

# Implementing Adaptive Vegetation Management in Mediterranean Landscapes through CAFE-DSS

**Salam-MED:** Sustainable Approaches to Land and water Management in Mediterranean Drylands

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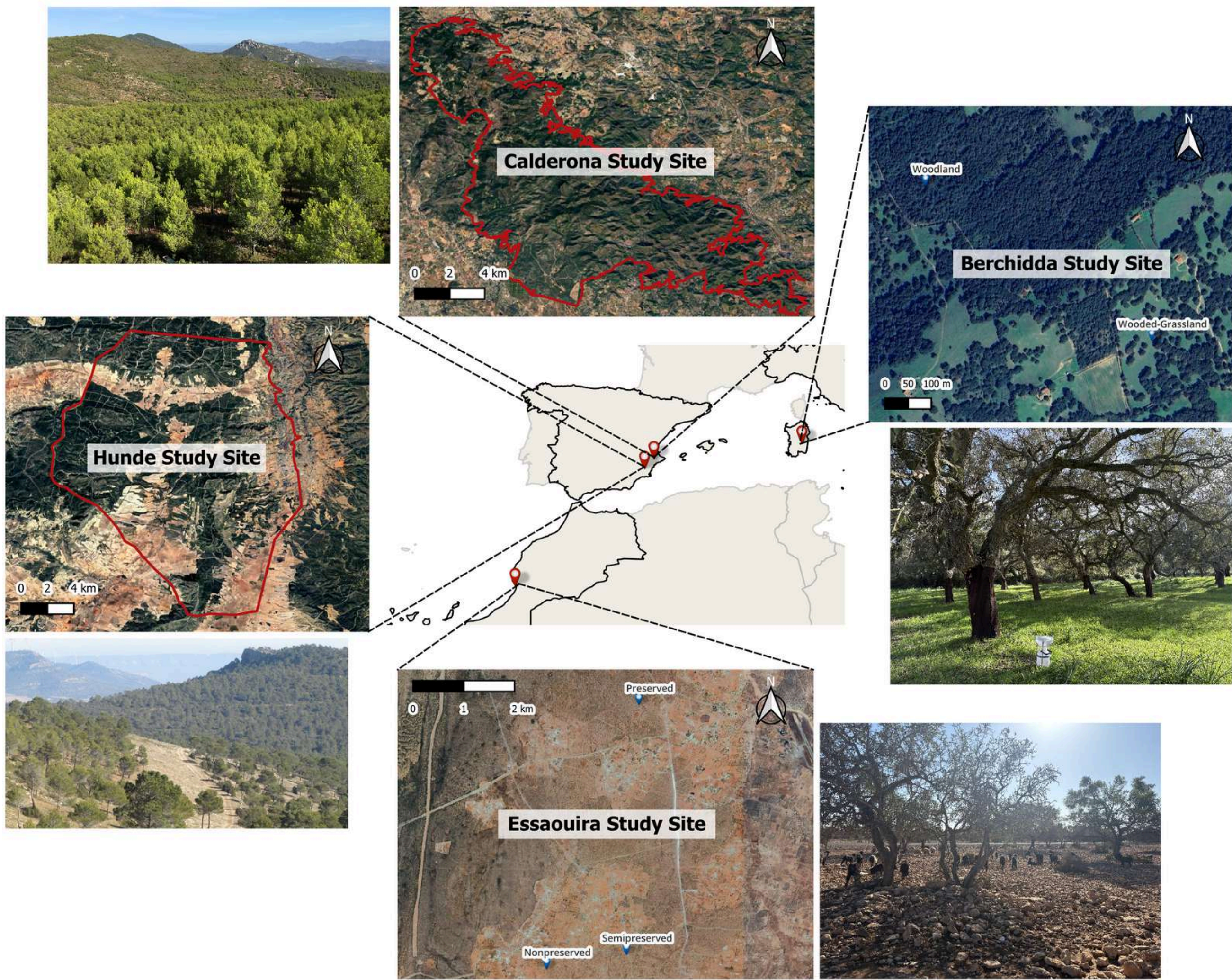
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## INTRODUCTION

Land degradation and desertification in the Mediterranean are worsening due to climate change and increasing pressure on agricultural and forest lands, compromising the provision of ecosystem services. SALAMMED addresses this challenge through an integrated approach that combines science, co-design with local stakeholders, and decision-support tools. Within this framework, the project evaluates and co-develops various technological and management solutions, among them the Adaptive Vegetation Management (AVM), which is implemented through the CAFE-DSS tool: it integrates field and remote sensing data with process-based models and ecosystem service indicators to compare management alternatives, quantify trade-offs (fire, water, carbon, biodiversity, ecoresilience), and propose portfolios of actions with scheduling and monitoring. The approach is validated in representative Mediterranean Living Labs (Spain, Sardinia, and Morocco), providing comparative evidence for adaptive and holistic land management.

### Mediterranean Study Sites for Adaptive Vegetation Management (AVM)

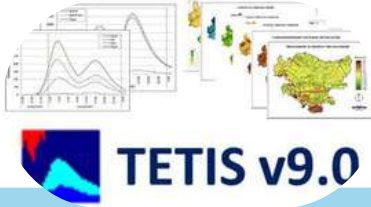


## OBJECTIVES

The AVM aims to develop adaptive management strategies that integrate ecohydrological and multifunctional criteria to enhance the provision of ecosystem services and reduce vulnerability to climate change. Its application seeks to balance productivity, conservation, and resilience, promoting landscapes that are more diverse, functional, and resistant. Through CAFE-DSS, these objectives are translated into operational management decisions that address the four key questions of silviculture (when, how much, how, and where to intervene) and enable the comparison and transfer of solutions across Mediterranean regions.

- Calderona and Hunde:** Reduce wildfire risk and fuel loads; enhance aquifer recharge, carbon sequestration, and biodiversity through selective thinning.
- Berchidda:** Maintain silvopastoral multifunctionality by maximizing cork yield and tree vigor, reducing water stress, and increasing deep percolation and fire resistance.
- Essaouira:** Balance argan oil production and goat grazing, safeguarding regeneration and long-term productivity.

## AVM PROCEDURE



Delimitation, baseline and prioritization of ES

Data preparation, calibration, and ecohydrological simulation

Integration into CAFE-DSS (multi-objective optimization)

Visualization, filtering, and operational selection

In each site, the study area is defined, and an ecohydrological baseline is established to guide multifunctional management. **Ecosystem services** are prioritized, and **operational indicators** are selected for their evaluation and optimization.

Climate, soil, vegetation, and management parameters are compiled and harmonized to parameterize and calibrate the models incorporated in CAFE, selecting the most suitable one for each case. These models aim to **reproduce current conditions** and simulate each scenario, generating the **baseline** and trajectories of key variables that feed into the subsequent analysis.

Using these inputs, CAFE performs multiple simulations and applies **multi-objective optimization** (evolutionary algorithms) to identify the Pareto front: the set of management alternatives that improve at least one objective without worsening the others relative to the baseline.

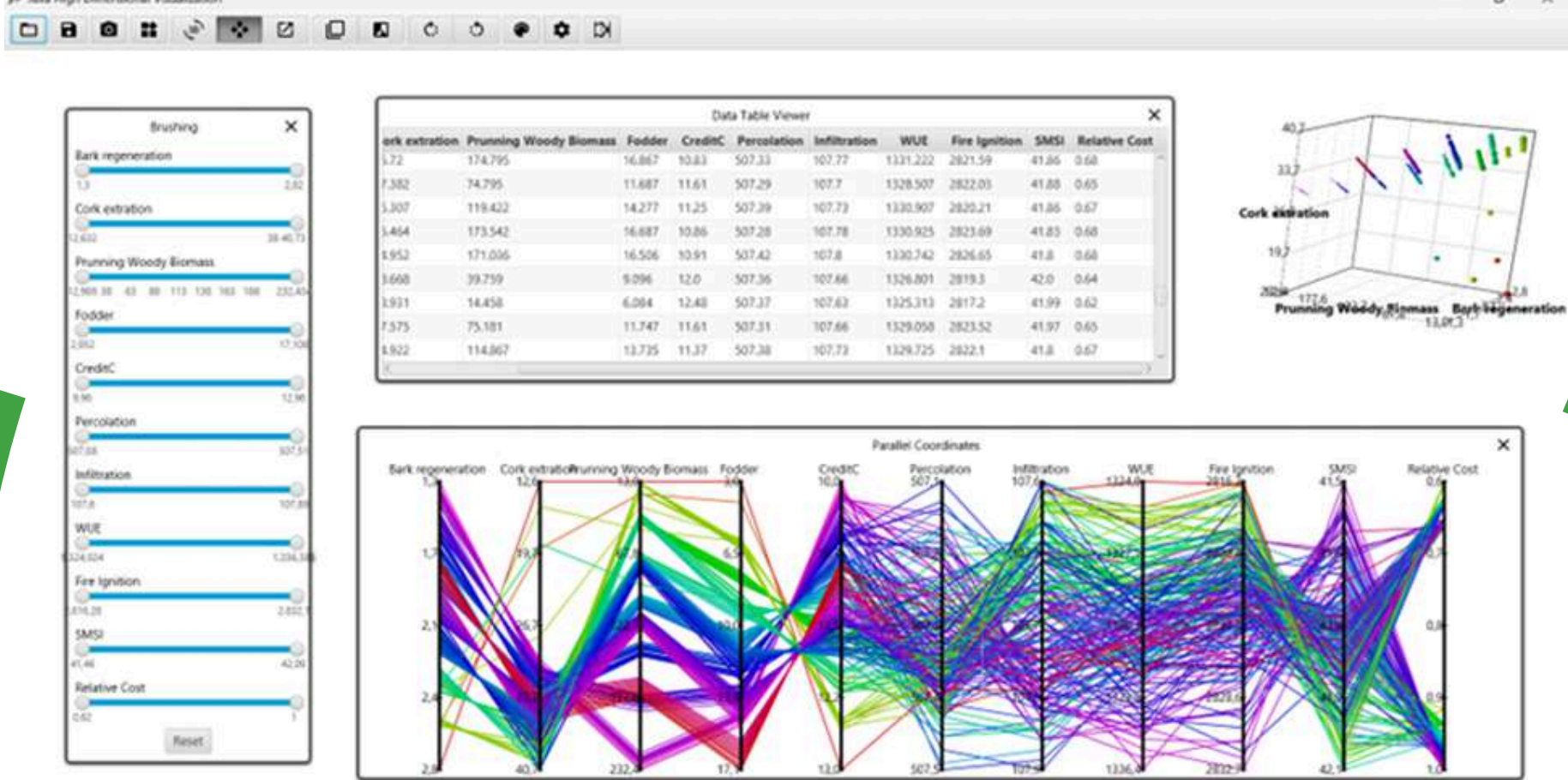
Exploration of alternatives through the “equalizer” type **interactive panel**: the user adjusts the indicators according to their priorities, allowing comparison of trade-offs. The selected alternatives are translated into **operational responses**, assessing their technical and economic feasibility based on expert judgment and the local context.

## RESULTS

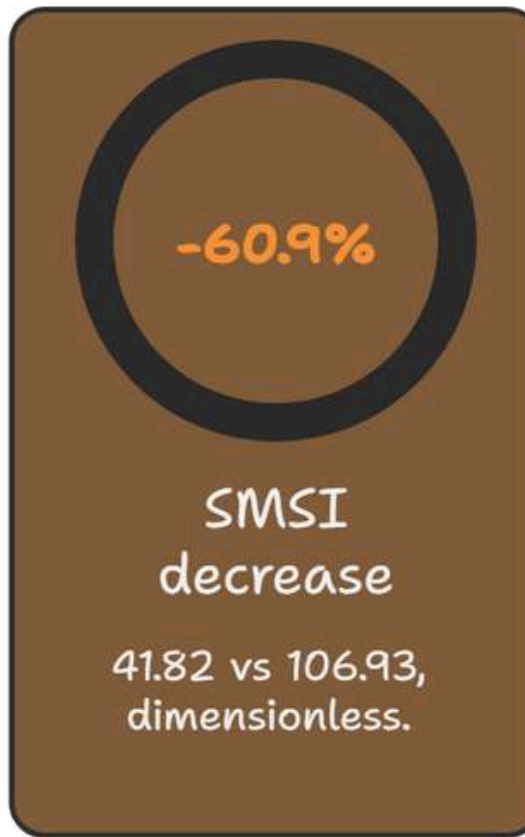
### Ecosystem Services and Indicators Assessed Across the Mediterranean Living Labs

Type of Function	Ecosystem Service	Indicator	Calderona LL	Hunde LL	Sardinia LL	Morocco LL
Carbon	Sequestration	NEP (kgC/m <sup>2</sup> /year)	X	X		
		Sequestered carbon (kgC/m <sup>2</sup> /year)		X		
	Exploitation	Extracted biomass (kgC/m <sup>2</sup> )		X		
	Carbon storage	Soil carbon (kgC/m <sup>2</sup> /year)	X	X		
	Bark regeneration	Carbon dead stem (kgC/m <sup>2</sup> )			X	
	Cork extraction	Woody carbon extracted (only fixed) (kg*intervention/tree)			X	
	Pruning woody biomass	Woody carbon extracted (removing fixed extraction cork) (kg*intervention/tree)			X	
	Fodder	Sum cumulative annual no woody carbon loss (kg*intervention/tree)			X	
	Carbon credits	Final carbon storage (kgC/m <sup>2</sup> )			X	
Water	Fruit Production	Carbon fruit (kgC/m <sup>2</sup> )				X
	Grazing	Woody biomass extracted (kgC/m <sup>2</sup> )				X
	Provision	Percolation (mm/year)	X	X	X	X
	Regulation	Transpiration (mm/year)	X			X
	Retention	Infiltration (mm/year)			X	
Fire	WUE	Surface moisture (%)	X			
		Water Use Efficiency (mm/kgC)			X	X
	Fuel load	Woody extracted biomass (kgC/m <sup>2</sup> )	X			
Biodiversity	Ignition	KBDI (DIM)		X		
	Intensity and Severity	Labile carbon in litter * VPD (kgC/m <sup>2</sup> *kPa)			X	X
Ecoresilience	Diversity	Soil moisture surface (m <sup>3</sup> /m <sup>2</sup> )			X	
	SMSI	Y-Biodiversity (DIM)		X		
		Soil moisture stress index (SMSI) (DIM)			X	X

### Interactive Equalizer for Multi-Objective Optimization in CAFE-DSS (Sardinia case study)



### Enhanced Ecosystem Services



Living Lab	Where	When	How much	How
Calderona	Aleppo pine forest resulting from post-fire regeneration	Before 2030	30-70% of Thinning	
Hunde	Protective pine forest of Aleppo pine	Towards 2050–2055	20-80% of Thinning	Thinning in tree stratum (without intervention in scrubland)
Sardinia	Cork oak woodland (Cork oak silvopastoral system)	3 interventions in 20 years at 6-7 year intervals or 2 interventions in 20 years at 11-12 year intervals	Combination of pruning = 6-36% and debarking = 4% (fixed)	
Morocco	Semipreserved plot of Argania spinosa with goat grazing	Annual (from 21 years of simulation)	3-30 goats/ha/year	Regulated grazing (9 months/year)