Harmonized Geospatial Databases of Environmental parameters to Assess Land Degradation and Support Sustainable Cultivation of Neglected and Underutilized Species in the Mediterranean Region

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VENUS

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INTRO & AIM

The Mediterranean region is increasingly affected by water scarcity, land degradation, and desertification processes driven by unsustainable land management practices and climate change, with significant impacts on agricultural sustainability and food security. In this context, Neglected and Underutilized Species (NUS) offer a promising solution to enhance agroecosystem resilience while contributing to sustainable land management and restoration efforts, due to their adaptability to marginal and degraded environments and low input requirements.

NUS species

In this study, we develop a harmonized geospatial database of environmental and climatic parameters at the scale of the Mediterranean basin to identify areas with increasing unfavorable conditions for conventional crop productions, corresponding to higher levels of land marginality and degradation susceptibility, that might benefit from low-input NUS productive systems.

WORKFLOW

HARMONIZED ENVIRONMENTAL AND CLIMATIC DATABASES

Data Selection — ISRIC, WorldClim, Copernicus, FAO, ESA, USGS

Elaboration — Derived parameters

Data Harmonization — Coordinate system Resolution

Data Selection

We prioritized freely accessible datasets that provide regional to global coverage, and offer adequate spatial resolution for environmental assessment, including:

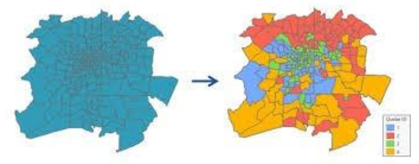
- Soil properties: ISRIC SoilGrids
- Climate data: WorldClim v2.1 (historical and CMIP6 future projections)
- Topography: TanDEM-X DEM
- Vegetation cover: USGS VIIRS NDVI
- Land cover: ESA Climate Change Initiative

Elaboration & Data Harmonization

All datasets were harmonized to a common spatial resolution (30 arc-seconds) and coordinate system (EPSG:4326). Soil properties were averaged across three depths (0-5 cm, 5-15 cm, and 15-30 cm) to obtain values for the root zone (0-30 cm). Derived parameters include: Aridity index, derived from annual precipitation and Reference Evapotranspiration, globally corrected Hargreaves-Samani method (Aschonitis et al., 2017); Mineral-Associated Organic Carbon (MAOC), estimated using the linear model of Six et al. (2024) as a function of silt and clay; and Retention Curve Index (RCI), calculated from clay content using a function developed by Aschonitis et al. (2025) based on Dexter's (2004) soil structure model.

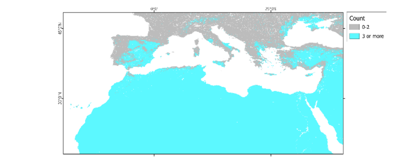
SPATIAL ZONATION TOWARDS SUITABILITY MAPS

Classification



literature thresholds
cluster analysis

Zonation



Areas where ≥5 parameters may limit crop productivity
= area selected for future NUS suitability analysis maps

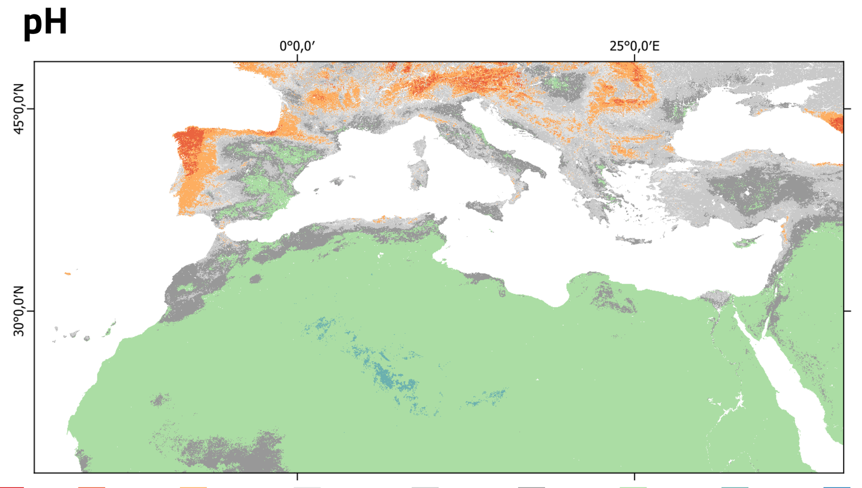
Classification & Zonation

Using internationally recognized classification standards and unsupervised clustering techniques, we performed a spatial zonation of abiotic environmental conditions by first classifying each individual parameter according to threshold-based schemes indicative of soil functional limitations or climate-induced stress.

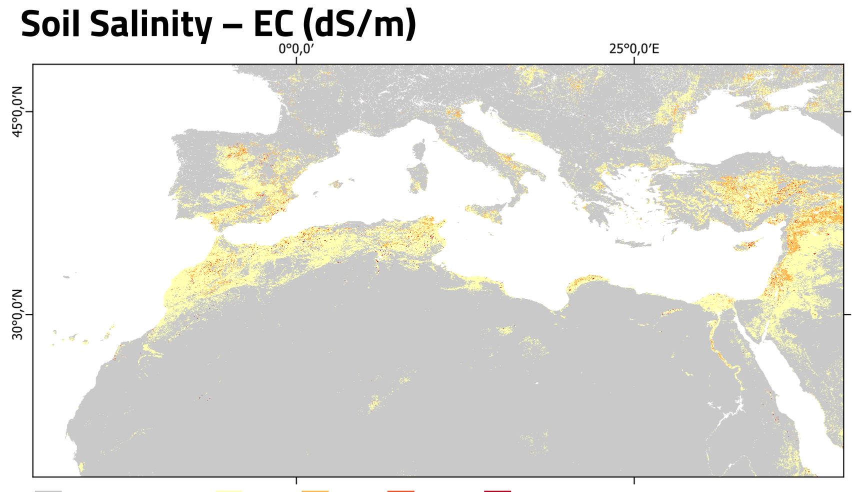
In the maps below, areas shown in grayscale represent values below the threshold, indicating conditions suitable for crop production, whereas areas displayed with colored scales correspond to values above the threshold, potentially limiting crop production. These classifications were subsequently integrated through a linear combination of the parameter-specific classes to jointly assess cumulative environmental constraints. This approach enabled the spatial identification of areas where an increasing concentration and severity of unfavorable conditions correspond to higher levels of land marginality and degradation susceptibility, and thus potential suitability for sustainable, low-input NUS cultivation across the Mediterranean basin.

CLASSIFICATION

pH

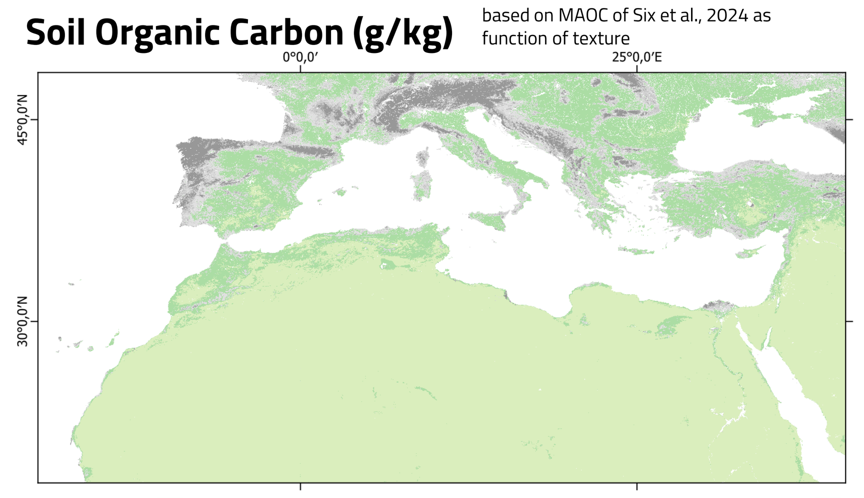


Soil Salinity – EC (dS/m)



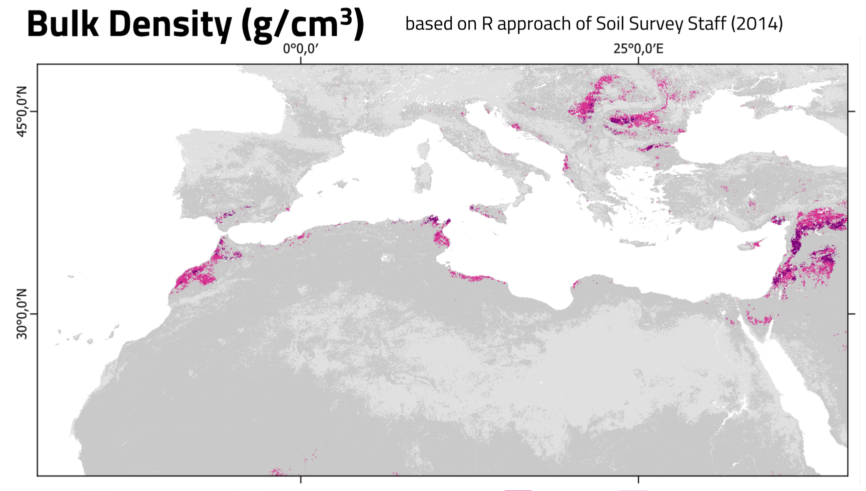
Soil Organic Carbon (g/kg)

based on MAOC of Six et al., 2024 as function of texture

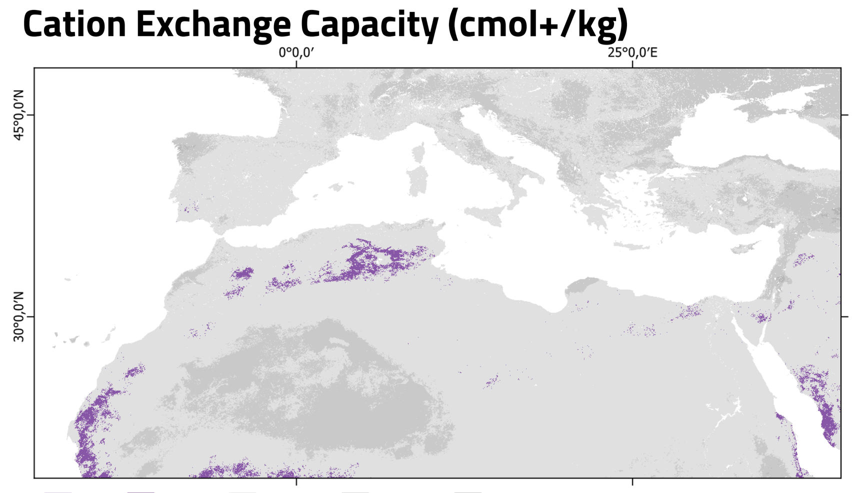


Bulk Density (g/cm³)

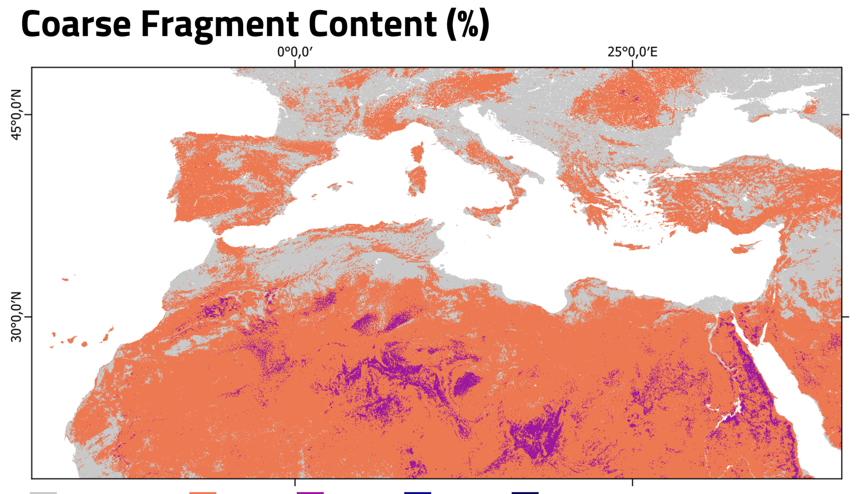
based on R approach of Soil Survey Staff (2014)



Cation Exchange Capacity (cmol+/kg)

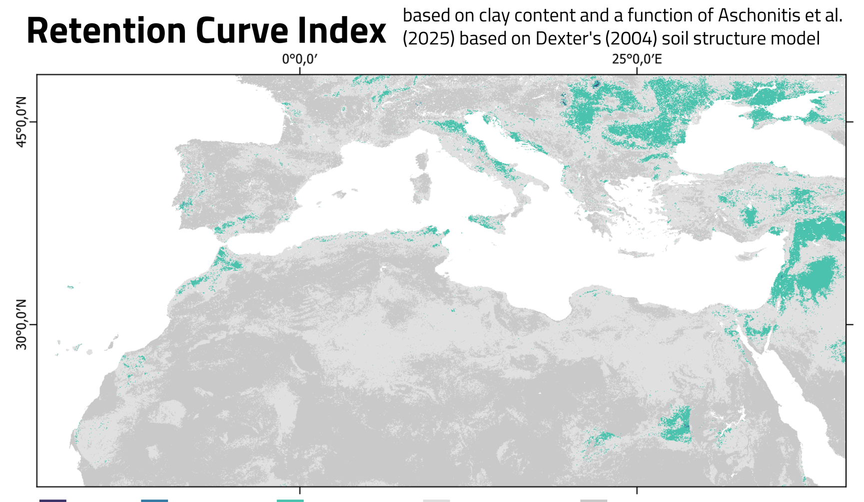


Coarse Fragment Content (%)

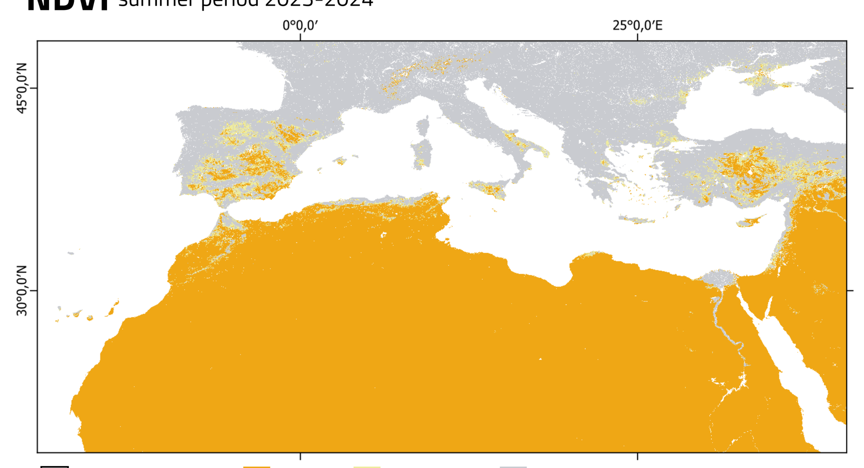


Retention Curve Index

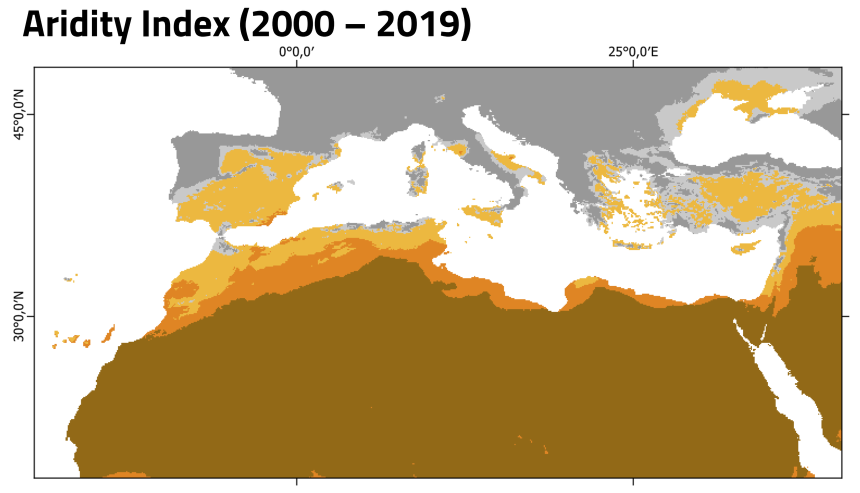
based on clay content and a function of Aschonitis et al. (2025) based on Dexter's (2004) soil structure model



NDVI summer period 2023-2024

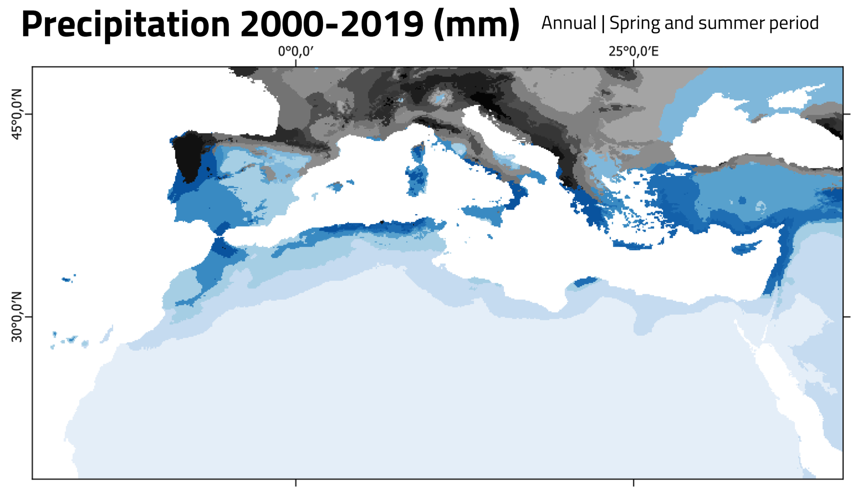


Aridity Index (2000 – 2019)

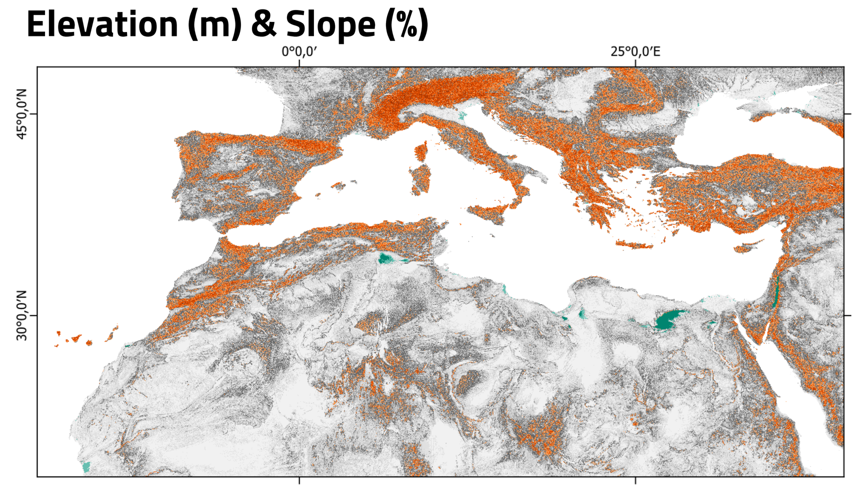


Precipitation 2000-2019 (mm)

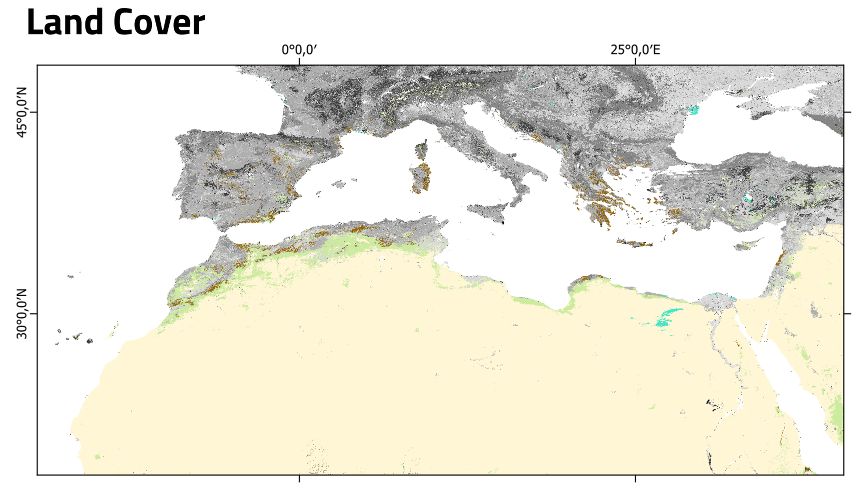
Annual | Spring and summer period



Elevation (m) & Slope (%)



Land Cover

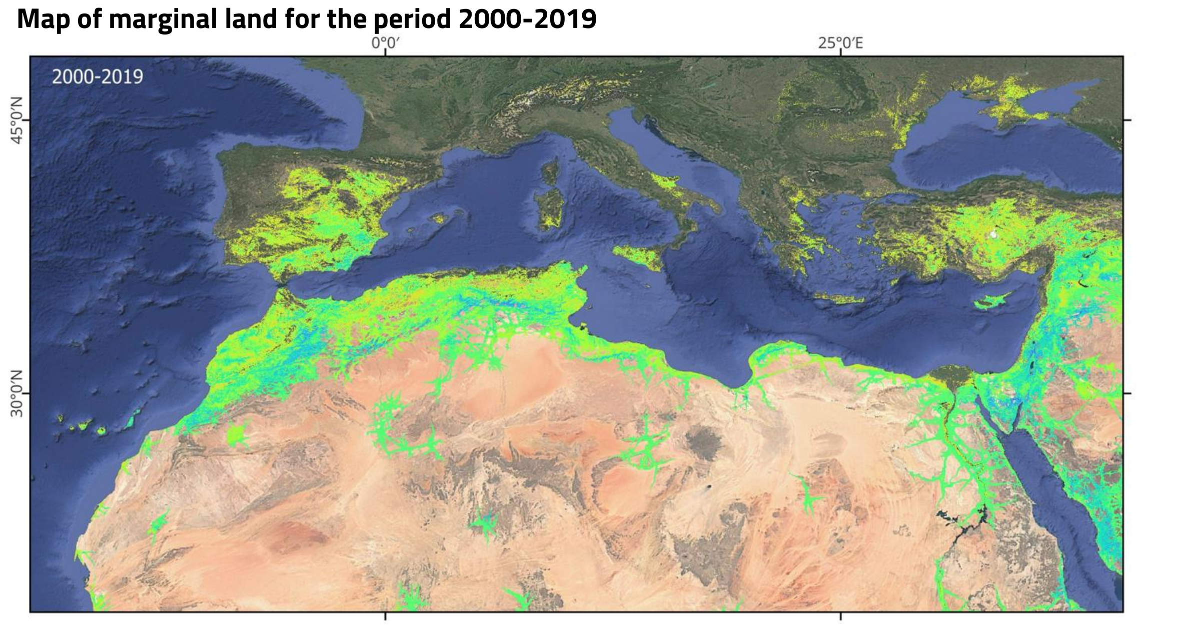


ZONATION

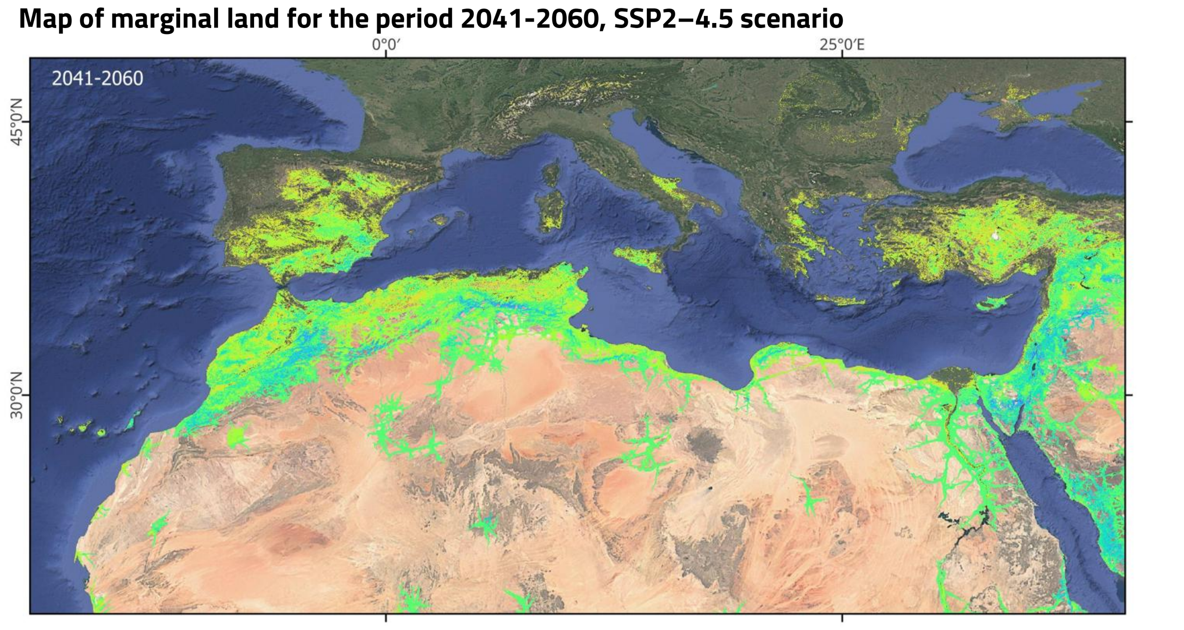
Number of parameters with bad quality characteristic that may limit crop productivity

5 6 7 8 9 10 11 12

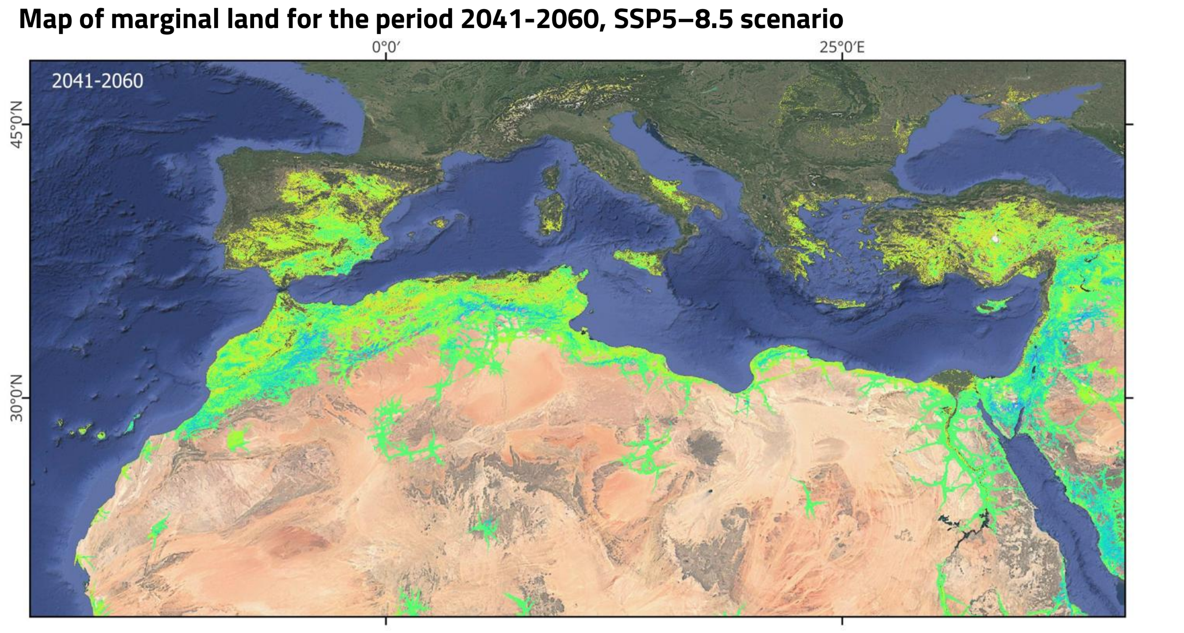
Map of marginal land for the period 2000-2019



Map of marginal land for the period 2041-2060, SSP2–4.5 scenario



Map of marginal land for the period 2041-2060, SSP5–8.5 scenario



The linear aggregation of the classified layers results in a composite index expressing increasing levels of abiotic constraints for conventional cropping systems. Higher index values indicate the co-occurrence of multiple limiting factors. A threshold of 5 unhealthy parameters is then applied to identify areas exhibiting marginal land characteristics, which, in this study, are operationally defined as areas where the combined effects of soil and climatic constraints may reduce suitability for conventional crop cultivation. To enhance the practical relevance of the analysis at the Mediterranean scale, socioeconomic considerations are integrated through the inclusion of a spatial layer representing distance from urban centers. This step allows the exclusion of areas that, despite exhibiting marginal land characteristics, are not effectively accessible and where the implementation of NUS production systems would be unlikely to be feasible.

Future steps include a NUS-specific suitability assessment, which is going to be conducted exclusively within the areas identified as marginal land characteristics. In the suitability assessment, key abiotic parameters regulating the performance of each NUS species will be selected and combined to produce a composite suitability index for each NUS species.