Carbon Negativity Estimates for Grassland Biomass

Abstract. Tilman, Hill, and Lehman propose high-diversity biofuels to combine energy production with carbon sequestration, a process which saturates over time. Adding carbon capture and storage technology, however, expands their proposal fivefold and eliminates saturation, helping reverse the decades-long anthropogenic transfer of carbon from the lithosphere to the biosphere.

Tilman, Hill, and Lehman ("Carbon-Negative Biofuels from Low-Input High-Diversity Grassland Biomass," David Tilman *et al*., Research Article, 8 Dec. 2006, p. 1598) examined the effect of replacing fossil fuels with “carbon-negative” biofuels such as diverse restored prairie flora to reduce greenhouse emissions. The term “carbon-negative” is used because the roots and soils of restored prairie systems will sequester carbon at the same time as the harvested biomass is used for energy production—resulting in a net transfer of carbon from the atmosphere to the soils, saturating after about a century. This is an important new possibility for ameliorating climate change. However, the authors neglected another important possibility: combining their approach with technology for carbon capture and storage (CCS) can amplify the effect and avoid saturation indefinitely.

Obersteiner *et al* (1) pointed out that biomass energy production combined with CCS can be used to remove carbon from the atmosphere and return it to deep reservoirs within the lithosphere, thereby actually reversing the effect of fossil fuel consumption. Picking up on this idea, Kraxner *et al* (2) examined forest management schemes using CCS technology and estimated a potential net removal of 2.5 t C $ha^{-1}yr^{-1}$ for timberland managed to maximize the CCS benefit.

If the prairie grasses discussed by Tilman *et al* were processed in power plants equipped with CCS technology, then the “carbon negativity” of this energy source could be increased substantially. Their computations indicate that the carbon sequestration in the soil and roots would amount to about 21 t C ha^{-1} during the first two decades of converting degraded cropland to native prairie grasses. Their experiments also indicate that these grasses will produce between 3.7 and 5.6 tonnes of biomass per hectare per year, depending on the fertility of the soil. Assuming this biomass is roughly 50% carbon, energy generation using CCS technology could potentially store between 1.85 and 2.8 t C $ha^{-1}yr^{-1}$, which is within the same range as the forest management scheme examined by Kraxner et al. This amount is considerably more than the average of 1.05 t C $ha^{-1}yr^{-1}$ of soil sequestration, and it has a qualitatively different effect—that of permanently transferring the carbon from the biosphere back to the lithosphere.

The figures show the simulated effect of converting 0.5 Gha (the amount of agriculturally abandoned and degraded land estimated by Tilman *et al*) to prairie grass and using the biomass for energy production with CCS technology. It is assumed that the conversion occurs linearly over the course of 50 years. The soil sequestration is assumed to saturate geometrically, estimated from the first two decades described by Tilman *et al*. The carbon content of the biomass is assumed to be 2.3 t C $ha^{-1}yr^{-1}$, a number in the midrange of their estimate. Ninety percent of the CO_2 is assumed to be captured.

Decades of burning fossil fuels have resulted in an anthropogenic transfer of carbon from the lithosphere to the biosphere. That transfer will be permanent on a millennial scale unless anthropogenic activity returns it to the lithosphere. The use of grassland biomass energy with CCS can be an important part of the solution to the problem of restoring biospheric carbon to its preindustrial levels.

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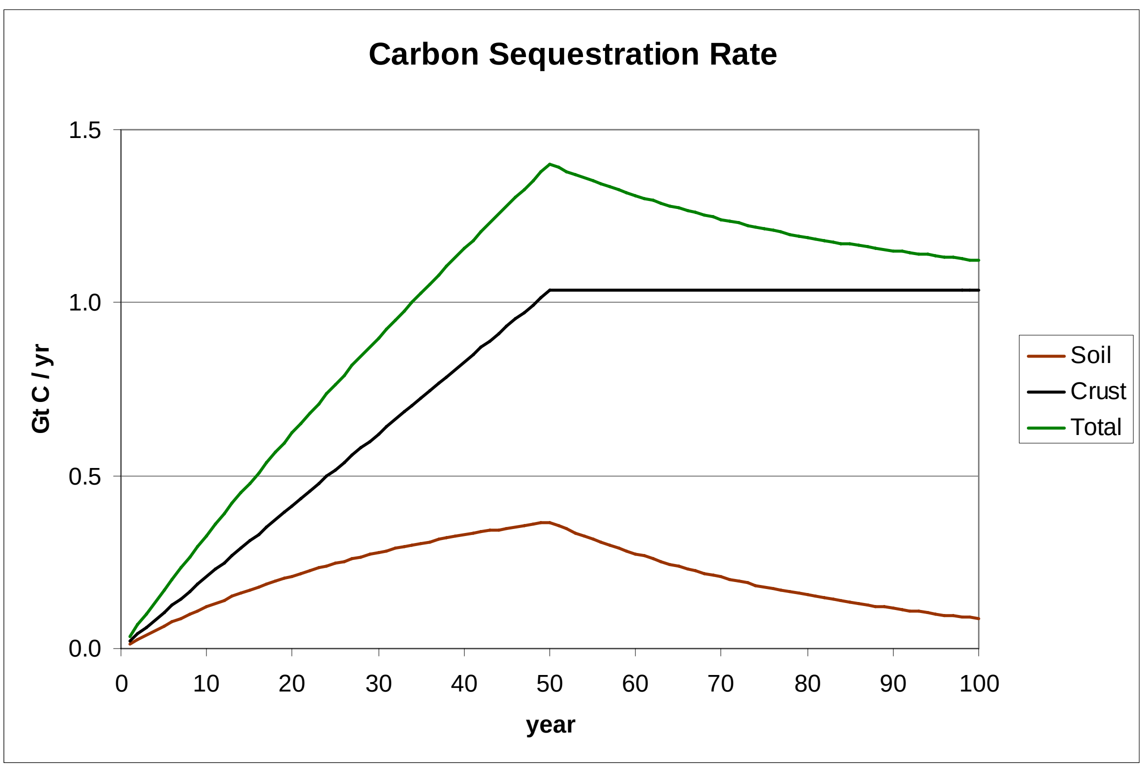
References

1. M. Obersteiner, Ch. Azar, P. Kauppi, K. Mollersten, J. Moreira, S. Nilsson, P. Read, K. Riahi, B. Schlamadinger, Y. Yamagata, J. Yan, J.-P. van Ypersele, *Science* 26 Oct. 2001, p. 786.

2. Florian Kraxner, Sten Nilsson, Michael Obersteiner, *Biomass & Bioenergy* 24 (2003) p. 285.

3. The author thanks the members of the University of Minnesota Temperature Cycles Seminar, in the Department of Ecology, Evolution, and Behavior, for discussions leading to these ideas.



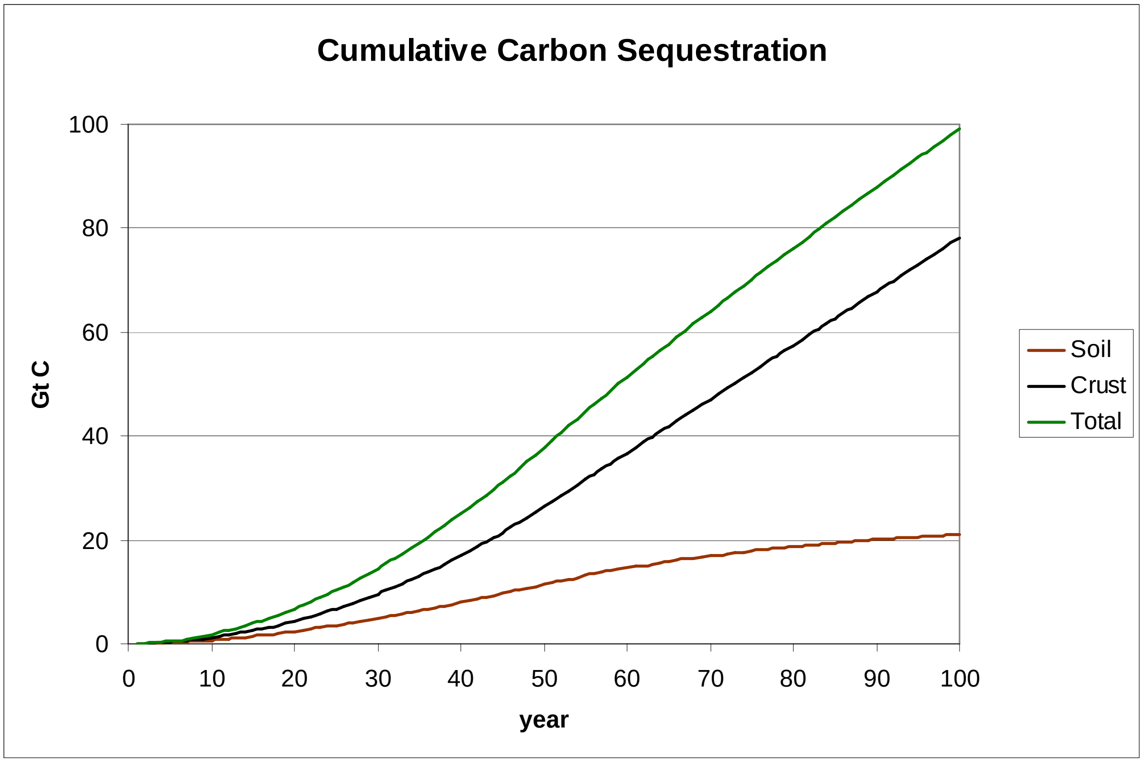


Figure 1. Carbon sequestration over the first century. In this scenario, land area is converted to biofuel and CCS energy plants are developed steadily, with all available lands (0.5 Gha) converted after 50 years. **(A)** The rate of sequestration in the soil increases as land is converted, then decreases as the soil saturates. That in the lithosphere (crust) remains proportional to land area converted. Total sequestration asymptotically approaches a constant rate. **(B)** After one century, 80% of the carbon sequestered is permanently removed from the biosphere. Lithospheric sequestration continues approximately linearly in future centuries.