Final Report DE-FG02-08ER64648

Impacts of Climate Change on Biofuels Production

Study Period: 2009-2013

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The overall goal of this research project was to improve and use our biogeochemistry model, TEM, to simulate the effects of climate change and other environmental changes on the production of biofuel feedstocks. We used the improved version of TEM that is coupled with the economic model, EPPA, a part of MIT's Earth System Model, to explore how alternative uses of land, including land for biofuels production, can help society meet proposed climate targets.

During the course of this project, we have made refinements to TEM that include development of a more mechanistic plant module, with improved ecohydrology and consideration of plant-water relations, and a more detailed treatment of soil nitrogen dynamics, especially processes that add or remove nitrogen from ecosystems. We have documented our changes to TEM and used the model to explore the effects on production in land ecosystems, including changes in biofuels production. Below, we list the publications that we credit to DE-FG02-08ER64648:

Publications -

Felzer, B. S., T. W. Cronin, J. M. Melillo, D. W. Kicklighter and C. A. Schlosser (2009) Importance of carbon-nitrogen interactions and ozone on ecosystem hydrology during the 21st century. *Journal of Geophysical Research* **114**, G01020, doi: 10.1029/2008JG000826.

Melillo, J. M., J. M. Reilly, D. W. Kicklighter, A. C. Gurgel, T. W. Cronin, S. Paltsev, B. S. Felzer, X. Wang, A. P. Sokolov and C. A. Schlosser (2009) Indirect emissions from biofuels: how important? *Science* **326**, 1397-1399. [doi: 10.1126/science.1180251]. [Supporting Data]

Tian, H., J. Melillo, M. Liu, D. Kicklighter, J. Liu, W. Ren, C. Lu, X. Xu, G. Chen, C. Zhang, S. Pan and S.Running. 2011. Mechanisms of China's terrestrial carbon sink: responses to nitrogen inputs and other environmental changes. *Global Biogeochemical Cycles*. 25:GB1007 doi:10.1029/2010GB003838.

Felzer, B, T. Cronin, J. Melillo, D. Kicklighter, and Shree Sharma, C.A. Schlosser. 2011. Carbon-Water Coupling in Forests, Grasslands, and Shrublands in the Arid Western U.S.

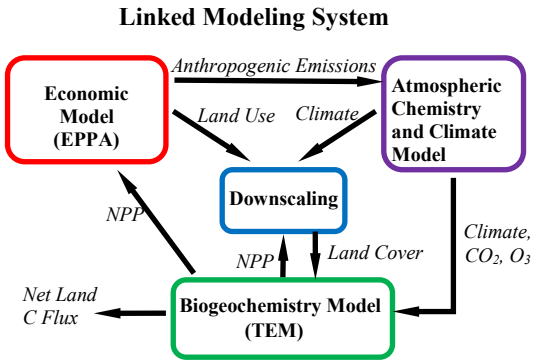
Journal of Geophysical Research Journal of Geophysical Research-Biogeosciences, doi: 10.1029/2010JG001621.

Kicklighter, D. W., A. C. Gurgel, J. M. Melillo, J. M. Reilly, and S. Paltsev (2012) *Potential Direct and Indirect Effects of Global Cellulosic Biofuel Production on Greenhouse Gas Fluxes from Future Land-use Change.* MIT Joint Program on Science and Policy of Global Change Report No. 210. Massachusetts Institute of Technology, Cambridge, Massachusetts. (see also http://globalchange.mit.edu/files/document/MITJPSPGC_Rpt210.pdf).

Reay, D.S., E.A. Davidson, K. Smith, P. Smith, J.M. Melillo, F. Dentener and P.J. Crutzen. 2012. Nitrous Oxide and Anthropogenic Climate Change. *Nature Climate Change.* 2:410–416. doi:10.1038/nclimate1458.

Reilly, J., J.M. Melillo, Y. Cai, D. Kicklighter, A. Gurgel, S. Paltsev, T. Cronin, A. Sokolov, A. Schlosser. (2012) Using Land to Mitigate Climate Change: Hitting the Target, Recognizing the Tradeoffs. *Environmental Science and Technology*. 46:5672-5679. doi: 10.1021/es2034729.

The Reilly et al. 2012 publication represents the most recent advances in our coupling of the EPPA and TEM models. The dynamically linked modeling system consists of EPPA,TEM and either a dynamic or "hand off" link to atmospheric chemistry and climate models, which are all components of MIT's Earth System Model. The linked modeling systems can be visualized as follows:



The abstract of the Reilly et all paper is as follows:

Land can be used in several ways to mitigate climate change, but especially under changing environmental conditions there may be implications for food prices. Using an integrated global system model, we explore the roles that these land-use options can play in a global mitigation strategy to stabilize Earth's average temperature within 2 °C

of the preindustrial level and their impacts on agriculture. We show that an ambitious global Energy-Only climate policy that includes biofuels would likely not achieve the 2 °C target. A thought-experiment where the world ideally prices land carbon fluxes combined with biofuels (Energy+Land policy) gets the world much closer. Land could become a large net carbon sink of about 178 Pg C over the 21st century with price incentives in the Energy+Land scenario. With land carbon pricing but without biofuels (a No-Biofuel scenario) the carbon sink is nearly identical to the case with biofuels, but emissions from energy are somewhat higher, thereby results in more warming. Absent such incentives, land is either a much smaller net carbon sink (+37 Pg C − Energy-Only policy) or a net source (−21 Pg C − No-Policy). The significant tradeoff with this integrated land-use approach is that prices for agricultural products rise substantially because of mitigation costs borne by the sector and higher land prices. Share of income spent on food for wealthier regions continues to fall, but for the poorest regions, higher food prices lead to a rising share of income spent on food.