Biodiversity Impacts of Biofuels: Focus on Ethanol from Corn

Bill Freese, Science Policy Analyst
Center for Food Safety
March 2011
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

<table>
<thead>
<tr>
<th>Year</th>
<th>Acres corn planted (mill.)</th>
<th>% production for ethanol</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990</td>
<td>74.2</td>
<td>4.4%</td>
</tr>
<tr>
<td>2000</td>
<td>80.0</td>
<td>6.3%</td>
</tr>
<tr>
<td>2005</td>
<td>81.8</td>
<td>14.4%</td>
</tr>
<tr>
<td>2010</td>
<td>88.2</td>
<td>34.8%</td>
</tr>
<tr>
<td>Through 2020</td>
<td>90-92</td>
<td>36% (average)</td>
</tr>
</tbody>
</table>

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
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)

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

Corn vs. Soybeans: Herbicide Use

- 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.)

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)

Biodiversity Impacts of Glyphosate: Soil Life

- Glyphosate absorbed by RR crops/weeds, moves to roots to kill
- Some exuded from roots $\rightarrow$ 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)

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

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

<table>
<thead>
<tr>
<th>Source</th>
<th>2008</th>
<th>2015</th>
<th>2025</th>
<th>2035</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn</td>
<td>4.7%</td>
<td>6.9%</td>
<td>7.2%</td>
<td>8.2%</td>
</tr>
<tr>
<td>Cellulosic</td>
<td>0.0%</td>
<td>0.1%</td>
<td>0.9%</td>
<td>2.4%</td>
</tr>
<tr>
<td>Imports</td>
<td>0.3%</td>
<td>0.2%</td>
<td>0.9%</td>
<td>2.4%</td>
</tr>
<tr>
<td>Total</td>
<td>5.0%</td>
<td>7.2%</td>
<td>9.0%</td>
<td>12.9%</td>
</tr>
</tbody>
</table>

## Miles and Efficiency

<table>
<thead>
<tr>
<th>Vehcile Miles Traveled and Fuel Efficiency of Light-Duty Vehicles</th>
<th>2008</th>
<th>2015</th>
<th>2025</th>
<th>2035</th>
<th>Increase</th>
</tr>
</thead>
<tbody>
<tr>
<td>VMT (bill.)</td>
<td>2676</td>
<td>2916</td>
<td>3554</td>
<td>4203</td>
<td>57%</td>
</tr>
<tr>
<td>Light-Duty Stock (mpg)*</td>
<td>20.9</td>
<td>22.3</td>
<td>26.2</td>
<td>29.3</td>
<td>40%</td>
</tr>
<tr>
<td>CAFÉ light duty vehicle (new)</td>
<td>25.0</td>
<td>32.5</td>
<td>35.5</td>
<td>35.8</td>
<td>43%</td>
</tr>
</tbody>
</table>

* 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?