Timing effects of land use change induced radiative forcing and its impacts on biofuel development policies

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Green Design

Introduction

Corn ethanol production in the U.S. has increased from 1.8-10.6 Bgal/yr from 2001 to 2009 (1). The current \$0.45/gal corn ethanol subsidy means B\$4.8 in 2009 alone (2). The Energy Independence and Security Act of 2007 (EISA) mandates 15 Bgal/yr of "Renewable Fuel" by 2016 (7% of U.S. annual gasoline use).

A "Renewable Fuel" must emit at least 20% less GHG emissions than gasoline as of 2005. EPA's 2010 life cycle assessment (LCA) concludes that the mean value for U.S. corn ethanol GHG emissions is 20% below gasoline (3).

LCA uses GHG inventories to estimate the GHG balance of corn ethanol relative to gasoline, e.g., 74 g CO_2e/MJ vs. 93 g CO_2e/MJ. This means corn ethanol has a -20% GHG balance with respect to ethanol.

The GHG balance used in policy making is interpreted as a proxy for climate change impacts. However, the GHG balance does not tell us at what year during the life cycle the emissions occur. This can be a problem when corn ethanol and gasoline have very different emission time profile.

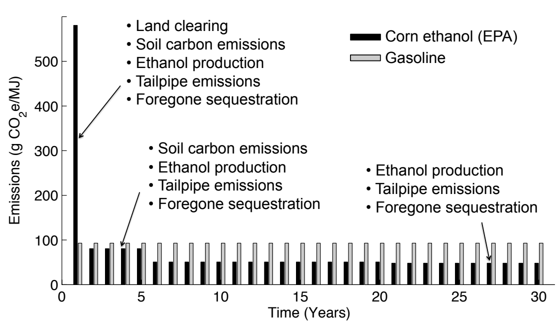
A biofuel GHG balance is an important decision metric for policy-makers, but it does not account for timing of emissions.

Problem of emissions timing

Emissions time profiles of corn ethanol and gasoline are different due to land use change (LUC) effects.

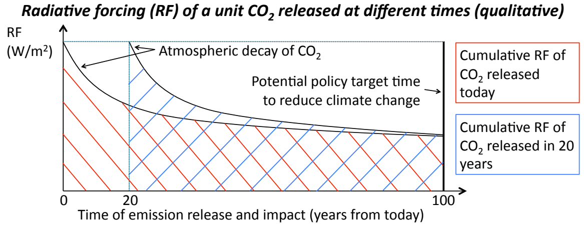
- LUC occurs when the ethanol feedstock displaces other crops, forests, pasture before ethanol is produced.
- Changes the carbon stock of the land through biomass burning and decay.
- LUC can be direct or indirect, e.g., displaced crops are planted elsewhere.
- EPA estimates that LUC contributes on average 38% (!) to overall life cycle emissions of corn ethanol.
- Uncertainty analysis estimates LUC emissions to range from 10-340 g CO_2e/MJ/yr.

Emissions time profiles of corn ethanol and gasoline



Greenhouse gas emissions from LUC are released early in the life cycle of corn ethanol. The distribution of LUC emissions over time was adopted from the BTIME model (4). Measured over the next century, emissions released today affect climate more than later emissions.

Radiative forcing (RF) of a unit CO_2 released at different times (qualitative)



The objective of this work is to quantify this timing effect for the case of corn ethanol:

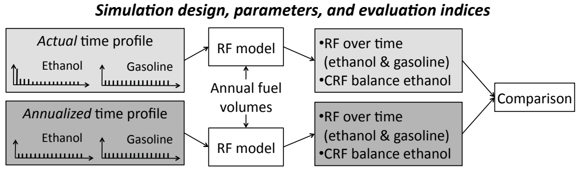
- ***Is there a need to worry about emissions timing in biofuel LCA?***
- ***If yes, at what policy time frames (impact time)?***
- ***What is the magnitude of the maximum climate impacts from corn ethanol?***

Method for quantifying the timing effect

We developed a model to estimate RF from gasoline and corn ethanol over time. Our method of evaluating timing effects based on RF is a further development of earlier works (5, 6).

- Based on "Simple Climate Models" (SCM) used in IPCC AR4
- SCMs replicate the global scale average behavior of complex models
- Literature gasoline and corn ethanol life cycle GHG emissions (incl. LUC)

Simulation design, parameters, and evaluation indices



CRF balance of ethanol:

$$CRF\ balance(t) = \frac{\sum_T RF_{Ethanol} - \sum_T RF_{Gasoline}}{\sum_T RF_{Gasoline}}$$

Cumulative RF of ethanol relative to gasoline over time frame T (%)

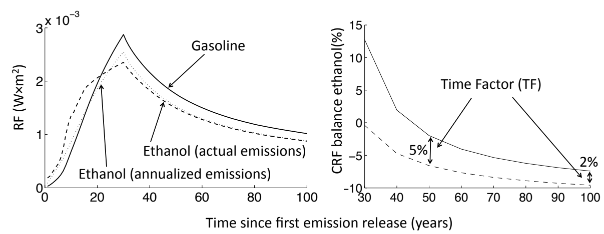
Time Factor (TF):

$$TF(t) = CRF\ balance_{actual}(t) - CRF\ balance_{annualized}(t)$$

Ignoring timing underestimates impacts by how much (%)

Results

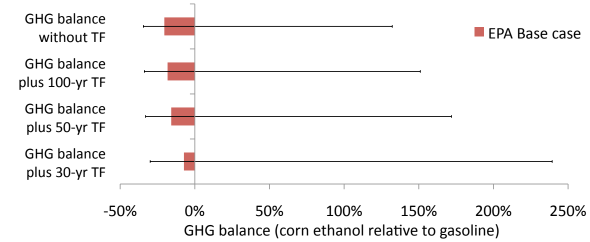
RF of corn ethanol and gasoline, and CRF balance over time



Considering time frames of 50 years or higher, applying both the actual and the annualized emissions profile does *not* change cumulative RF significantly. The maximum RF (base case, year 10) causes the mean global surface temperature to increase by 0.0007 °C.

The time factor (TF), i.e., the amount by which disregarding the actual emissions time profile underestimates cumulative RF, may be added to the GHG balance. However, the uncertainty of the LUC estimate is more than an order of magnitude higher than TF.

GHG balance incl. TF and LUC uncertainty (Plevin et al. 2010)



Conclusions and policy implications

Emissions timing adds very little to our understanding of the climate change impacts of biofuels based on cumulative RF.

- The influence of emissions timing is about an order of lower than the LUC estimates used as model inputs.
- Timing is insignificant for impact time frames of 50 years or higher.
- Timing is less relevant for feedstocks that cause less LUC than corn ethanol.

Adaptations to biofuel GHG LCA are *not* recommended.

- Disregarding emissions timing in GHG accounting does not significantly underestimate climate impacts.

References

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