GHG EMISSIONS IMPACT OF SUSTAINABLE AVIATION FUELS PRODUCED FROM THE HYDROPROCESSING OF OILSEED CROPS

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BACKGROUND

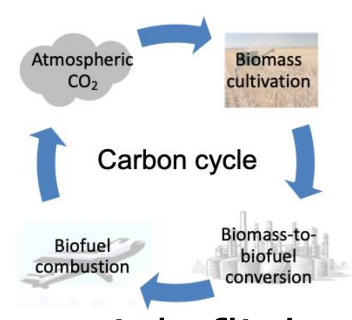
Emissions from aviation

- 2.1% of global greenhouse gas emissions (GHG) in 2019.
- International aviation: 1.3%

ICAO (International Civil Aviation Organization)

- Tracks emissions from international civil aviation
- Aspirational goals
  - Medium-term: Carbon neutral growth from 2020
  - Long-term: Reduce net emissions to 50% of what they were in 2005 by 2050

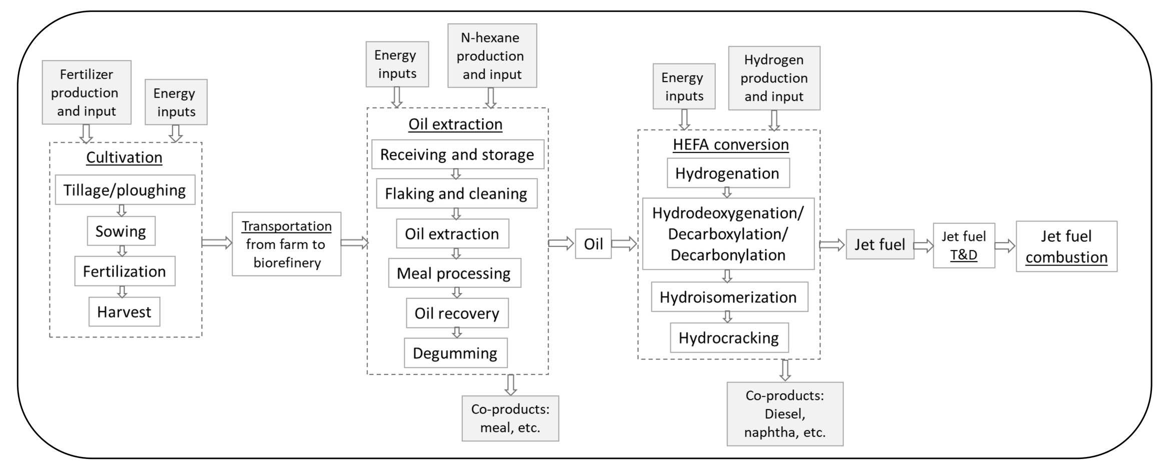
Basket of measures



- Sustainable aviation fuels (SAF)
  - Drop-in: Usable with existing infrastructure in a mixture with kerosene up to 50%
  - 40 million L of SAF was used by commercial flights globally in 2019, less than 1% of total use (ATAG 2020)
  - *Hydroprocessed esters and fatty acids (HEFA) fuels*: Hydroprocessing produces paraffin-rich liquids from the triglyceride molecules in the lipid feedstocks such as plant oils, waste oils and algal oils
- Market-based measures
  - e.g. CORSIA (Carbon Offsetting and Reduction Scheme for International Aviation)
  - *Using CORSIA Eligible Fuels (CEF)*: 10% net GHG reductions should be achieved, and biomass for these fuels should not be obtained from land with high carbon stock

Life Cycle Assessment (LCA)

- Methodology used to understand environmental impacts associated with a product, process or service
- Functional Unit: gCO_2e/MJ jet fuel
- System Boundary: Well-to-wake



System boundary for SAF

- Baseline: ICAO Baseline for jet fuel is 89 gCO_2e/MJ jet
- Co-products: Emissions can be distributed/allocated among co-products using various allocation methods or displacement
- Attributional LCA: Input/output analysis
- Stochasticity: Probability density functions were assigned into key parameters for Monte Carlo analysis, using available data from the literature and industry sources.
- Direct land use change (DLUC): Conversion of land from previous uses to agricultural production (e.g., to grow biofuel feedstock).
  - IPCC's Tier 1 procedure: GHG emissions from DLUC estimated as differences in land carbon stocks before and after the land conversion

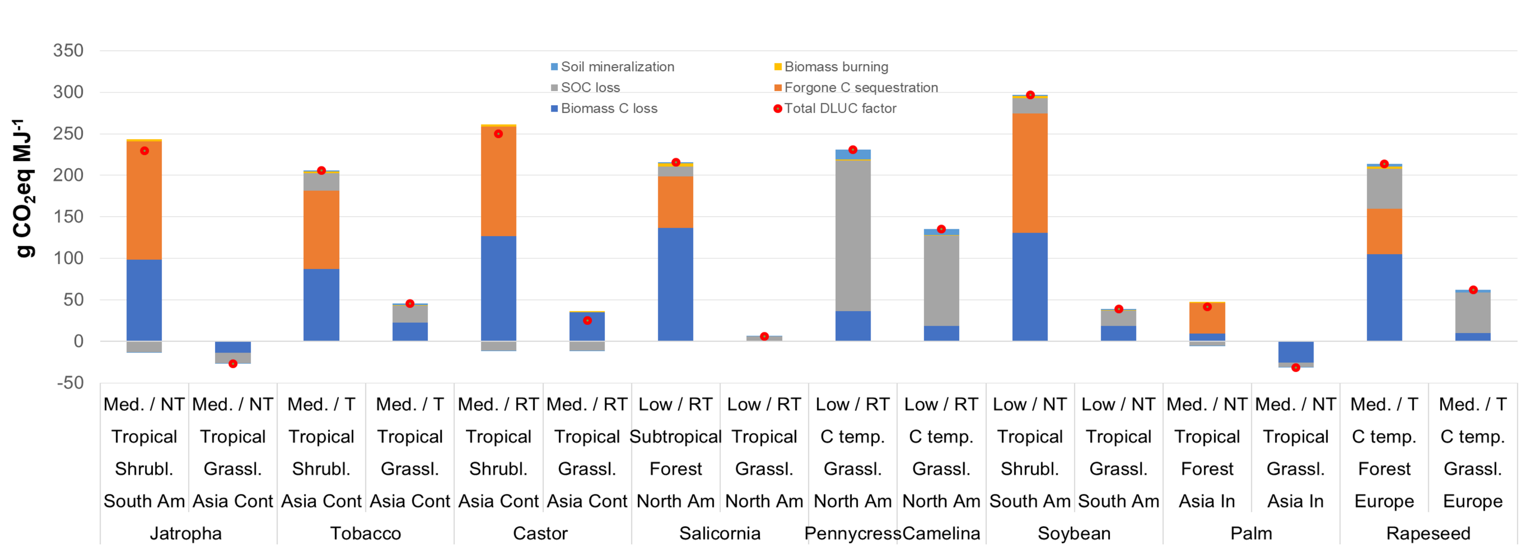
RESULTS AND CONCLUSIONS

Oilseed crops for ALTERNATE

Feedstock[1]	Distribution	Av.Yield (t/ha-yr)	Oil content (wt %)	Potential jet fuel production range (L/ha)[7]	Co-products: oil extraction	Co-products used as
Camelina	N. America, EU	1.9[2]	36.0	799-3,085	Meal	Fodder
Castor	India, Brazil, China	1.1[3]	47.0	398-1,535	Meal	Fertilizer, fodder (after detox.)
Jatropha	Asia, Africa, S. America	2.5[4]	35.0	1,185-4,573	Meal/ husk/ shell	Fertilizer, fodder (after detox.) / combusted
Palm (OP)	Malaysia, Indonesia	17.9[5]	22.4	10,018-38,666	Palm kernel meal	
Pennycress	Eurasia, N. America	1.0	34.0	456-1,759	Meal	Fodder
Rapeseed	EU	3.4[5]	44.0	1,238-4,779	Meal	Fodder
Salicornia	Africa, Middle East, S. America, China, US	2.0[4]	28.2	1,169-4,511	Meal / straw	Fodder/ fuel production
Soybean	N. America, Brazil	3.2[5]	19.1	2,723-10,511	Meal	Fodder
Tobacco	China, Brazil, India, US, Greece	2.1[6]	38.0	925-3,568	Meal	Fodder

[1]Shaded rows indicate ALTERNATE feedstocks that are evaluated for this work, [2]Angelini et al. 2020, [3]Carrino et al. 2020, [4]Stratton et al. 2010, [5]FAOSTAT, [6]Fatica et al. 2019 [7] Estimated using the product slate from Pearlson et al. 2013.

Scenario-specific DLUC emission factors *

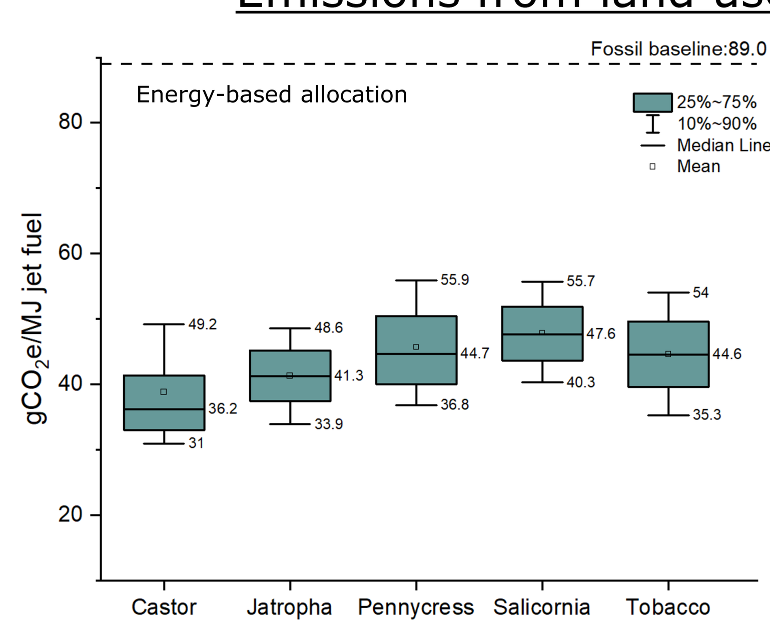


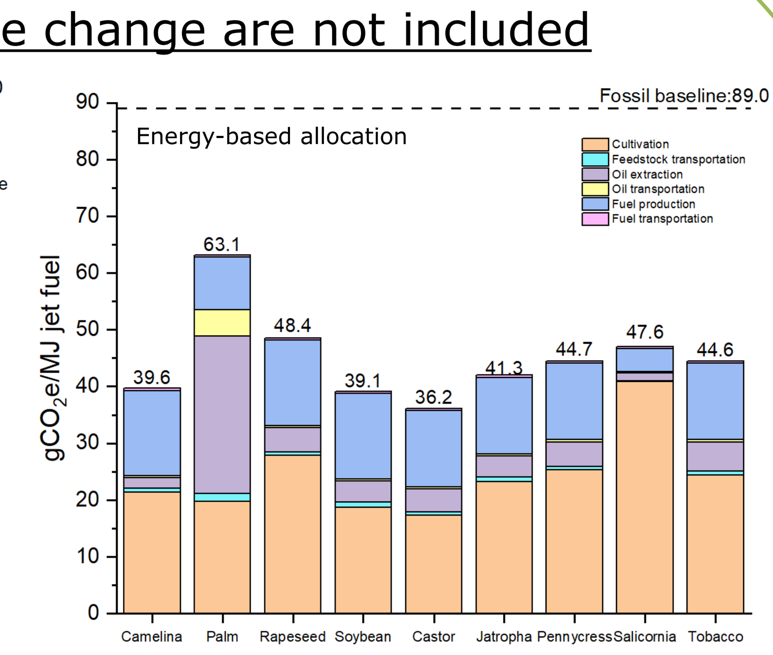
Asia Cont: Asia continental; Asia In: Asia insular; C. temp: cool temperate; Deg. Grassl.: Degraded grassland; Grassl.: grassland; High: high input intensity; low: low input intensity; Med.: medium input intensity; NT: No tillage; RT: Reduced tillage; South Am: South America; T: Tillage; W. temp: warm temperate.

- DLUC emission factors are high if forest or shrubland is converted for cultivation. High DLUC emission factors are also due to low seed yields from the corresponding crops.
- Grassland and degraded grassland yield the lowest DLUC emission factors if they are converted into cropland.

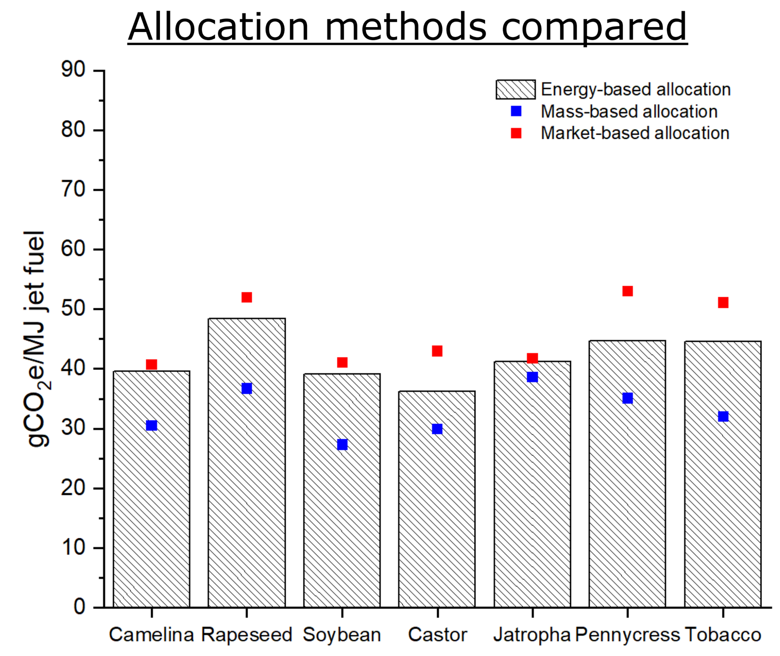
Attributional LCA Results*

Emissions from land use change are not included



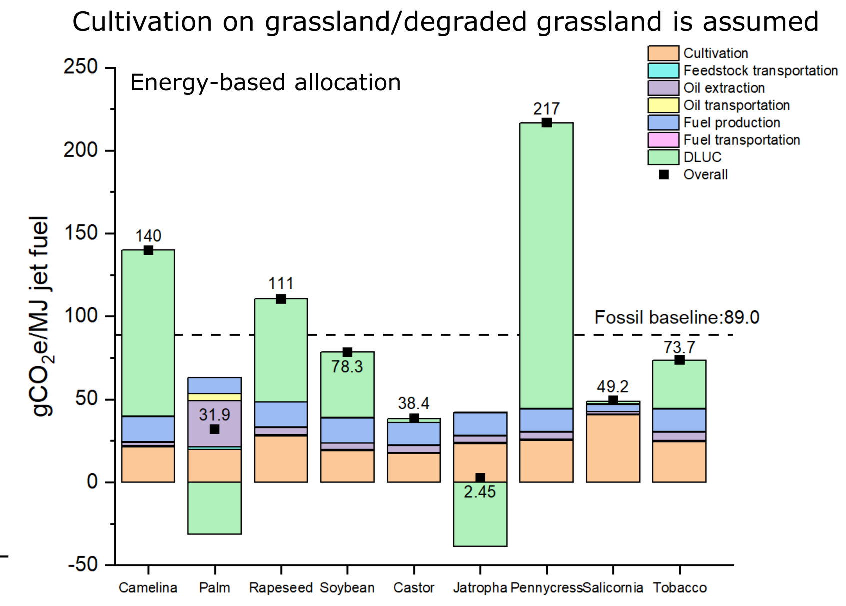


Allocation methods compared



Emissions from land use change: included

Cultivation on grassland/degraded grassland is assumed



- The main contributors to the life cycle emissions are cultivation and fuel production steps.
- The results show at least ±15 % variability. Parameters such as fertilizer and diesel use for cultivation are the main reasons for this variability. Sensitivity analysis also show a dependence on the hydrogen production technology.
- Energy allocation assigns a relatively small share of the emissions into the meal, whereas mass allocation allocates a high share of emissions due to large mass of meal produced as a co-product in most cases. Market-based allocation is done based on calculated prices from the literature, and or using soybean meal as proxy.
- Most of the ALTERNATE feedstocks provide GHG emissions savings (at least 17%) if they are grown on grassland or degraded grassland.

*UNPUBLISHED RESULTS, DO NOT QUOTE

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