CORRESPONDENCE:

CO_2 emissions from crop residue-derived biofuels

To the Editor — In the May issue of *Nature Climate Change*, Liska *et al.*[1] presented a comprehensive analysis of the soil organic carbon (SOC) loss due to harvest of corn residues for bioethanol production. We do not dispute the main findings that harvest of residues has a negative impact on SOC levels and that this impact should be addressed when evaluating the potential benefits of cellulosic biofuels. We do, however, find that the conclusion, that cellulosic biofuels increase CO_2 emissions, builds on an incomplete analysis and that the analysis could have reached the opposite conclusion had it been more complete.

Liska *et al.* refer to consequential life cycle assessment (LCA) as the reason why SOC loss must be incorporated in greenhouse-gas analyses of biofuels. Consequential LCA requires that mass balances are closed and if not, some impact allocation must take place. In cellulosic ethanol production based on agricultural residues 20–25% of the carbon in the biomass ends up in ethanol and half of that amount in CO_2. Approximately 40% is retained in the lignin residue and the rest (~20–30%) in molasses/vinasse[2,3]. Liska *et al.* surprisingly disregard a considerable part of that carbon mass and attribute all CO_2 interactions between the product system and the atmosphere to ethanol. The lignin fraction is not accounted for in the main comparison between cellulosic and fossil fuels (Fig. 3 in ref. 1). If the lignin fraction was used for electricity generation, the authors report a potential to save greenhouse-gas emissions worth 55 g CO_2 equivalent MJ^{-1}. Otherwise it can, due to its recalcitrance, constitute a valuable contribution to SOC if returned to the soil, as also noted, but not accounted for, by the authors. C5-molasses may be used to feed livestock or generate energy through anaerobic digestion, displacing in either case other production or energy use. This fraction is not accounted for at all. The feed fraction from corn residue ethanol is reported to make up ~17% of the total greenhouse-gas displacement potential from cellulosic ethanol production[4].

The analysis by Liska *et al.* shows that growing corn after corn, in itself, reduces SOC, and that the harvest of residues accelerates SOC loss. Owing to the exponential decay of carbon in soil (Supplementary Fig. 1 in ref. 1), time, so to speak, dilutes the average annual carbon emissions[5]. While Liska *et al.* chose a 5–10-year time perspective in their analysis, the IPCC recommends a 20-year perspective[6], the same as the European Union Renewable Energy Directive[7]. And much LCA work applies a 100-year time perspective[5]. Applying any of these time perspectives to the analysis of Liska *et al.* would reduce the greenhouse-gas impact of cellulosic biofuel and render cellulosic biofuels capable of reducing CO_2 emissions and perhaps even meeting the Renewable Fuel Standard reduction target.

Loss of SOC from biofuel production is a critical issue for greenhouse-gas emissions and soil quality, and it should be addressed in both science and management. But it is highly important that all biogenic carbon is included in greenhouse-gas analyses and that relevant time frames are applied, which is not the case for the analysis by Liska and co-authors. ❐

References

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To the Editor — The claim by Liska *et al.*[1] that corn stover-derived ethanol can be worse than gasoline has generated lots of media interest, but offers little value to the research community or to policymakers. They have merely demonstrated that if you model an irresponsible and unsustainable scenario, the results will look irresponsible and unsustainable. No one who has given serious thought to crop residues for biofuels would find their proposed across-the-board 6 Mg ha^{-1} collection rate in the US Corn Belt at all reasonable.

A decade ago, Sheehan *et al.*[2] used soil carbon and life cycle assessment (LCA) modelling to show that corn stover for ethanol would only make sense if farmers simultaneously adopted conservation tillage practices and constrained removal rates to account for local yield, soil, climate and topographical conditions. Numerous other field and modelling studies[3–6] have shown that soil carbon levels can be maintained with conservation tillage and moderate stover removal.

In contrast, Liska *et al.* applied a very simplistic soil carbon model that ignores important variables such as soil moisture and soil texture — making regional extrapolations highly questionable — and doesn't allow for varying management practices. This is an important shortcoming, as farmers can reduce their tillage intensity with stover harvest, saving money, without compromising yields[7]. Figure 1a illustrates these weaknesses when net changes in soil carbon emissions are modelled with DayCent[8] (the analysis was using the DayCent model version used in the most recent US national greenhouse-gas emissions inventory: www.epa.gov/climatechange/ghgemissions/usinventoryreport.html) for the Mead, Nebraska site in Liska *et al.*'s study.

The results for 50% stover removal at this site are consistent with the 6 Mg ha^{-1}