ASCENT Project 01

Alternative Jet Fuel Supply Chain Analysis - CORSIA Fuels Support

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Objective:

- Provide data and modeling practices to **estimate ILUC values for alternative SAF pathways**
- Develop required economic analysis to **assess economic feasibility and profitability of SAF pathways**

Project Benefits:

- Improve ILUC estimation method for SAF pathways
- Develop methodologies to calculate direct land use change (DLUC) emissions
- Improve emissions factor databases and modeling approach

Research Approach:

Sustainable aviation fuels (SAFs) are essential in achieving carbon-neutral growth in aviation

Biomass-based SAFs may induce global land use changes and associated carbon stock

CORSIA Life Cycle Analysis (LCA) has two components: **Core LCA** and **ILUC**

- Use GTAP-BIO model to **assess induced land use change (ILUC) emissions**
- Use PE models for **economic feasibility analysis**
- Use Techno-Economic Analysis to study supply chain from feedstock production to aviation fuel

Major Accomplishments (to date):

Provided required data and modeling practices to **estimate ILUC values for alternative SAF pathways** and **developed required land use analyses** to support the Fuels Task Group (FTG) activities and goals

Future Work / Schedule:

- Further improve the GTAP-BIO model to assess ILUC values for new pathways and new regions
- Develop economic and policy analyses to support SAF production

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Feedstock availability and contributions of yield improvements

Taheripour F., Sajedinia E., Karami O.

CORSIA sustainability criteria: Implications for the US pathways

- Sustainability criteria for an eligible fuel:
  - S1: At least 10% GHG emissions relative to 89 gCO_2e/MJ
  - S2.1: If land converted after 1 January 2008, it shall not be a high carbon land
  - S2.2: If land converted after 1 January 2008, DLUC emissions shall be calculated. If DLUC> ILUC, then DLUC will apply
- Regarding ILUC, the sustainability criteria will not be a concern for:
  - Pathways that use waste and residue
  - Pathways with negative ILUC values (lignocellulosic and second oil crops)
  - Pathways using corn and soybeans, except for corn ETJ
- For more than 10% GHG reduction targets, e.g. a 50% reduction:
  - Core LCA and ILUC emissions will not be a point to concern for waste, residue, lignocellulosic, and 2nd oil crop pathways
  - Core LCA and ILUC emissions could impose restrictions for those pathways that use corn and soybeans
- CORSIA allows actual LCA as a replacement for Core LCA, upon verification
- CORSIA does not allow a Replacement for ILUC, but it opens a way through Low LUC Risk.

US SAF pathways and their GHG emissions (gCO_2e/MJ)

Description	Pathway	Technology	Core LCA	ILUC	LS_f
Global pathways that can be produced in the US	Agri. residues	FTJ	7.7		7.7
	Fore. residues	FTJ	8.3		8.3
	Municipal solid waste	FTJ	5.2		5.2
	Tallow	HEFA	22.5		22.5
	Used cooking oil	HEFA	13.9		13.9
	Palm fatty acid distillate	HEFA	20.7		20.7
	Corn oil: Dry mill ethanol	HEFA	17.2	0.0	17.2
	Agri. residues	ATJ	29.3		29.3
	Fore. residues	ATJ	23.8		23.8
	Agri. residues standalone	ETJ	39.7		39.7
	Agri. residues integrated	ETJ	24.6		24.6
	Fore. residues standalone	ETJ	40.0		40.0
	Fore. residues integrated	ETJ	24.9		24.9
US lignocellulosic pathways	Poplar	FTJ	12.2	-5.2	7.0
	Miscanthus	FTJ	10.4	-32.9	-22.5
	Switchgrass	FTJ	10.4	-3.8	6.6
	Brassica carinata oil	HEFA	34.4	-21.4	13.0
	Miscanthus	ATJ	43.4	-54.1	-10.7
	Switchgrass	ATJ	43.4	-14.5	28.9
	Miscanthus	ETJ	43.3	-42.6	0.7
	Miscanthus	ETJ	28.3	-42.6	-14.3
	Switchgrass	ETJ	43.9	-10.7	33.2
	Switchgrass	ETJ	28.9	-10.7	18.2
US corn and oilseeds pathways	Carinata oil	HEFA	34.4	-21.4	13.0
	Soybean oil	HEFA	40.4	24.5	64.9
	Corn grain	ATJ	55.8	22.1	77.9
	Corn gain	ETJ	65.1	25.1	90.8

Figures represent CORSIA default GHG emissions values.

Several key considerations

- Conventional jet fuel emissions: 89 gCO_2e/MJ
- All pathways pass the CORSIA 10% emissions reduction, except corn ETJ
- All pathways pass the US grand challenge 50% emissions reduction, except soy oil HEFFA, corn pathways
- Even with ILUC=0, corn pathways do not pass the 50% emissions reduction
- Actual Core LCA could help
- Low LUC Risk could help:
  - Yield improvement
  - Unused land approach
- Yield improvements contribute significantly to expansions in supplies of corn and soybeans
- Unused land could be a major source of feedstock production for all pathways

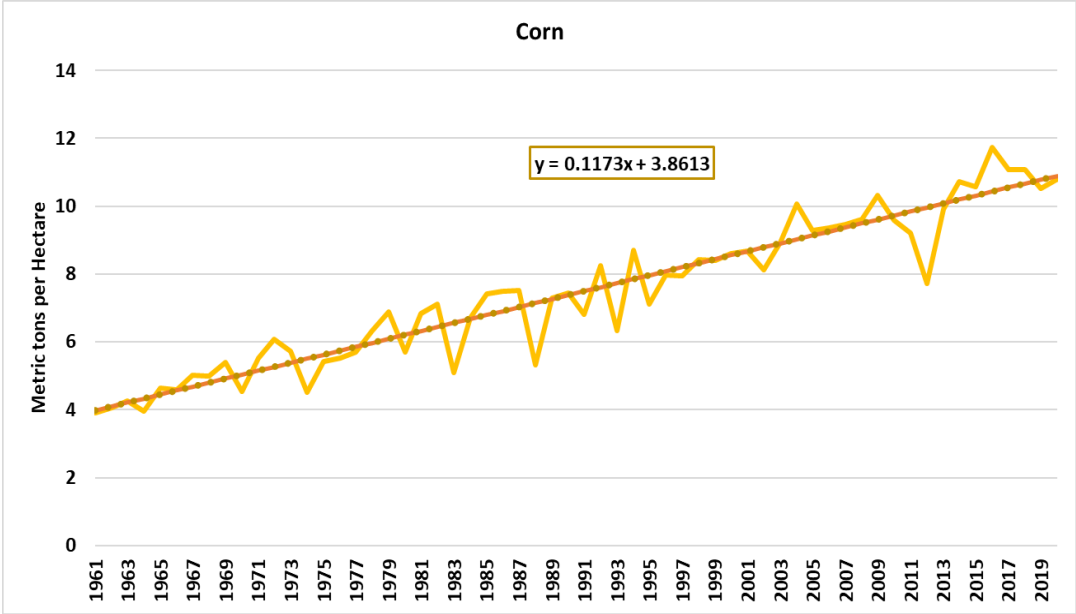
Low Risk Practices in CORSIA

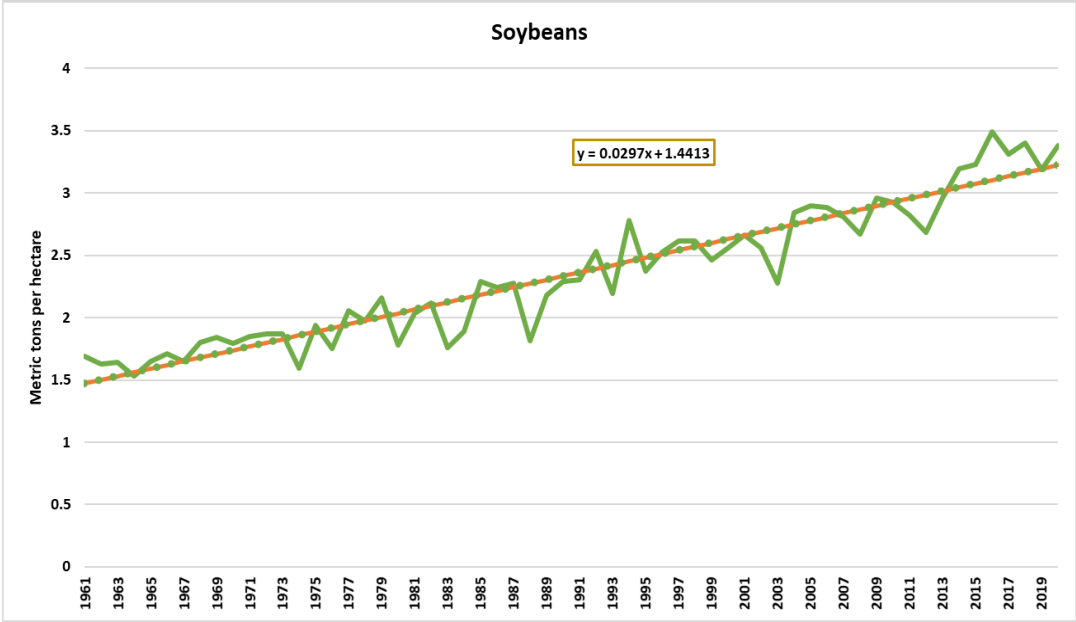
- Under CORSIA:
  - Certain land types, land management practices, and innovative agricultural practices can be considered to contribute to low risk for land area change.
  - These practices receive a value of zero for induced land use change (ILUC) in the life cycle analysis of the produced SAF.
  - CORSIA specifies two approaches for Low LUC Risk practices for SAF production:
    - a) Yield Increase Approach,
    - b) Unused Land Approach.
  - Feedstock production due to yield improvement gets ILUC=0, upon the verification process.
    - Verification should occur at farm level,
    - We need to concentrate on this approach.
  - Eligible lands for the unused land approach could include, among others, marginal lands, underused lands, unused lands, degraded pasture lands, and lands in need of remediation.
    - We have considerable area of land that could fall in this category,
    - We need to concentrate on this approach.

- This presentations highlights the role of Low LUC risk practices for feedstock production.

Low Risk Practices: Potential yield improvements in the U.S.

Corn and soybeans yields 1961-2020





- Between 2000-2020 corn yield has increased by 27.5%.
- Between 2000-2020 soybean yield has increased by 22.6%.
- Identifying the sources of yield improvements and defining methods of assessing yield improvements are required to use Low LUC Risk.
- Establishing a way to certify yield improvement at farm level will help to produce SAF under Low Risk practices with zero ILUC.
- Yield improvement could help to achieve the short and long term goal of the Grand Challenge.

Potential increases in aviation fuels that can be produced from improvements in corn and soybeans yields in the U.S.

Potential SAF production due to increases in corn and soybeans yields (million gallons)

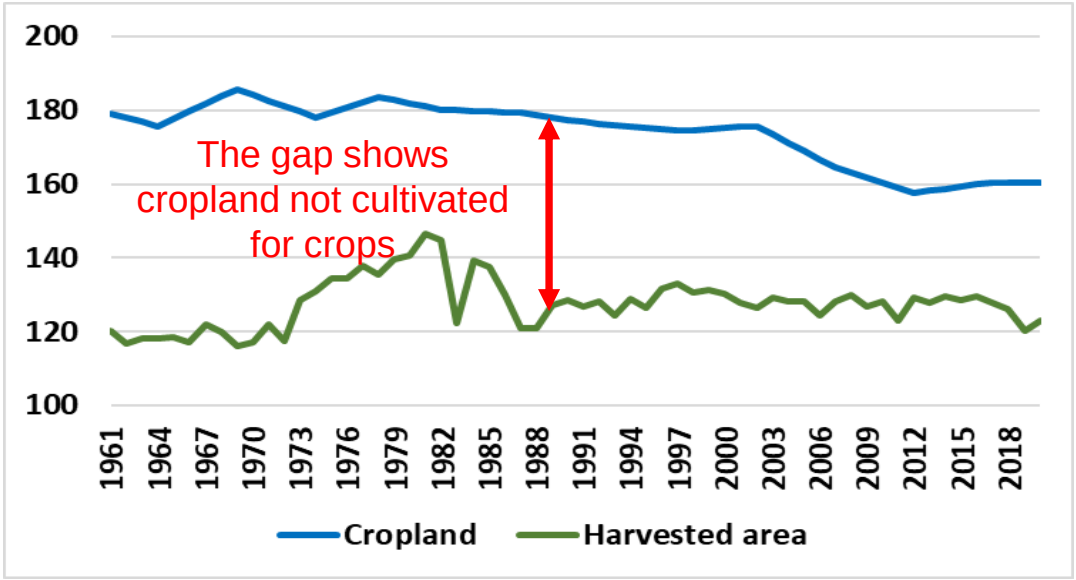
Year	Full allocation to aviation		50% allocation to aviation	
	Corn ETJ	HEFA	Corn ETJ	HEFA
2023	693	165	347	82
2024	925	220	462	110
2025	1,156	275	578	137
2026	1,387	330	693	165
2027	1,618	384	809	192
2028	1,849	439	925	220
2029	2,080	494	1040	247
2030	2,311	549	1156	275
2031	2,543	604	1271	302
2032	2,774	659	1387	330
2033	3,005	714	1502	357
2034	3,236	769	1618	384
2035	3,467	824	1734	412

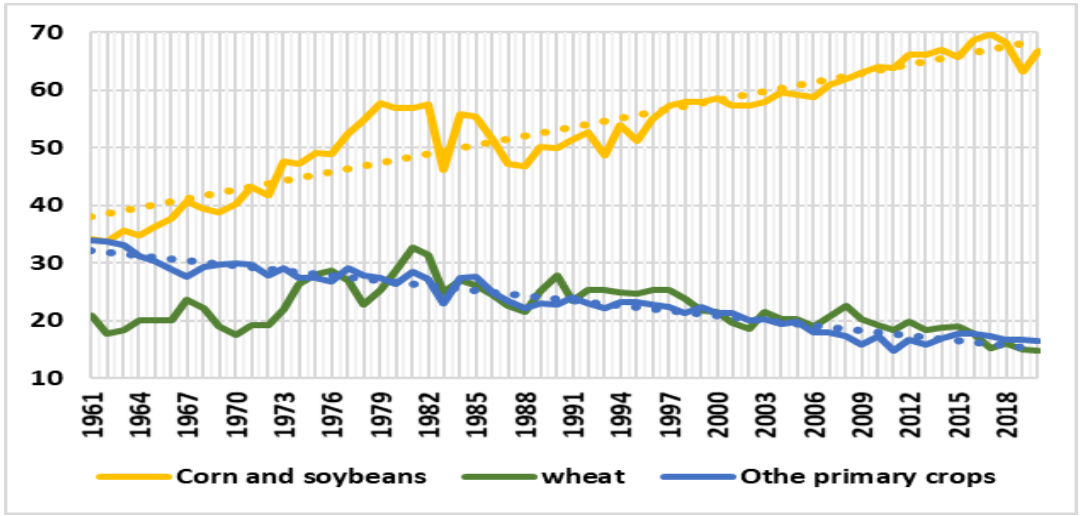
Implemented assumptions:

- Corn and soybeans yield will continue to grow following their past long run trend
- Yield improvements with areas of corn and soybeans in 2020 are used to assess additional corn and soybeans supplies
- Core LCA of CORSIA is used to calculate fuels produced
- Additional supplies due to yield improvements could be used for SAF and non-SAF uses:
  - Scenario 1 100% use for SAF
  - Scenario 2 50% for non-SAF uses.

Low Risk Practices: Unused land in the U.S.

Cropland, harvested area, and unused cropland over time (million hectares)





- In 2017 we have about 31 million hectares of unused cropland, more than total are of Iowa and Illinois (30 million hectares).
- Available area of unused cropland could support feedstock production for SAF.
- Over time total area of corn and soybeans followed increasing trend due to reductions in unwanted feed crops and conversion of unused land to active cropland.
- Total area of corn and soybeans will continue to grow.

Source: USDA data

Potential increases in aviation fuels that can be produced from expansions in corn and soybeans in the U.S.

Potential SAF production due to increases in areas of corn and soybeans (million gallons)

Year	Full allocation to aviation		50% allocation to aviation	
	Corn ETJ	HEFA	Corn ETJ	HEFA
2023	1,098	334	549	167
2024	1,269	385	635	192
2025	1,440	435	720	218
2026	1,611	485	806	243
2027	1,782	536	891	268
2028	1,953	586	977	293
2029	2,124	636	1062	318
2030	2,295	687	1148	343
2031	2,466	737	1233	368
2032	2,637	787	1319	394
2033	2,808	838	1404	419
2034	2,979	888	1489	444
2035	3,150	938	1575	469

Implemented assumptions:

- Total area of corn and soybeans will continue to grow following the historical trend
- Corn and soybeans yields in 2020 are used to assess increases in corn and soybeans
- Core LCA of CORSIA is used to calculate fuels produced
- Additional supplies of corn and soybeans due to area expansion could be used for SAF and non-SAF uses:
  - Scenario 1 100% use for SAF
  - Scenario 2 50% for non-SAF uses.

Other sources of Low LUC Risk feedstocks for SAF

Corn ethanol and excess supply of corn ethanol in million gallons

Year	Production	Consumption	Net Export
2000	1,622	1,653	-5
2001	1,765	1,741	-13
2002	2,140	2,073	-13
2003	2,804	2,826	-12
2004	3,404	3,552	-149
2005	3,904	4,059	-136
2006	4,884	5,481	-731
2007	6,521	6,886	-439
2008	9,309	9,683	-530
2009	10,938	11,037	-198
2010	13,298	12,858	383
2011	13,929	12,893	1,023
2012	13,218	12,882	247
2013	13,293	13,216	242
2014	14,313	13,444	772
2015	14,807	13,947	741
2016	15,413	14,356	1,134
2017	15,936	14,485	1,313
2018	16,091	14,420	1,655
2019	15,778	14,552	1,272
2020	13,941	12,681	1,163

Potential SAF production due to expansion in demand for electric cars (million gallons)

Year	Reduction in demad for ethanol due to EV		
	5%	10%	15%
2023	54	108	163
2024	108	217	325
2025	163	325	488
2026	217	434	651
2027	271	542	814
2028	325	651	976
2029	380	759	1,139
2030	434	868	1,302
2031	488	976	1,465
2032	542	1,085	1,627
2033	597	1,193	1,790
2034	651	1,302	1,953
2035	705	1,410	2,116

Potential expansion in supplies of second oil crops

- Various types of second oil crops (carinata, camelina, and pennycress) could be produced in rotation with corn and soybeans. Up to 29 million hectares.
- This crops provide negative ILUC values
- With proper agricultural policies, these crops can help to expand SAF with no additional demand for land (Taheripour et al. 2022)

Conclusions

- Regarding ILUC, the sustainability criteria will not be a concern for US SAF pathways, except for corn ETJ with the current core LCA and ILUC values,
- For a 50% GHG reduction targets, Core LCA and ILUC emissions could impose restrictions for those pathways that use corn and soybeans
- CORSIA specifies two approaches for Low LUC Risk practices
  - a) Yield Increase Approach,
  - b) Unused Land Approach.
- The Low LUC Risk practices provide opportunities to achieve the short and long term goals of the US Grand Challenges.