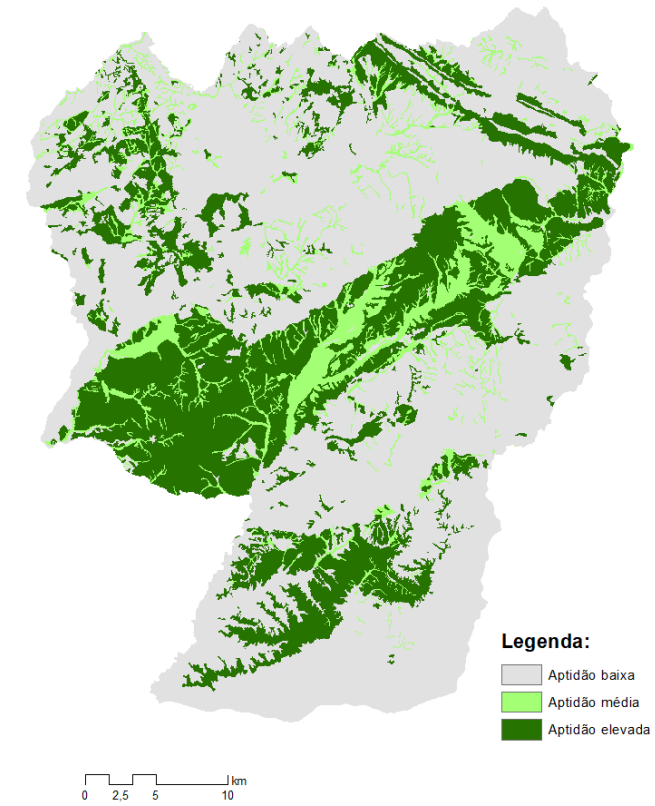


Topics 2023 WEBINARS

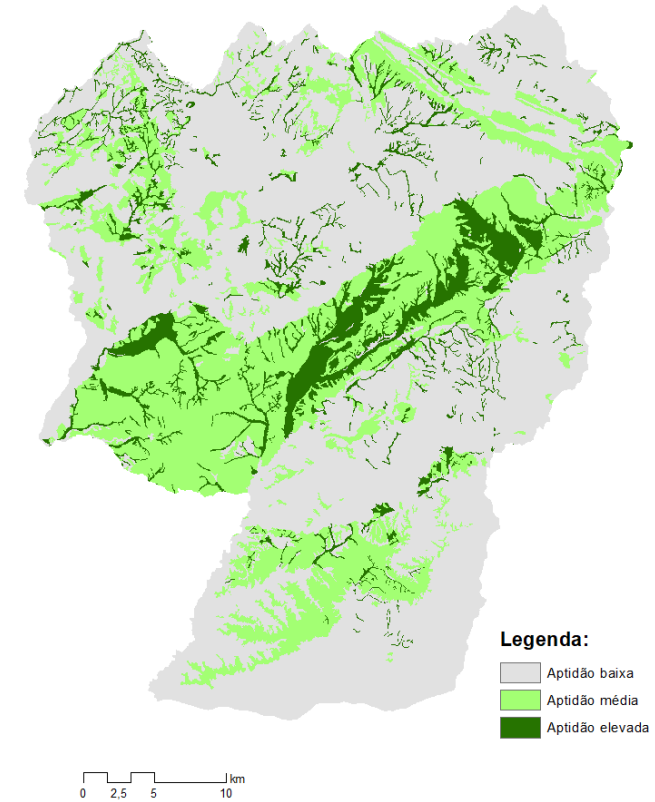
MDPI

Suitability maps - Idanha-a-Nova municipality

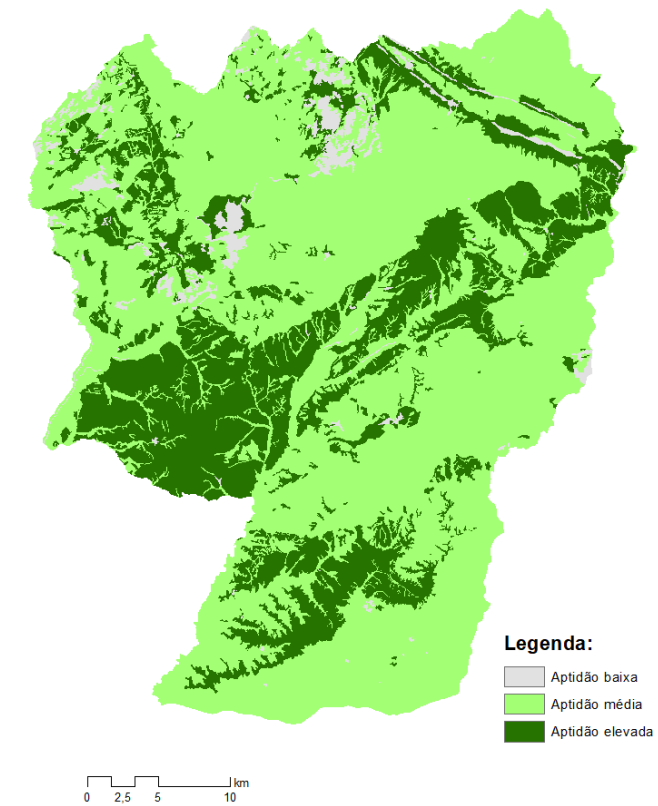
Production forest



Intensive agriculture



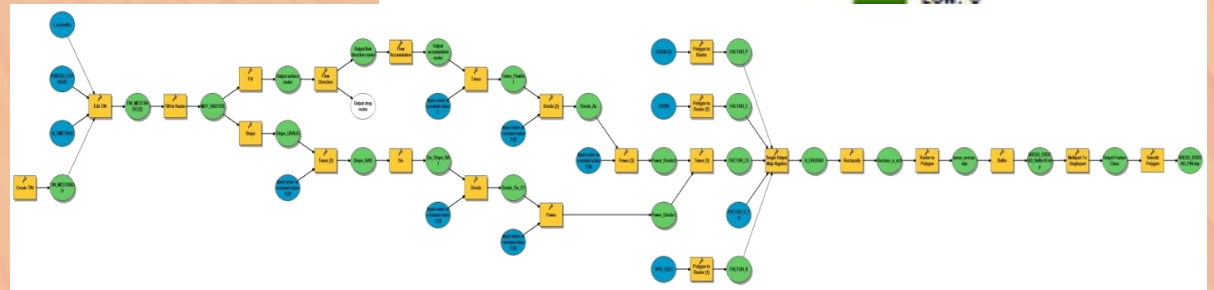
Extensive agriculture/ Multifunctional use



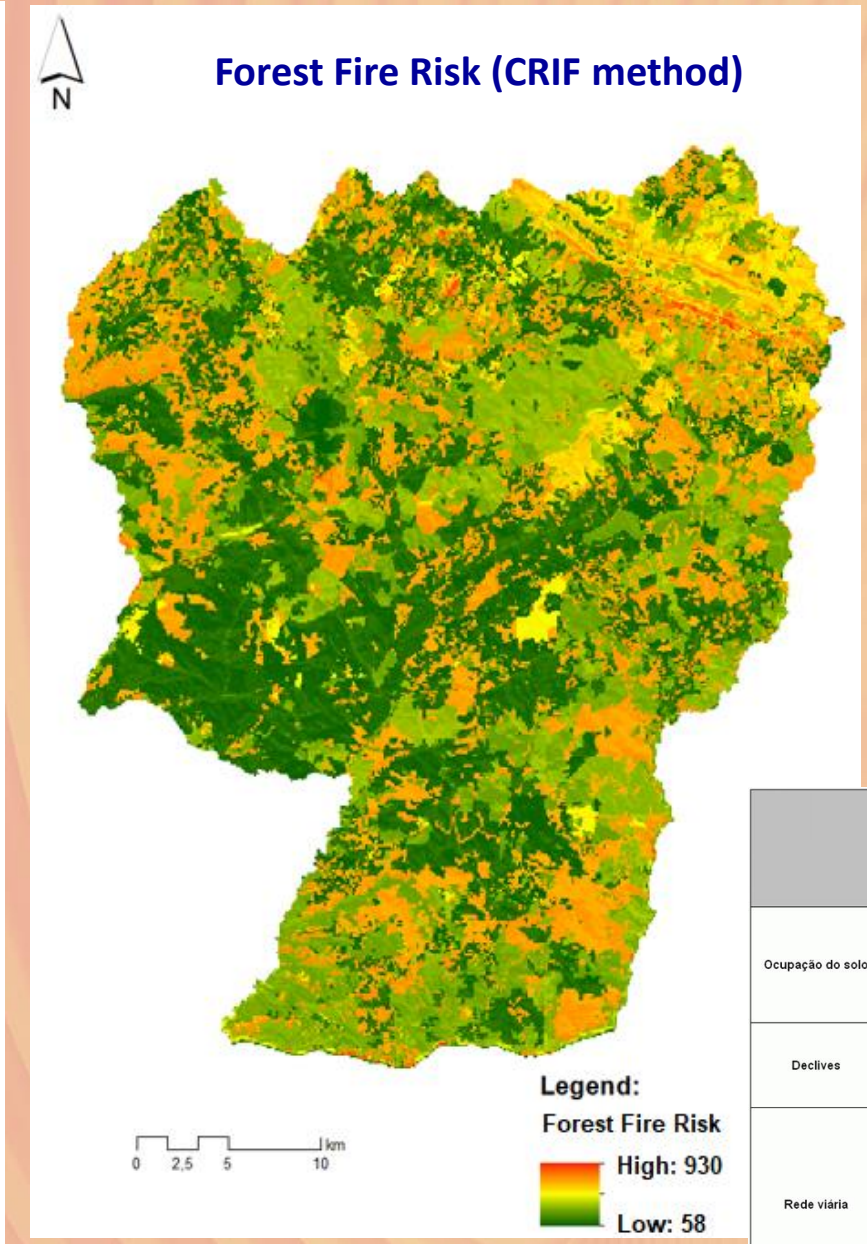
Topics 2023 WEBINARS

MDPI

Soil Erosion Risk (RUSLE)



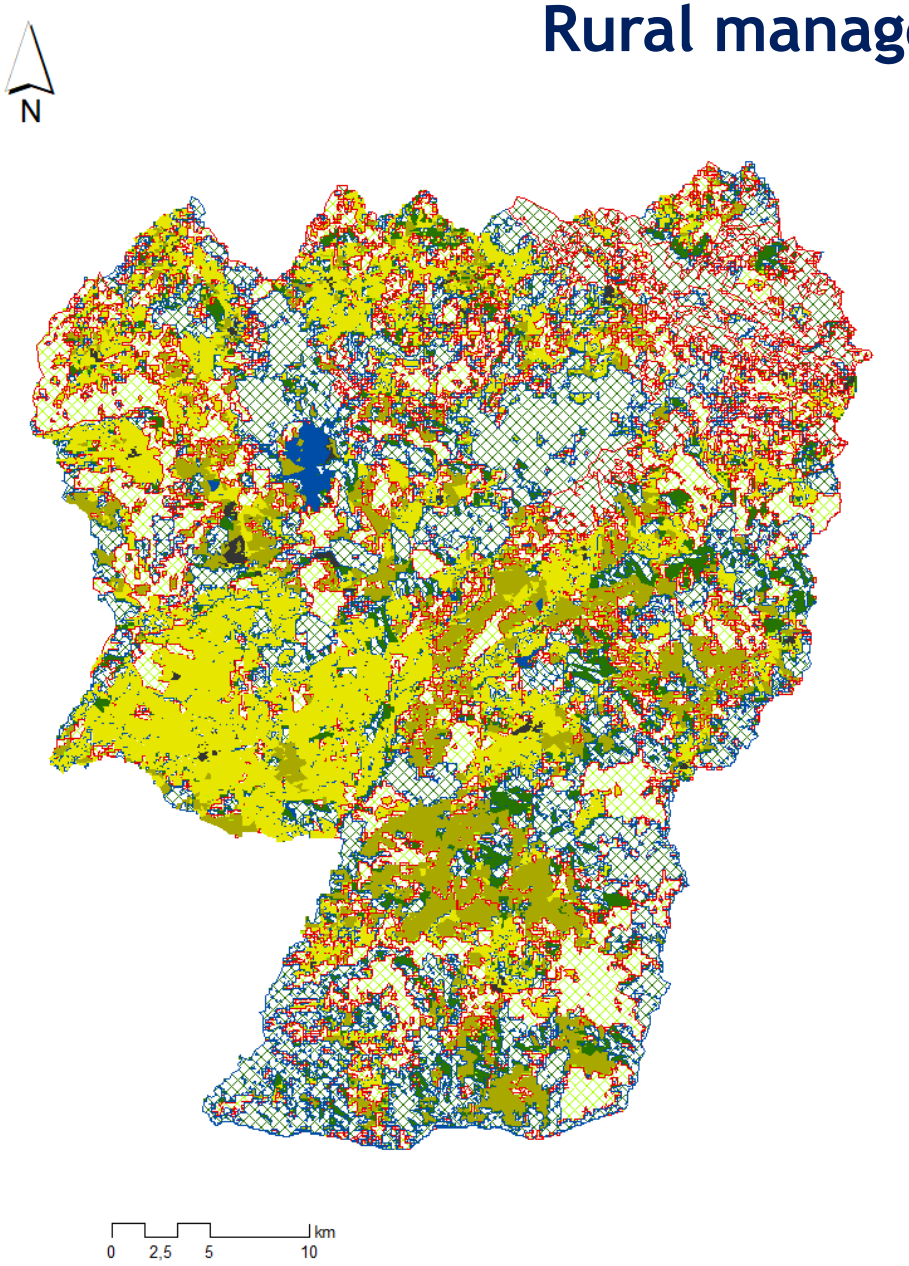
Forest Fire Risk (CRIF method)



	Amplitude de valores		Contribuição de cada classe para o valor de risco de cada critério		Contribuição do critério para o valor do risco de incêndio potencial	
			%	Valor	%	Valor max do critério
Ocupação do solo	**Classe 1ª**		**100%**	**590**	59%	590
	Classe 2ª		80%	472		
	Classe 3ª		70%	413		
	Classe 4ª		40%	236		
	Classe 5ª		30%	177		
	Classe 6ª		10%	59		
	Classe 7ª		1,5 %	9		
Declives	**acima de 40%**		**100%**	**210**	21%	210
	30 - 40%		66,67 %	140		
	20 - 30%		22,38 %	47		
	10 - 20%		11,43 %	24		
	0 - 10%		3,81 %	8		
Rede viária	Proximidade à rede viária	**Até 25 m**	**100%**	**90**	9%	90
		25 – 50 m	46,32 %	42		
		50 – 100 m	20,58 %	19		
		100 – 150 m	9,55 %	9		
	Densidade de caminhos agrícolas e florestais	**Inf. a 5 m/ha**	50%	45		
		5 – 12,5 m/ha	23,52%	21		
		12,5 – 20 m/ha	10,29 %	9		
		20 – 30 m/ha	5,14 %	5		
		30 – 40 m/ha	5,14 %	5		
		40 – 65 m/ha	10,29 %	9		
		65 – 80 m/ha	23,52 %	21		
		Sup. a 80 m/ha	50%	45		
Exposições	**135º - 225º**		**100%**	**60**	6%	60
	225º - 315º		57,45 %	34		
	45º - 135º		21,28 %	13		
	315º - 45º		6,38 %	4		
	-1 Plano		0%	0		
Densidade demográfica	**Até 250 hab / Km2**		**100%**	**50**	5%	50
	Entre 250 e 1500 hab / Km2		21,05 %	11		
	Acima de 1500 hab / Km2		**100%**	**50**		

Topics 2023 WEBINARS

Rural management proposals



Legend:

- Urban fabric and other artificial spaces
- Forest
- Water bodies
- Agroforestry
- Agroforestry - high erosion risk
- Agroforestry - high fire risk
- Agroforestry - moderate fire risk
- Arable land
- Arable land - high erosion risk
- Arable land - moderate erosion risk
- Shrub and/or herbaceous vegetation associations
- Shrub and/or herbaceous vegetation associations - high erosion risk
- Shrub and/or herbaceous vegetation associations - high fire risk
- Shrub and/or herbaceous vegetation associations - moderate erosion risk
- Shrub and/or herbaceous vegetation associations - moderate fire risk
- Forest - high fire risk
- Forest - moderate fire risk

Topics 2023 WEBINARS

MDPI

Final remarks

- **The land suitability analysis of agroforestry systems considering future climate scenarios** allowed us to assess the suitability of different types of forest stands and crop systems. Those approaches could provide a guide map for decision-makers to achieve a more sustainable use of the territory facing their ecological limitations and considering future climate scenarios.
- **Integrated agroforest suitability models** to determine the suitability of the soil for agricultural and forestry uses, including information regarding risks with direct implications for the use of rural spaces, may be of interest as an aid to public administration agents with functions in the area of territorial planning and management.