Life Cycle Associates

Stefan Unnasch
1. 650.461.9048 direct
1.484.313.9504 facsímile
unnasch@LifeCycleAssociates.com
884 Portola Road, Suite A11
Portola Valley, CA 94028 USA

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California Air Resources Board
Katrina Sideco
(916) 323-1082
ksideco@arb.ca.gov

Reference: **Comments on the Treatment of Nitrogen Fixation in Soybeans**

Dear Ms. Sideco,

Life Cycle Associates would like to take this opportunity to provide comments and insight to the new California GREET model. The comments herein address the analysis and treatment of N_2O emissions from soybean farming and time impacts on biofuel pathways. CA_GREET2.0-v180 estimates the releases of N_2O due to fertilizer application, crop residue, volatilization, and the secondary effects from leaching as per the IPCC methods. GREET does not include emissions from nitrogen fixation in legumes. The emissions from the nitrogen fixed in the plants are a major contributor to lifecycle greenhouse gas emissions from soybeans, which affects soy bio- and renewable diesel pathways as well as co-product credits for other pathways.

The emissions from soybean production have been examined in many fuel LCA models and the latest research from the JRC's GNOC model as well as other studies shows that the emissions from nitrogen fixation are significant. The effect is well described by Venkat, 2010:

> "IPCC (2006) does not include biological nitrogen fixation as a direct source of N_2O, instead relying solely on the nitrogen inputs from crop residues (above and below ground) to account for all legume N_2O emissions. The problem with this is that the IPCC crop residue model does not seem to capture the magnitude of N_2O emissions in the late-growth stages of soybeans (this is the one crop that I have looked at in detail; others may have a similar problem). There is in fact almost an order of magnitude difference between the worst-case (high) N_2O emissions from crop residue and the conservative (low) N_2O emissions in the late-growth stages (crop residue emissions are smaller by a factor of 5 to 10)."

These comments address the N_2O release from soybean farming in GREET and compare the results to the EPA RIA analysis, the EU GNOC (Global Nitrous Oxide Calculator) and the 2013 JRC WTT report. Results from these studies suggest that the GREET inputs underestimate the N_2O emissions from soybean production, which affects soy biodiesel, renewable diesel, and corn ethanol pathways with soy displacing corn. Figure 1 shows the N_2O contribution to the total GHG emissions of the finished fuel produced, based on data from GREET and the various leading studies addressed in these comments.

ARB should evaluate these studies and re-examine the GREET methodology and values to ensure that the treatment of corn and soy is commensurate to the N_2O emissions generated.

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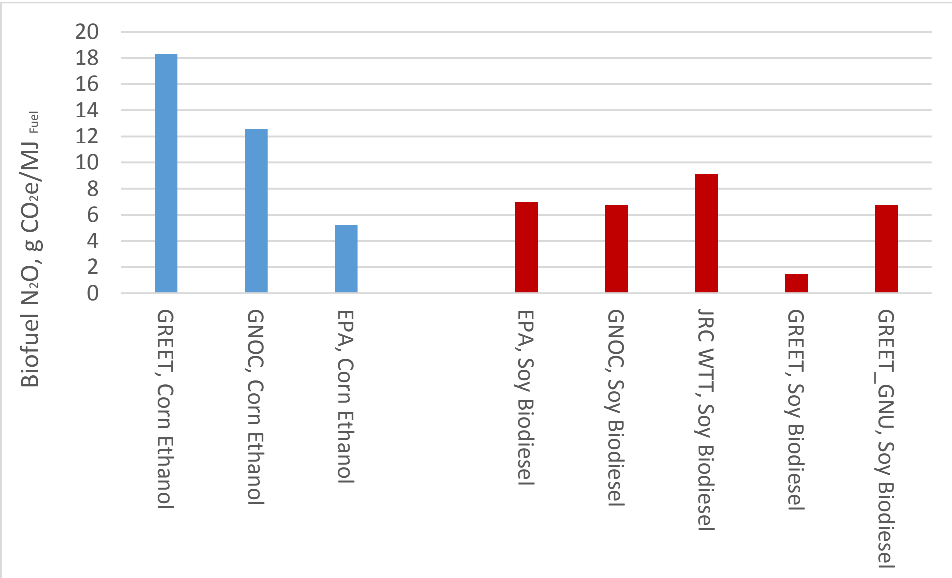

Figure 1. N_2O contribution to GHG emissions from corn and soy crops.
[a] Emissions are calculated from GREET data and data in the EU and EPA studies, crop yields are based on 2013 NASS data for corn and soy.

EPA RIA N_2O Emissions Analysis

The EPA evaluated the nitrous oxide emissions for soy and corn biomass as part of the RIA analysis (EPA, 2013). Figure 2 shows the EPA RIA N_2O emissions form bioenergy crops in the U.S. The N_2O emissions attributed to the crop residue and leaching from soy and corn bioenergy crops account for approximately 40% and 25% of the total N_2O emissions.

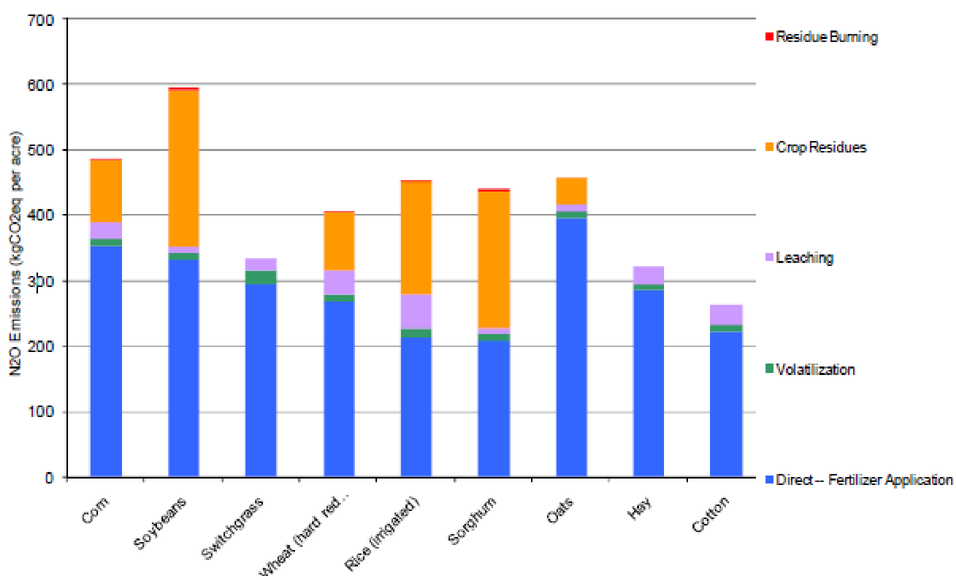

Figure 2. EPA RIA N_2O emissions form bioenergy crops

Table 1 shows the N_2O emissions from the biomass fixation and leaching and also the contribution of these emissions to the total GHG emissions of the finished fuel produced, based on data for the EPA RIA. NASS average crop yields for 2014 is assumed for calculation of the total N_2O emissions (kg/ha).

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Table 1. EPA RIA Nitrous Oxide Emissions from Soybean and Corn Farming

EPA RIA Result	Corn	Soybean
Fertilizer and Leaching	2.98	2.82
Crop Residue	0.83	19.9
Total N_2O, g/bu	3.81	22.7
Total N_2O, kg/ha*	1.8	2.2
g CO_2e/MJ_{Fuel}	5.2	7.0

*NASS 2014 Average crop yield assumed for conversion to kg/ha.

JRC GNOC N_2O Emissions Analysis

The European JRC GNOC (Global Nitrous Oxide Calculator) (Köble, 2014) calculates N_2O emissions based on the 2006 IPCC guidelines (Eggleston, 2006) combining TIER1 and TIER2. The IPCC guidelines distinguishes different pathways (direct, indirect) and different nitrogen sources (e.g. mineral fertilizer, manure, crop residues, and drained organic soils). For the indirect pathways (leaching/runoff and volatilization) the GNOC follows the IPCC TIER1 approach for all nitrogen sources. The same holds for direct emissions from crop residues and drained organic soils.

Table 2 shows the GNOC and the JRC WTT study (CONCAWE, 2013) N_2O emissions from soy and corn farming and also the contribution of these emissions to the total GHG emissions of the finished fuel produced.

Table 2. JRC GNOC Nitrous Oxide Emissions from Soybean and Corn Farming

N_2O result	GNOC, Corn	GNOC, Soybean	JRC WTT
Region	Iowa	Iowa	EU
Crop	Corn	Soybean	Soybean
Crop Yield, kg/ha	23,827	5,291	--
Chemical N, kg/ha	198	3.05	--
Manure N, kg N/ha	0	0	--
Total N_2O, g/bu	9.16	21.57	29.53
Total N_2O, kg/ha	4.36	2.13	2.92
g CO_2e/MJ_{Fuel}	12.6	6.7	9.1

GREET N_2O Emissions Analysis

Table 3 shows the GREET N_2O emissions from soybean and corn farming and the contribution of these emissions to the total GHG emissions of the finished fuel produced. Table 3 also shows the imputed GREET_GNU soybean results if a constant for N fixation in the biomass consistent with the GNOC results was applied. A constant for the corn analysis can also be applied (not shown here).

GREET does not include biological nitrogen fixation as a direct source of N_2O, instead relying on the nitrogen inputs from crop residues to account for total N_2O emissions. As previously stated by Venkat, 2010, this analysis does not accurately capture the magnitude of N_2O emissions in the late-growth stages of soybeans. The omission of nitrogen fixation leads to a misrepresentation of the total GHG emissions from soybeans and affects the soy biofuel pathways and other pathways where soybean meal is a substitute co-product.

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Table 3. GREET N_2O emissions from both soybean and corn, and the imputed soybean results if a constant for Soybean N fixation was applied.

Case	**Corn**	**Soybean**	**Soybean, matched GNOC**	**Source**
Chemical N, g/bu	415.3	30.9	30.9	GREET
Crop Density, lb/bu	56	60	60	GREET
Crop Yield				
bu/acre	193	40	40	NASS
kg/ha	23,827	5,291	5,291	Calculation
N Fertilizer, g/acre	197,978	3,053	3,053	Calculation
N in Biomass, g	141.6	200.7	200.7	GREET
Chemical N, kg/ha	198.0	3.05	3.05	GREET
Crop Residue N kg/ha	67.50	19.83	19.83	Calculation
N_2O Chemical	1.525%	1.325%	1.325%	GREET
N_2O Crop Residue	1.525%	1.325%	1.325%	GREET
N_2O from fixation, g/bu			17	LCA
GREET Result N_2O kg/ha				
Chemical Fertilizer	4.74	0.06	0.06	Calculation
Crop Residue	1.62	0.41	0.41	Calculation
Total N_2O, g/bu	13.3	4.8	21.7	
Total N_2O kg/ha	6.36	0.48	0.48	
g CO_{2e}/MJ_{Fuel}	18.3	1.5	6.7	

Figure 3 shows a graphical comparison of the GREET N_2O emissions (g/ha) versus the leading studies identified here. The GREET Soybean N_2O emissions (kg/ha) are ~ 5 times lower than the other leading studies.

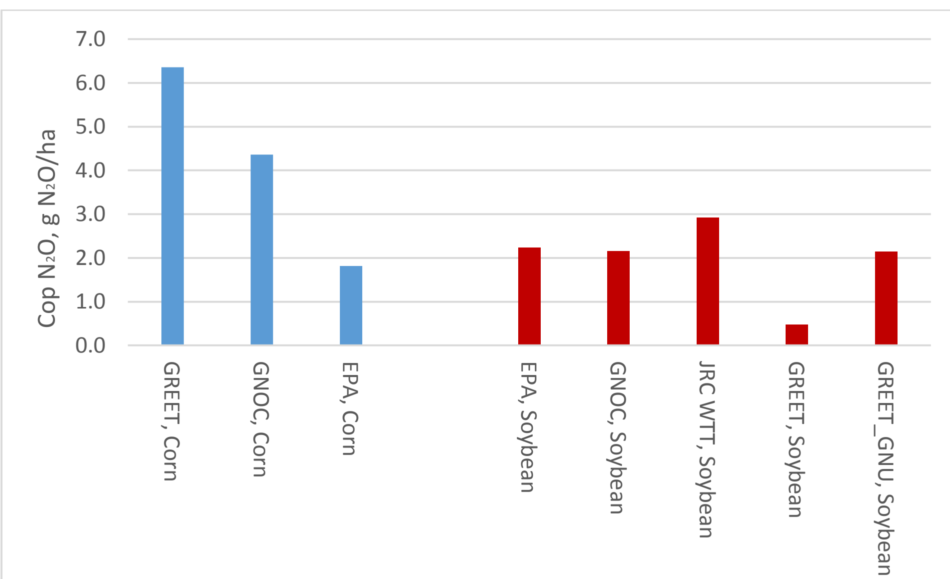

Figure 3. Total N_2O emissions from corn and soybean production.

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We hope that these comments have illustrated that the N_2O emissions in GREET are in need of thorough evaluation. Thank you for taking into account these comments. I look forward to discussing these comments with you in more detail.

Best Regards,

Stefan Unnasch
Managing Director
Life Cycle Associates, LLC

References

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