

D6.3: LanDS scenarios to inform policy making



PRIMA
PARTNERSHIP FOR RESEARCH AND INNOVATION
IN THE MEDITERRANEAN AREA

**REACT
4MED**

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Inclusive Outscaling of Agro-ecosystem
REstoration ACTions for the MEDiterranean

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List of acronyms

Acronym	Definition	Acronym	Definition
API	Application Programming Interface	CAP	Common Agricultural Policy
CBD	Convention on Biological Diversity	CDD	Consecutive Dry Days (ETCCDI)
CMIP6	Coupled Model Intercomparison Project Phase 6	CY / EG / ES / GR / IL / IT / MA / TR	Cyprus / Egypt / Spain / Greece / Israel / Italy / Morocco / Turkey
DEM	Digital Elevation Model	DM	Decision Maker
DoA	Description of Action	EGD	European Green Deal
ERLL	Ecosystem Restoration Living Lab	ETCCDI	Expert Team on Climate Change Detection and Indices
FAO	Food and Agriculture Organization of the United Nations	GA	Grant Agreement
GAUL	Global Administrative Unit Layers	GCM	Global Climate Model
GFDL-ESM4	Geophysical Fluid Dynamics Laboratory Earth System Model 4	GIS	Geographic Information System
GWLs	Global Warming Levels	HMU	Hellenic Mediterranean University
IPCC	Intergovernmental Panel on Climate Change	IPM	Integrated Pest Management
ISIMIP / ISIMIP3a / ISIMIP3b	Inter-Sectoral Impact Model Intercomparison Project / Phase-3 historical-counterfactual / Phase-3 future	IWRM	Integrated Water Resources Management
IVS	Input Variable Selection	LanDS	Land degradation Decision-Support (toolbox/platform)
LDN	Land Degradation Neutrality	LULC	Land Use/Land Cover
ML	Machine Learning	PA	Pilot Area
PCA	Principal Component Analysis	PRIMA	Partnership for Research and Innovation in the Mediterranean Area
RA	Restoration Action	SDG	Sustainable Development Goal
SH	Stakeholder	SOC	Soil Organic Carbon
SOFTW	SoftWater s.r.l.	SPI / SPEI	Standardized Precipitation Index / Standardized Precipitation-Evapotranspiration Index
SSP	Shared Socioeconomic Pathway	STAC	SpatioTemporal Asset Catalog
TUC	Technical University of Crete	TXx	Annual Maximum of Daily Maximum Temperature (ETCCDI)
UNFCCC	United Nations Framework Convention on Climate Change	WANA / MENA	West Asia and North Africa / Middle East and North Africa
WFD	Water Framework Directive	WSDI	Warm Spell Duration Index (ETCCDI)

Executive Summary

This deliverable identifies where the restoration actions piloted in REACT4MED can be out- and up-scaled across the Mediterranean under present and future conditions, and frames these results for policy use. It operationalises the LanDS toolbox at regional scale by combining a machine-learning clustering of biophysical, climatic and socio-economic indicators with action specific expert filters co-created with pilot teams. The baseline period (2001–2019) yields twelve functional typologies that act as a common interpretive frame and the same workflow is then applied to two scenario slices, Near-term (2025–2044) and Mid-term (2045–2060) under SSP2-4.5 and SSP5-8.5. Outputs comprise reproducible maps, administrative summaries and interactive dashboards on the LanDS platform.

Three cross-cutting signals emerge. First, persistence dominates over novelty: areas that are suitable in the baseline generally remain suitable in the near term, often at lower scores, while genuinely new opportunities are few and typically low score. Second, shifting typologies: semi-arid envelopes tend to expand, intensively farmed plains contract in several regions, and uplands-foothills remain comparatively stable; changes are most visible along semi-arid/temperate boundaries and lowland mosaics. Third, timing: most shifts appear in the near term and consolidate by the mid-term rather than reverse, underscoring the value of early action and adaptive portfolios.

At the level of restoration actions, the patterns are differentiated but coherent with these envelopes. Terraced agriculture (RA1) shows robust persistence centred on eastern Mediterranean uplands and foothills, with several baseline-moderate belts strengthening in the near term. Afforestation of former farmland (RA2) and organic vineyard restoration (RA3) present baseline pockets but no scenario suitability at Mediterranean scale with current thresholds, implying a need for highly local, micro-refugia strategies if pursued. Soil restoration via chipped prunings (RA4) weakens from moderate–high to low and very low across large parts of Iberia and the central Mediterranean, though the Cànyles pilot area remains a stronghold. Conservation agriculture (RA5) contracts sharply across Morocco–Algeria–Iberia, with residual low suitability mainly along northern Algeria and parts of the Libyan coast. Integrated water and soil conservation for biodiversity (RA6) does not register regional-scale suitability in scenarios with present thresholds. By contrast, salinity/alkalinity management (RA7) remains one of the more transferable options under change, general weakening in the west is offset by relative strengthening in Egypt by the mid-term, while agro-ecosystem restoration through organic/bio-fertilisation and soil-structure improvement (RA8) persists around Tamia (Fayoum) with modest, low-score extensions into neighbouring southern-rim districts.

These findings translate into guidance. Priority should be given to persistent belts for early scale-up and long-term maintenance as low-regret investments. Where suitability declines but does not vanish, opportunities should be treated as conditional and supported by complementary practices—such as cover crops, residue retention, micro-harvesting, precision irrigation and fire-smart establishment—paired with advisory services, results-based incentives and risk tools to overcome adoption barriers. Near-term maps should steer immediate programming, while mid-term signals are used to stress-test pipelines and align with the European Green Deal, the Nature Restoration Law and Land Degradation Neutrality targets, including through EU-MENA cooperation where hazards and value chains are shared.

To deliver on the project vision, turning Living-Lab evidence into scalable restoration practice, all underpinning data layers, indicator definitions, cluster maps, expert filters and administrative summaries are published on the LanDS platform as a living, FAIR-aligned resource. Beyond download, LanDS supports co-creation through interactive dashboards and standards-based catalogues. In this way, the platform functions as a shared evidence base for adaptive programming, linking science to decision cycles and helping partners and authorities across the Mediterranean reuse, refine and scale restoration actions.

1 Introduction

REACT4MED advances scalable, evidence-based pathways to reverse land degradation across the Mediterranean. Building on data, tools and practice generated in the project's pilots and Living Labs, the LanDS toolbox is used to translate local restoration actions into spatially explicit options for out- and up-scaling under present and future climate and socio-economic conditions. This deliverable reports those results and frames them for policy use.

1.1 Purpose of the deliverable

This deliverable (D6.3) identifies suitable areas for wider deployment of the restoration actions tested in REACT4MED, for both a historical baseline and future climate–socioeconomic scenarios. It operationalises the LanDS workflow at Mediterranean scale—combining functional typologies derived through machine-learning clustering with action-specific expert filters—to quantify and map suitability for each restoration action over near-term (2025–2044) and mid-term (2045–2060) horizons. Results are aggregated to policy-relevant administrative units to support prioritisation, highlight persistence or decline of opportunities, and extract regional insights that inform programme design and financing. All layers and dashboards are available through the LanDS platform. The scope is that of screening and prioritisation; site-level permitting, detailed cost–benefit analysis and environmental impact assessment remain outside this deliverable.

1.2 Link with REACT4MED objectives and related work packages

D6.3 is produced within WP6 (Policy), which aims to translate project knowledge into actionable guidance for decision-makers. Its development is tightly coupled to the other work packages shown in Figure 1.1 WP2 (Baseline and drivers) provides the indicator library—climate, land condition and socio-economic—and the data lineage used in LanDS and informs the selection of scenario windows and the reading of degradation pressures. WP3 (Ecosystem Restoration Living Labs) supplies the contextual understanding of practices and thresholds for each restoration action, co-defines the expert filters with local stakeholders and supports validation of maps and insights. WP4 (Tools) designs and implements LanDS—requirements, prototype and toolbox—enabling consistent processing, clustering, expert filtering and webGIS publication. Evidence from WP5 (Restore & assess) on pilot performance and feasibility constraints is used to calibrate filters and interpret suitability. WP1 and WP7 (Coordination and Communication) ensure alignment, quality assurance and dissemination to policy communities. Through this workflow, D6.3 delivers a multi-operational decision-support product—harmonised maps and statistics that show where each restoration action is most promising today and how those opportunities shift under plausible futures—thereby supporting programme design, sequencing and investment across the Mediterranean.

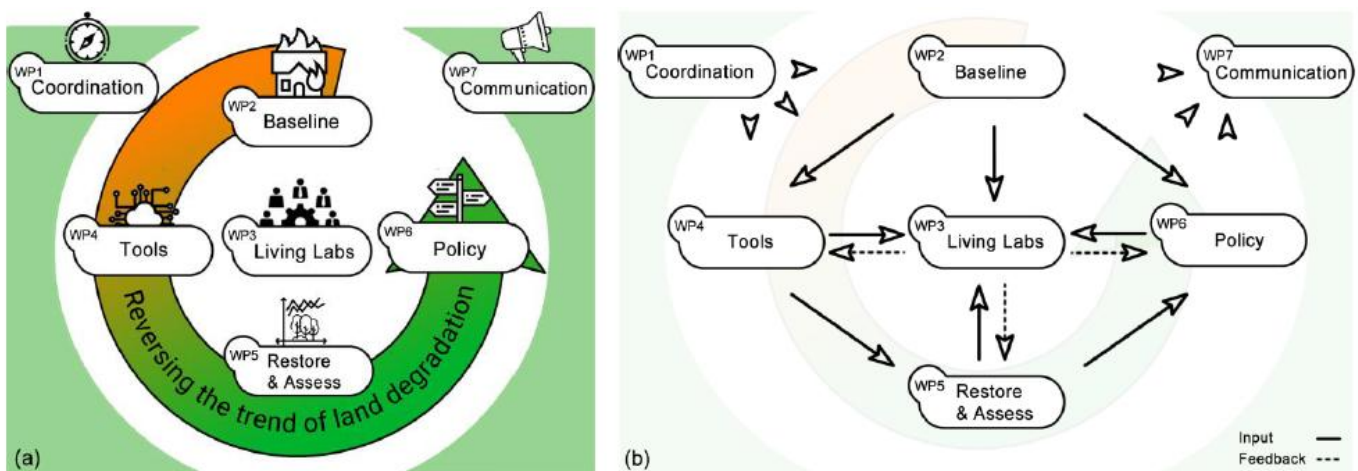


Figure 1.1 REACT4MED Work Package (WP) structure (a) and information flow within its conceptual framework (b)

2 Policy and regional context

REACT4MED operates across a Mediterranean macro-region that is simultaneously a climate-change hotspot and a mosaic of governance regimes. Land degradation, water stress, biodiversity loss, and rural socio-economic fragility interact non-linearly, so the feasibility of out- and up-scaling restoration actions hinges as much on the surrounding policy fabric as on biophysical performance. This section (i) synthesizes the land-degradation challenge in the Mediterranean and (ii) positions our work within EU and global policy frameworks that can enable uptake, linking to Sustainable Land and Water Management (SLWM) priorities highlighted in D6.1.

2.1 Land degradation challenges in the Mediterranean

The Mediterranean basin faces converging pressures that erode land productivity and ecosystem functions:

- Climatic stressors: Intensifying heat and hydrological extremes (droughts punctuated by floods) drive soil moisture deficits, wildfire risk, and accelerated erosion, undermining rainfed systems that dominate large parts of the region. These trends sit within a well-documented “hotspot” dynamic affecting food, water, and ecosystem security.
- Soil degradation pathways: Water erosion, salinization, compaction, nutrient mining, and vegetation loss remain pervasive, especially on sloping, shallow Mediterranean soils and in overgrazed rangelands. Degradation is amplified where conservation measures are absent or inconsistently enforced.
- Water scarcity and groundwater depletion: Chronic deficits, rising competition among sectors, and pollution (salinity, nitrates) degrade both surface and aquifer resources, creating feedback that constrain restoration choices and agricultural viability.
- Land-use and socio-economic drivers: Urban expansion, infrastructure, and specialized export agriculture can displace traditional mosaics, while fragmented institutions, limited enforcement capacity, and inconsistent incentives slow adoption of SLWM. Several WANA/MENA countries, deeply entwined with EU value chains, face high import dependence for food, making them acutely vulnerable to climate and market shocks.

D6.1 highlights that, although many countries have adopted elements of integrated water resources management, drought programs, and agri-environmental measures, implementation capacity and cross-sector coordination remain binding constraints, particularly along the southern and eastern shores. In parallel, EU Member States on the northern rim are aligning with Green Deal legislation but still face gaps in enforcement, monitoring, and financing at regional and local levels. These asymmetries matter for REACT4MED because they shape (i) the uptake risk for restoration practices, (ii) the policy mixes needed for durability (regulatory, incentive-based, knowledge, and social protection measures), and (iii) opportunities for transboundary cooperation on shared hazards and value chains.

2.2 Relevance to EU and global policy frameworks (e.g., EU Green Deal, Paris Agreement)

REACT4MED’s activities relate closely to, and may support the operationalisation of, the following policy architectures reviewed in D6.1:

European Green Deal (EGD) and associated strategies

- Nature Restoration Law/Regulation (NRL) proposal: restoration measures on $\geq 20\%$ of EU land and sea by 2030, with all ecosystems in need addressed by 2050; benefits span climate mitigation/adaptation, biodiversity, health, and jobs. SLWM actions (e.g., erosion control, re-vegetation, peatland/soil carbon measures) directly contribute to NRL target delivery and monitoring.

- Biodiversity Strategy for 2030: recovery of ecosystems via expanded and better-managed protected areas and restoration of degraded habitats; REACT4MED’s agro-ecosystem focus supports biodiversity-friendly farming and green infrastructure in productive landscapes.
- Farm-to-Fork Strategy: incentives and standards to reduce inputs (fertilizers, pesticides), enhance nutrient efficiency, and build resilient, sustainable food systems - areas where conservation agriculture, agroecology, and water-saving irrigation provide tangible pathways.
- Zero Pollution Action Plan: targets for air, water, and soil quality; SLWM practices reduce runoff, sediment, and nutrient/pesticide loads, supporting compliance and co-benefits for downstream wetlands and coasts.
- Deforestation-free supply chains & circular economy measures (e.g., packaging): while global in scope, they reinforce traceability, resource efficiency, and lower externalized degradation-relevant to Mediterranean export systems.

Regional WANA/MENA strategies and national reforms.

D6.1 catalogs water, climate, and agricultural strategies (e.g., IWRM, drought plans, green growth and agricultural modernization programs) that are moving toward integrated, nexus-aware governance, yet often struggle with financing, institutional fragmentation, and enforcement. REACT4MED’s evidence on cost-effectiveness, co-benefits (soil, water, carbon, livelihoods), and implementation pathways can de-risk policy adoption and help align EU–MENA cooperation.

Global climate and land agendas

- Paris Agreement (UNFCCC): SLWM underpins adaptation (reducing climate risk to soils, crops, and water) and contributes to mitigation via soil and biomass carbon gains; project indicators can feed into NDC implementation/stocktake processes.
- UNCCD Land Degradation Neutrality (LDN, SDG 15.3): REACT4MED pilots map directly to LDN response hierarchies (avoid–reduce–reverse) and can inform LDN target setting monitoring (land cover, soil productivity, carbon) across EU and non-EU shores.
- Convention on Biological Diversity: restoration in working landscapes advances ecosystem connectivity and nature-positive production, consistent with D6.1’s emphasis on reversing biodiversity loss through measurable objectives and restoration planning.

To make these links operational, Table 2.1 summarises how each REACT4MED action connects to Green Deal pillars, the Nature Restoration Law, and UNCCD-LDN indicators.

Table 2.1. Policy alignment matrix for REACT4MED restoration actions.

REACT4MED Action (pilot)	EGD Pillars / Strategies – primary hooks	Nature Restoration Law (NRL) – most relevant levers	UNCCD LDN core indicators – expected direction of change	Typical co-benefits / programme metrics
RA1 Terraced agriculture (CY)	Soil Strategy; Biodiversity 2030; Climate Adaptation	Restore/maintain agro-ecosystem condition on erosion-prone slopes; landscape features/connectivity	Land productivity ↑; SOC ↑ (mulch/cover); Land cover stability ↑ (reduced erosion/abandonment)	Reduced soil loss; flood/runoff moderation; cultural landscape value; CAP eco-schemes uptake
RA2 Afforestation of former farmland (GR)	Biodiversity 2030; EU Forest Strategy; Soil Strategy	Habitat area & condition (native forests/wooded strips); fire-resilient design	Land cover gain; SOC ↑; Productivity trend ↑ (long-term)	Micro-climate buffering; wind/erosion control; pollinator habitat; fire-smart planting success
RA3 Organic vineyard restoration (IT)	Farm-to-Fork; Biodiversity 2030; Zero-Pollution	High-diversity landscape features in	SOC ↑ (cover crops/compost);	Reduced pesticide/fertiliser use; water quality

		farmland; pesticide/nutrient pressure ↓	Productivity stability ↑; Land cover maintained	benefits; IPM adoption; certification share
RA4 Soil restoration via chipped prunings (ES)	Soil Strategy; Circular Economy (bio-waste); Zero-Pollution	Soil erosion reduction & soil health in cropland	SOC ↑; Productivity ↑; Land cover stability ↑	Infiltration ↑; runoff/sediment ↓; residue recycling rate; farmer adoption costs
RA5 Conservation agriculture (MA)	Soil Strategy; Farm-to-Fork; CAP-type eco-schemes analogues	Farmland condition (cover, reduced tillage); landscape connectivity	SOC ↑; Productivity resilience ↑; Land cover stability ↑	Fuel/input savings; seasonal cover extent; erosion risk ↓; drought buffering
RA6 Integrated water & soil conservation for biodiversity (IL)	Biodiversity 2030; Climate Adaptation; Soil Strategy	Semi-natural/agro-natural habitat condition; connectivity & buffer strips	Land productivity stability ↑; SOC ↑; Land cover fragmentation ↓	Habitat quality indices; pollinator/field-margin metrics; evapotranspiration efficiency
RA7 Salinity/alkalinity management (drainage, leaching, amendments) (TR)	Soil Strategy; Water Framework/Zero-Pollution (agri pressures)	Degraded agro-ecosystems restored (soil chemical status)	Productivity ↑ (trend reversal); SOC ↔/↑ (with organics); Land cover stability ↑	Soil EC/ESP ↓; yield recovery; irrigation water management; return-flow salinity ↓
RA8 Agro-ecosystem restoration (bio/organic fertilisation, soil structure) (EG)	Soil Strategy; Farm-to-Fork; Zero-Pollution	Soil health & farmland biodiversity improvement	SOC ↑; Productivity ↑; Land cover stability ↑	Nutrient-use efficiency ↑; pesticide dependence ↓; soil structure/infiltration ↑

3 Scenario Framework

The scenario framework connects the LanDS up- and out-scaling analysis to climate-policy-relevant futures and the data architecture established in WP2 and WP4. We adopt a three-part framing: (i) emissions-socioeconomic pathways (SSPs/RCPs), (ii) time-slice horizons and (iii) associated global warming levels (GWLs) used to compute the indicators that feed the LanDS ML workflow. The design ensures that suitability patterns for restoration can be read both as biophysical envelopes and as decision contexts that matter to Paris Agreement and EU Green Deal implementation. The choices below follow the climate data and indicator conventions set out in D2.4 and the LanDS tool processing in D4.2 and D4.3.

3.1 Climate and socio-economic

Future forcing follows the ISIMIP3b protocol, using bias-corrected CMIP6 climate data and harmonised socio-economic inputs. We analyse two pathways that bracket plausible Mediterranean futures: SSP2-4.5 (intermediate) and SSP5-8.5 (high), consistent with the datasets compiled in WP2 and previously used in LanDS developments (D2.4; D4.2; D4.3). To keep results policy-relevant while avoiding over-specification, we summarise futures in two time slices:

- Near-term (2025–2044): This window broadly coincides, for many CMIP6 models, with the period when the running mean global mean temperature first approaches or exceeds ~ 1.5 °C of global warming under higher-emission pathways and begins to do so under intermediate forcing. (See D2.4 Table 2.2 for model-specific central years).
- Mid-term (2045–2060): This window aligns with the transition towards ~ 2 °C under high forcing and late-1.5 °C/early-2 °C conditions under intermediate forcing in several CMIP6/ISIMIP3b models (model-dependent central years in D2.4 Table 2.2).

This timing link offers operational guidance for planning and investment cycles and allow readers to interpret suitability shifts against widely used global-warming benchmarks without imposing a strict GWL selection.

3.2 Biophysical, climate, and socio-economic indicators

In line with D4.2/D4.3, the scenario runs are not single-variable projections but indicator bundles that capture the biophysical envelope within which restoration can be feasible and durable. Indicators are computed at 0.125° for the Mediterranean hydro-basin domain and then harmonised for the ML pipeline (details in Section 4). We group them as follows (full definitions and code in WP4 resources):

- Climate & hydro-climate: temperature means/extremes, precipitation means/extremes, aridity, rainfall erosivity, drought-relevant indices—all derived from WP2 datasets and rolled up on the above time slices (e.g., precipitation, temperature, TXx, R5d, SPI/SPEI).
- Land-degradation proxies (aridity, salinity, erosion factors, slope)
- Socio-economic context proxies, e.g., gridded GDP, population density-urbanisation and related accessibility constraints used as coarse proxies for investment opportunities or barriers in up- and out-scaling.

These indicator families are passed to the Input-Variable Selection (IVS) and k-means clustering stages to derive functional typologies under baseline and future scenarios. Expert filters subsequently tailor suitability to each Restoration Action (RA). The scenario framework thus serves the purpose to ensure that shifts in typologies and suitability maps are interpretable against clear, policy-relevant futures, while remaining consistent with the data architecture validated in D2.4 and implemented in D4.2 and D4.3.

4 Methodology

4.1 Overview of the LanDS ML-based tool procedure

The LanDS ML-based tool has been designed to generalise restoration insights from the REACT4MED pilot areas to the broader Mediterranean region. It operationalises a structured workflow combining:

- multi-source input datasets (biophysical, climatic, and socio-economic indicators);
- statistical pre-processing through Input Variable Selection (IVS);
- unsupervised machine learning method (k-means clustering);
- expert-based filtering for local refinement.

The main goal is to identify suitable areas in the Mediterranean for applying the restoration actions already demonstrated in the eight REACT4MED pilot areas, generating suitability maps for potential upscaling and outscaling under both present and future climate and socio-economic conditions.

The LanDS ML procedure is fully described and discussed in Section 2.4 of D4.3 (see Figure 4.1), while the following Section 4.2 consists in a summary of the methodology before applying the expert-based filtering to obtain the suitability maps (Section 4.3).

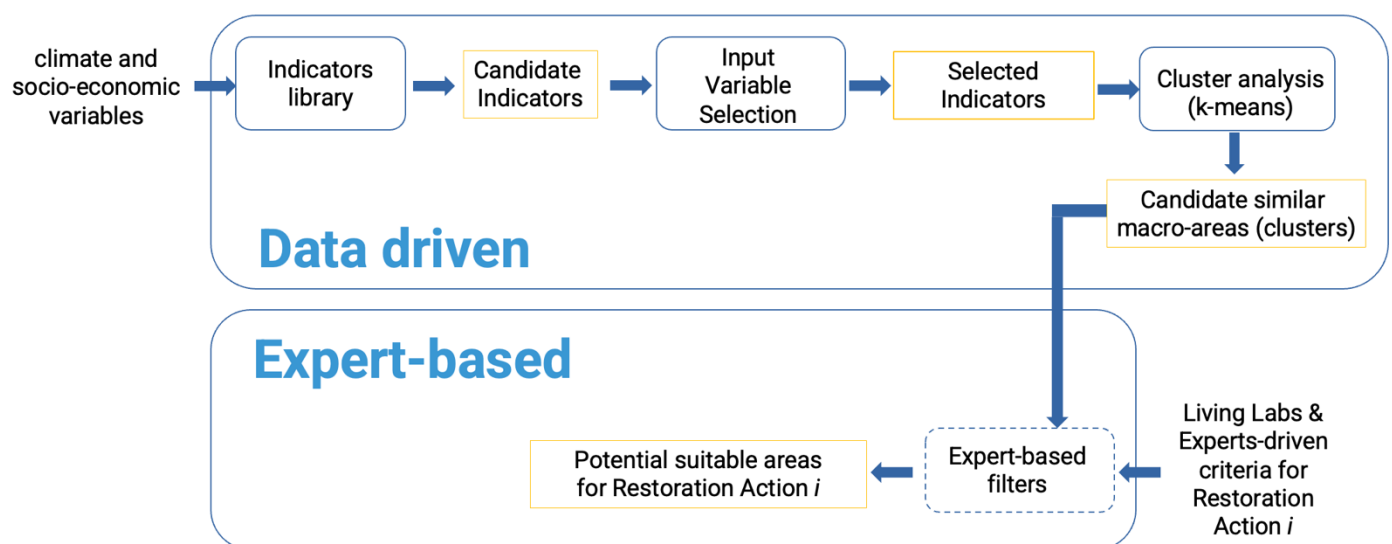


Figure 4.1 ML procedure workflow updated from Deliverable D4.3.

4.2 Clustering and identification of similar areas

The clustering procedure represents the core analytical component of the LanDS ML tool. The methodology mainly follows three steps and has been applied to the entire Mediterranean region, considering the data described below, assumed for the period between 2001-2019:

1. Computation of the LanDS indicators¹:

¹ A list of 56 indicators has been implemented and computed starting from biophysical, climate, and socio-economic datasets compiled for the whole Mediterranean area in WP2. These datasets are based on global repositories and sound literature providing gridded data at different spatial and temporal resolutions (e.g., ISIMIP protocol ³¹, ESACCI¹, Yang et al., 2019, Wang and Sun, 2023), covering past and future periods (see Section 2 of D2.4 *LanDS Prototype* for more details).

- Starting from a pool of 56 candidate variables, covering biophysical (e.g. elevation, slope, soil depth), climatic (e.g. precipitation, temperature, extreme indices such as TXx, R5days), and socio-economic domains (e.g. population density, GDP, land use).
 - At the sub-basin level (about 12.5 km resolution) to ensure comparability across the Mediterranean region.
2. Input Variable Selection (IVS):
- A-priori selection of indicators based on their spatial distribution and temporal variability, comparing historical and future scenarios datasets, leading to 40 indicators (see Table 4 and Figure 26 in D4.3).
 - A correlation analysis was applied to remove collinear (redundant) indicators (threshold set to 0.7).
 - Principal Component Analysis (PCA) was performed to identify the most informative variables (i.e., those explaining the largest share of variance).
 - The final set comprised 20 indicators (see Figure 27 of D4.3), considered as the most representative and non-redundant ones to run the clustering analysis.
3. Clustering (k-means):
- The k-means method was applied to classify the Mediterranean sub-basins into a limited number of clusters.
 - After sensitivity testing with different k values (3 to 15), k = 12 was selected for the representative application case as it was found being a good compromise facilitating interpretability.
 - Each cluster groups areas with similar combinations of climate, land, and socio-economic conditions (see Figure 30 and Annex of D4. for more details).

The outcomes of the clustering analysis (step 3 of the methodology of the ML procedure) identifying similar macro-areas in the Mediterranean region is used as input for the expert-based filter analysis, which integrates higher resolution datasets and specific local conditions to find potentially suitable areas for each specific restoration action run in the PAs (see following section 4.3).

4.3 Expert-based filtering and suitability areas

The clustering analysis provides a robust statistical classification, but its resolution and abstraction can limit applicability for site-specific decision-making. To overcome this, the tool integrates an expert-based filtering step, which refines suitability assessments for individual restoration actions.

The methodological steps of the expert-based filtering analysis are summarised as follows:

1. Load and preprocess higher resolution datasets (e.g. 90 m Digital Elevation Model, land use/land cover maps, soil depth databases) with a global or Mediterranean spatial coverage, with the aim of applying different filters correspondently to the requirements of the restoration actions implemented in each PA;
2. Define expert-based criteria and suitability rules, collaborating with local experts defining thresholds and/or specific conditions based on the additional data experts (e.g., slope thresholds for terraced agriculture; specific range of soil organic matter for organic farming).
3. Apply the filters and generate an Expert-Based Suitability map for each restoration action, by aggregating the identified criteria.
4. Iterative validation with PA experts, allowing refinement and contextual adjustment towards the identification of areas potentially suitable for out- and upscaling of restoration actions;
5. Further aggregation of pixel-based Suitability Maps in a synthetic Suitability Score Index, aggregated by regional administrative layer, to provide summarised information to policy makers.

To support the identification of filters, a shared excel file was created in the project's repository and developed in a collaborative way with PA experts (more than 10 bilateral meetings held and regular email exchange

to set up and refine it). The file is accessible to REACT4MED partners within WP4 folder (R4M_expert_filters_MED.xlsx)² and a screenshot is reported in Figure 4.2 for PA1-Cyprus example.

filter_type	filter_name	unit	RA1_criteria	dataset	link	spatial extent	spatial resolution	temporal extent (if any)	temporal resolution (if any)	comments
core filter	slope (%)	%	15 - 60 (8.53° - 30.96°)	Copernicus 90-m DEM (slope)	https://portal.opentopography.org/raster?openTopoID=OTSDEM_032021.4326_4	World	90 m			downloaded from global COP90m in three parts for the Med and then merged into one raster. 90m resolution is already quite high!
complementary	soil depth	m	> 0.20	Global 1-km Gridded Thickness of Soil, Regolith, and Sedimentary Deposit Layers, Oak Ridge National Laboratory (ORNL)	https://doi.org/10.3334/ORNLDAAC/1304	World	1 km			NASA Earthdata
complementary	soil texture (top soil)		classes (all except fine and very fine with more of 35-40% clay) = [2,3,4,5,7,8,9,11,12]	soil texture map in 12 USDA classes which can be grouped into the 3 desired broader classes: course (sandy), medium (loamy), fine (clayey) soils; available at each depth (0, 5, 15, 30 cm)	https://data.isric.org/geonetwork/srv/ita/catalogsearch?metadata/9a3a4e0-27a8-4acc-861f-26c112699c3e	World	250 m	1950-2015		very good scientist reference Hengl et al. (2017) DOI: 10.1371/journal.pone.0169748; one could adapt the filter criteria to be applied directly to the 12 USDA texture classes
complementary	Soil Organic Carbon (top soil 0-30 cm)	t/ha	> 4 t/ha (assuming a bulk density of 1.3 g/cm ³)	GSOC v1.5 is the first global soil organic carbon content map (country-based) from GloSIS (FAO)	https://data.apps.fao.org/catalog/iso/7730e747-eb73-49c9-bfe6-84ebae718743	World	1 km	2019		report FAO 2018 https://openknowledge.fao.org/serve/api/core/bitstreams/c3ccec06-4e75-4b67-9a4c-ee0a5777e0b/content
complementary	land cover	-	shrub, herbaceous vegetation, cropland; classes = [20, 30, 40]	Land Cover 2019 (raster 100 m), global, yearly – version 3	https://land.copernicus.eu/en/products/global-dynamic-land-cover/copernicus-global-land-service-land-cover-100m-collection-3-epoch-2019-globe#download	Global	100 m	2019	annual	see exact criteria used in the sheet: PA1_land_cover_criteria
complementary	rainfall, average	mm/yr	300 - 1000 (0.822 - 2.740 mm)	LandS PrAvg (current long-term annual average)	https://thredds.gfdl.usc.es/thredds/catalog/GLOBALWDFTP/catalog.html	Med	about 12 km	1991-2019	daily mean, historical period	
complementary	GW table	m	> 2 m below ground surface (< -2 m)	Groundwater table depths (compute 10-year mean from 2004-2014 annual means): https://doi.org/10.1126/science.1229881 (2013), https://doi.org/10.1073/pnas.1712381114 (2017) results are better than https://doi.org/10.5194/gmd-17-275-2024	https://thredds.gfdl.usc.es/thredds/catalog/GLOBALWDFTP/catalog.html	World	30 arc sec (1 km)	2004-2014	annual means	> 1 Mi wells measurements used to build a continuous global map (GW model) (Fan et al., 2013; Science); data on unidata Inetds server hosted by UNICAR - Boulder, US)

Figure 4.2 Screenshot of the shared Excel file on which the expert-based filtering is based, including type of filters, criteria and thresholds, references of the high-resolution datasets used, and related links, defined in collaboration with PA experts.

In the expert-based filtering process, the criteria/thresholds are grouped into two filters categories: *core* and *complementary*. The so-called *core* variables represent essential conditions for a restoration action to be feasible (e.g., slope thresholds for PA1-Cyprus terraced agriculture) and are combined using a multiplicative (product) approach, meaning that if one core criterion is not met, the overall suitability score yields 0 (no suitability). *Complementary* variables describe additional favourable factors (e.g., land cover) and are aggregated using an additive approach to enhance differentiation among suitable areas. The final suitability index results from the product of core variables and the sum of complementary variables, producing a normalised value according to the specific restoration action. The ranking scale of the suitability index differs depending on the restoration action (e.g., 0 = lowest, 6 = highest for PA1-Cyprus terraced agriculture), ensuring that suitability reflects both essential and context-specific/favourable conditions. The result is an Expert-Based Suitability Map for each restoration action, showing areas with high potential for effective implementation, bridging modelled clustering outputs with practical, field-level/local relevance (see Section 5 for insights on the resulting suitability maps).

To deploy this workflow a novel toolbox has been added to LandS, i.e., the Expert filter tool, which includes code to perform filtering and map creation, and released with an open-source licence in the LandS code repository³. The filters source files have been added to dataset page of each PA organised in the LandS Collections⁴ (see screenshot for the Cyprus example in Figure 4.3) and displayed in the LandS Expert-based Suitability Map Dashboard⁵. Finally, the Suitability Score Index summarises local suitability information at the scale of regional administrative units, enabling easier interpretation and comparison across territories. The aggregated Suitability Score Maps provide a policy-relevant overview of where restoration actions are most promising, offering a bridge between detailed spatial modelling and strategic land management planning. These maps are available on the LandS Suitability Score Maps dashboard⁶, supporting decision-makers in prioritising areas for investment and policy intervention.

²<https://teicrete.sharepoint.com/:x/s/REACT4MED2/EeEbnxHqdBg6nVXBe2jY0B8bDoUxGQLIGdSbENq0gquA?e=Btt6cw>

³ <https://gitlab.com/lands-r4m>

⁴ E.g., for PA1-Cyprus restoration action: https://lands.soft-water.it/lds-stac-browser/collections/Cyprus%20-%20Troodos%20Mountains/items/PA1_troodosmountains

⁵ See filters and source maps in the legend on the right-hand side of the page: <https://lands.soft-water.it/node/8>

⁶ LandS Suitability Score Map Dashboard: <https://lands.soft-water.it/node/9>

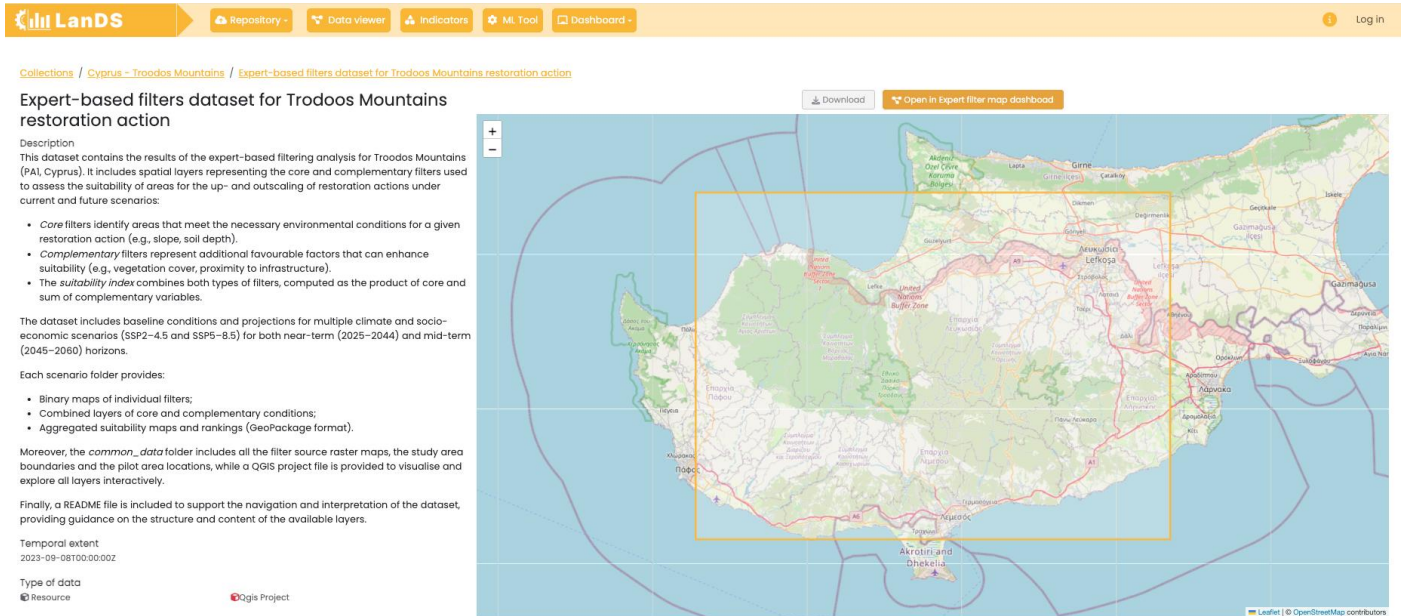


Figure 4.3 Screenshot of the Expert-based filters dataset page on the LanDS for Trodoos Mountains restoration action.

4.4 Integration of future climate and socio-economic scenarios

To represent temporal dynamics and uncertainty in a way that remains physically coherent, LanDS recomputes the clustering and the expert-based suitability filters under two CMIP6/ISIMIP3b pathways—SSP2-4.5 and SSP5-8.5, for Near-term (2025–2044) and Mid-term (2045–2060) windows, using the same indicator logic as the baseline (see Section 3; D2.4; D4.2; D4.3). Climate indicators include means and extremes (precipitation/temperature statistics, TXx, R5d, drought indices such as SPI/SPEI, aridity/erosivity), while socio-economic proxies (population, GDP, land use) provide coarse information on investment opportunities and barriers to adoption. This preserves methodological continuity with the WP2 repository described in D2.4 and the LanDS pipeline in D4.2 and D4.3.

Rather than averaging across GCMs, we force all future indicators with a single model (GFDL ESM4) to maintain cross-variable physical consistency and avoid synthetic fields that can result from simple multi-model averaging. The decision follows the literature showing that an ensemble mean (or “model median”) may not correspond to any physically realisable circulation state, whereas selecting a representative/median model yields more coherent spatial–temporal patterns for regional impact assessments (Christensen et al., 2010; Kjellström et al., 2013; Herger et al., 2018). Among the ISIMIP3b GCMs (IPSL-CM6A, MPI-ESM1-2, GFDL-ESM4, MRI-ESM2, UKESM1-0-LL), comparative evaluations identify GFDL-ESM4 as a balanced choice over the Mediterranean. It exhibits relatively small systematic biases in temperature and precipitation and satisfactory large-scale behaviour over the Euro-Atlantic storm-track (Palmer et al., 2023), and it credibly reproduces the dominant circulation patterns that govern Mediterranean hydroclimate (Olmo et al., 2025).

The selected time slices also provide a light connection to global-warming contexts documented in D2.4: for many CMIP6 members, 2025–2044 broadly coincides with the period when the running mean global mean temperature approaches or first exceeds ~ 1.5 °C, and 2045–2060 aligns with a transition toward ~ 2 °C (model-dependent central year in D2.4 Table 2.2). The scenario integration in LanDS includes:

- Indicator computation: Historical and future indicators are generated on the common 0.125° grid using GFDL-ESM4 forcings consistent with ISIMIP3b and SSP-consistent socio-economic layers.
- Clustering under future scenarios: The IVS + k-means configuration ($k = 12$) calibrated on the baseline is re-run with the future indicator bundles, producing scenario-specific functional typologies that are directly comparable with the baseline (Section 5).

- Suitability under future scenarios. For each Restoration Action, expert filters remain fixed. Only the cluster mask and climate-dependent layers change. This supports comparisons of persistence, emergence, and decline in suitability across pathways, and keeps outputs traceable to policy frames (EU Green Deal, UNCCD-LDN, Paris Agreement).

5 Results: Identification of Suitable Areas

All processed datasets developed in the methodology outlined in Section 4 have been published on the LanDS platform (<https://lands.soft-water.it>). The platform provides access to both historical and future scenario outputs, along with interactive dashboards that implement expert-defined criteria and thresholds stored in the shared Excel file. These dashboards integrate an enhanced webGIS, enabling interactive visualization, overlay and query of both input (source maps, expert-based filters) and output (potential suitability areas under different scenarios), of the ML Tool and Expert based filtering processes.

The results are presented in the following order. First, we show the baseline clustering and introduce the functional typologies used as a common frame for interpretation, together with brief descriptions of each class. Second, we present representative LanDS screenshots for a sample Restoration Action (RA1 - terraced agriculture in the Cyprus Pilot Area) to illustrate the baseline suitability workflow. Third, we report the future clustering results and, subsequently, the future scenario outputs for RA1 using the same filtering logic. Finally, we summarise insights into regional variations, highlighting shifting suitability patterns across the Mediterranean region.

It is important to note that the results produced by LanDS and presented in this deliverable are conditioned by the datasets, parameters, and thresholds applied within the LanDS workflow. Consequently, the resulting suitability and clustering maps should be interpreted as relative indications of potential rather than deterministic predictions. These outputs provide valuable guidance for identifying promising areas and emerging trends; however, further validation and refinement with local data and expert knowledge are recommended before operational use.

5.1 Baseline clustering and functional typologies

To support interpretation of suitability results, we first summarise the functional typologies emerging from the clustering. These typologies group sub-basins with similar combinations of biophysical, climatic and socio-economic conditions and are used as a common frame to read both baseline and scenario maps. The methodological details are summarised in Section 4.2 and fully documented in D4.3, including the indicator set, IVS, and the k-means configuration adopted for the representative run ($k = 12$).

Figure 5.1 presents the baseline cluster map, which we use as the common frame for interpreting suitability in the following sections. The clusters represent functional typologies - areas sharing similar combinations of aridity and precipitation regimes, temperature and heat-stress indices (e.g., TXx, WSDI), dry/wet conditions (e.g., CDD, SPI), topography, land cover, and socio-economic proxies (population, GDP, settlement). D4.3 provides the detailed distributions of indicators per cluster. Table 5.1 summarises the cluster taxonomy with brief descriptions. These typologies are used to guide the expert-based filtering in the RAs and compare baseline with future scenarios.

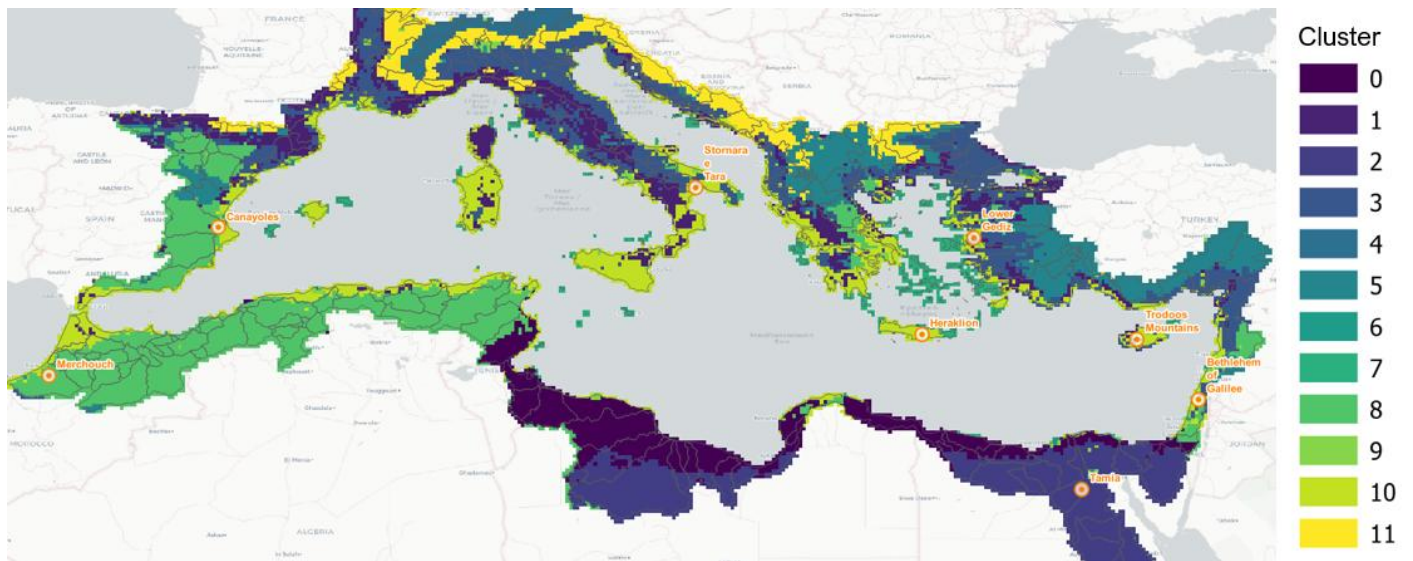


Figure 5.1. Baseline Mediterranean functional typologies derived from the LanDS clustering workflow at sub-basin resolution.

Table 5.1. Taxonomy of the baseline functional typologies with similar combinations of biophysical, climatic and socio-economic characteristics.

Cluster	Name	Description
C0	Warm semi-arid lowlands, mixed agro-systems	Moderate aridity and low-moderate precipitation with pronounced seasonal dry spells; low relief with cropland-shrub mosaics. Socio-economic pressure present but not dominant.
C1	Temperate uplands	Cooler means and higher heavy-rain indices (Rx1/Rx5/R10/R20) on steeper slopes and higher elevations; larger forest share and sensitivity to erosion from intense rainfall.
C2	Hot-dry extreme	Highest heat stress (TXx/WSDI), lowest mean precipitation and longest dry spells (high CDD); sparse population; shrub/rangeland dominance. Represents the arid to hyper-arid belt.
C3	Mediterranean temperate coasts	Moderate temperatures and rainfall with mixed land cover and medium densities; balanced envelopes but sensitive to shifts in wet/dry SPI and summer heat.
C4	Wet foothills / erosion-prone	Higher mean precipitation and wet-day frequencies with appreciable slopes; forest and mixed agriculture; storm-driven runoff and erosion are key constraints.
C5	Wind-exposed coastal/agro-mosaics	Mid-aridity and low relief with notable wind/evaporative demand; cropland - shrub mixes where soil-moisture stress can intensify despite moderate means.
C6	Transitional	Very small, fragmented occurrences (often coastal/insular or boundary pixels) without regional dominance
C7	Urban/metropolitan nodes	Highest population, GDP and settlement cover; limited permeable land; strong infrastructure footprint.
C8	Intensively farmed plains	Very low slope/elevation, high cropland share, moderate precipitation supporting production, with recurrent summer dryness; medium socio-economic density.
C9	Insular/coastal fragments	Small insular and shoreline patches with maritime exposure and variable wind/salinity signals.
C10	Semi-arid hilly agro-forest mosaics	Moderate elevation and slope with shrub-agriculture mixes; summer heat/dryness; representative of many Aegean-type landscapes.
C11	Cooler northern rim / mixed agro-forest	Lower temperature extremes, balanced precipitation regime and mixed agriculture - forest; growing-season length is an important control.

5.2 Baseline suitability results (historical data)

For the historical baseline, each available dataset (including land cover, slope, soil texture, soil depth, rainfall, and groundwater table) was processed and filtered according to expert-defined criteria.

Variables defining the necessary conditions for implementing the considered restoration action, such as slope thresholds for RA1, were classified as core filters. Additional variables that served to refine or further constrain the areas selected by the core filters, for example soil texture or land cover type for RA1, were treated as complementary filters.

In addition to the physical and environmental filters, only areas belonging to the same clusters as the Pilot Area (PA) associated with the considered RA were retained. This ensures that the selected areas share similar combinations of climate, land, and socio-economic conditions with the demonstration site.

For RA1, the corresponding PA1 is located in the Troodos Mountains, Cyprus. The selection of the cluster classes corresponding to this region produced a binary filter map, shown in Figure 5.2.

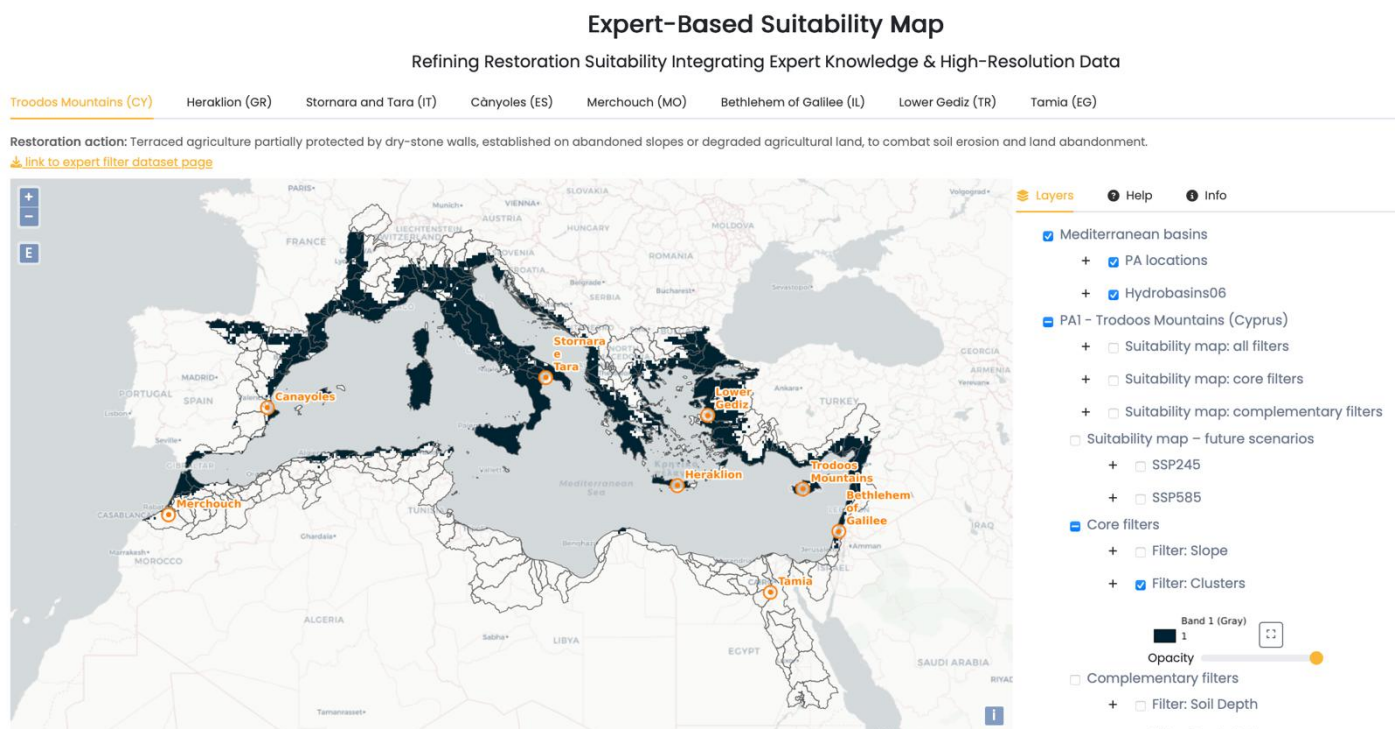


Figure 5.2. Binary map showing areas (in black) having same clustering classes as the pilot area in Cyprus (Troodos Mountains, PA1).

Similarly, the application of core and complementary filters produced binary maps, highlighting areas that meet the defined suitability conditions. As an example, Figure 5.3 shows the binary map obtained for the core filter based on slope values.

Expert-Based Suitability Map

Refining Restoration Suitability Integrating Expert Knowledge & High-Resolution Data

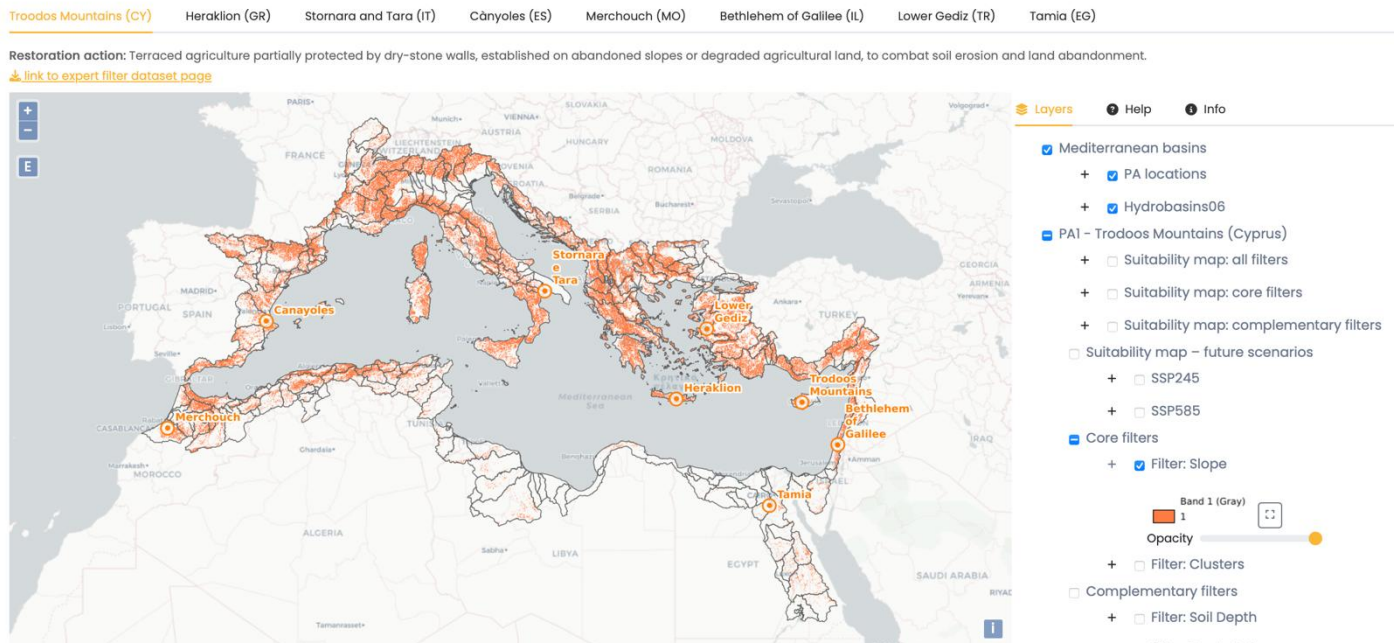


Figure 5.3. Binary map showing areas (in orange) meeting the condition on slope values for the application of RA1.

After selecting areas that meet the conditions of each core and complementary filter, the combination of all core filters was applied, resulting in a binary map that illustrates where the necessary, primary conditions for implementing the considered RA are satisfied (Figure 5.4).

Expert-Based Suitability Map

Refining Restoration Suitability Integrating Expert Knowledge & High-Resolution Data

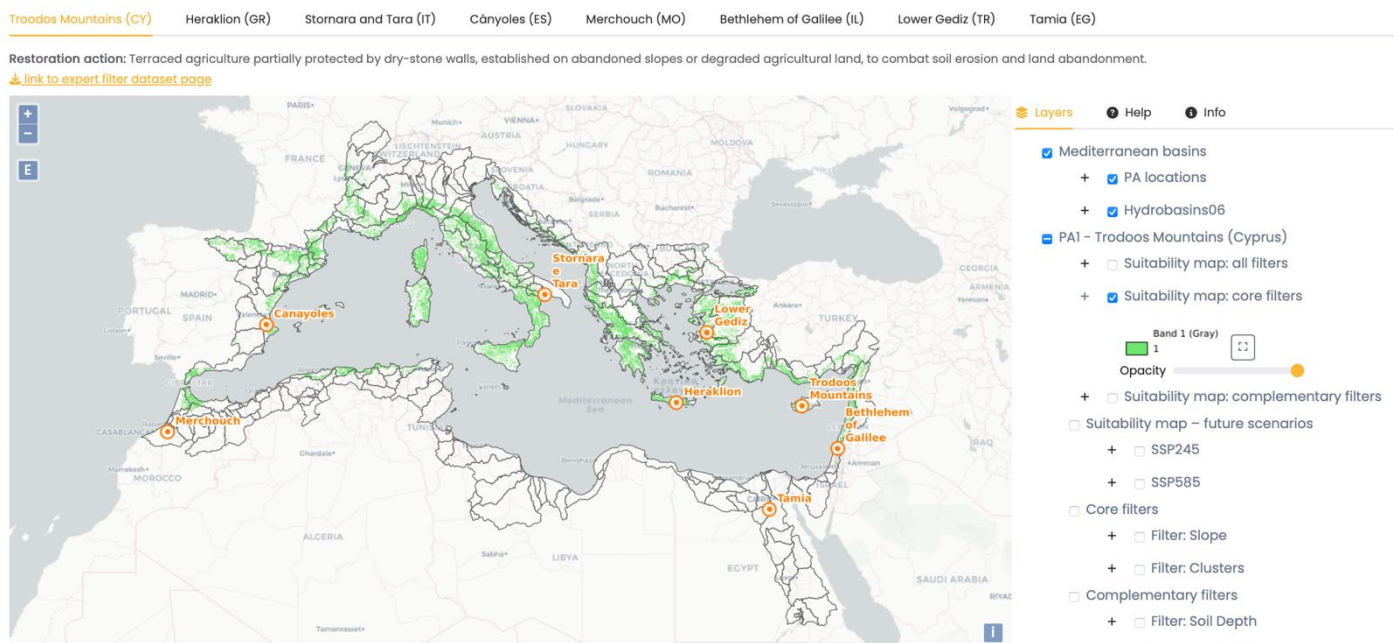


Figure 5.4. Binary map showing areas (in green) meeting the combination of all core filters associated with RA1 (i.e., clustering classes and slope values).

For the complementary filters, the corresponding binary maps were summed, producing a map that indicates the number of complementary conditions met across the study area. In this map, values range from 0 (no complementary conditions met) up to the total number of complementary filters associated with the RA (Figure 5.5).

Expert-Based Suitability Map

Refining Restoration Suitability Integrating Expert Knowledge & High-Resolution Data

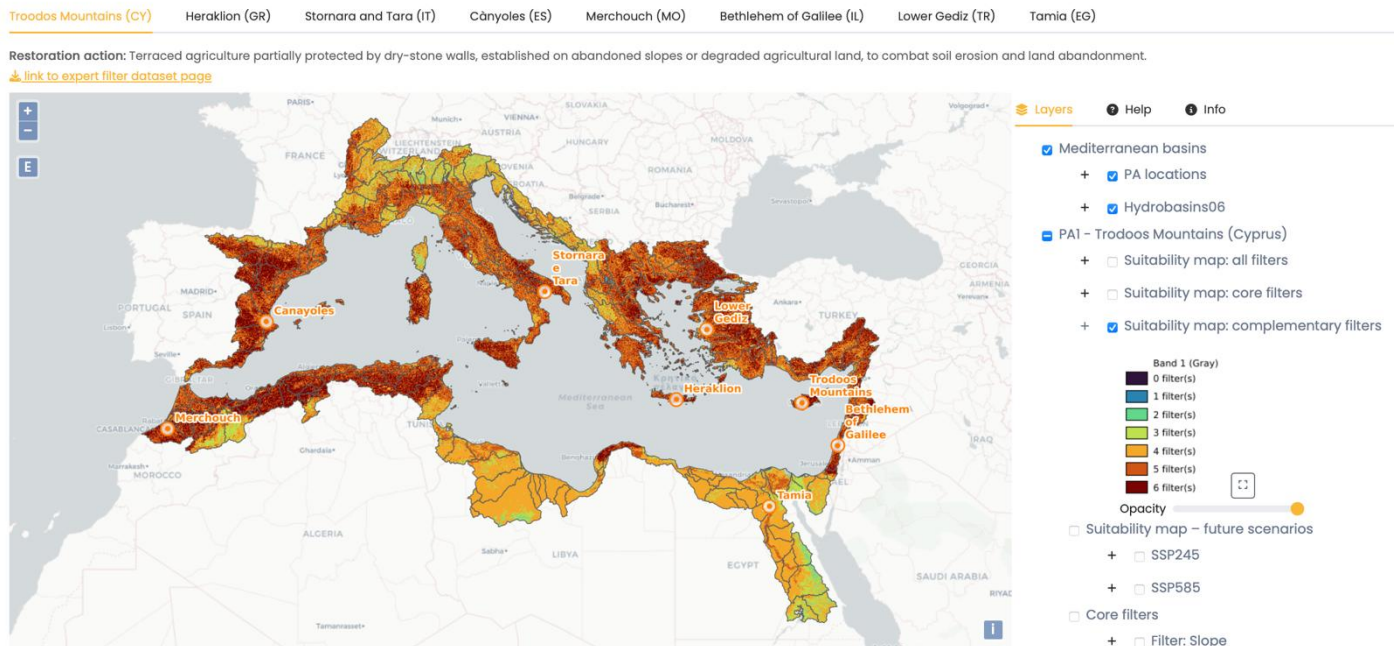


Figure 5.5. Sum of all complementary filters, including soil depth, precipitation, land cover, groundwater table, oil organic carbon, oil texture). The map ranges values from 0 (no condition met on any complementary filter) to 6 (total number of complementary filters).

Finally, combining the binary map of all core filters with the summed map of complementary filters produced the overall suitability map (Figure 5.6). In this map, values range from 0 (no core or complementary conditions met) up to the total number of complementary filters (for RA1, this total is 6).

Expert-Based Suitability Map

Refining Restoration Suitability Integrating Expert Knowledge & High-Resolution Data

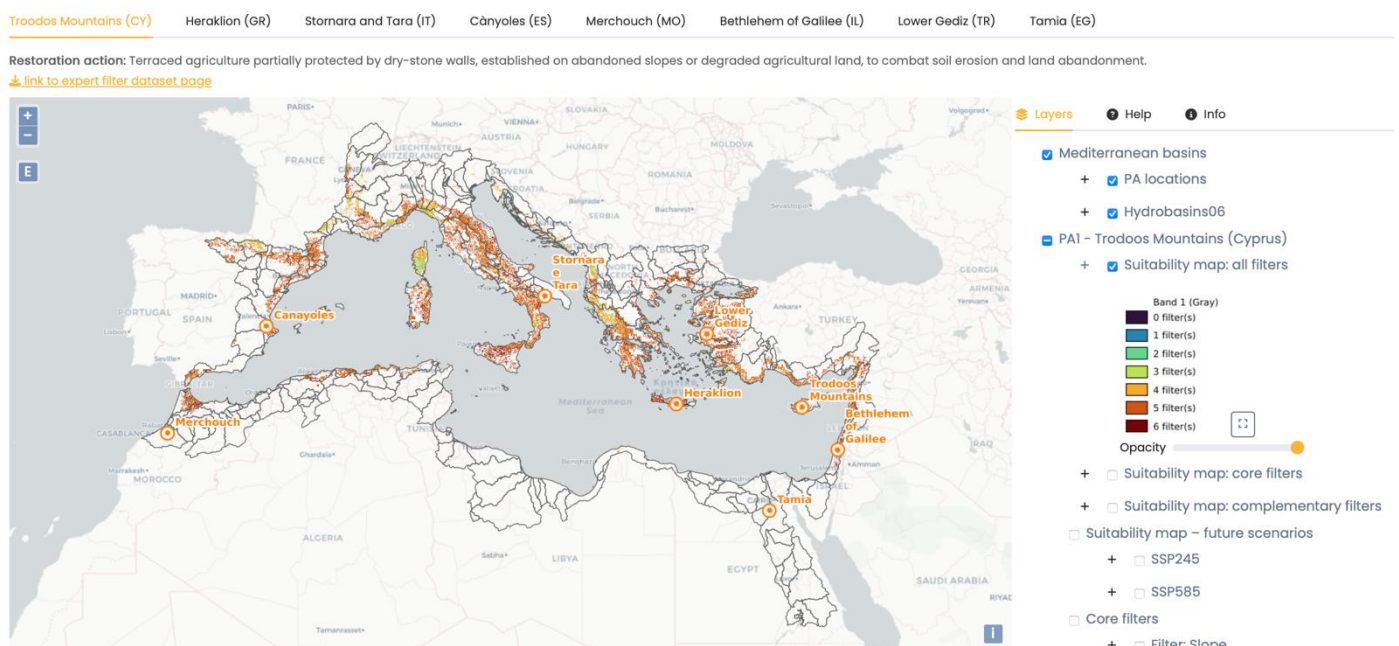


Figure 5.6. Product between the combination of all core filter and the sum of all complementary filters. The map ranges values from 0 (no condition met on any core/complementary filter) to 6 (all core and complementary filters are met).

All the results described above are available on the Expert-Based Suitability Map of the LanDS platform⁷.

5.3 Future scenario clustering outputs

The suitability of the restoration actions in the Mediterranean area under future conditions was assessed using projections from two shared socio-economic pathways (SSP2-4.5 and SSP5-8.5). The methodology follows the same workflow as the baseline analysis, with scenario-specific adjustments applied to the cluster map and precipitation data, while all other variables and filters were assumed to remain constant in the future.

In particular, two new runs of the ML tool cluster analysis were generated, using as inputs the same set of indicators re-computed on the time horizon 2025-2060 for the two future scenarios considered (SSP2-4.5 and SSP5-8.5), while maintaining the same combination of factors defining each cluster as in the baseline period. This allows tracking how areas characterized by specific baseline conditions may shift spatially under future climate scenarios, highlighting regions where the same combination of environmental and socio-economic conditions is expected to occur in the future. Moreover, the time horizon has been divided in two sub periods in order to identify temporal trends and shifts, resulting in four output cluster maps, one for each future scenario, over a near-term and mid-term period, respectively 2025-2044 and 2045-2060. All outputs and scenarios can be visualized in the LanDS Mediterranean collection dataset page (ML tool outputs)⁸ and in the cluster map dashboard page⁹, while Figure 5.7 shows the near-term period for the SSP2-4.5 and SSP5-8.5 scenarios, as shown in the LanDS Dashboard.

⁷ <https://lands.soft-water.it/node/8>

⁸ <https://lands.soft-water.it/lds-stac-browser/collections/Mediterranean%20area>

⁹ <https://lands.soft-water.it/node/7>

Cluster map

Machine-Learning Clusters Map: Identifying Similar Areas in the Mediterranean Region

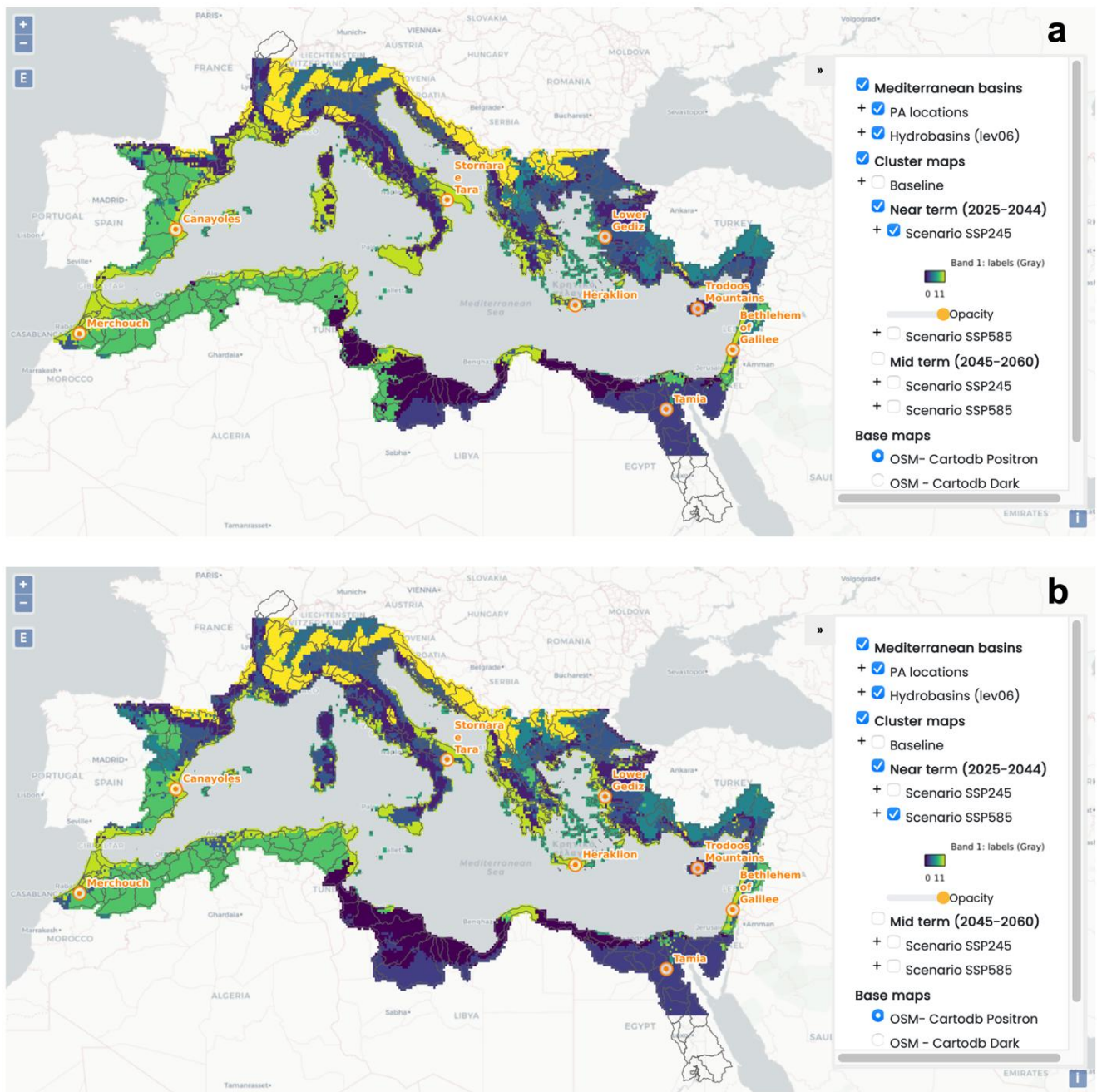


Figure 5.7. Output of the ML tool procedure initialized from the historical baseline for the near-term (2025-2044) scenarios: SSP2-4.5 (a) and SSP5-8.5 (b).

Building on the scenario outputs, Figure 5.8 summarizes the spatial distribution of clusters for Near-term (2025–2044) and Mid-term (2045–2060) under SSP2-4.5 and SSP5-8.5. Table 5.2 reports the areal fraction (%) of each cluster across baseline and scenarios. This allows a consistent reading of how the biophysical envelopes that underpin restoration feasibility are likely to persist or shift.

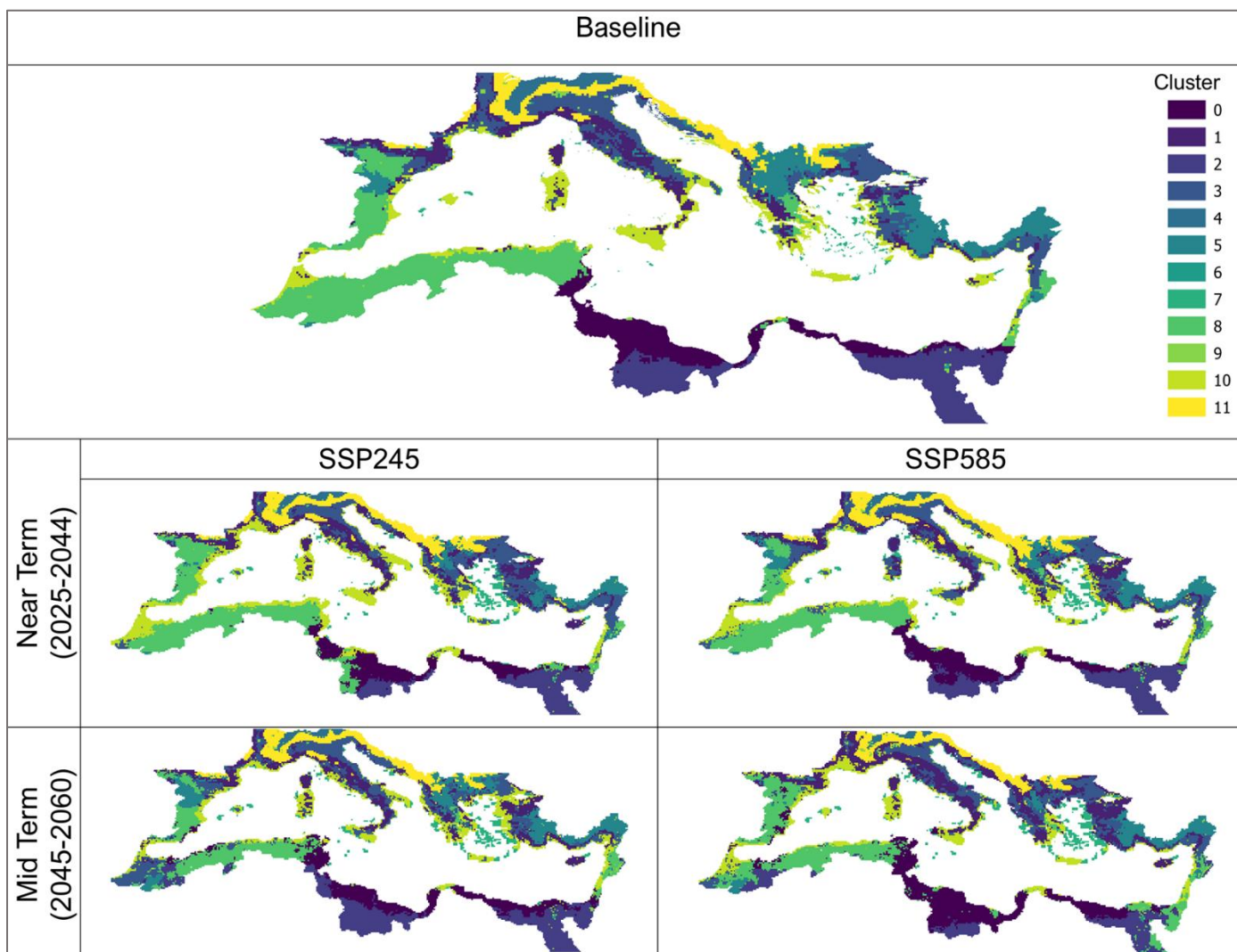


Figure 5.8. Baseline (2001–2019) and scenario cluster maps for Near-term (2025–2044) and Mid-term (2045–2060) under SSP2-4.5 and SSP5-8.5.

The aggregated suitability maps, obtained by combining core and complementary filters, highlight how areas of high restoration potential may shift under future climate conditions, allowing the identification of regions that are likely to remain suitable and those that may experience a decline in suitability. Semi-arid envelopes (C0) gain ground by the mid-term, most clearly under SSP5-8.5 (to 15%), consistent with drying/warming along parts of the southern and eastern rim. In parallel, temperate uplands/foothills (C1) expand across futures (up to 19% in SSP5-8.5 mid-term), indicating a reallocation from neighbouring mid-altitude classes where wet-day frequency and intensity remain supportive. The hot-dry extreme (C2) shows a scenario-dependent divergence, with a rebound in SSP2-4.5 mid-term (14%) versus a contraction in SSP5-8.5 (8%), suggesting shifts at the arid/semi-arid boundary rather than a uniform expansion of hyper-aridity. Mediterranean temperate coasts (C3) are broadly stable near-term but decline under SSP5-8.5 mid-term (from 16% to 12%). Wind-exposed coastal/agro- mosaics (C5) drop in the near-term and partly recover only in SSP2-4.5 by mid-term. The largest baseline class intensively farmed plains (C8), contracts most under SSP2-4.5 mid-term (from 20% to 12%) and less under SSP5-8.5 (to 16%) with pixels reassigning to C0/C10 in several lowland settings. Urban/metropolitan nodes (C7) increase modestly (to 3–4%), while transitional/insular fragments (C6/C9) remain a small, stable share.

Table 5.2. Areal fraction of clusters (%) across baseline and future scenarios.

	Near Term (2025-2044)	Mid Term (2045-2060)
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Cluster	Cluster Name	Baseline (% extent)	SSP2-4.5 (% extent)	SSP5-8.5 (% extent)	SSP2-4.5 (% extent)	SSP5-8.5 (% extent)
C0	Warm semi-arid lowlands, mixed agro-systems	10%	9%	9%	11%	15%
C1	Temperate uplands	10%	13%	12%	13%	19%
C2	Hot-dry extreme	12%	9%	11%	14%	8%
C3	Mediterranean temperate coasts	16%	15%	16%	15%	12%
C4	Wet foothills / erosion-prone	2%	1%	1%	1%	1%
C5	Wind-exposed coastal/agro mosaics	10%	6%	7%	10%	6%
C6	Transitional	0%	0%	0%	0%	0%
C7	Urban/metropolitan nodes	1%	3%	3%	3%	4%
C8	Intensively farmed plains	20%	18%	15%	12%	16%
C9	Insular/coastal fragments	1%	1%	1%	1%	1%
C10	Semi-arid hilly agro-forest mosaics	11%	16%	13%	12%	11%
C11	Cooler northern rim / mixed agro-forest	7%	9%	10%	8%	6%

For RA1 we apply the same expert-based filters used in the baseline (core and complementary criteria held constant), but replace the cluster mask and the precipitation data with the scenario-specific cluster and precipitation maps. This keeps the feasibility logic unchanged while testing how functional similarity to the pilot area evolves under future climate. The aggregated suitability is then derived as in Section 5.2.

For the Near-term (2025–2044), the RA1 suitability pattern remains broadly coherent with the baseline, with persistent hotspots around comparable mountain/foothill settings and local changes at the edges of the cluster envelope. Differences between SSP2-4.5 and SSP5-8.5 are visible where semi-arid classes expand or contract, affecting the continuity of suitable bands. Representative maps are shown in Figure 5.9. For the Mid-term (2045–2060), the same procedure can be applied to the maps, allowing a comparison with the near-term. Where the functional envelope stabilises, suitability remains stable or slightly reduced.

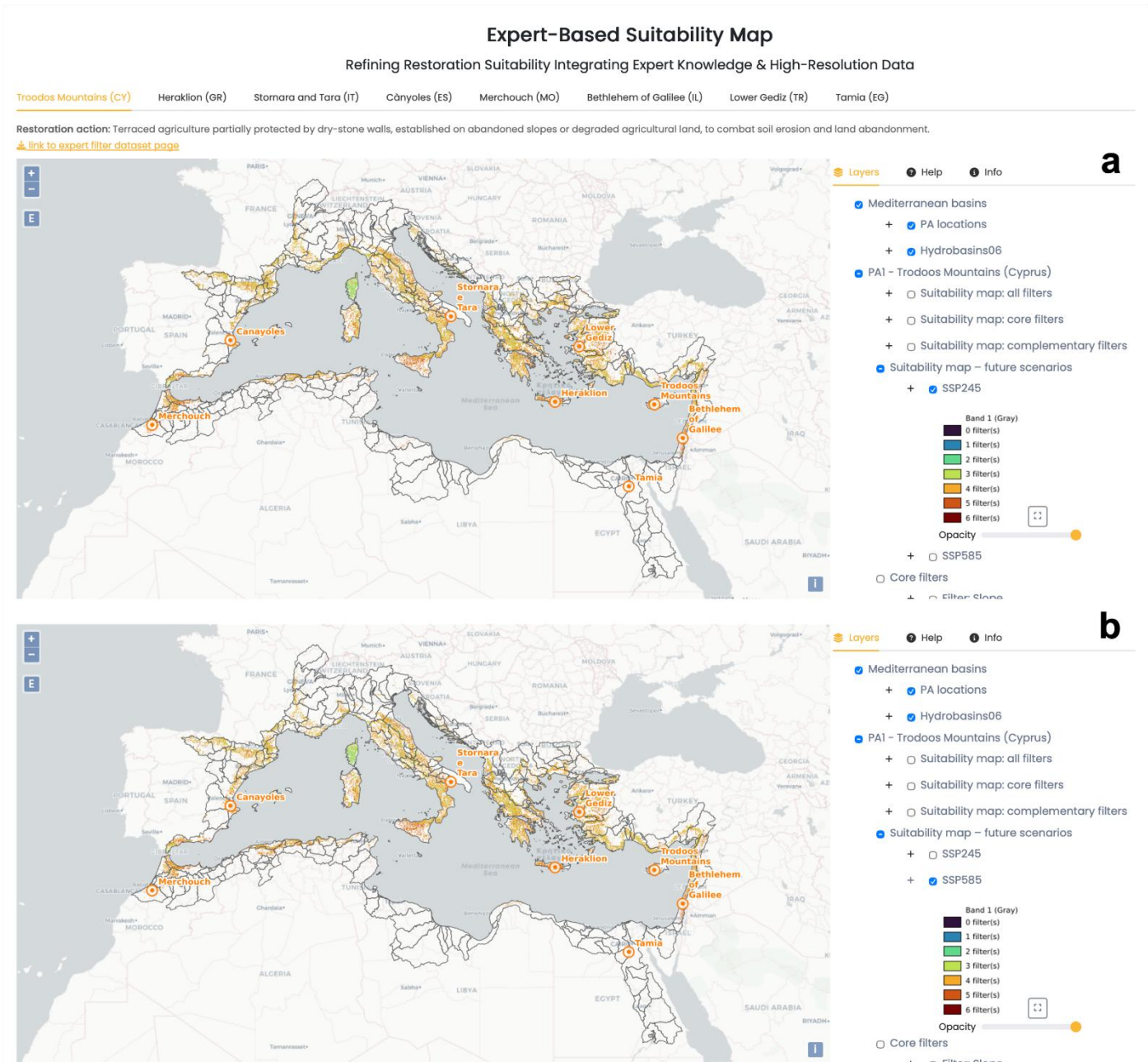


Figure 5.9. Expert-Based Suitability maps for the near-term (2025-2044) scenarios: SSP2-4.5 (a) and SSP5-8.5 (b).

5.4 Suitability score maps for potential upscaling restoration actions

To support regional-scale decision-making, pixel-level suitability values were spatially aggregated according to the FAO Global Administrative Unit Layers (GAUL 2024) dataset (FAO, 2024), generating a quantitative suitability score that reflects the proportion of high-potential areas within each region. Based on these scores, regions were ranked according to their relative suitability, enabling the prioritization of areas for the upscaling of restoration actions. Focusing on the example of the restoration action associated with Cyprus, i.e., dry stone terraces (Figure 5.10), the comparison between the baseline and the near-term (2025–2044) scenarios reveals a general increase in the suitability across several Mediterranean regions, particularly in Italy, Greece, and along the coasts of Spain, with only limited areas showing unchanged suitability levels. Notably, along the Libyan coast, the suitability score increases from no suitability in the baseline to a very low degree under the SSP2-4.5 scenario, while it remains null under the SSP5-8.5 scenario, indicating a divergence in projected restoration potential under different future pathways.

The resulting suitability score maps provide policy-relevant insights, highlighting regions where restoration investments are expected to deliver the greatest ecological and socio-economic benefits. All Suitability Score Maps can be accessed and explored on a dedicated LandS Dashboard page¹⁰.

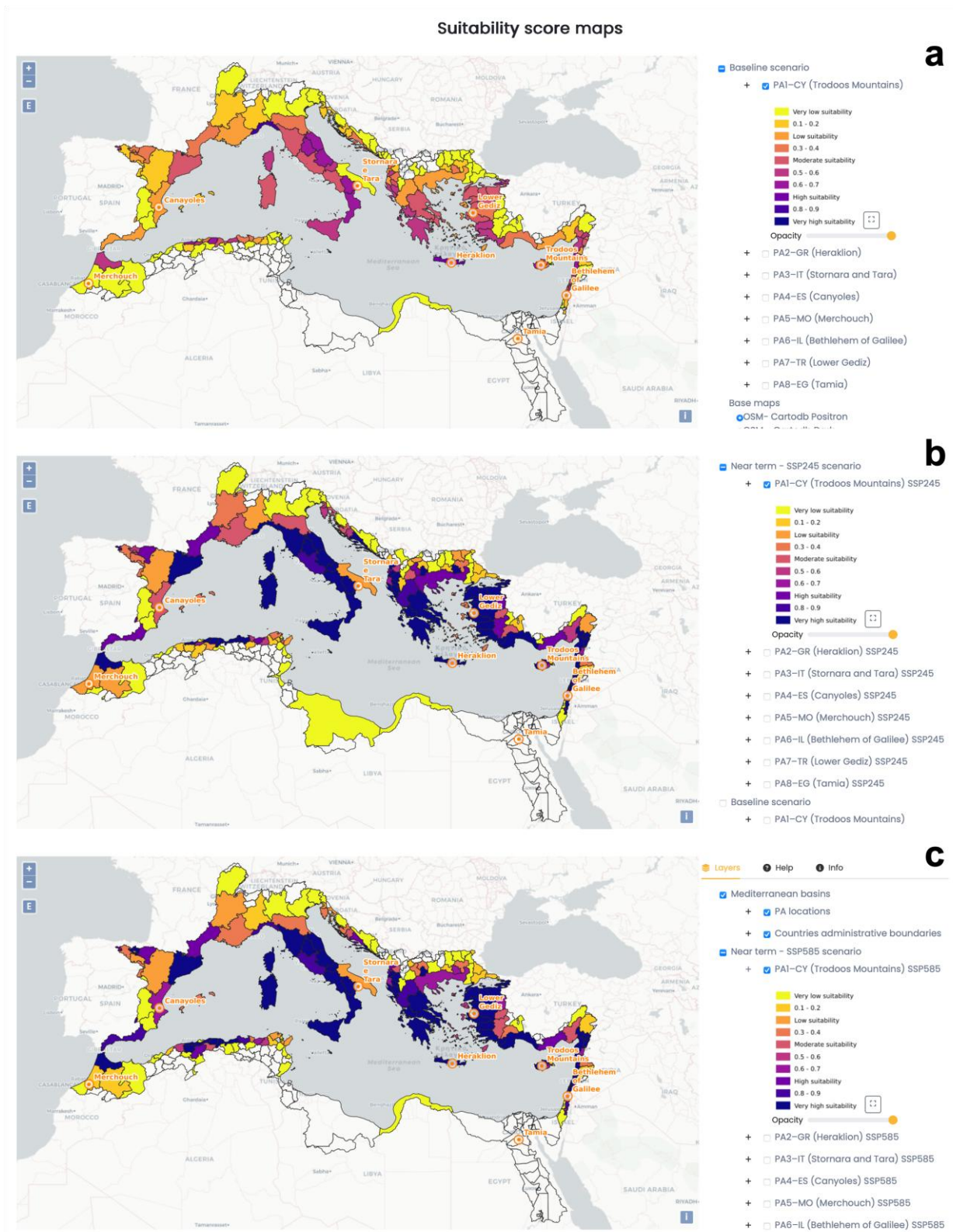


Figure 5.10. Suitability score maps for the baseline (a) and for two near-term (2025-2044) scenarios: SSP2-4.5 (b) and SSP5-8.5 (c).

¹⁰ <https://lands.soft-water.it/node/9>

5.5 Insights into regional variations and implications of RAs

This subsection synthesises where suitability persists, where it weakens, and where new suitability appears across the Mediterranean for all Restoration Actions (RAs). We compare the baseline maps against the near-term (2025–2044) projections under SSP2-4.5 and SSP5-8.5, using the same expert-based filters and administrative aggregation adopted in the example above. The aim is to identify opportunities, emerging areas, and declining feasibility at regional scale, to inform programme targeting and sequencing. Detailed maps for each RA (baseline and scenarios) are provided in the Annex (RA1-RA8).

RA1 – Terraced agriculture (CY pilot)

As shown in the RA1 example of terraced agriculture, suitability concentrates along mountainous and foothill belts with active or abandoned tree-crop systems, especially in the eastern Mediterranean (Cyprus/Troodos and the Aegean–western Turkey arc), with additional patches in southern Italy and parts of Iberia. Low values dominate the southern rim and broad lowlands where slope/land-cover conditions are absent. The spatial pattern mirrors the prevalence of C1/C10 typologies (temperate uplands and semi-arid hilly mosaics), which provide the terrain and land-use context required for terraces. Under both SSP2-4.5 and SSP5-8.5, suitability intensifies across the Aegean - western Turkey corridor and around Cyprus, with several baseline-moderate provinces moving to high/very high suitability. Improvements also appear in southern Italy and selected Adriatic districts. Conversely, margins along the southern and western Mediterranean show weakening or remain very low, reflecting re-allocation toward drier lowland classes where the cluster mask limits transferability. Differences between SSP2-4.5 and SSP5-8.5 are modest in the near term as both scenarios preserve the eastern Mediterranean core and show only local rearrangements at the edges of current hotspots. Terraced agriculture retains a robust feasibility envelope centred on eastern Mediterranean uplands/foothills, with stable or higher suitability in the near term. Programme design can prioritise these persistent belts (early investments/maintenance), while treating new scattered gains as pilot opportunities that may require enabling measures (advisory, incentives) to move from potential to uptake.

RA2 – Afforestation of agricultural land for environmental protection (GR pilot)

Suitability is spatially fragmented and largely coastal and insular. Localised moderate–high scores emerge across parts of the Aegean (Crete and neighbouring islands), sections of mainland Greece, isolated belts in southern Italy and Sicily (very high in a few municipalities), small pockets in the Balearics/Valencia arc, Cyprus, and short stretches along the Levantine coast. These areas combine erosion pressure, fire exposure and land-abandonment signals with biophysical envelopes where establishment success is plausible. Under both SSP2-4.5 and SSP5-8.5, in the near-term and mid-term horizons, suitability falls below the operative threshold across the Mediterranean domain, meaning that no areas are flagged as suitable in the scenario runs. This indicates high sensitivity of this action to projected warming/drying, lengthening dry spells and intensified fire-weather, together with limiting socio-economic proxies, which collectively suppress the feasibility window for new afforestation on former agricultural land. Where afforestation remains a strategic priority, implementation should focus on micro-refugia, and buffered niches identified at local scale and should be coupled with fire-smart design and water-efficient establishment. The detailed baseline map is provided in Annex (RA2), with scenario panels omitted as no suitability is detected.

RA3 – Organic vineyard restoration and agro-ecosystem management optimisation (IT pilot)

Suitability is concentrated along established viticultural belts, with moderate-high scores in parts of northern Greece (Aegean/Thrace) and selected Italian districts (Adriatic and Tyrrhenian arcs, isolated pockets in Sicily and central Italy). Smaller low-moderate patches appear in eastern Spain and a few coastal/insular municipalities. These areas couple existing/peri-vineyard land uses with the required soil and bioclimatic windows for organic transition and ecosystem-based practices. Under SSP2-4.5 and SSP5-8.5 (near- and mid-term), no suitability is detected at Mediterranean scale. The feasibility window closes where cluster re-allocation shifts pixels out of the required bioclimatic bands and where expert thresholds (land cover, slope, precipitation/heat constraints) are no longer co-met. Programme design should prioritise site-specific

management within existing vineyards rather than spatial expansion, e.g., drought-tolerant rootstocks and varieties, soil organic-matter build-up (mulches/composts/cover crops), micro-irrigation/deficit strategies, canopy/groundcover management, and integrated pest management.

RA4 – Soil restoration through chipped pruned branches (ES pilot)

Moderate to high suitability appears across several Iberian provinces (Valencia, Catalonia, and parts of Andalusia), with additional patches in southern-central Italy, Sicily, and Greece. The Cànyoles pilot region stands out with the highest scores. These areas combine degraded cropland on gentle-moderate slopes with management contexts where soil-organic-matter inputs and surface protection can effectively reduce erosion and improve infiltration. In the near-term (SSP2-4.5 and SSP5-8.5), suitability weakens widely to low/very low across the western and central Mediterranean, with only isolated remnants of moderate scores. The Cànyoles area largely retains the strongest signal in SSP2-4.5, while SSP5-8.5 shows further contraction. RA4 remains feasible in a limited set of districts, mainly around Cànyoles, but most regions shift to marginal suitability. Where programmes consider deployment, it should be targeted (fields with acute erosion/structure decline) and paired with complementary measures (cover crops, contouring, residue retention, local water-harvesting) to sustain benefits under drier and warmer futures.

RA5 – Conservation agriculture (MA pilot)

Suitability is high to very high across broad cropland belts in Morocco and northern Algeria, extending into south-western Spain and scattered districts of Tunisia/Libya. These areas couple extensive rain-fed agriculture on gentle slopes with soils where residue retention, crop rotation and reduced tillage can effectively curb erosion and buffer soil-moisture deficits. In future scenarios (near-term, SSP2-4.5 and SSP5-8.5) suitability contracts sharply. Most Iberian and Maghreb provinces drop from moderate-high to low/very low, with residual pockets along northern Algeria and the Libyan coast. The reduction is stronger in SSP5-8.5, and where mid-term runs were inspected the pattern persists, indicating consolidation rather than recovery. The spatial signal aligns with re-allocation of lowland productive plains from C8 toward drier C0/C10 typologies and longer dry spells, which diminish the effectiveness of CA under the fixed expert thresholds. Out-scaling of RA5 becomes location-specific. Where programmes still pursue CA, prioritise fields with severe structure/erosion issues, and bundle with water- and soil-enhancing measures (cover crops, mulching, contour strips, small water-harvesting, drought-tolerant varieties) or combine with RA4/RA7 depending on context.

RA6 – Integrated water and soil conservation for biodiversity restoration (IL pilot)

Suitability appears as scattered bands along the Aegean and eastern Greek mainland, parts of the central Mediterranean islands (e.g., Sardinia/Sicily pockets), and short stretches on the Levantine coast. These areas combine mixed agro-natural mosaics on gentle to moderate slopes with signals of erosion pressure, summer dryness, and habitat fragmentation, where combined water-saving (e.g., drip, rainwater harvesting) and soil-formation practices (mulching, chop-and-drop, Terra Preta) can enhance ecosystem resilience. Under the near-term SSP2-4.5 and SSP5-8.5 scenarios, no suitability is detected at Mediterranean scale. The feasible envelope closes where cluster re-allocation shifts pixels toward drier lowland typologies (C0/C10). With current thresholds, RA6 is not transferable at regional scale in future conditions. If pursued, implementation should target local micro-refugia identified through higher-resolution and wider climate projections assessments.

RA7 – Integrated soil and water management for salinity/alkalinity (TR pilot)

Suitability is widespread along intensively farmed coastal and lowland belts northern Morocco, Algeria, Tunisia, parts of eastern Spain, the Adriatic/Ionian rim, and western, central Turkey, with moderate to high classes in several districts. These areas combine irrigated peri-irrigated cropland, shallow groundwater or secondary salinisation signals, and gentle slopes where drainage, leaching, soil amendments and reduced tillage can be effective. Under SSP2-4.5 and SSP5-8.5, suitability weakens overall from moderate-high to

low-moderate, especially across the western Mediterranean belts (Spain–Maghreb). Nevertheless, relative persistence remains around baseline hotspots in Turkey and segments of North Africa, indicating continued feasibility where salinity-alkalinity pressures are chronic. In line with the clustering re-allocation toward drier classes on the southern rim, several inland pixels drop to very low. By contrast, Egypt shows a relative strengthening in the future, consistent with increasing salinity risk and the action’s focus on remediation rather than water addition. RA7 remains one of the transferable measures under change, but expected performance will hinge on design (drainage plus leaching plus amendments) and water quality/availability for leaching. Prioritisation could consider (i) persistent belts where baseline suitability remains at least moderate; (ii) problem districts with documented secondary salinisation; and (iii) emerging hotspots (e.g., Egypt) for pilot scaling. Pair with salinity monitoring of and irrigation management to avoid re-salinisation and consider synergies with RA5 (conservation practices) where soil cover and rotations can stabilise gains.

RA8 – Agro-ecosystem restoration through organic/bio-fertilisation and soil-structure improvement (EG pilot)

Suitability is concentrated around the Tamia pilot area and adjacent Nile Valley fringes, with additional low-moderate patches along the Libyan coast. These districts couple degraded/arid agro-ecosystems, shallow/alkaline soils and management needs where organic and bio-fertilisation, soil-structure improvement and salinity-tolerant practices can raise resilience. Under SSP2-4.5 and SSP5-8.5, the core Egyptian focus persists, while suitability in surrounding belts drops from moderate to low-moderate. Small new patches appear intermittently along the Libyan littoral and, at the margins of Morocco and southern Iberia, but these remain low in score. RA8 offers targeted out-scaling potential centred on Upper-Lower Egypt with pilot-level opportunities in neighbouring Libya and scattered southern-rim districts. Programme design could emphasise: (i) organic matter build-up (composts, manures, biochar) and soil structure rehabilitation; (ii) salinity-tolerant varieties and deficit or precision irrigation; (iii) monitoring of soil salinity and SOC to track benefits. In new, low-score areas, deployment should be treated as pilot initiatives coupled with advisory support and incentives; pairing with RA7 (drainage, leaching, amendments) could enhance effectiveness where salinity-alkalinity is a co-limiting factor.

6 Conclusion

This deliverable operationalises the LanDS workflow at Mediterranean scale to identify where REACT4MED restoration actions can be out- and up-scaled under present and future conditions. Using a consistent indicator bundle and a physically coherent climate driver, we derived a 12-class functional typology for the baseline and reassigned pixels under SSP2-4.5 and SSP5-8.5 for near-term (2025–2044) and mid-term (2045–2060) horizons. Across actions, three signals are clear. First, persistence: several baseline hotspots remain suitable, most notably terrace-compatible uplands/foothills in the eastern Mediterranean and salinity-management districts with chronic soil-water constraints. Second, contraction: suitability for organic-matter additions, conservation agriculture and broader integrated actions generally weakens across western-southern lowlands; where it endures, it becomes more location-specific. Third, limited emergence: new opportunities appear mainly as scattered, low-to-moderate patches rather than new continuous belts.

These patterns translate into concrete programme guidance. Prioritise persistent belts for early scale-up (low-regret deployment). Treat declining yet non-vanishing areas as conditional opportunities, pairing actions with complementary measures (e.g., cover crops, residue management, water-harvesting, precision irrigation, fire-smart management) and with enabling instruments (advisory services, results-based incentives, drought risk tools). Use the near-term monitoring to steer immediate programming and the mid-term signals to stress-test and monitoring adaptation implementation, align with Green Deal/Nature Restoration and LDN targets, and shape EU–MENA cooperation where hazards and value chains are shared. Packaging restoration actions (e.g., salinity remediation with organic amendments; terraces with vegetation management) will increase durability and co-benefits for soil, water and biodiversity.

To deliver on the project vision of turning Living-Lab evidence into scalable restoration practice, all underpinning data layers, indicator definitions, cluster maps, expert filters and aggregated statistics are published on the LanDS platform as a living, FAIR-aligned resource. In this way the platform functions as a shared evidence base for adaptive programming, linking science to decision cycles and enabling partners and authorities across the Mediterranean to reuse, refine and scale restoration actions while tracking progress toward policy targets.

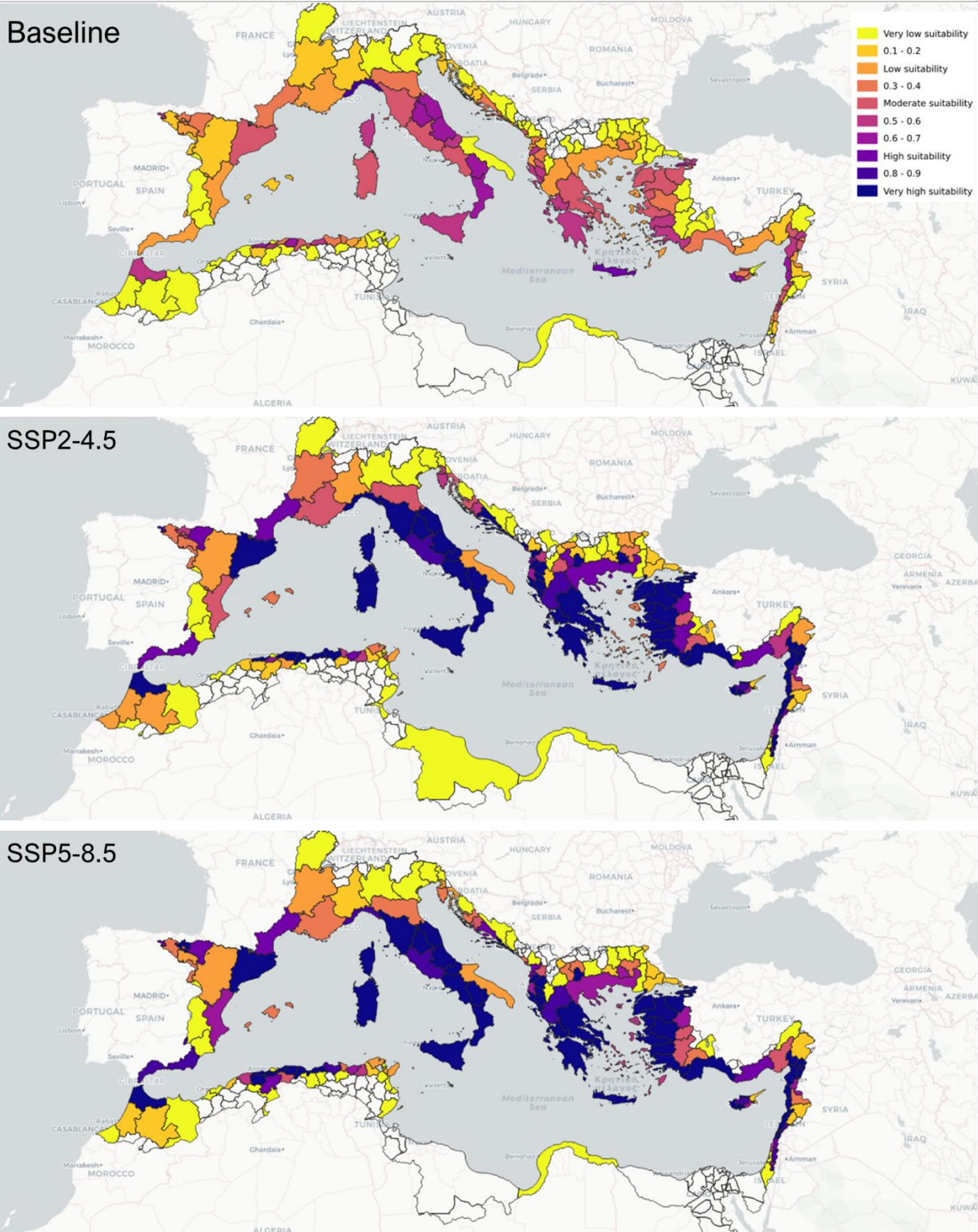
Finally, the release of the main LanDS components as open-source tools enables further analyses – allowing users to integrate new datasets, re-tune clustering parameters, or adapt filtering thresholds – to explore alternative scenarios and generate additional insights.

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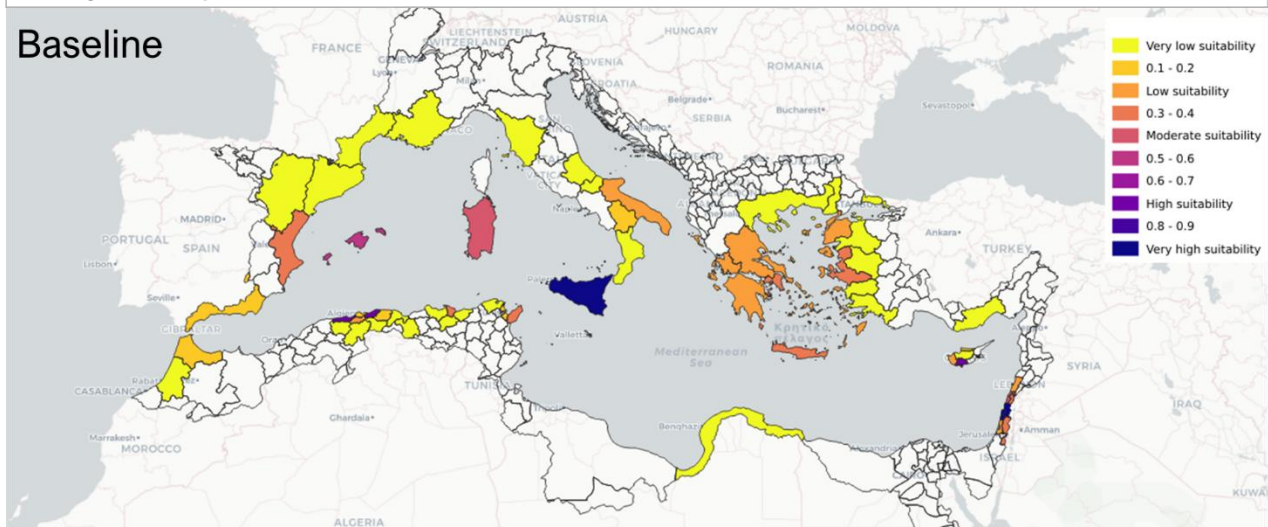
8 Annex

RA1: Terraced agriculture partially protected by dry-stone walls, established on abandoned slopes or degraded agricultural land, to combat soil erosion and land abandonment.



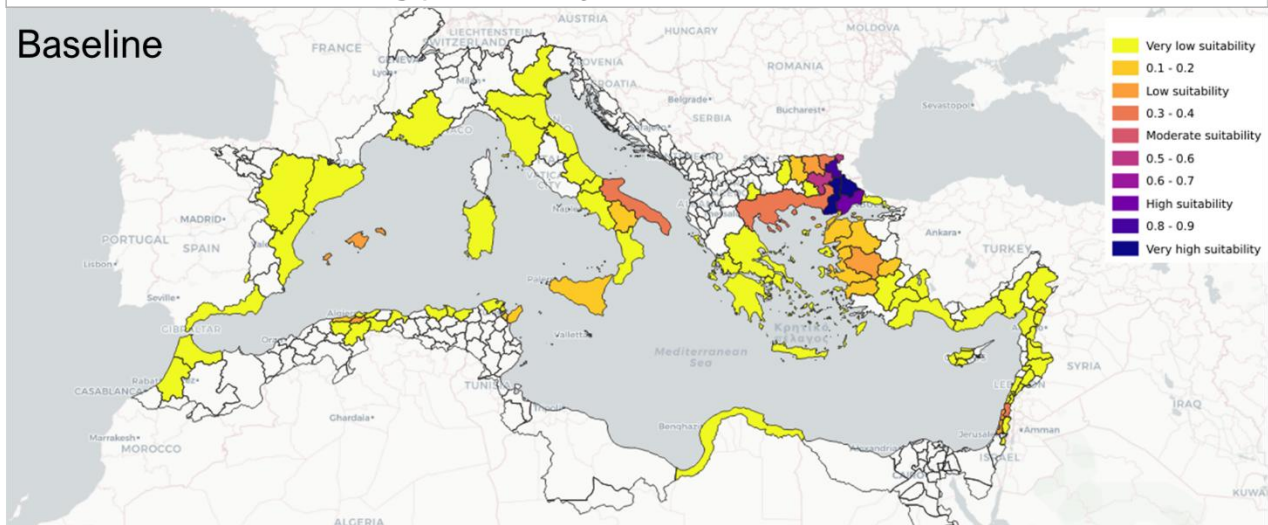
RA2: Afforestation of agricultural land for environmental protection (including fires and climate hazards), expansion and improvement of forest resources, supporting ecosystems preservation.

Baseline



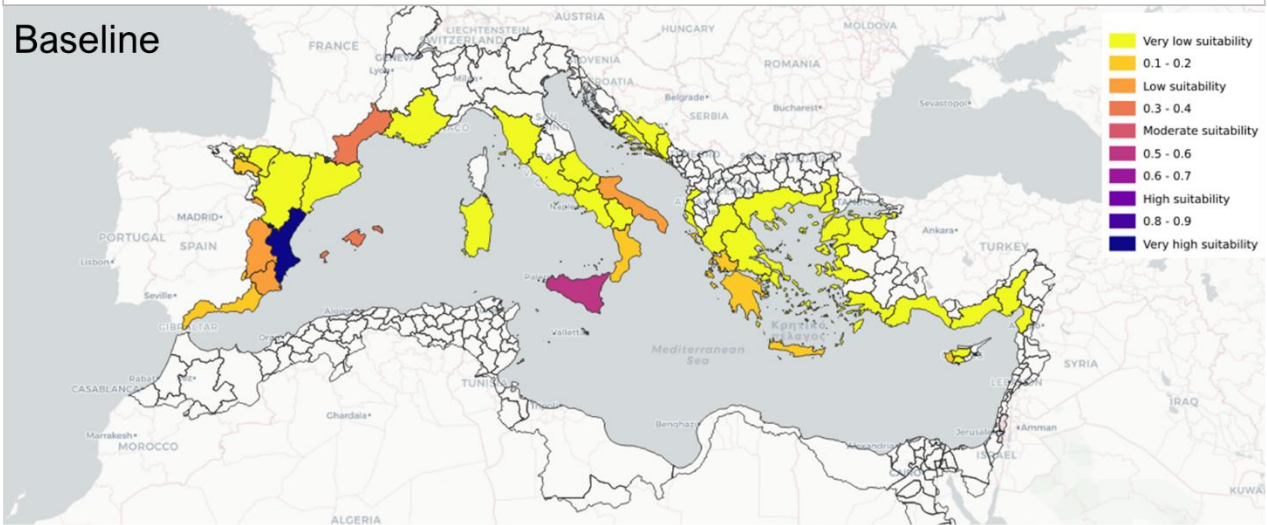
RA3: Organic vineyard restoration by reducing pesticides, enhancing plant biodiversity, and optimizing agro-ecosystem management to minimize pests and diseases while maintaining productivity.

Baseline

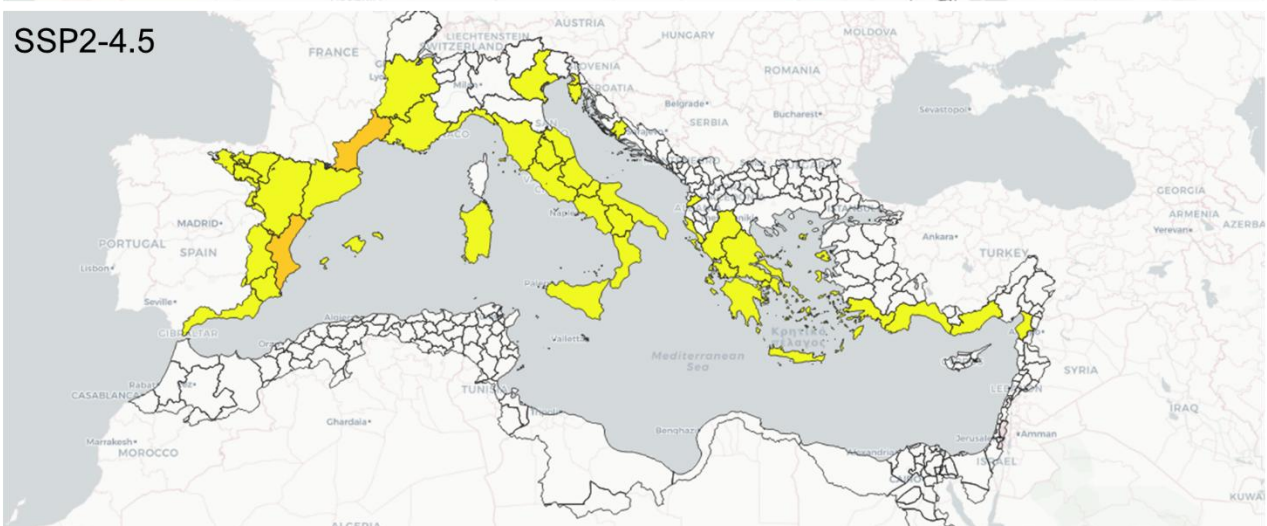


RA4: Soil restoration through chipped pruned branches to enhance soil organic matter, reduce erosion, improve water infiltration, and restore soil structure, providing a scalable, nature-based solution for sustainable agriculture.

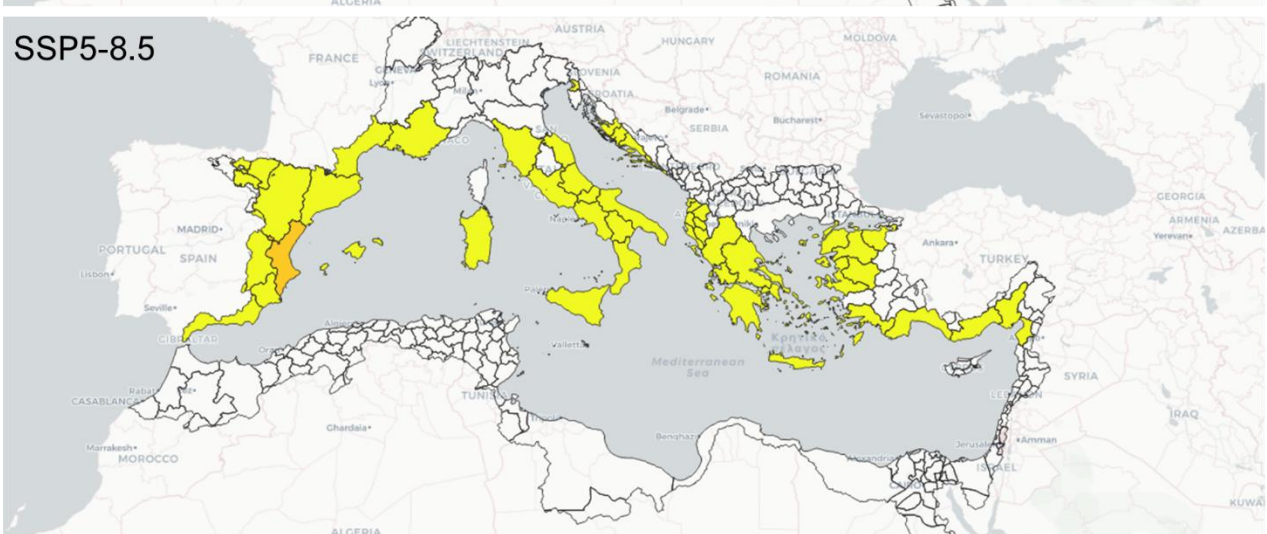
Baseline



SSP2-4.5

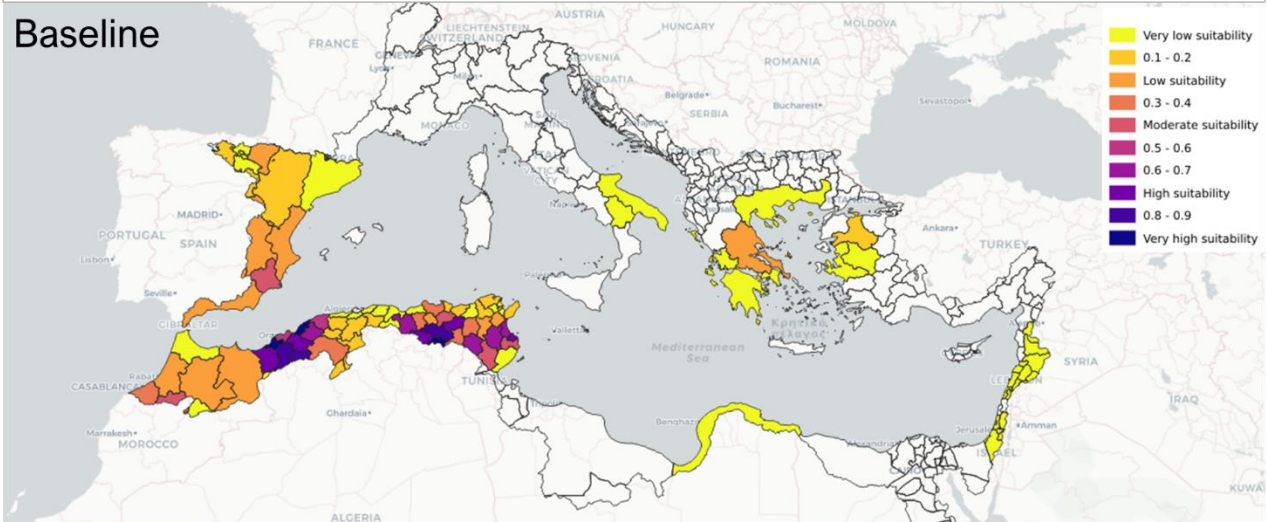


SSP5-8.5

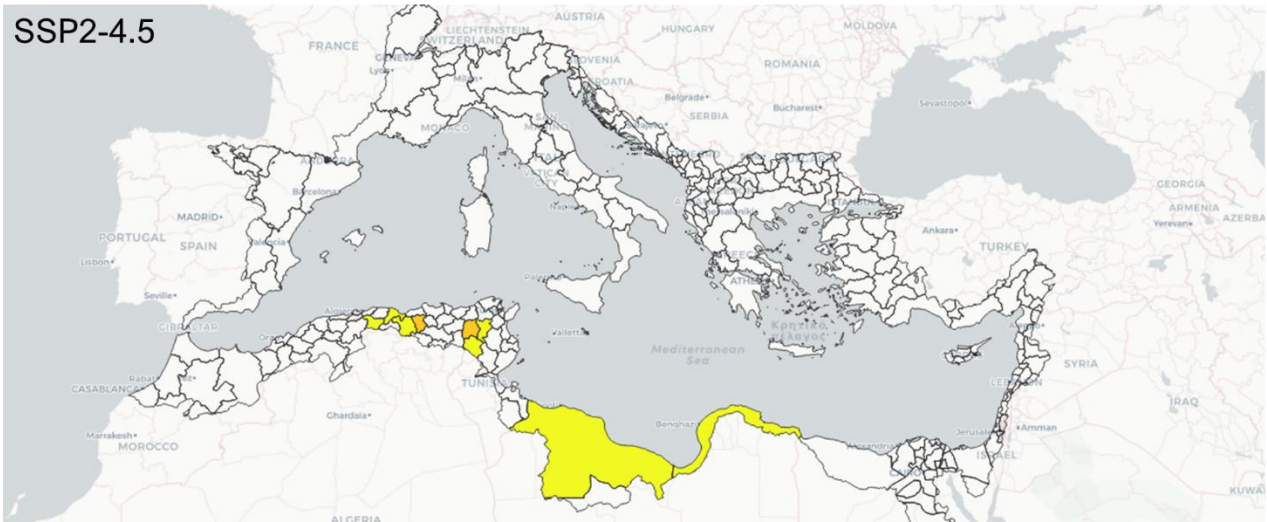


RA5: Conservation agriculture (directing seeding, crop rotation and residue management) with best management practices in terms of crop seeding, harvesting, fertilization and protection.

Baseline



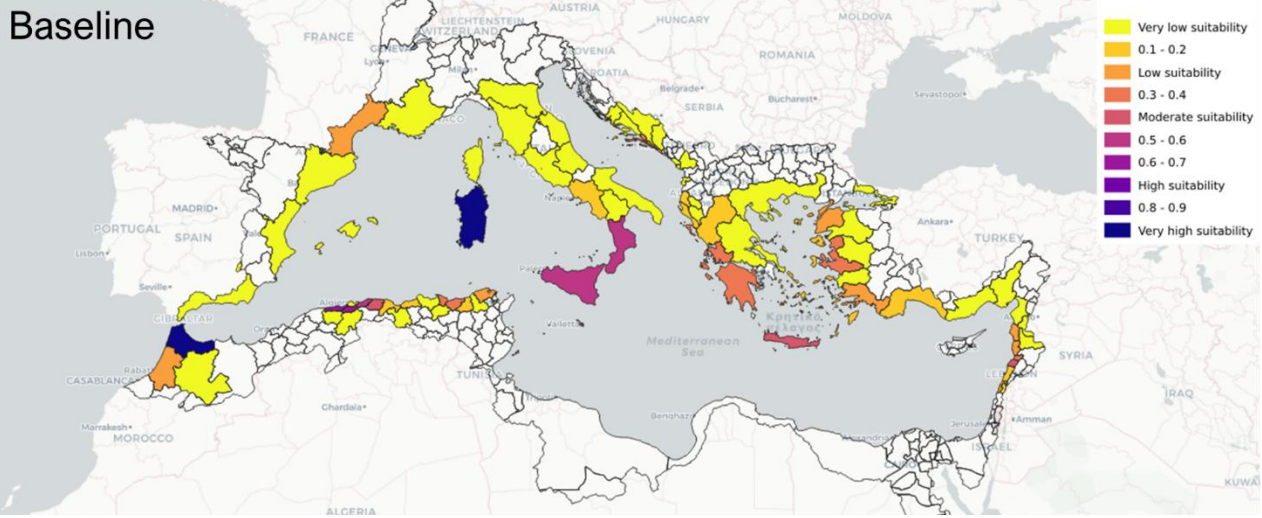
SSP2-4.5



SSP5-8.5

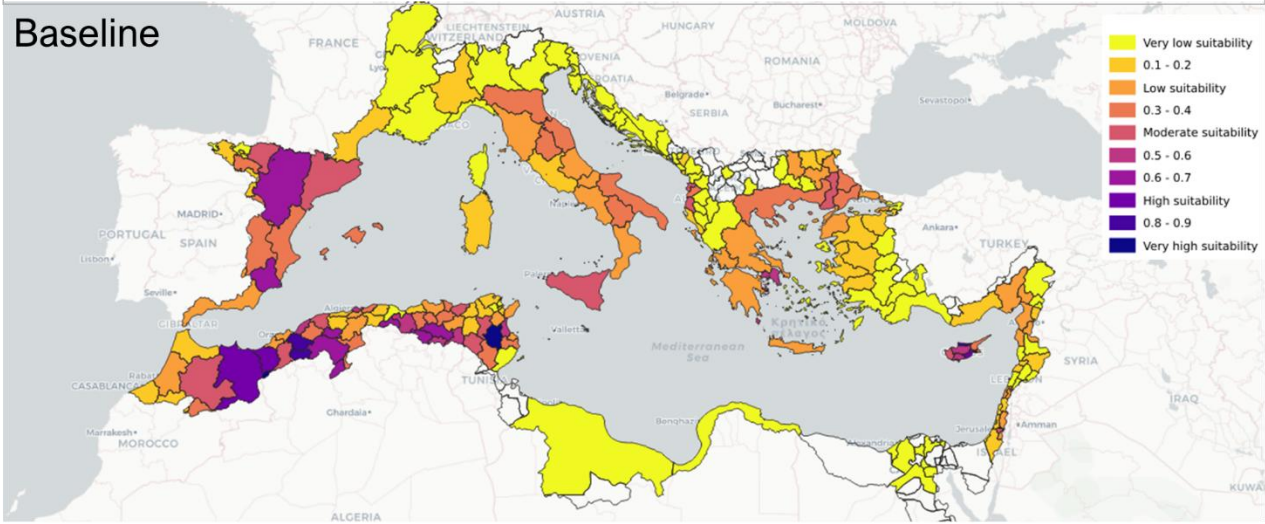


RA6: Integrated water and soil conservation for biodiversity restoration, combining water conservation (e.g., drip irrigation, rainwater harvesting) and soil formation (e.g., chop-and-drop, mulching, Terra Preta) to enhance ecosystem resilience.

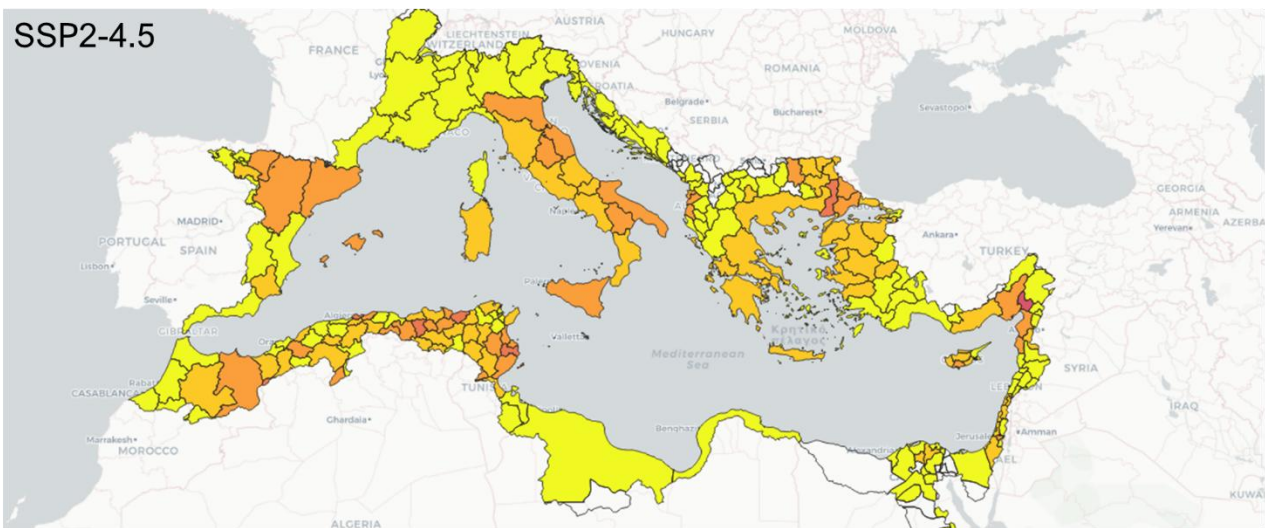


RA7: Integrated soil and water management through drainage systems, leaching, PGPR application, and soil amendments (sulfur, gypsum) to reduce salinity and alkalinity, combined with reduced tillage and green manure for sustainable agriculture in arid regions.

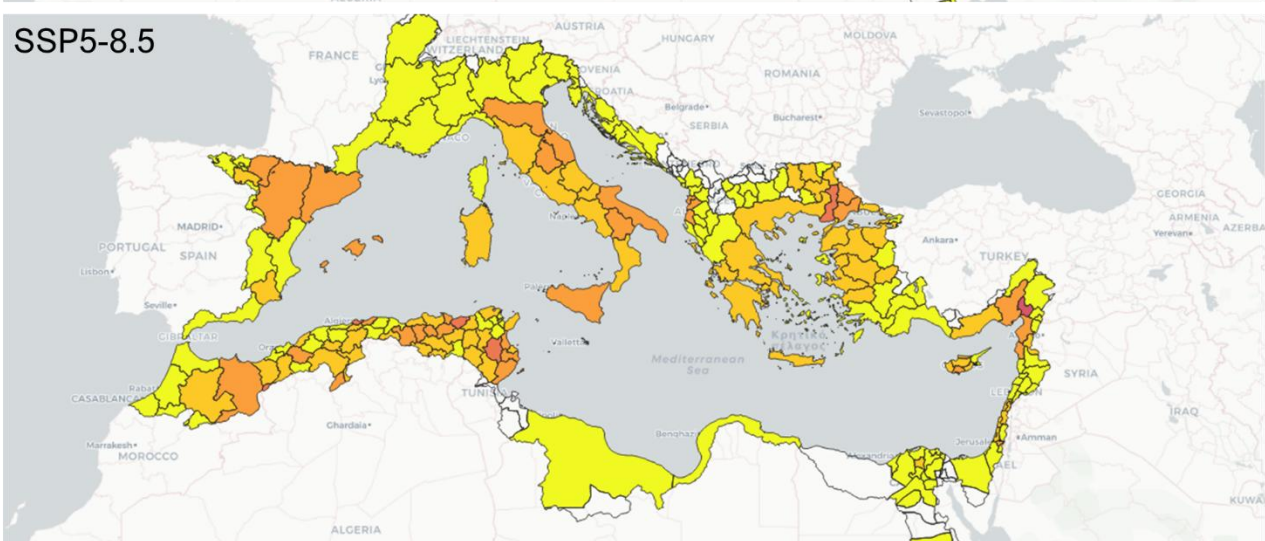
Baseline



SSP2-4.5

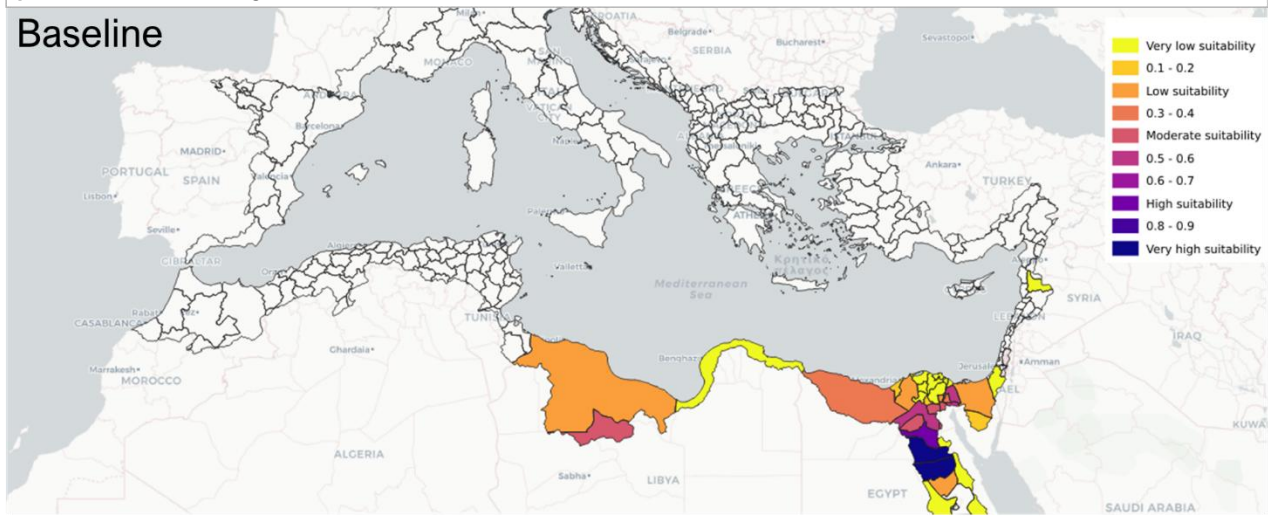


SSP5-8.5

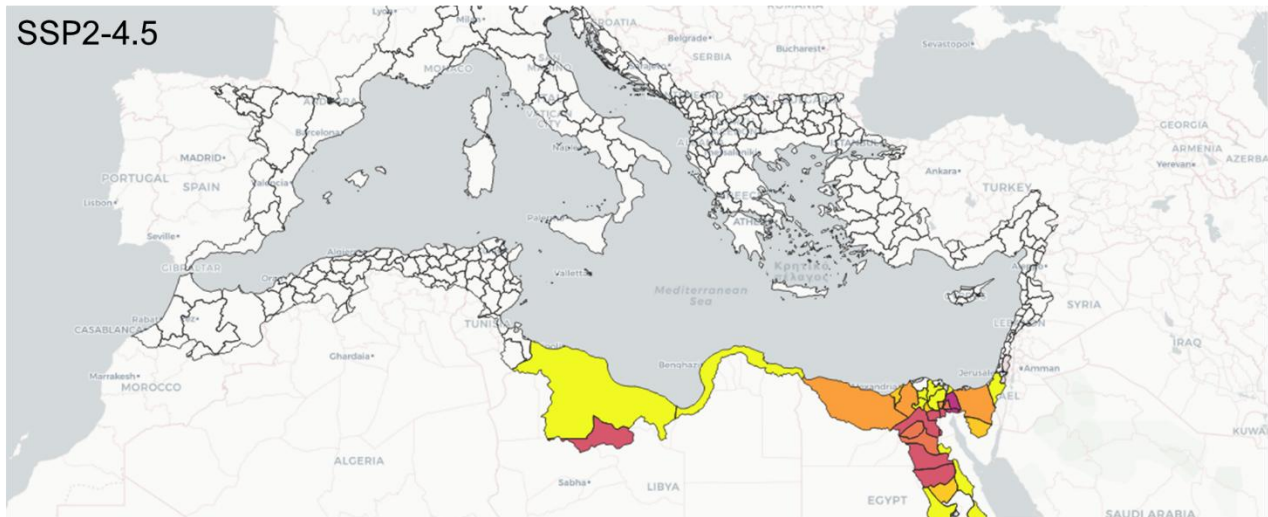


RA8: Agro-ecosystem restoration through organic and biofertilization, soil structure improvement, reduced chemical fertilizers, salinity-tolerant crops, and enhanced plant biodiversity.

Baseline



SSP2-4.5



SSP5-8.5

