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Transportation Biofuels: For greenhouse gas mitigation, energy security or other reasons
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Atmospheric Chemistry and Physics

N_2O release from agro-biofuel production negates global warming reduction by replacing fossil fuels

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A global assessment in 4 steps

- Global N_2O release estimated from atmospheric concentrations and stratospheric photolysis rate
- Assessment of global rate of N fixation as activity number determines an emission factor (yield factor)
- “Carbon saved” calculated from carbon content of plant tissue and carbon mass balance of biofuel production
- “Carbon equivalent emitted” calculated from nitrogen content of plant tissue and nitrogen use efficiency

Step 1: Global emissions

- Mass of Atmosphere: $5.2x10^{18}$ kg
- Equilibrium concentration of N_2O (pre-industrial):
  270 ppb = $2.1x10^{12}$ kg N_2O
- Atmospheric lifetime: 135 years (photochemical sink)
- Global sink = global source = 10.2 Tg N_2O-N

Soil emissions

- Pre-industrial (Case 1):
  only land-based sources considered
  → 6.2 – 7.2 Tg N_2O-N/yr

- Increment of industrial agriculture (Case 2):
  Total source from current concentrations (315 ppb), annual increment 0.8 ppb/yr = 3.9+11.9 Tg N_2O-N/yr

- subtract natural, chemical industry emissions = 4.3-5.8 Tg N_2O-N/yr

Step 2: Yield factor

- E = EF * A, A from appropriate statistics
- Here: A … fixing of atmospheric nitrogen (>99% of N is N_2 not available to plants)
- Pre-industrial (Case 1): N_2 fixing by leguminous plants
- Industrial (Case 2): N_2 fixing in Haber-Bosch process, fossil fuel combustion
- Yield factor (EF): 3-5%

Step 3: CO_2 emissions saved

- Mass fraction of plant tissue going into biofuel C determines conversion efficiency (note: not energy related)
- Energy density of biofuels per unit of C is largely identical to that of fossil fuels (ethanol vs. gasoline and RME vs. diesel, all near 50 MJ/g C)
- CO_2 emissions from biofuels equal fossil CO_2 avoided

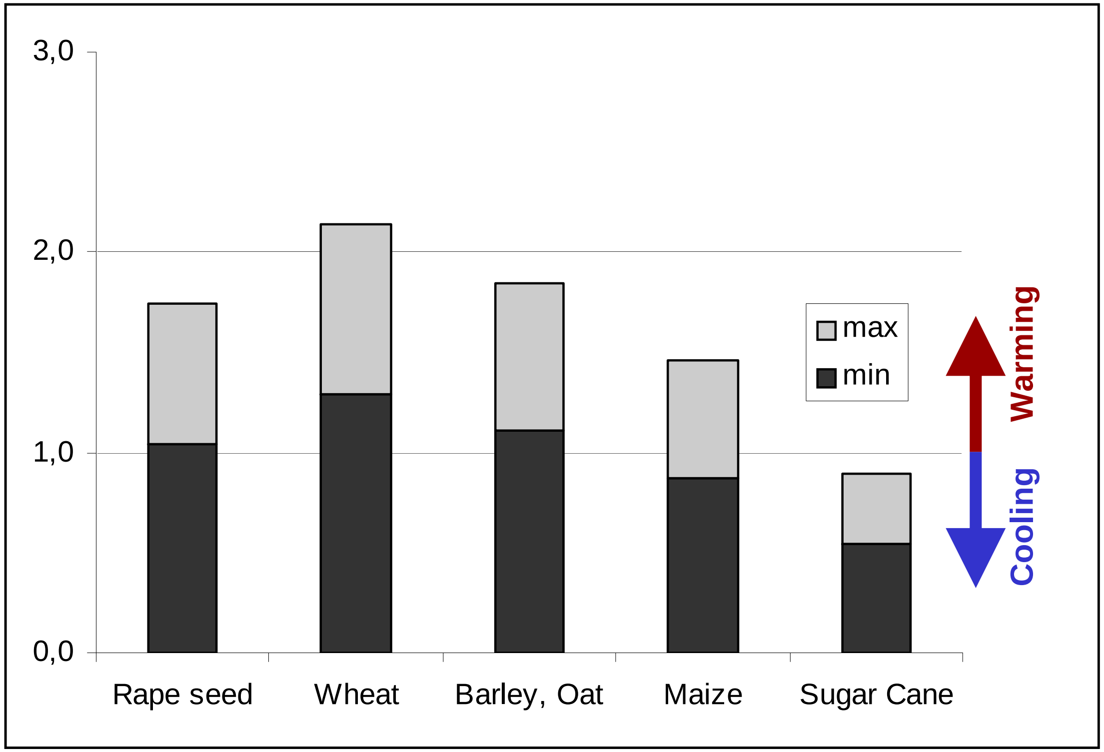
$$M = rC * \mu CO_2/\mu C *cv$$

Step 4: CO_2-eq (N_2O) emissions

- N in plant tissue derives from fertilizer use
- Nitrogen use efficiency determines amount of N taken up by plants
- N_2O emissions related to biofuel production calculated using yield factor (even if emissions occur far from the plot)

$$Meq = rN * y * \mu N_2O/\mu N_2 * GWP /e$$

Result: Meq/M ratio



Additional GHG-balances

N_2O released ↔ Fossil CO_2 saved

Energy in Mineral fertilizer & Biofuel process ↔ by-products

Farming energy ↔ Savings in fossil fuel chain

Soil carbon loss ↔ Enhanced C sink due to N availibility

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Sensitivities and improvements

- Increase nitrogen use efficiency (=global average)
- Apply manure-N as fertilizer
- By-products used to replace traditional crops (and their associated N_2O emissions)

In general:

- Use low-N biofuels

Compare to IPCC default factor

- IPCC default N_2O yield (plot level): c. 1% (0.3 – 3 %)
- IPCC default N_2O yield (indirect): c. .5% (0.1 – 3 %)
- Apparent discrepancy: IPCC default 1.5%
this work: y=4% ± 1%
- Both “plot” and “indirect” processes are not well understood
- Animal husbandry and manure related emissions are part of “background” in our approach
- IPCC attempts to be source specific – this work aims for full coverage

Conclusions

- Biofuels – when grown to reduce GHG emissions – need to proof they are fulfilling their purpose
- Many first generation biofuels may under non-ideal (=practical) conditions produce same amount or more greenhouse gases (N_2O) than comparable fossil fuels do (CO_2)
- Whether or not biofuels balance GHG better than fossil fuels is a difference of uncertain numbers

- Conclusions are strongly different for cellulosic plants requiring little or no N fertilization:
grasses, trees, …