Biofuels induced land use change emissions: The role of implemented emissions factors in assessing terrestrial carbon fluxes

Farzad Taheripour, Hoyoung Kwon, Steffen Mueller, Isaac Emery, Omid Karami, Ehsanreza Sajedinia

25th Annual Conference on Global Economic Analysis
Accelerating Economic Transformation, Diversification and Job Creation
June 8-10, 2022: Virtual

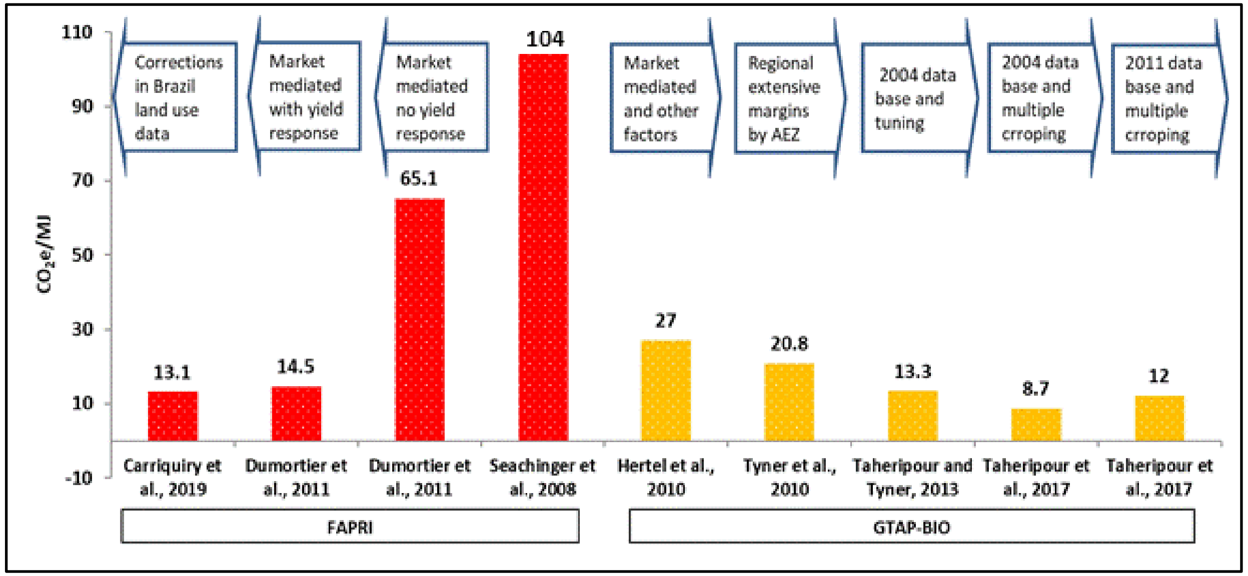
Outline of this presentation

- 1. Background and literature review
- 2. Research goals
- 3. Common approach in ILUC calculation
- 4. Land use emission factors
- 5. Data sources on land use emission factors
- 6. Comparison of land use emission factors
- 5. Carbon accounting models
- 6. Results
- Conclusion

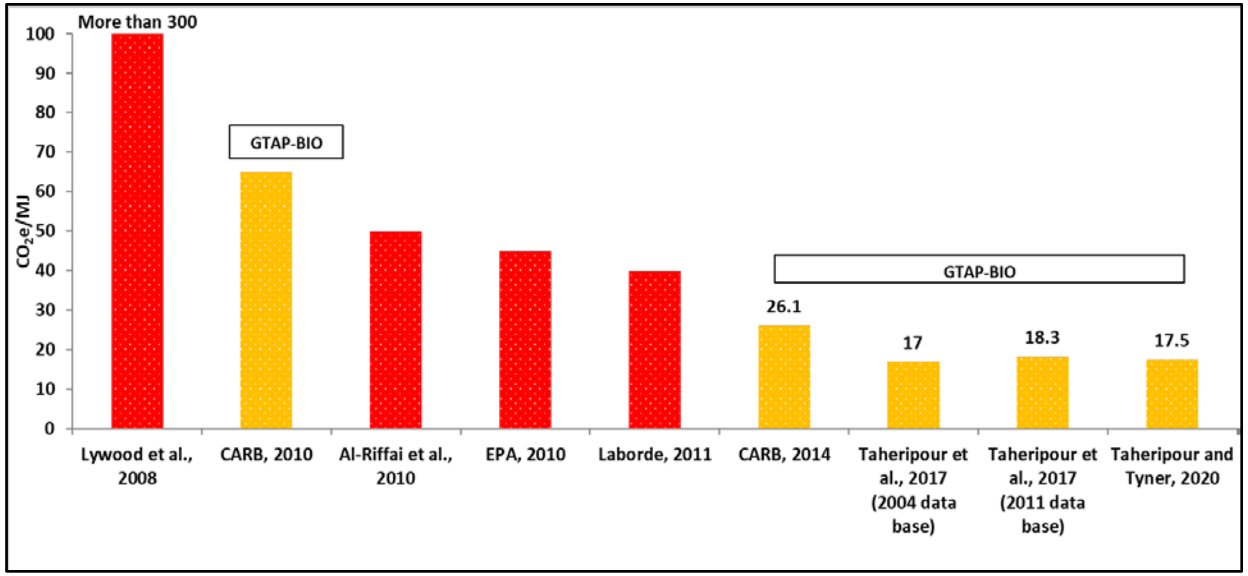
Background and literature review (1)

- Since the late 2000s, various efforts have been made to assess Induced Land Use Change (ILUC) emissions due to biofuel production and policy.
- Various economic models have been used to assess ILUC: Source Taheripour et al (20121)

Case of corn ethanol



Case of soy biodiesel



- ILUC values vary significantly across modeling practices

Background and literature review (2)

- Many papers have addressed uncertainties in modeling land use changes due to:
  - Differences across models,
  - Differences across data bases of a given model,
  - Uncertainties in models' parameters.
  - Some references are EPA, 2010; Plevin et al., 2010; Laborde, 2011; Taheripour and Tyner, 2013; CARB, 2014; Valin et al, 2015; Zilberman, 2017; Chen et al., 2018; and many more.
- However, only a few papers have studied uncertainties in land use emission factors and their associated assumptions: Plevin et al. (2015) and Taheripour and Tyner (2013).
- A few common data sources in this area of research are IPCC, WINROCK International, Woods Hole, and TEM data sets.
- No major effort has been made to compare these data sources or assess their validity.

Research Goals

- This research aims at:
  - Highlighting uncertainties in data on land use emission factors,
  - Collecting and review the existing data sources including TEM; Woods Hole, Winrock International, and IPCC to determine their prose and cons.
- To compare two carbon accounting models (AEZ-EF and CCLUB) that have been developed to covert GTAP-BIO results to ILUC values:
  - AEZ-EF has been developed by Plevin et al. (2014) and adopted by CARB
  - CCLUB has been adopted by Argonne National Laboratory and used in combination with the GREET model
- To evaluate ILUC values for various Sustainable Aviation Fuels (SAF) using both the AEZ-EF and CCLUB accounting models and land use changes obtained from GTAP-BIO.

A common approach in ILUC calculation

- To calculate an ILUC value for a biofuel pathway, two sets of information are needed:
  - An estimate for land use changes ($\Delta \boldsymbol{L_{ikr}}$) due to the targeted biofuel, usually obtained from economic models.
  - A set of Land Use Emission Factors $\boldsymbol{LUEF_{ikr}}$, usually obtained from the exiting data sources.
  - Common data sources are: IPCC, Winrock, Woods Hole, and TEM.
- In an abstract way, the ILUC formula is:

$$\boldsymbol{LIUC} = \frac{\sum_{ikr} \Delta \boldsymbol{L_{ikr} LUEF_{ikr}}}{\boldsymbol{T \times E}}$$

  - Here T represents amortization time horizon and E shows annual energy produced
  - Indices are: *i* represents the list of all types of land transitions (e.g., forest to cropland, forest to pasture, etc.), index *k* shows spatial resolution, and index *r* indicates countries.
  - $\boldsymbol{LUEF_{ikr}}$ captures the above and under ground carbon fluxes including vegetation and soil carbon.

Land use emission factors: Tier 1 and gridded data sources

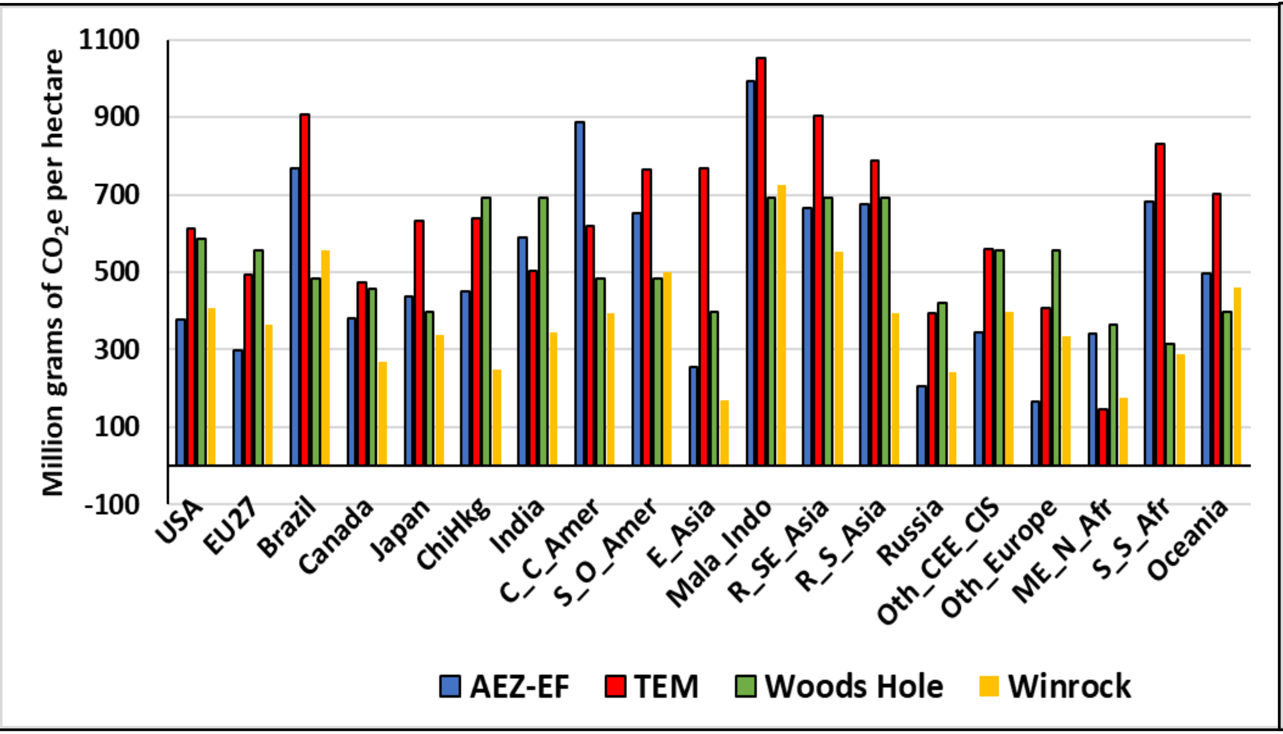
- Examples of Tier 1 data sources: IPCC, WINROCK, Woods Hole.
- Tier 1 data sources:
  - May represent incomparable regional boundaries,
  - Do not follow a unique set of definitions for land types,
  - Do not represent the same base year.
  - May not represent recent changes in land cover.
- Grided data sources are usually obtained from modeling practices using terrestrial ecosystem models (e.g., TEM).
- The grided data could be aggregated to any regional level.
- Gridded data source also my not represent recent changes in land cover.
- It is difficult to check the accuracy of both tier 1 and gridded data sources.
- It is not an easy task to compare the data sources on emission factors

Comparison of data sources on emissions factor

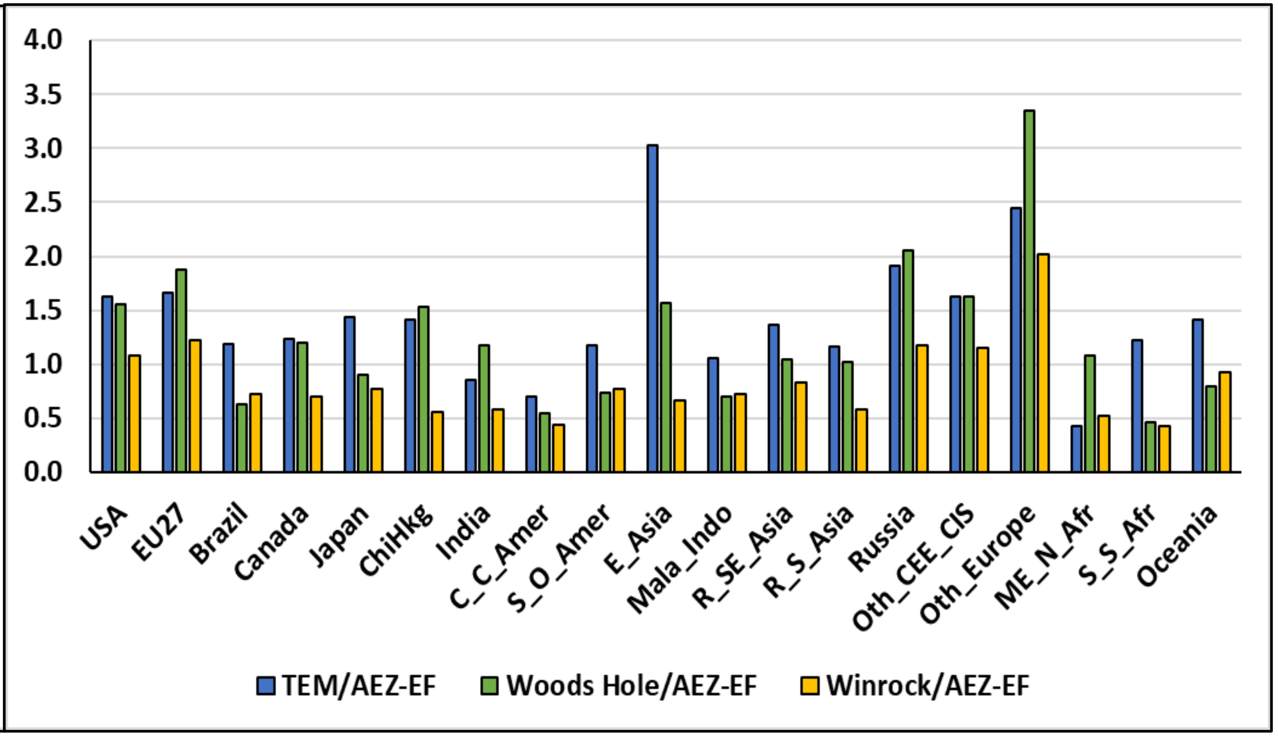
- To provide a meaningful comparison across data sources on emission factors we used the following steps:
  - Land cover items have been classified in three categories: Forest, pasture, and cropland according to the GTAP-AEZ land type definitions.
  - Following the GTAP-BIO geographical aggregation, we divided the whole world into 19 regions.
  - The existing data sources on emissions factors were matched with the above definitions and aggregation.

Forest to cropland emissions factors by GTAP-BIO regions and data source

Absolut emissions per hectare



Emissions relative to AEZ-EF

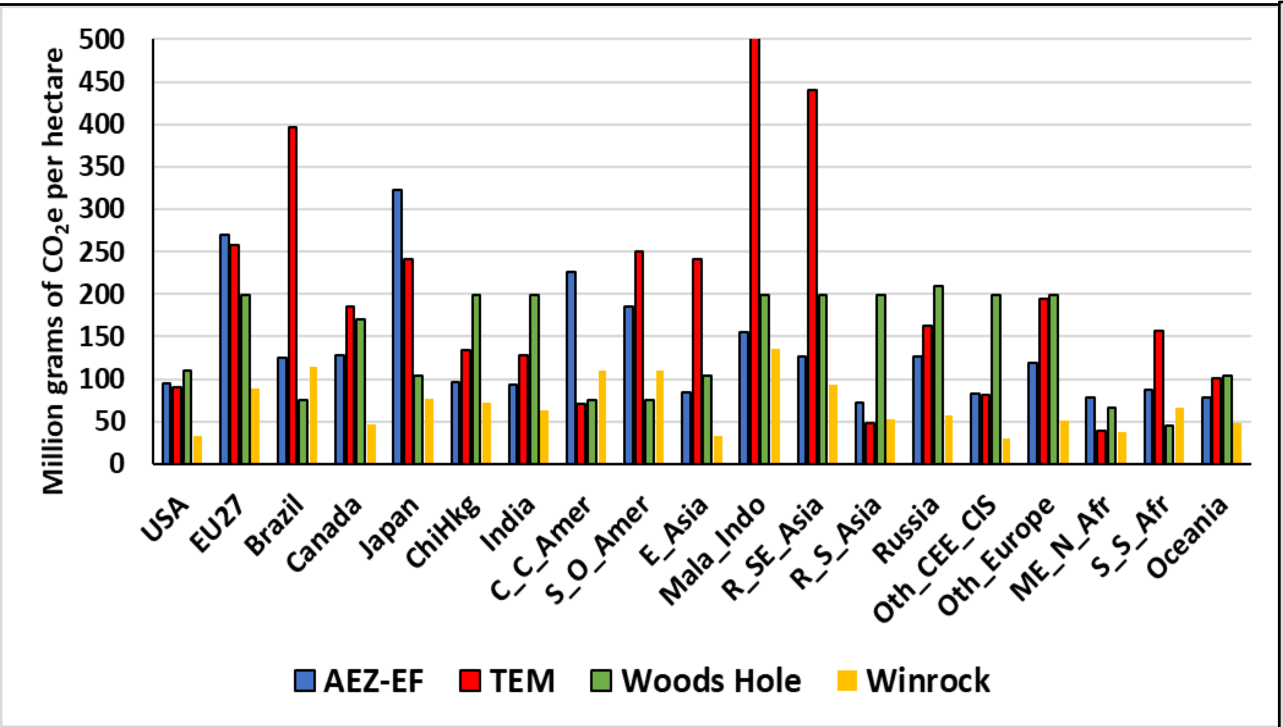


These figures show major differences across data sources

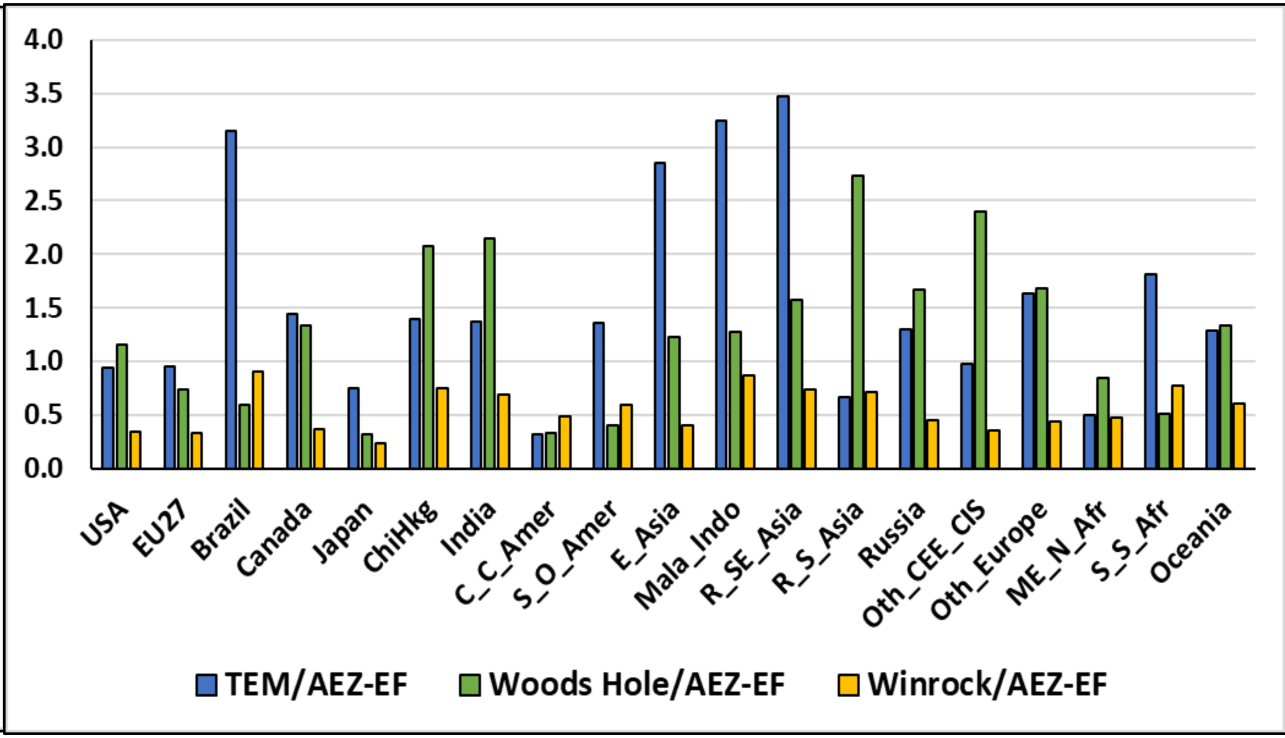
PURDUE
UNIVERSITY

Pasture to cropland emissions factors by GTAP-BIO regions and data source

Absolut emissions per hectare



Emissions relative to AEZ-EF



These figures show major differences across data sources

Two carbon accounting models: AEZ-EF and CCLUB

- Two carbon accounting models have been developed to convert the GTAP-BIO land use results to ILUC values: AEZ-EF and CCLUC
- The AEZ-EF relays on IPCC 2006 data sources and makes some assumptions to convert land use results to ILUC values.
  - For example, AEZ-EF assumes that the emission factor from cropland pasture (a marginal cropland) is half of the emission factor of pastureland.
- The CCLUB follows Winrock and Woods Hole data sources and makes its own assumptions to convert land use results to ILUC values.
  - For example, CCLUB uses a general model of plant-soil nutrient cycling (Century model) to assess emission factors for cropland pasture.

ILUC values for some SAF pathways: AEZ-EF and CCLUB results

Estimated ILUC values for various SAF pathways using different emissions accounting models for a 25-year amortization time horizon (gCO_2 e/MJ)

Pathways	ILUC obtained from AEZ-EF model						ILUC Obtained from CCLUB	Difference: AEZ-EF - CCLUB
	Natural Vegetation	Foregone Sequestration	Soil Organic Carbon	Biomass Carbon	Peat Oxidation	AEZ-EF Total		
Soy oil HEFA	8.0	0.6	5.0	1.6	4.9	20.0	15.0	5.0
Miscanthus FTJ	12.5	1.5	-33.6	-17.8	0.2	-37.3	-12.8	-24.5
Switchgrass FTJ	18.1	2.5	-17.3	-11.8	0.3	-8.2	1.0	-9.2
Poplar FTJ	15.4	2.2	-7.8	-19.5	0.2	-9.6	7.0	-16.6
Miscanthus ATJ	16.1	1.6	-51.0	-25.3	0.1	-58.5	-26.1	-32.3
Switchgrass ATJ	25.1	3.0	-28.7	-18.5	0.3	-18.9	-14.1	-4.7
Grain ATJ	12.5	1.5	8.4	-0.3	0.3	22.5	14.4	8.1
Grain ETJ	13.9	1.6	9.4	-0.3	0.4	24.9	15.6	9.3

ILUC values for some SAF pathways: AEZ-EF and CCLUB results

Estimated ILUC values for various SAF pathways using different emissions accounting models for 25- and 30-years amortization time periods (gCO_2 e/MJ)

Pathways	Amortization time horizon			
	25 years		30 years	
	AEZ-EF	CCLUB	AEZ-EF	CCLUB
Soy oil HEFA	20.0	15.0	16.6	12.5
Miscanthus FTJ	-37.3	-12.8	-31.1	-10.7
Switchgrass FTJ	-8.2	1.0	-6.8	0.9
Poplar FTJ	-9.6	7.0	-8.0	5.9
Miscanthus ATJ iBuOH	-58.5	-26.1	-48.7	-21.8
Switchgrass ATJ iBuOH	-18.9	-14.1	-15.7	-11.8
Grain ATJ	22.5	14.4	18.7	12.0
Grain ETJ	24.9	15.6	20.8	13.0

Conclusions

- The existing literature has extensively discussed uncertainties in assessing induced land use changes due to biofuels,
- No major effort has been made to evaluate uncertainties in land use emission factors.
- The paper indicates that variations in the available data sources that provide land use emission factors are substantially large.
- Moving from one data source to another one significantly affects the estimated ILUC emissions, for a given set of estimated land use changes for a given pathway.
- The AEZ-EF and CCLUB model provide different assessments for ILUC emissions for the same estimated land use changes.
- Finally, more research is needed to validate the accuracy of the emission factors.

Thanks

Questions and Comments