Bio4A
Advanced Sustainable Biofuels for Aviation

Mapping the potential Camelina yield *and* environmental sustainability *in the EU Mediterranean region for advanced biofuel production*

EUROPEAN COMMISSION JRC

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Calogero Schillaci & Arwyn Jones *EC JRC*

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Why Camelina?

JRC Unit D3, Calogero Schillaci & Arwyn Jones

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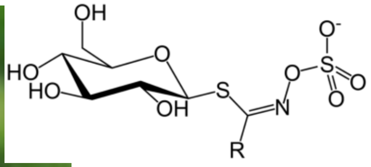
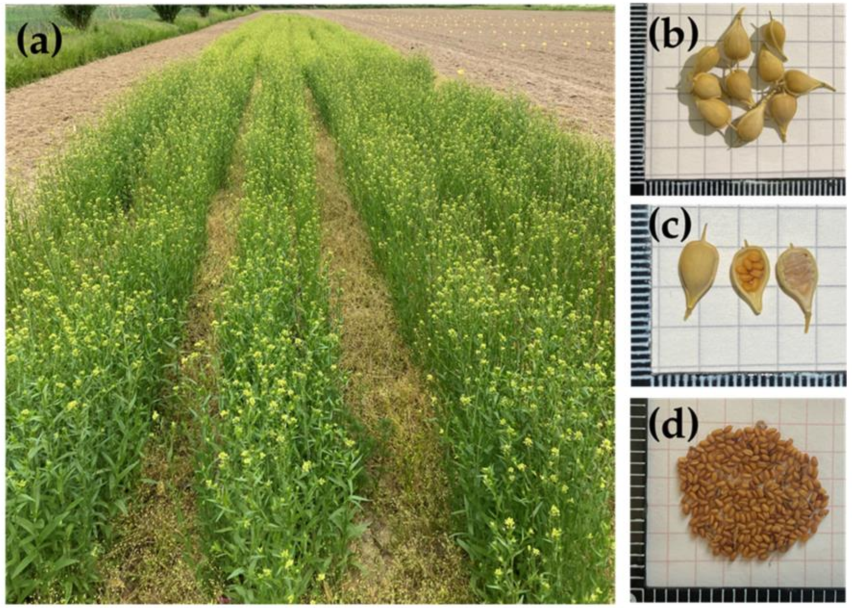


Glucosinolate general structure



Camelina sativa crop. (**a**) Flowering plants; (**b**) silique; (**c**) opened silique; (**d**) seeds. From Ghidoli et al. 2023 Plants, 12(3), 570; https://doi.org/10.3390/plants12030570

Camelina sativa (L.) Crantz is attracting the scientific community's interest for several desirable features.

Its **oil** extracted from the seeds can be used either for food and feed, or for industrial uses such as biofuel production.

From an agronomic point of view, it can grow in **marginal lands** with little inputs, and is practically resistant to the most important pathogens of Brassicaceae.

Camelina Espana company is conducting breeding work to improve this plant, also because of the low genetic variability present in this hexaploid species

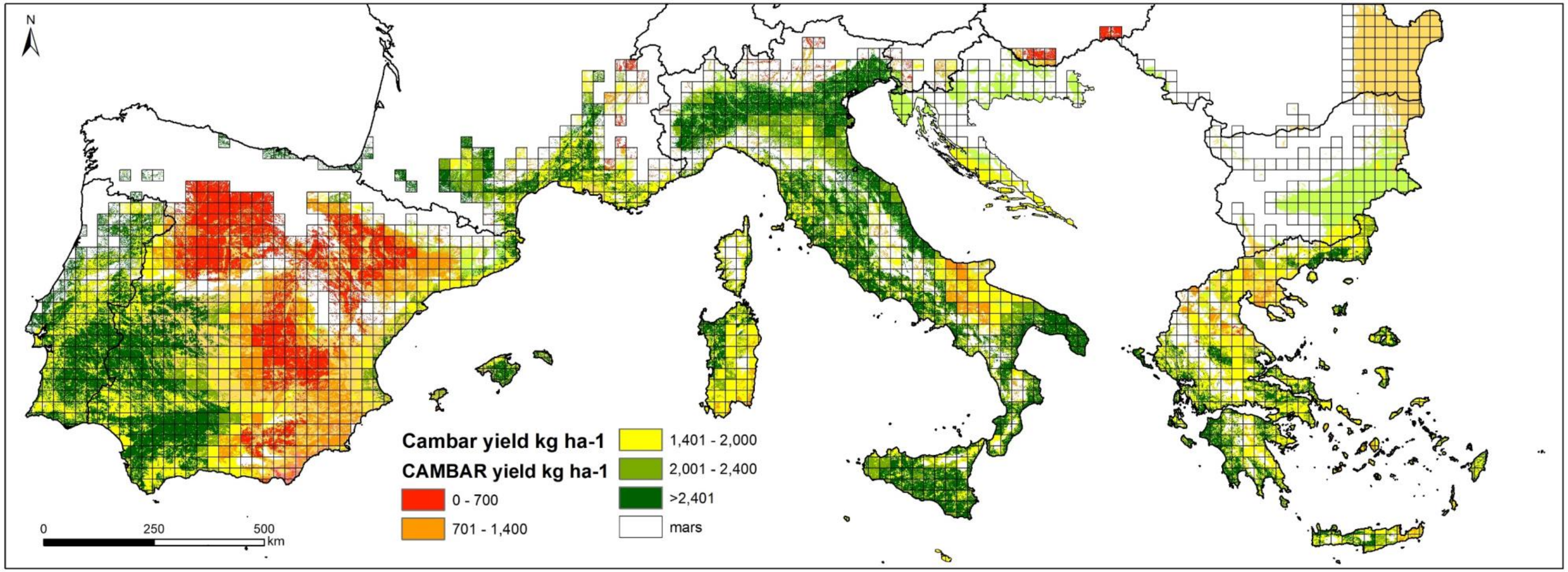
Seed quality traits improved

Seed yield increase → Seed protein content → Seed oil modulation

Camelina seed improvement performed by engineering techniques
Ghidoli et al. 2023 Plants, 12(3), 570; https://doi.org/10.3390/plants12030570

Task 2.7 and 4.6 Assessment of potential for drought-resistant oil crop in marginal land of Southern Europe and abroad (JRC)

Mapping of sustainable **potential** for advanced biofuel production on **marginal lands** in the **Mediterranean** Region



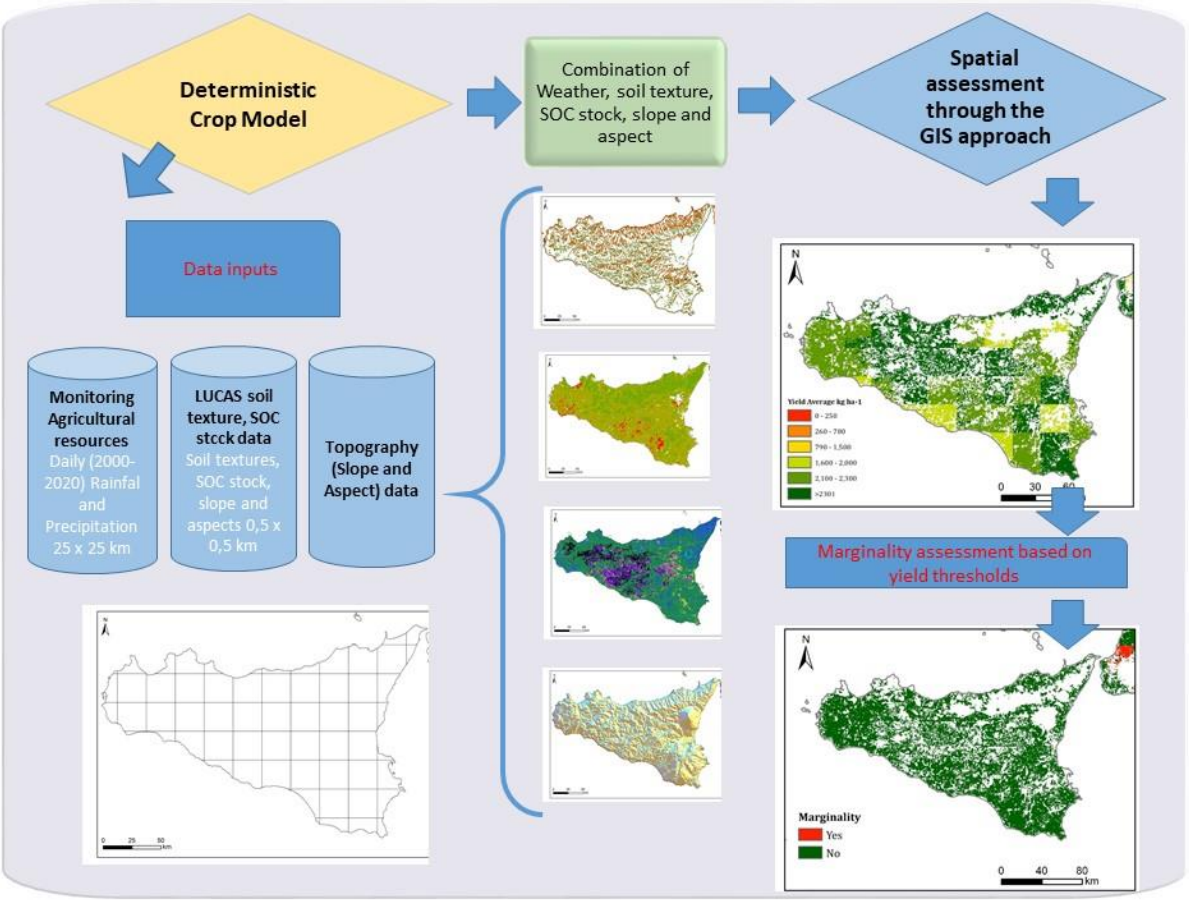
From biophysical land assessment -> Winter Camelina Yield potential (Schillaci et al., submitted manuscript)

Intro

Modelling **Camelina** yield (using a process based modelling approach ARMOSA) to assess suitable areas based on:

- Experimental field trials yield retrieved by literature searching of international peer review publications
- Weather patterns from the Monitoring Agricultural ResourceS (MARS) gridded agro-meteorological data,
- soil properties form LUCAS soil
- Topography from SRTM digital elevation model and derived Slope and Aspect.

Camelina yield potential in a Camelina-Barley rotation and soil organic carbon pools were modelled for the past 20 years.



Camelina+bee and Graphical abstract

Intro

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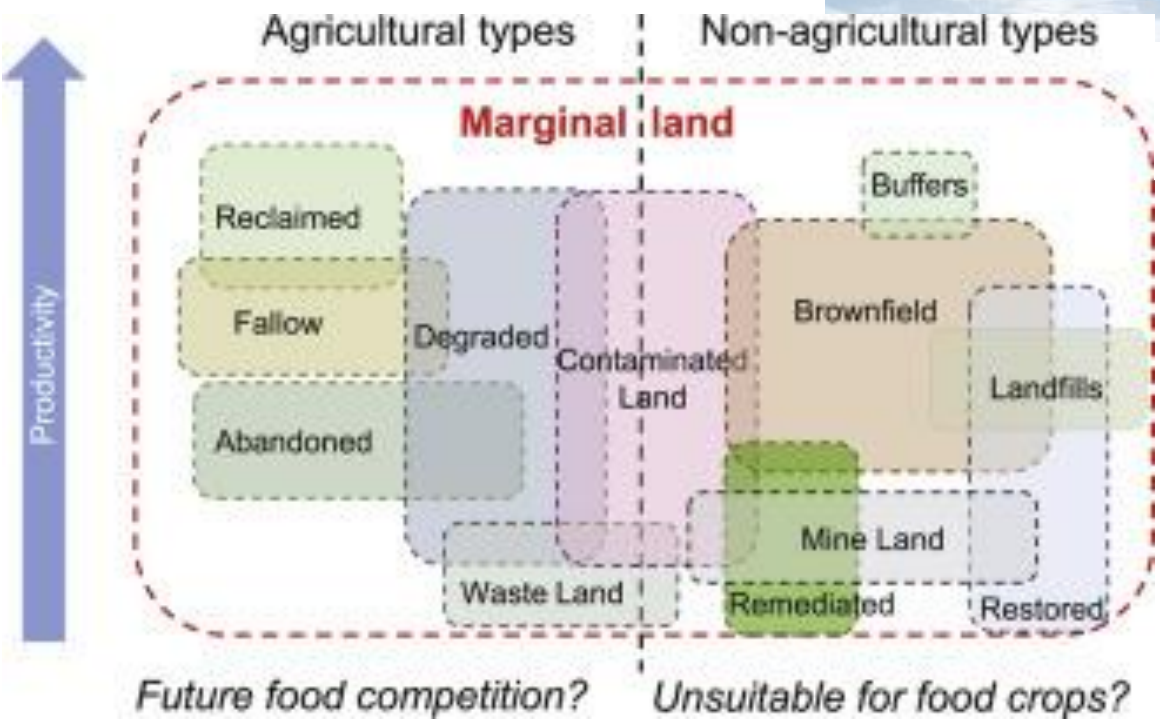


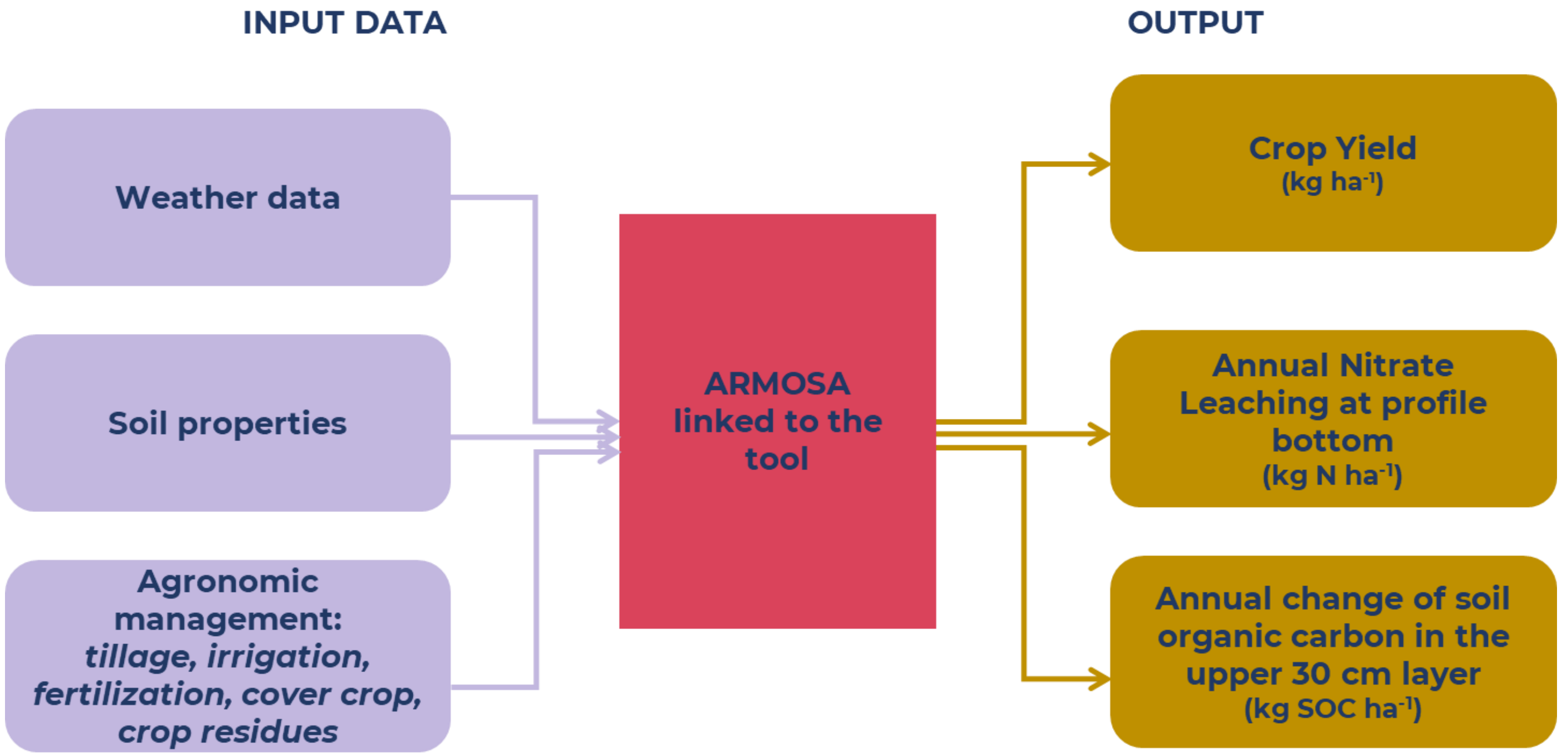
Mellor, et al.,2021 Identifying non-agricultural marginal lands as a route to sustainable bioenergy provision - A review and holistic definition, Renewable and Sustainable Energy Reviews

Energy crops are plants which are produced with the express purpose of using their biomass energetically and at the same time reduce carbon dioxide emission. Biofuels derived from lignocellulosic plant material represent an important renewable energy alternative to transportation fossil fuels

Marginal land is used in the literature to indicate unused land for agriculture such as abandoned, under used, degraded, fallow (**Shortall, 2013**). In this work, we aimed at identifying economically feasible marginal land for the viable agricultural production of Camelina (seed yield >1000 kg ha^{-1})

Materials and methods

The ARMOSA cropping system model (Perego et al., 2013; Valkama et al., 2020) simulates the agricultural production of selected crops, crop development and soil properties at a daily time-scale. It consists of four main modules: (1) crop growth and development, (2) soil water dynamics, (3) carbon and nitrogen cycling and (4) agronomic management operations.



Perego et al. 2013. Italian Journal of Agrometeorology
Groenendijk et al. 2014. Science of the total environment
Valkama et al. 2020. Geoderma

Materials and methods

ARMOSA **parameters** which were modified during the process are:

- Crop development partitioning coefficients;
- Nitrogen dilution curve specific parameters;
- CO_2 potential assimilation rate at light saturation;
- Water stress sensibility;
- Specific leaf area with respect to biomass.

The validation process was check using the same weighted RMSE utilized for the calibration process. In the same way, a test of homogeneity of variances (F based) and a t test was carried out within each site to compare the simulated against the measured means.

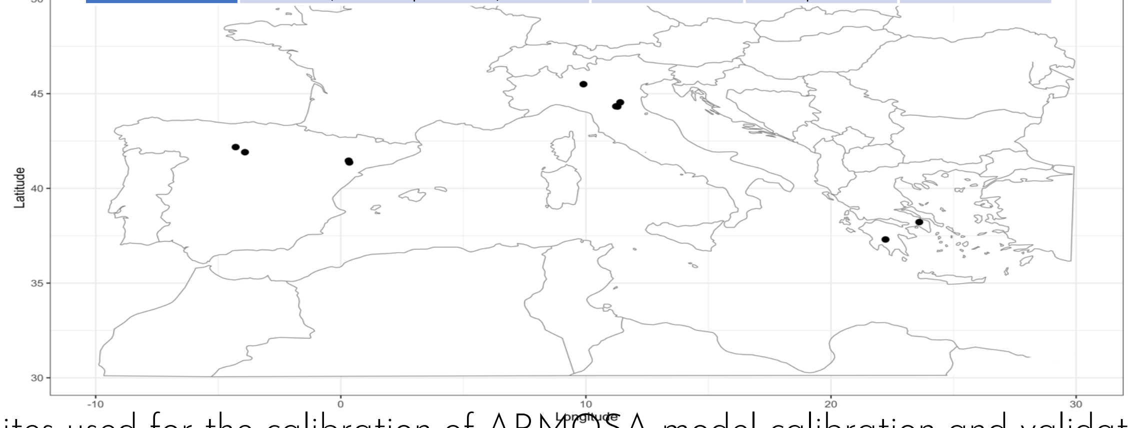
Variables
Maximum air temperature (°C),
Minimum air temperature (°C),
Mean air temperature (°C),
Mean daily wind speed at 10m (m/s),
Vapour pressure (hPa),
Sum of precipitation (mm/day),
Penman-Monteith grassland ET from a crop canopy (mm/day),
Total global radiation (KJ/m2/day)

Weather variables available in the AGRI4Cast database

Materials and methods

Calibration and validation

ID	Publication	Year of cultivation	Country	Utilization
1	(Angelopoulou et al., 2020)	2020	Greece	calibration
2	(Zanetti et al., 2020)	2017	Greece	calibration
3	(Matteo et al., 2020)	2020	Italy	calibration
4	(Masella et al., 2014)	2014	Italy	calibration
5	(Cappelli et al., 2019)	2019	Italy	calibration
6	(Royo-Esnal and Valencia-Gredilla, 2018).	2018	Spain	calibration
7	(Royo-Esnal and Valencia-Gredilla, 2018)	2017	Spain	calibration
8	(Stefanoni et al., 2020)	2020	Spain	calibration
9	(Stefanoni et al., 2020)	2020	Spain	calibration
1	(Martinez et al., 2021)	2021	Spain	validation
2	(Avola et al., 2021)	2021	Italy	validation
3	(Angelini et al., 2021)	2020	Italy	validation
4	(Tedone et al., 2022)	2020	Italy	validation
5	(Righini et al., 2019)	2019	Italy	validation
6	Camelina España Company (Bio4A partner)	2019	Spain	validation



Sites used for the calibration of ARMOSA model calibration and validation

Management

The management used for the simulation of Camelina and Barley is the following:

- sowing date: 15th October;

- harvest date: 10th June;

- one ploughing operation before sowing (specify depth, 20 cm);

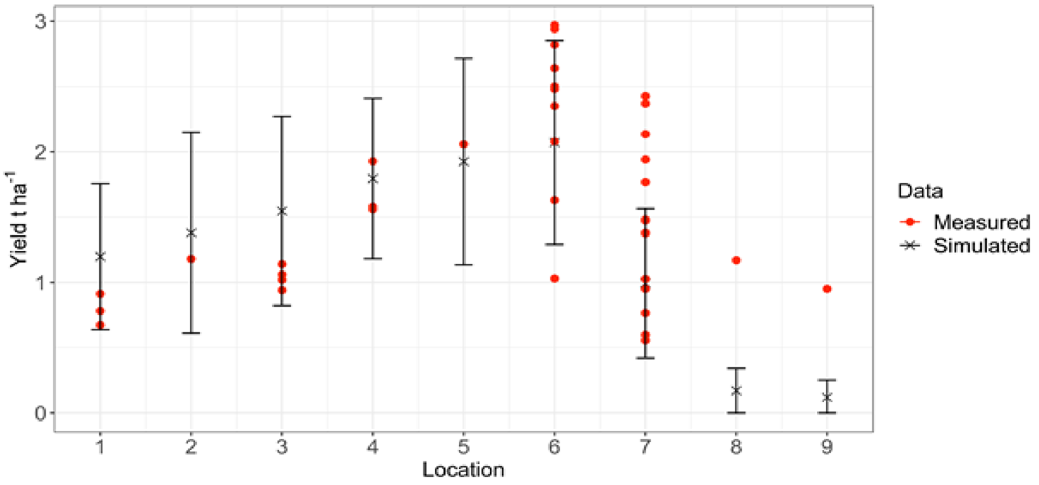
- one arrowing operation before sowing (specify depth, 10 cm);

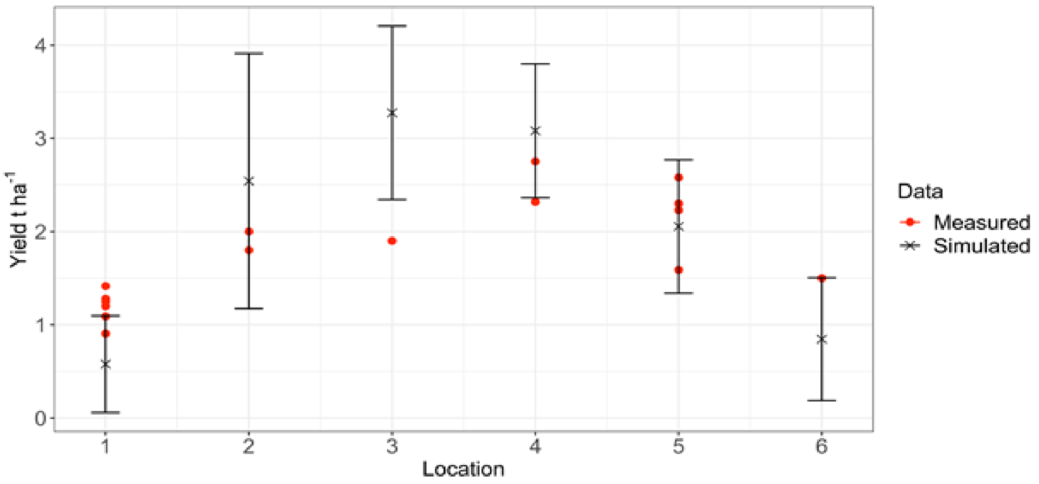
- one inorganic N fertilization at stem elongation of 50 kg ha^{-1} of nitrogen.

- crop residues incorporated into the first 20 cm of soil profile at harvest;

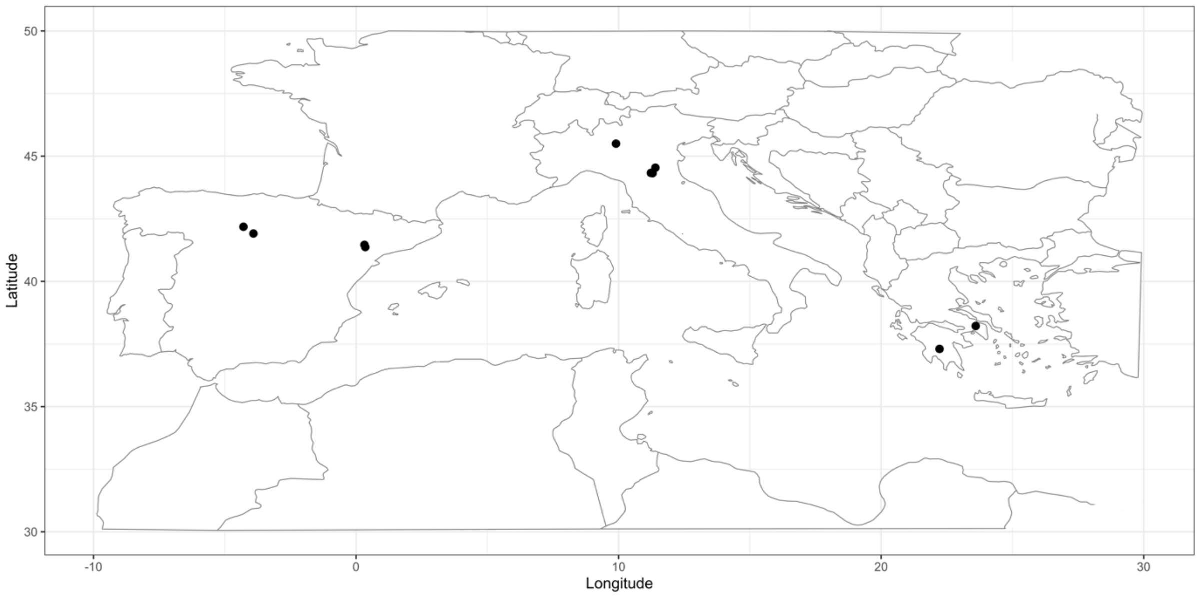
- no irrigation;

Results



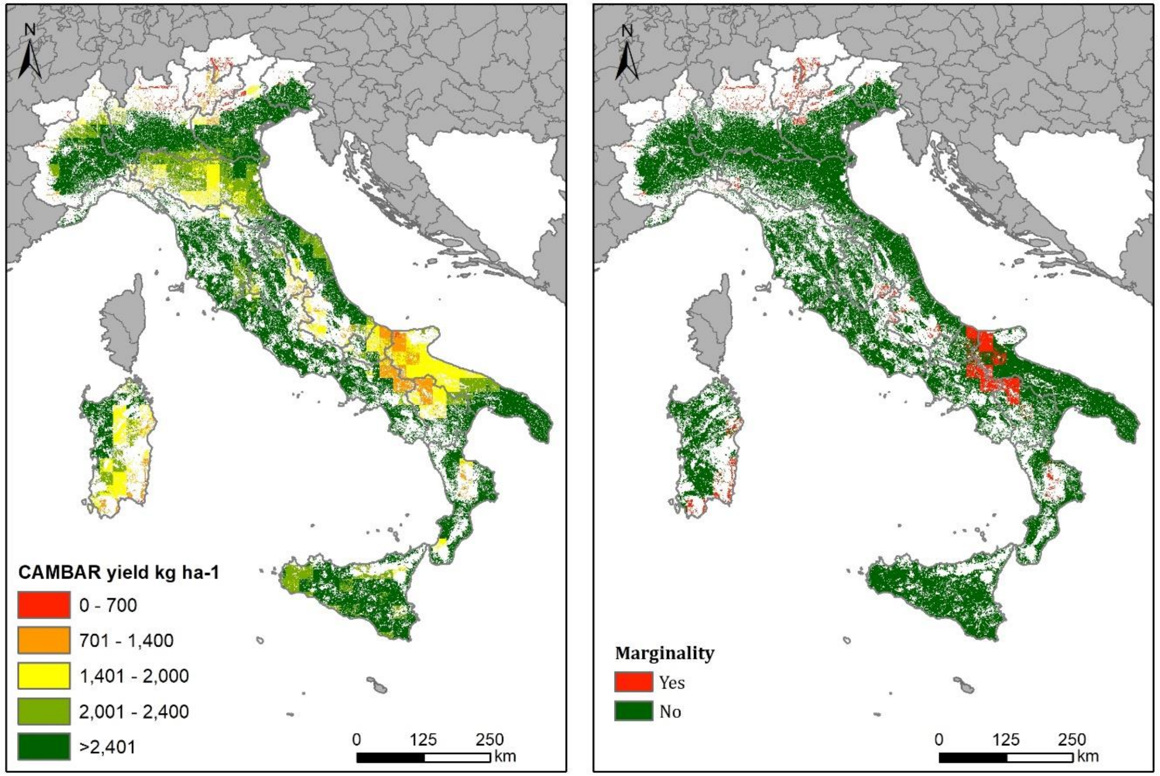


Yields data, calibration in the upper panel with 9 sites, and validation set in the lower panel with 6 sites

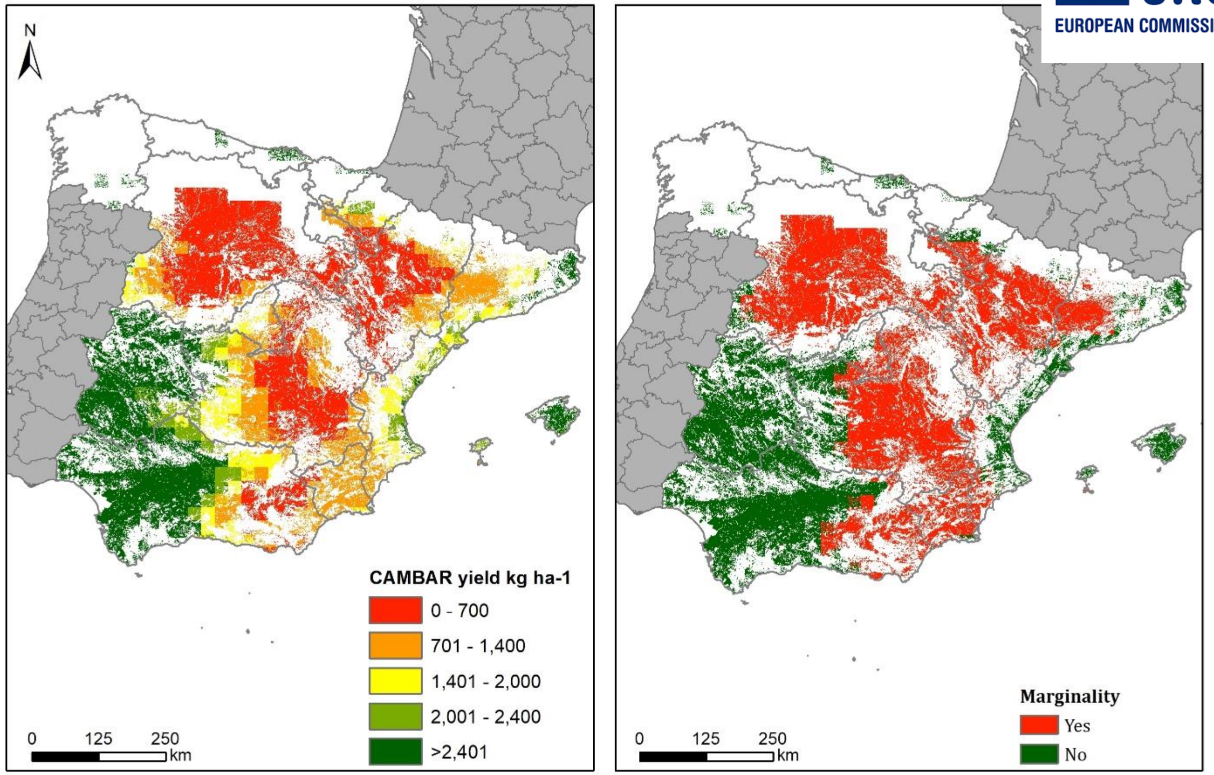


Sites used for the calibration of ARMOSA model calibration and validation sites

Results



CAM-BAR model average yield 2000-2020 kg ha^{-1} Greece. Left panel modelled yield in t ha^{-1}, right panel marginality assessment using the 1.4 t ha^{-1} threshold.



CAM-BAR model average yield 2000-2020 kg ha-1 Italy. Left panel modelled yield in t ha^{-1}, right panel marginality assessment using the 1.4 t ha^{-1} threshold.

Source Deliverable 2.6 and Schillaci et al., submitted manuscript

Results

- The **CAMBAR** scenario obtained an **average yield** of **2,468 kg ha^{-1} yr^{-1}**, with high standard deviation **(+- 641**) due to fluctuations for extreme weather patterns.

- The results of the present scenarios showed a **slight increase of SOC stock (0.1-0.15% yr^{-1})**.(SOC), CAMBAR showed an increase of **+43 kg ha^{-1} yr^{-1},(assuming Barley residue retention, no fire!!!!)** which is in line with other studies carried out in Mediterranean or continental climates under crop rotation with minimum tillage and straw retention.

- In particular, 33 NUTS 2 regions (out of 56 considered in the study) CAMBAR results in a positive annual SOC changes **(+0.90, to + 6.27 Mg ha^{-1}).**

- The Camelina cultivation area where **SOC stock changes are positive (over 310,000 km^2)**, accounting for more than 60% of the study area, is more than four times larger than the areas where it declines

Source Deliverable 2.6 and Schillaci et al., submitted manuscript

Results

The Environmental sustainability of feedstock potential production on marginal land

The Environmental sustainability of feedstock production was assessed through the application of a Convergence of Evidences (CoE) approach that has been applied to the main soil and plant threats. For the details about the products used, a reference after the indicator proposed is provided after the indicator in the following list.

- Soil Erosion (Panagos et al., 2015)
- Soil Compaction (Gergely Tóth, Luca Montanarella, 2015)
- Nitrogen inputs (de Vries et al., 2021)
- Soil biodiversity (Orgiazzi et al., 2016)
- Aridity index (Zomer et al., 2022)

Results

Environmental sustainability data inputs

Scores for class	Soil Erosion	Soil compaction Mg m-3 (taken as a proxy from Soil Bulk Density from SoilGrid 0-30 cm)	Nitrogen inputs kg ha-1 yr-1	Soil biodiversity (Potential threat to biological functions)	Aridity index AI ET0Annual V3 Robert J. Zomer, Jianchu Xu & Antonio Trabucco 2022
5	<0.5	<1.3	<50	High	>0.65
4	0.5-1	1.3-1.4	50-80	Moderate -high	0.5–0.65
3	1-3	1.4-1.5	80-120	Moderate	0.2–0.5
2	3-5	1.5-1.5	120-150	Low Moderate	0.03–0.2
1	5-10	>1.6	>150	Low	<0.03

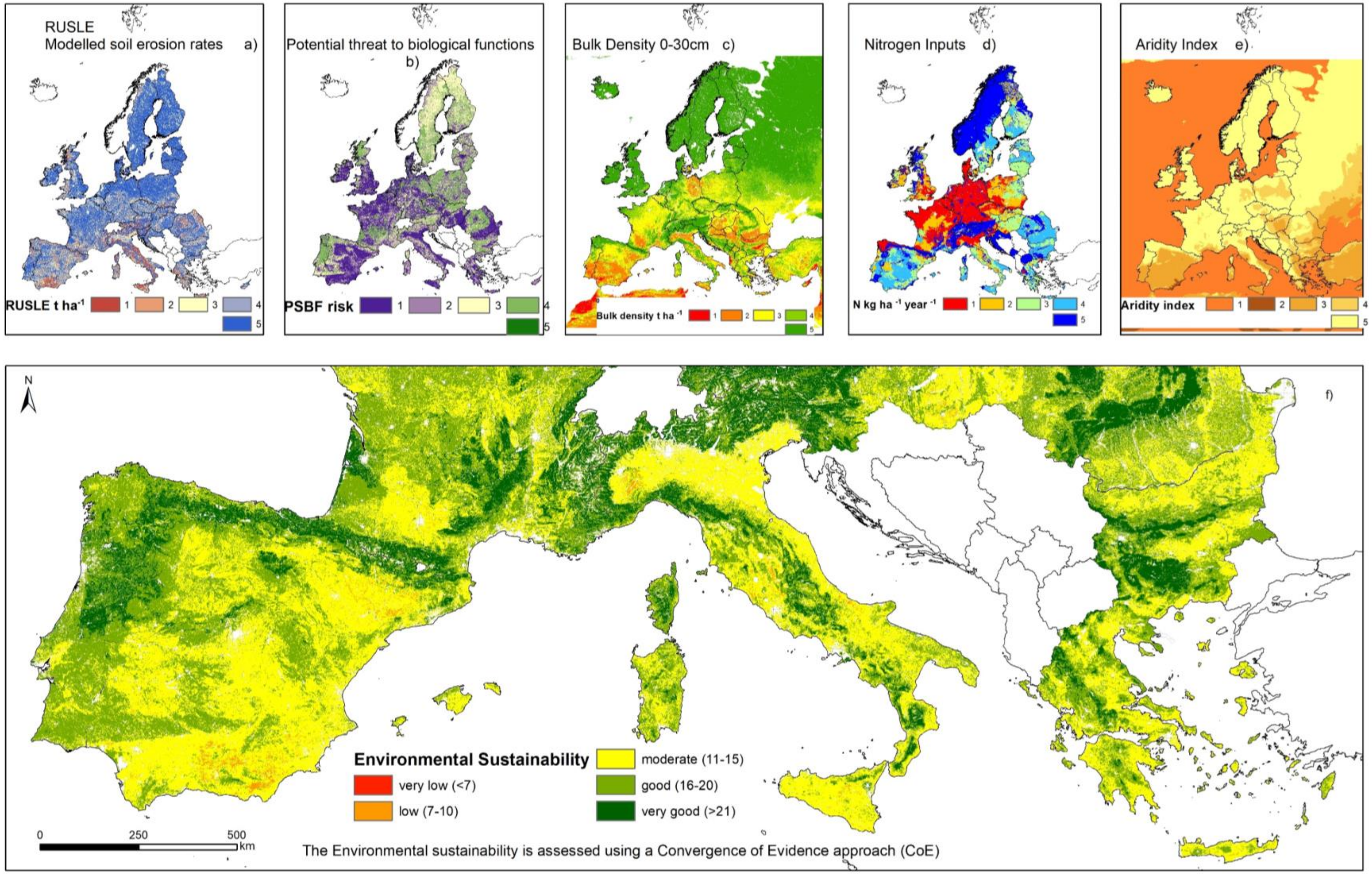
Environmental sustainability (ES) Classes related to scores
Very high (20-25)
High (15-20)
Moderate (10-15)
Low (5-10)
Very low (1-5)

CAMBAR predicted Camelina Yield
Very high (>2500 kg ha^{-1})
High (2000-2500 kg ha^{-1})
Moderate (1500-2000 kg ha^{-1})
Low (750-1500 kg ha^{-1})
Very low (<750 kg ha^{-1})

Each indicator is reclassified in potential risk classes of ES o understand the significance of these results, modelled yield an environmental sustainability have been reclassified using the **Likert scale (1=low, 2=moderate, 3=adequate, 4=high and 5=ver high) as it was adopted in (Pe'er et al., 2019).**

Results

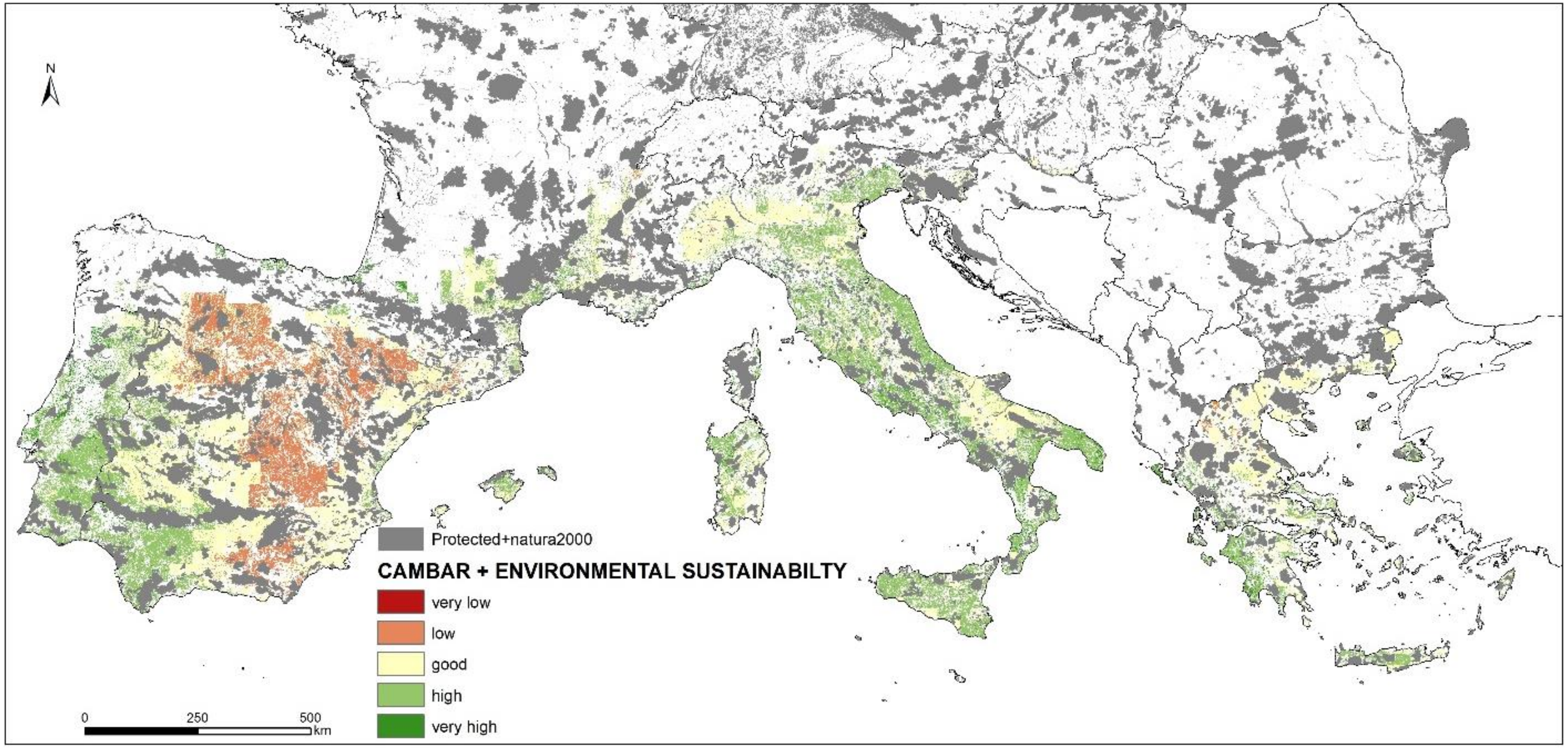
Environmental sustainability via Convergence of Evidences



- The higher the number of cases with a potential increased risk of degradation, the lower the environmental sustainability.
- Very few spots report in northern Italy and southern Spain low ES, the dominant class is the moderate condition which is almost the half of the entire area under study.

Results

Environmental sustainability and CAMBAR potential Camelina yield



Overlay of CAMBAR average yield modeled (2000-2020) and the ENIVIRONMENTAL SUSTAINABILITY.

PotY_EnvS = Σ [(CAMBARi) + (ENV-SUSTAINABILITYi)]

Protected + Natura 2000 areas masked.

Conclusions

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The work performed in the Task 2.7 and 4.6 Assessment of potential for drought-resistant oil crop in marginal land of Southern Europe and abroad (JRC) and selected Key Performance Indicators are work in progress

- **Marginality** needs to be flagged as **potentially contaminated** land (where all crop production must serve as energy feedstock) and **geographical marginality or land** not suitable due to biophysical constraints or bad road connections in which the crop production can be used alternatively for food and feedstock.
- The **spatial distribution of suitable land** can affect **quantity** of CAMELINA production and **quality** of the environment and related ecosystems services (SOC stock).
- We must focus on territories whose limitations can be removed with technical means (agronomy and nature based solutions)
- Energy crop can help in recovering degraded lands, maintaining soil cover the soil throughout the year, and mitigating climate change by improved soil management.

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Project Partners

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