Camelina oil for sustainable aviation fuel production: A scenario assessment for recovering European degraded soils

ALMA MATER STUDIORUM
UNIVERSITÀ DI BOLOGNA

European Commission

Maria Giovanna Sessa
DISTAL – University of Bologna

Marco Buffi
Joint Research Centre – European Commission

European legislative framework

EU Green Deal (2019)

→ Climate neutrality by 2050

Fit for 55 (2021)

→-55% GHG emissions by 2030

RED III (2023)

→42.5% renewable energy

→14.5% GHG reduction

→5.5% advanced biofuels & RNBOs

CAP 2023-2027

→Incentives for sustainable farming

→Prevention of land degradation

Carbon farming (Farm to Fork)

→Promotion of soil carbon sequestration

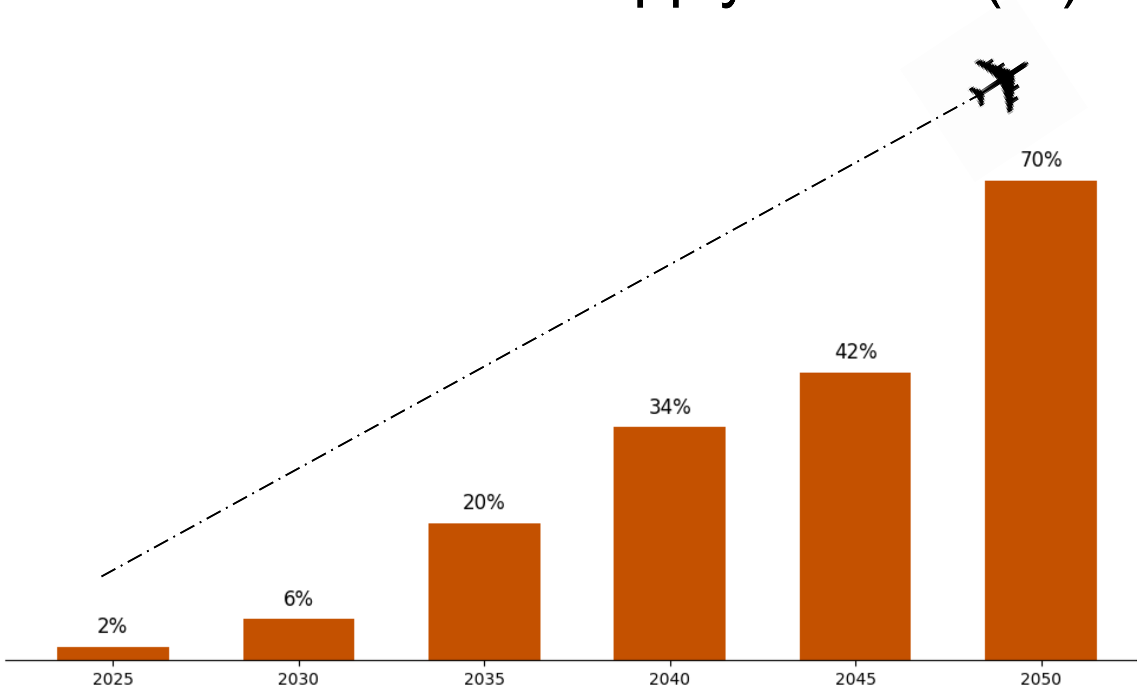
EU Soil Strategy

→ Sustainable soil management & biodiversity

Alternative fuels for hard-to-abate transport modes

ReFuelEU Aviation

Minimum share of supply of SAF (%)



- **Mandatory** for all EU departing flights
- Target: **70% by 2050**
- SAF includes: a) synthetic fuels b) **biofuels** c) recycled carbon fuels
- Eligible aviation fuels are: a) **advanced biofuels** b) biofuels produced from the feedstock listed in Part B of Annex IX of RED c) **biofuels that are not produced from food and feed crops and which comply with the sustainability criteria and lifecycle emissions savings**

What is an advanced biofuel?

- According to the Renewable Energy Directive (RED II, 2018/2001), advanced biofuels are biofuels produced from the **feedstock listed in Part A of Annex IX.**
- The list includes many types of lignocellulosic material, **non-food crops from severely degraded lands & intermediate crops (only for aviation)**, animal manure, sewage sludge, and algae, as well as selected other wastes and residues.
- Moreover, the contribution of biofuels produced from **the feedstocks defined in Annex IX, part B**, including **Used Cooking Oil and animal fats.**

1) Degraded lands

”Land that for a significant period of time has either been significantly salinized, presented significantly low organic matter content and/or has been severely eroded” (RED II).

a) < 3.4% SOM + erosion (>1.5 t/ha/yr)
b) 4 dS/m salinity
(Guidehouse Netherlands, 2024)

2) Intermediate crops

Intermediate crops are not explicitly defined in RED II, leading to uncertainty in their eligibility and certification.

Camelina sativa (L. Crantz)

Annual oilseed crop: *Brassicaceae*

Seed production: 1.5-3.0 t DM ha^{-1}

Oil content: 26-49%

Protein content: 24-32%

Cycle length: 1200 GDD, 110-220 d

Winter and spring biotypes

CASE STUDY

Energy Policy 210 (2026) 115043

Contents lists available at ScienceDirect

Energy Policy

journal homepage: www.elsevier.com/locate/enpol

Camelina oil for sustainable aviation fuel production: A scenario assessment for recovering European degraded soils

M. Buffi [a,*], S. Bergonzoli [b], E. Medina-Martos [c], O. Hurtig [a], D. Chiaramonti [d], F. Tozzi [e], A. Monti [f], M.G. Sessa [f], C. Thiel [a], C. Schillaci [a]

[a] *European Commission, Joint Research Centre (JRC), Ispra, Italy*
[b] *Consiglio per la Ricerca in Agricoltura e l'Analisi dell'Economia Agraria CREA), Centro di Ricerca Ingegneria e Trasformazioni Agroalimentari, Monterotondo, Rome, Italy*
[c] *National Renewable Energy Centre (CENER), Ciudad de la Innovación, Sarriguren, Navarra, Spain*
[d] *Energy Department—DENERG, Politecnico di Torino, Turin, Italy*
[e] *Renewable Energy COnsortium for R&D (RE-CORD), Florence, Italy*
[f] *Department of Agricultural and Food Science (DISTAL), University of Bologna, Bologna, Italy*

AIM OF THE STUDY

Assessment of camelina-based SAF produced via HEFA on degraded land

EU GHG emission accounting methodology (RED)

- LCA based approach adapted to EU policy requirements.
- Simplified (Well-to-Wheel), attributional methodology with minor exceptions.
- RED framework targets GHG emissions as grams of CO_2 equivalent (**gCO_2eq**). The climate-impact calculation accounts for emissions of CO_2, CH_4, and N_2O.
- No emissions from combustion of biogenic carbon, considered Carbon neutral: the CO_2 is reabsorbed by biomass growth.
- All cultivation emissions are considered, including emissions from the use of synthetic or organic fertilizers.
- Emissions from carbon stock changes caused by Land-Use Changes are annualized over a period of 20 years.
- Infrastructure and end-of-life emissions (including waste disposal) are not included.

ALMA MATER STUDIORUM
UNIVERSITÀ DI BOLOGNA

Full value chain evaluation approach

Feedstock production	Feedstock logistics	Conversion	Distribution	End use
• Agricultural crops • Agricultural residues • Energy crops • Forest residues • Wastes	Harvesting and Collection Storage Preprocessing Transportation	**Biochemical conversion** -Acid hydrolysis -Pretreatment and enzymatic hydrolysis -Fermentation **Thermochemical Conversion** -Gasification -Pyrolysis -Hydrothermal depolymerisation **Chemical** - Transesterification	**Transporation**- Truck, Rail, Pipeline **Storage**- Blending terminals **Dispensing**- Dedicated pumps, Blending pumps	• Light duty vehicles • Light duty trucks • Heavy duty trucks • Off road vehicles • Locomotives • Airplanes • Jets • Boats • Ships etc.

Sources: eai.in/ref/ae/bio/biz/biomass; doi.org/10.3389/fenrg.2023.1222787

Methodology for GHG emissions calculation

$$E = e_{ec} + e_i + e_p + e_{td} + e_u - e_{sca} - e_{ccs} - e_{ccr}$$

GHG emissions from:	GHG emissions savings through:
e_{ec} = extraction and cultivation of raw materials e_i = carbon stock changes caused by land-use change e_p = processing e_{td} = transport and distribution e_u = fuel combustion	e_{sca} = soil carbon accumulation via improved farming practices e_{ccs} = capture and geological storage e_{ccr} = capture and replacement of CO2

EU GHG emission accounting methodology for biofuels

- GHG emissions calculation are available in the **Annex V & VI (part C) in RED II** (developed by JRC).
- The calculation model considers also savings and credits generated by some cultivation practices and/or initial feedstock (e.g. use of manure).
- Operators can use default values listed in **Annex V and VI** (only if Land Use change emissions = 0) to simplify calculation... or declare their actual values.
- Default values include a "safety" factor of 20-40% increase in emissions from processing compared to typical values.
- Disaggregated default values are specified:
  - cultivation (with or without N_2O); processing; transport and distribution, total emissions;
  - a combination of default for some production steps + actual for others can be used.

GHG reduction and carbon farming (RED)

- RED II already provides a bonus of **29 g CO2eq/MJ** for those biofuels cultivated in "restored" severely degraded land (Annex VI part C point (8)).
- RED II Implementing Regulation (EU) 2022/996 introduces "rules to verify sustainability and greenhouse gas emissions saving criteria and low indirect land-use change-risk criteria" and definitions on unused, abandoned, and degraded lands that might be suitable for biomass production.
- RED II Implementing Regulation (EU) 2022/996 introduces also emission savings from soil carbon accumulation via improved agricultural management (e_{sca}). This option allows to receive a GHG emissions credit for producing biofuels in the same lands where such practices are performed, with the scope of increasing soil organic carbon (max **25 g CO2eq/MJ** for the entire period applying e_{sca} practices).

GHG emissions savings (RED)

In the RED II, the functional unit of the fuel is **1 MJ of fuel** and has to be compared with the emission factor of the fossil fuel comparator (**94 g CO2eq/MJ**).

$$\text{GHG saving potential}[\%] = \frac{GHG\ emission\ fossil\ reference - GHG\ emission\ |biofuel}{GHG\ emission\ fossil\ reference} * 100$$

ALMA MATER STUDIORUM
UNIVERSITÀ DI BOLOGNA

Camelina as a way to restore degraded land

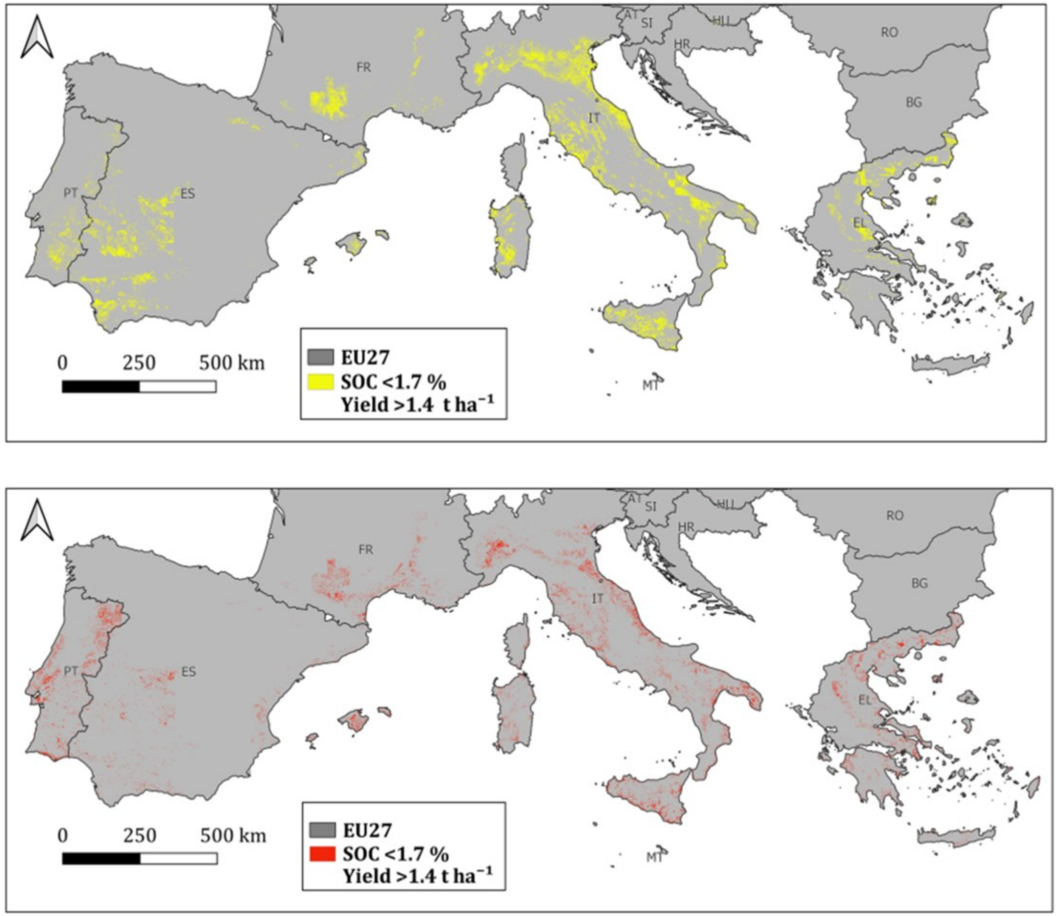


Figure 1. Geographic position of the areas indicated by CAM-BAR applicability where camelina seeds yield above 1.4 t/ha in lands with SOC ≤ 1.7% classified under CLC 211 (yellow-colored distribution) and 241,242,243 (without agroforestry) (red-colored distribution).

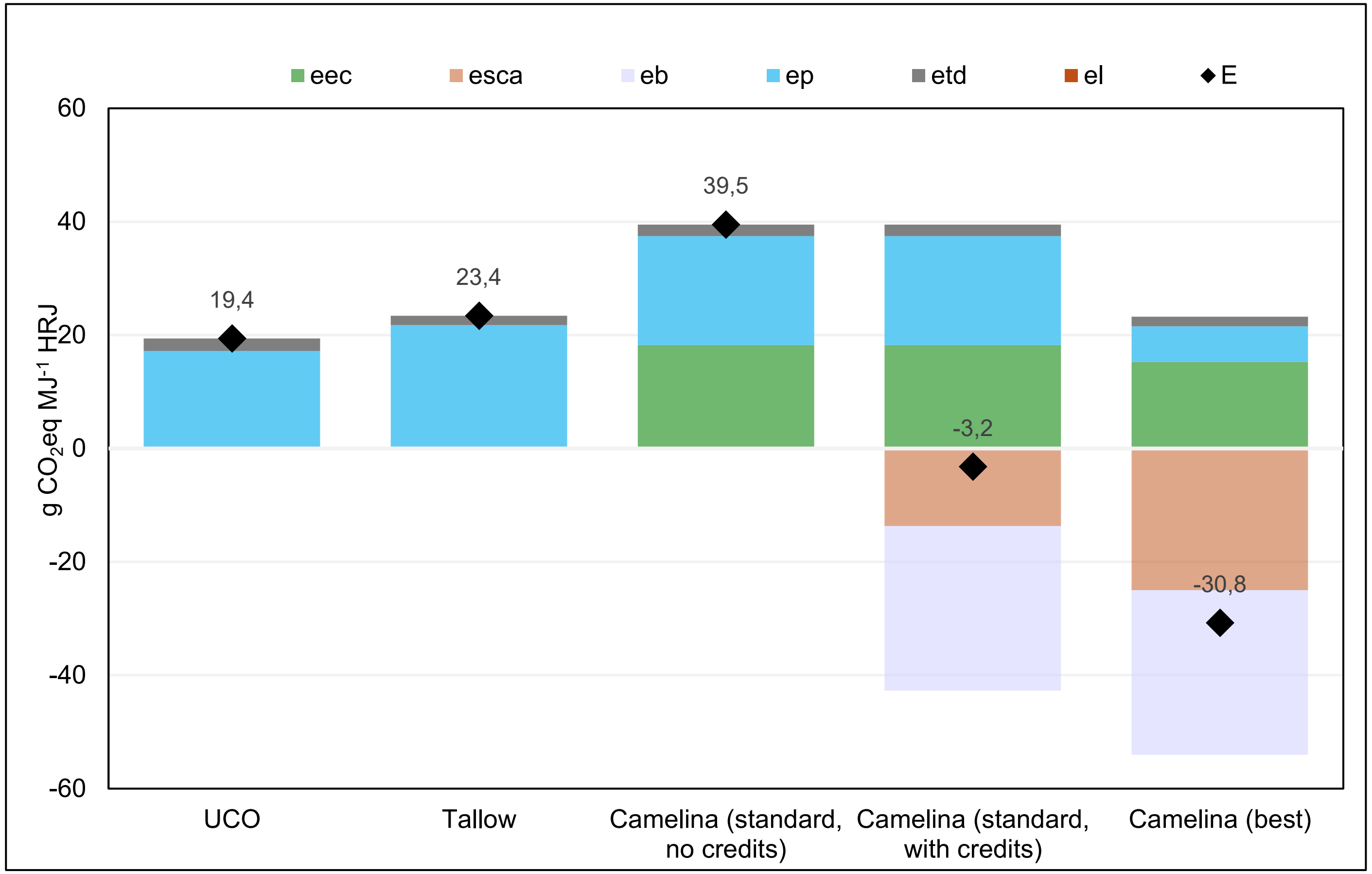


Figure 2. Carbon intensity of different feedstocks: Used Cooking Oil (UCO), Tallow, and Camelina under three scenarios: standard, with credits or not, and best case.

ALMA MATER STUDIORUM
UNIVERSITÀ DI BOLOGNA

Conclusion

Camelina can be a sustainable feedstock for SAF production

- Suitable for degraded lands (low-iLUC).
- Tailored for Mediterranean regions.
- CI up to -30.8 gCO2eq/MJ
- Benefits from carbon farming and land restoration.

Future perspective

- Extend the assessment to other oilseed crops for SAF production.
- Test *Brassica carinata* (A. Braun) as an intermediate crop under field conditions.
- Evaluate GHG emissions, yield and sustainability performance.
- Validate its role as a low-iLUC feedstock in the Mediterranean cropping systems.

EUBCE
34th European Biomass Conference & Exhibition

ALMA MATER STUDIORUM
UNIVERSITÀ DI BOLOGNA

Credits:

Maria Giovanna Sessa

DISTAL – University of Bologna

mariagiovanna.sessa2@unibo.it