Biodiversity Impacts of Biofuels: Focus on Ethanol from Corn

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America's First and Future Biofuel

- First promoted as key to energy independence by Carter Admn. (and Archer Daniels Midland) in wake of OPEC oil embargoes
- Languished for decades, just 1-7% of corn to ethanol thru 2001 despite subsidies
- Reborn in 2005 with subsidies and quotas from Energy Policy Act

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Corn Acres Driven Up by Ethanol

Year	Acres corn planted (mill.)	% production for ethanol
1990	74.2	4.4%
2000	80.0	6.3%
2005	81.8	14.4%
2010	88.2	34.8%
Through 2020	90-92	36% (average)

24% increase in corn acreage since 1990
Source: USDA data; USDA Agricultural Projections to 2020.

Corn Monoculture Reduces Biodiversity in Ag Ecosystems

- Study on biocontrol of soybean aphid in different scenarios (14% hike corn acres in 4 states, 2006-2007)
- Aphid control reduced w/ increasing % corn in local landscape (1.5 km)
- Aphid predators (e.g. ladybugs) less prevalent on corn
- Less available to control soybean aphid
- Landis, D.A. et al (2008). "Increasing corn for biofuel production reduces biocontrol services in agricultural landscapes," PNAS 105: 20552-557.

Corn in Monoculture More Prone to Corn Rootworm

- More corn on corn due to ethanol demand
- Corn in rotations (e.g. corn-soy, more complex) less susceptible to corn rootworm
- Adaptation to corn-soy in some regions
- More soil-applied insecticides, or
- Biotech fix: Bt corn rootworm-resistant corn
- Entomologists concerned evolution of resistance to Bt insecticidal toxin(s)

Corn vs. Soybeans: Fertilizer Use

- N fertilizer: 10.88 billion lbs. (corn 2005)
- 49-fold more than soybeans (over 3-fold more vs. wheat)
- 4.8-fold more phosphate
- 2.9-fold more potash (K)

Impacts of N Fertilizer on Soil Quality

- Long-term experiment since 1955 in Illinois
- Compares continuous corn, corn-soy, corn-oats-alfalfa rotations
- Declining soil N in continuous corn despite huge N inputs
- Mineral N stimulates microbial C decomposition
- Depletes soil organic C that is major reservoir of soil N
- Productivity declines in continuous corn vs. rotations with legumes (less N needed)

- Mulvaney, R.L. et al (2010). "The Browning of the Green Revolution," http://www.organic-center.org/reportfiles/Browning%20of%20the%20Green%20Revolution-2%20(2).pdf

Biodiversity Impacts of N Fertilization

- In continuous corn, only half of applied N is recovered in N embodied in grain
- Implies huge runoff of N into waterways
- Dead zone in Gulf of Mexico continues to expand

- Mulvaney, R.L. et al (2010). "The Browning of the Green Revolution," http://www.organic-center.org/reportfiles/Browning%20of%20the%20Green%20Revolution-2%20(2).pdf

Corn vs. Soybeans: Herbicide Use

- USDA NASS data: corn (2005) vs. soy (2006)
- 46% more herbicides in corn, including 80+% of overall atrazine use
- 77% more insecticides
- 40+% of all herbicides used in U.S. agriculture are applied to corn (169.5 of 407 million lbs.)

- US EPA data on overall herbicide use for 2006. Corn herbicide use from USDA NASS 2005.

Herbicide Use: Glyphosate/Atrazine

- Top two herbicides in U.S. agriculture
- Glyphosate use up >10-fold from 1993 to 2007 (10-15 to 180-185 million lbs./year)
- Due to massive adoption of Roundup Ready soybeans, corn, cotton, canola and sugar beets
- RR corn from 11% to 70% all corn 2002-2010
- Atrazine: 70-82 mill. lbs./year past 20 years, 80+% applied to corn

- US EPA data on glyphosate/atrazine use; USDA ERS on RR corn adoption.

Impacts Glyphosate/Atrazine on Amphibians

- Some glyphosate formulations lethal to frogs at field-relevant usage rates
- Impacts to tadpoles at low ppm concentrations
- Glyphosate overspray of wetlands common
- Atrazine feminizes male frogs at even lower (ppb) levels (Tyrone Hayes) and suppresses their immune systems, increasing susceptibility to snail-born parasitic worm larvae (Jason Rohr)

- Relyea, R.A. (2005). "The lethal impact of Roundup on aquatic and terrestial amphibians," *Ecological Applications* 15(4): 1118–1124; Relyea et al (2005). "Pesticides and amphibians: The importance of community context," *Ecological Adaptations* 15: 1125-1134; Tyrone Hayes

Biodiversity Impacts of Glyphosate: Soil Life

- Glyphosate absorbed by RR crops/weeds, moves to roots to kill
- Some exuded from roots → rhizosphere
- Fosters Fusarium (pathogenic fungi), suppresses Pseudomonas (bacteria)
- May promote Fusarium-related plant diseases
- Suppresses microbes needed for plant uptake of essential nutrients (e.g. manganese, iron)
- Some evidence of lasting impacts (increased disease incidence in follow-on crops)

- Kremer, R.J & Means, N.E. (2009). "Glyphosate and glyphosate-resistant crop interactions with rhizosphere microorganisms," *European Journal of Agronomy,* doi:10.1016/j.eja.2009.06.004/
- Fernandez, J.R. et al (2009). "Glyphosate associations with cereal diseases caused by *Fusarium* spp. in the Canadian Prairies," *Eur. J. Agron.*, doi:10.1016/j.eja.2009.07.003.

GHG Impacts of Biofuels from Land Use Change

- Diversion of corn to ethanol → conversion of soybeans & wheat → corn, reducing supplies and raising prices of all crops for food/feed uses
- Exports of corn, wheat, etc. fall → replacement by local production
- Pasture, but also grassland & forests, converted to ag uses to make up difference
- Huge release of stored carbon from conversion of native ecosystems swamps for many years marginal GHG biofuels benefits
- Searchinger, T. et al (2008). "Use of U.S. Croplands for Biofuels Increases Greenhouse Gas Emissions from Land-Use Change," Science 319: 1238-1240.

U.S. Corn Ethanol Contribution to Fuel Use

- 36% of corn to ethanol thru 2020
- Displaces just over 10% of gasoline by volume (7% on energy basis) by 2020
- 100% of corn would provide only 30% motor vehicle fuel (vol.) and 20% on energy basis

- USDA Agricultural Projections to 2020.

Ethanol for U.S. Motor Fuel Use

Ethanol as Share of Total Gasoline Use in U.S. (Energy Basis)				
Source	2008	2015	2025	2035
Corn	4.7%	6.9%	7.2%	8.2%
Cellulosic	0.0%	0.1%	0.9%	2.4%
Imports	0.3%	0.2%	0.9%	2.4%
Total	5.0%	7.2%	9.0%	12.9%
Motor fuel = E85 + motor gasoline. Calculated from Tables A17 & D3, EIA Annual Energy Outlook 2010. Reference Case projection				

Miles and Efficiency

Vehicle Miles Traveled and Fuel Efficiency of Light-Duty Vehicles					
	2008	2015	2025	2035	Increase
VMT (bill.)	2676	2916	3554	4203	57%
Light-Duty Stock (mpg)*	20.9	22.3	26.2	29.3	40%
CAFÉ light duty vehicle (new)	25.0	32.5	35.5	35.8	43%
* Combined car and light truck “on the road” estimate; EIA Annual Energy Outlook 2010					

Biofuels Share of World Transportation Fuels

- EIA projects world biofuels production rising from 1.2 to 4.1 million barrels/day from 2007 to 2035, 240% increase
- Yet this would mean rise from just 2.6% to 6.1% of total world liquid fuels consumption for transportation, due to strongly increasing VMT and minimal fuel efficiency increase in U.S., and increased auto use in Asia

- EIA International Energy Outlook 2010, Table 3 and Figure 31.

Fossil vs. Bio-Fuels

- Both are “bio”-fuels, derived from living organisms, past vs. present
- In just over one century, transportation demand has substantially depleted reserves formed over billions of years of life on earth
- Can biofuels derived from “real-time” life (one year’s harvest) be expected to ever make meaningful contribution? At least without radical reductions in usage, and increases in efficiency?