Science 17 August 2007:
Vol. 317. no. 5840, p. 902
DOI: 10.1126/science.1141361

Prev | **Table of Contents** | **Next**

POLICY FORUM

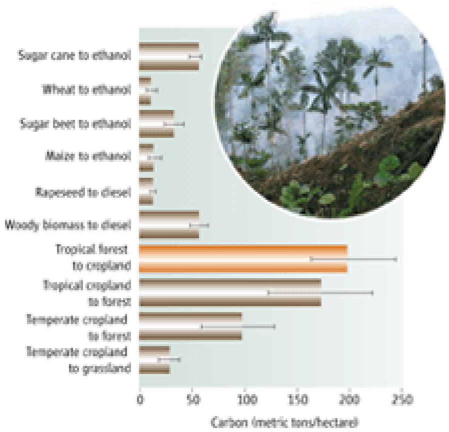
ENVIRONMENT:

Carbon Mitigation by Biofuels or by Saving and Restoring Forests?

Renton Righelato[1*] and Dominick V. Spracklen[2]

Choosing from among the host of strategies for mitigation of anthropogenic carbon emissions is not easy. There are competing environmental priorities, social and economic factors, and commercial and political interests. One strategy that has received extensive attention is the use of biofuels for transport, particularly ethanol from fermentation of carbohydrate crops as a substitute for petrol and vegetable oils in place of diesel fuel. Such an approach would require very large areas of land in order to make a significant contribution to mitigation of fossil fuel emissions and would, directly or indirectly, put further pressure on natural forests and grasslands. There are numerous assessments of the relative merits of different liquid biofuel strategies (e.g., 1-3), but few compare these with other uses of land (4).

Two issues need to be addressed before the efficacy of biofuels can be assessed: the net reduction in fossil carbon emissions (avoided emissions) arising from use of agriculturally derived biofuels and the effect of alternative land-use strategies on carbon stores in the biosphere. As land is the limiting resource, the appropriate basis for comparison is a function of land area (Mg C ha^{-1} $year^{-1}$). We use a period of 30 years as a basis for comparing strategies because it is likely to take that much time for carbon-free fuel technologies to be developed and introduced. Estimates of avoided emissions vary widely depending on crop, fuel type, and conversion technology used; some typical examples derived from lifecycle analyses are shown in the figure (right). In these analyses, no allowance has been made for emissions arising from change in land use to produce the fuel crop. In all cases, forestation of an equivalent area of land would sequester two to nine times more carbon over a 30-year period than the emissions avoided by the use of the biofuel. Taking this opportunity cost into account, the emissions cost of liquid biofuels exceeds that of fossil fuels.



Cumulative avoided emissions per hectare over 30 years for a range of biofuels compared with the carbon sequestered over 30 years by changing cropland to forest and the loss of carbon to the atmosphere by conversion of forest to cropland. Error bars indicate the ranges of values in the literature cited. Details are in the SOM.

PHOTO CREDIT: WORLD LAND TRUST

Moreover, large areas of land would be needed to make significant quantities of fuel. A 10% substitution of petrol and diesel fuel is estimated to require 43% and 38% of current cropland area in the United States and Europe, respectively (5). As even this low substitution level cannot be met from existing arable land, forests and grasslands would need to be cleared to enable production of the energy crops. Clearance results in the rapid oxidation of carbon stores in the vegetation and soil, creating a large up-front emissions cost (6) that would, in all cases examined here, outweigh the avoided emissions.

Of the biofuel sources shown, only conversion of woody biomass (1, 2, 4, 7) may be compatible with retention of forest carbon stocks. Woody biomass can be used directly for fuel or converted to liquid fuels. Although still in a development stage, avoided emissions in temperate zones appear similar to assimilation by forest restoration. Moreover, it may be possible to avoid environmental problems associated with extensive monoculture (8) by harvesting from standing forests. In this case, soil and above-ground carbon stocks may be built up in parallel with sustainable harvesting for fuel production.

If the prime object of policy on biofuels is mitigation of carbon dioxide-driven global warming, policy-makers may be better advised in the short term (30 years or so) to focus on increasing the efficiency of fossil fuel use, to conserve the existing forests and savannahs, and to restore natural forest and grassland habitats on cropland that is not needed for food. In addition to reducing net carbon dioxide flux to the atmosphere, conversion of large areas of land back to secondary forest provides other environmental services (such as prevention of desertification, provision of forest products, maintenance of biological diversity, and regional climate regulation), whereas conversion of large areas of land to biofuel crops may place additional strains on the environment. For the longer term, carbon-free transport fuel technologies are needed to replace fossil hydrocarbons.

References

1. *Well-to-Wheels Analysis of Future Automotive Fuels and Powertrains in the European Contex*t [European Council for Automotive R&D (EUCAR), European Commission Joint Research Center (JRC), and Conservation of Clean Air and Water in Europe (CONCAWE) joint study, Brussels, May 2006); **http://ies.jrc.ec.europa.eu/wtw.html**.
2. E. Larson, "A review of LCA studies on liquid biofuels for the transport sector," Scientific and Technical Advisory Panel of the Global Environment Facility (STAP) workshop on Liquid Biofuels, 29 August to 1 September 2005, New Delhi, India; **http://stapgef.unep.org/docs/folder.2005-12-07.8158774253/folder.2005-12-08.9446059805/**.
3. M. A. Elsayed, R. Mathews, N. D. Mortimer, *Carbon and Energy Balances for a Range of Biofuel Options* (Resources Research Institute, Sheffield Hallam University, Sheffield, UK, 2003).
4. M. U. F. Kirschbaum, *Biomass Bioenergy* **24**, 297 (2003).
5. International Energy Authority, *Biofuels for Transport: An International Perspective* (IEA, Paris, France, 2004), chap. 6; **www.iea.org/textbase/nppdf/free/2004/biofuels2004.pdf**.
6. R. T. Watson *et al.*, *Land Use*, *Land-Use Change and Forestry* (Intergovernmental Panel for Climate Change, Geneva, 2001), p 184.
7. D. Tilman, J. Hill, C. Lehman, *Science* **314**, **1598** (2006).

8. S. Raghu *et al.*, *Science* **313**, **1742** (2006).

Supporting Online Material
www.sciencemag.org/cgi/content/full/317/5840/902/DC1

10.1126/science.1141361

[1]R. Righelato, World Land Trust, Halesworth, Suffolk, IP19 8AB

[2]D. V. Spracklen, School of Earth and Environment, University of Leeds, Leeds, UK.

[*]Author for correspondence. E-mail: renton@worldlandtrust.org

Indicators of Carbon Storage in U.S. Ecosystems: Baseline for Terrestrial Carbon Accounting.
C. Negra, C. C. Sweedo, K. Cavender-Bares, and R. O'Malley (2008)
J. Environ. Qual. **37**, 1376-1382
Abstract » **Full Text »** **PDF »**

Use of U.S. Croplands for Biofuels Increases Greenhouse Gases Through Emissions from Land-Use Change.
T. Searchinger, R. Heimlich, R. A. Houghton, F. Dong, A. Elobeid, J. Fabiosa, S. Tokgoz, D. Hayes, and T.-H. Yu (2008)
Science **319**, 1238-1240
Abstract » **Full Text »** **PDF »**

Science. ISSN 0036-8075 (print), 1095-9203 (online)