# BIOFUELS:

## THE CARBON DEBT THEY OWE

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# BIOFUELS: THE CARBON DEBT THEY OWE

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> *When non-agricultural lands are cleared for the growing of biofuel crops … this process releases large amounts of $CO_2$ to the atmosphere due to the burning and microbial decomposition of organic carbon stored in plant biomass and soils.*
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> *This initial "carbon debt" must be repaid before there is any net reduction in $CO_2$ emissions from the use of the biofuel crops grown on the newly-cleared land.*

In an article entitled "Land Clearing and the Biofuel Carbon Debt," Fargione *et al*. (2008)[1] explore what happens when non-agricultural lands are cleared for the growing of biofuel crops. In addition to the destruction of precious habitat needed to support what could be called "wild nature," this process releases large amounts of $CO_2$ to the atmosphere due to the burning and microbial decomposition of organic carbon stored in plant biomass and soils. And this initial "carbon debt" must be repaid before there is any net reduction in $CO_2$ emissions from the use of the biofuel crops grown on the newly-cleared land.

As for just how big initial carbon debts can be, Fargione *et al*. made detailed calculations for six different scenarios of "native habitat conversion," which include "Brazilian Amazon to soybean biodiesel, Brazilian Cerrado to soybean biodiesel, Brazilian Cerrado to sugarcane ethanol, Indonesian or Malaysian lowland tropical rainforest to palm biodiesel, Indonesian or Malaysian peatland tropical rainforest to palm biodiesel, and U.S. central grassland to corn ethanol." These conversions, in their words, would release "17 to 420 times more $CO_2$ than the annual greenhouse gas reductions that these biofuels would provide by displacing fossil fuels." And they note the huge carbon debts they produce "would not be repaid by the annual carbon repayments from biofuel production for decades or centuries."

Much the same conclusions are reached by Searchinger *et al*. (2008), who write earlier studies of the benefits of substituting biofuels for gasoline "failed to count the carbon emissions that occur as farmers worldwide respond to higher prices and convert forest and grassland to new cropland to replace the grain (or cropland) diverted to biofuels." And by using a worldwide agricultural model to estimate emissions from such land-use changes, they find "corn-based

[1] http://www.co2science.org/articles/V11/N29/EDIT.php.

ethanol, instead of producing a 20% savings, nearly doubles greenhouse emissions over 30 years and increases greenhouse gases for 167 years," while "biofuels from switchgrass, if grown on U.S. corn lands, increase emissions by 50%." In light of such findings, Searchinger *et al*. conclude that "when farmers use today's good cropland to produce food," which is what past policy has always dictated they should do, "they help to avert [the release of] greenhouse gases from land-use change."

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Other scientists have reached similar conclusions.

Righelato and Spracklen (2007)[2] report the use of biofuels for transport, particularly ethanol from the fermentation of carbohydrate crops as a substitute for petrol, and vegetable oils in place of diesel fuel, "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." With respect to how much land, the two UK researchers calculate a 10% substitution of petrol and diesel fuel would require "43% and 38% of current cropland area in the United States and Europe, respectively." Yet, they add "even this low substitution level cannot be met from existing arable land," so "forests and grasslands would need to be cleared to enable production of the energy crops." But this latter option carries with it its own set of consequences, as the required land clearance would result in "the rapid oxidation of carbon stores in the vegetation and soil, creating a large up-front emissions cost that would, in all cases examined, out-weigh the avoided emissions." Furthermore, even without the large up-front carbon emissions, Righelato and Spracklen report individual life-cycle analyses of the conversion of sugar cane, of sugar beet, and of wheat and corn to ethanol, as well as the conversion of rapeseed and woody biomass to diesel, indicate "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." As a result, they conclude "the emissions cost of liquid biofuels exceeds that of fossil fuels."

[2] http://www.co2science.org/articles/V10/N41/EDIT.php.

Coming to much the same conclusion in a News & Views article in *Nature* was Laurance (2007)[3], who discussed the ability of forests to reduce catastrophic flooding. In addition to this important virtue, he writes "tropical forests, in particular, are crucial for combating global warming, because of their high capacity to store carbon and their ability to promote sunlight-reflecting clouds via large-scale evapotranspiration," noting "such features are key reasons why preserving and restoring tropical forests could be a better strategy for mitigating the effects of carbon dioxide than dramatically expanding global biofuel production."

Ciais *et al*. (2008)[4] analyzed national forest inventory data and timber harvest statistics of the EU-15 countries excluding Luxembourg, plus Norway and Switzerland, for the period AD 1950-2000. Over this half-century interval, they found the net primary productivity (NPP) of Europe's forests rose by approximately 67%, while their biomass carbon stocks rose by approximately 75%. In looking to the future, the international group of scientists (hailing from Belgium, China, Finland, France, Germany, Italy, the Netherlands, Romania and the United States) writes "European forests still have the potential to realize a build-up of their carbon stocks by a factor of two, within the next century." However, they say this "potential $CO_2$ sink is threatened by the proposal of the European Commission to increase the share of renewable energy to 20% of the total energy consumption by 2020," warning that "a return to using wood as biofuel ... could cancel out the benefits of carbon storage over the past five decades."

Danielsen *et al*. (2009)[5] explored the climatic impact of creating oil-palm plantations for biofuel production by assessing changes in land carbon stocks caused by replacing tropical forests and peatlands with oil-palms and comparing the results with the amount of carbon emissions avoided by replacing conventional fossil fuels with the biofuel. In addition, they explored the biodiversity impact of replacing tropical forests with oil-palms via assessments of other plant species growing in oil palm and forest plots in Indonesia, augmented with a meta-analysis of published studies that compare animal species found in tropical forests with those found in oil-palm plantations.

With respect to climatic impact, Danielsen *et al*. estimate "it would take between 75 and 93 years for the carbon emissions saved through use of biofuel to compensate for the carbon lost through forest conversion," and "if the original habitat was peatland, carbon balance would take more than 600 years." With respect to biodiversity impact, they found "trees, lianas, epiphytic orchids, and indigenous palms were wholly absent from oil-palm plantations," and "the majority of individual plants and animals in oil-palm plantations belonged to a small number of generalist species of low conservation concern." The eleven researchers, hailing from seven different nations, conclude "as countries strive to meet obligations to reduce carbon emissions under one international agreement (Kyoto Protocol), they may not only fail to meet their obligations under another (Convention on Biological Diversity) but may actually hasten global climate change" if they replace tropical forests or peatlands with oil-palm plantations. Hence, they take the logical position that "reducing deforestation is likely to represent a more effective climate-change mitigation strategy than converting forest for biofuel

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3 http://www.co2science.org/articles/V10/N41/EDIT.php.
4 http://www.co2science.org/articles/V11/N31/EDIT.php.
5 http://www.co2science.org/articles/V12/N28/B2.php.

production," and they say that it may also "help nations meet their international commitments to reduce biodiversity loss."

> *As countries strive to meet obligations to reduce carbon emissions under one international agreement (Kyoto Protocol), they may not only fail to meet their obligations under another (Convention on Biological Diversity) but may actually hasten global climate change if they replace tropical forests or peatlands with oil-palm plantations.*
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> *Hence, reducing deforestation is likely to represent a more effective climate-change mitigation strategy than converting forest for biofuel production, and it may also help nations meet their international commitments to reduce biodiversity loss.*

Pineiro *et al*. (2009)[6] evaluated "the effectiveness and economic value of corn- and cellulosic ethanol production for reducing net GHG [greenhouse gas] emissions when produced on lands that were previously under crop production, previously set aside, or remained as native vegetation, comparing them with carbon sequestration rates achieved by conservation programs," such as the Conservation Reserve Program (CRP), through which the U.S. federal government establishes 10-15 year contracts with farmers and pays them to keep land out of production. The evaluation revealed, in the words of the five researchers, that "carbon releases from the soil after planting corn for ethanol may in some cases completely offset carbon gains attributed to biofuel generation for at least 50 years." In addition, they report "soil carbon sequestered by setting aside former agricultural land was greater than the carbon credits generated by planting corn for ethanol on the same land for 40 years and had equal or greater economic net present value." And if forests are cleared for corn ethanol production, the outcome is determined to be even worse. Thus, "considering current ethanol incentives and typical CRP contracts," Pineiro *et al*. conclude "extending current CRP contracts or enrolling new CRP lands appear to be cheaper strategies for sequestering GHG than converting such lands to corn ethanol for at least a century."

Reijnders (2011)[7] reviewed several studies in another illustration that "greenhouse gas emissions linked to fossil fuel inputs are not the only greenhouse gas emissions associated with

6 http://www.co2science.org/articles/V12/N20/B2.php.
7 http://www.co2science.org/articles/V14/N11/B3.php.

[biofuel production]." The University of Amsterdam researcher reports that with respect to obtaining palm oil from trees planted on recently deforested soil in Southeast Asia (Wicke *et al*., 2008), soybean oil from crops planted on recently deforested soil in Brazil (Reijnders and Huijbregts, 2008), and rapeseed oil from crops planted on existing arable soil in Europe (Reijnders and Huijbregts, 2008), it has been found that "the greenhouse gas emissions associated with the life cycle of the oils considered are larger than the corresponding emissions associated with conventional fossil fuel-based diesel." And he further notes when there is a rapid expansion of oil crop production on existing arable soils, much of the shortfall in food and feed production "has to be met by expansion of agricultural land elsewhere," as noted by Searchinger *et al*. (2008); and he states "this in turn may lead to changes of (agro) ecosystem carbon stocks, which give rise to net emissions of greenhouse gases." Reijnders also notes that in the case of palm oil, the time required to pay back the subsequent "carbon debt" is probably on the order of 60-100 years "when oil palms are cultivated on mineral soils after recent deforestation (Fargione *et al*., 2008; Gibbs *et al*., 2008) and on the order of more than one century to over nine centuries, when the oil palms are cultivated on peat (Gibbs *et al*., 2008; Danielsen *et al*., 2009; Wicke *et al*., 2008)." And when soybeans are cultivated for oil on recently deforested land, he says "the carbon payback time is in excess of 300 years (Gibbs *et al*., 2008)." In light of these several considerations, Reijnders concludes "current plant oils such as European rapeseed oil, and soybean and palm oil from recently deforested soils have higher life cycle greenhouse gas emissions than conventional diesel."

In prefacing their work, Achten and Verchot (2011)[8] write "biofuels are receiving growing negative attention," because "direct and/or indirect land-use changes that result from their cultivation can cause emissions due to carbon losses in soils and biomass and could negate any eventual greenhouses gas reduction benefit." In further exploration of this subject, Achten and Verchot set out to evaluate "the implications of land-use change emissions on the climate-change mitigation potential of different biofuel production systems in 12 case studies in six countries," calculating "carbon debts created by conversion of different land-use types, ranging from annual cropland to primary forest," while evaluating "case studies using three different biofuel crops: oil palm, Jatropha, and soybean."

In doing so the two researchers identified carbon debts ranging from 39 to 1744 Mg $CO_2$/hectare, with oil palm case studies creating the largest debts (473-1744 Mg $CO_2$/hectare), because, as they learned about this crop, "most of the area expansion came at the expense of dense tropical forest." And given numbers such as these, they found that only soybean in certain parts of Brazil needed less than one human generation (30 years) to repay the initial carbon debt, while "highest repayment times were found for Jatropha (76-310 years) and oil palm (59-220 years)." Such findings, Achten and Verchot say, "raise serious questions about the sustainability of biofuel production," and they add that "due to direct land use change carbon implications following the conversion of (semi-)natural ecosystems with medium to high carbon content, and to indirect land-use changes following conversion of agricultural or pasture land, the potential of biofuels to contribute to climate-change mitigation is questioned."

[8] http://www.co2science.org/articles/V15/N31/B3.php.

In addition to the huge carbon emissions released in the conversion of natural land into land utilized for biofuel production, the emissions of other greenhouse gases must also be considered when growing plants for biofuel. Crutzen *et al*. (2008)[9] examined the subject of biofuels from this alternate perspective, calculating the amount of nitrous oxide ($N_2O$) that would be released to the atmosphere as a result of using nitrogen fertilizer to produce the crops used for biofuels, which analysis, in their words, "only considers the conversion of biomass to biofuel" and "does not take into account the use of fossil fuel on ... farms and for fertilizer and pesticide production." As they describe it, this work revealed that "all past studies have severely underestimated the release rates of $N_2O$ to the atmosphere, with great potential impact on climate warming."

As for why greater $N_2O$ emission rates have a tendency to cause the climate to warm, it is because $N_2O$ "is a 'greenhouse gas' with a 100-year average global warming potential 296 times larger than an equal mass of $CO_2$." The ultimate consequence of this phenomenon, as best Crutzen *et al*. could evaluate it, is that "when the extra $N_2O$ emission from biofuel production is calculated in '$CO_2$-equivalent' global warming terms, and compared with the quasi-cooling effect of 'saving' emissions of fossil fuel derived $CO_2$, the outcome is that the production of commonly used biofuels, such as biodiesel from rapeseed and bioethanol from corn (maize), can contribute as much or more to global warming by $N_2O$ emissions than cooling by fossil fuel savings." And as a result of these observations, Crutzen *et al*. conclude "on a globally averaged basis the use of agricultural crops for energy production can readily be detrimental for climate due to the accompanying $N_2O$ emissions." In addition, they note "increased emissions of $N_2O$ will also lead to enhanced $NO_X$ concentrations and ozone loss in the stratosphere." Taken together, they thus find that the relatively large emission of $N_2O$ associated with biofuel production "exacerbates the already huge challenge of getting global warming under control."

In a similar study Erisman *et al*. (2010)[10] state "there is much discussion on the availability of different biomass sources for bioenergy application and on the reduction of greenhouse gas emissions compared to [emissions from] conventional fossil fuels," but "there is much less discussion on the other effects of biomass, such as the acceleration of the nitrogen cycle through increased fertilizer use resulting in losses to the environment and additional emissions of oxidized nitrogen." Thus, Erisman *et al*. set out to provide "an overview of the state of knowledge on nitrogen and biofuels," particularly as pertaining to several sustainability issues.

According to the five researchers, "the contribution of $N_2O$ emissions from fertilizer production and application make the greenhouse gas balance for certain biofuels small positive or even negative for some crops compared to fossil fuels," because "$N_2O$ is a 300 times more effective greenhouse gas than $CO_2$," and because $N_2O$ emissions in the course of biofuel production "might be a factor 2-3 higher than estimated up until now from many field trials." In addition, they mention a number of other nitrogen-related environmental impacts of biofuel production, including modification of land for the growing of biofuels, wastes associated with biomass processing, and the "pollution entailed in constructing and maintaining equipment, transportation and storage facilities," as well as "the higher levels of eutrophication,

9 http://www.co2science.org/articles/V10/N43/EDIT.php.
10 http://www.co2science.org/articles/V13/N43/C1.php.

acidification and ozone depletion" associated with biofuels due to the nitrogenous compounds released to the atmosphere during their agricultural production. And, of course, there are the potentially serious negative consequences of using precious land and water resources to produce biofuels, when they could instead be used to provide much-needed food and fiber for the world's still-expanding human population.

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Bouwman *et al*. (2010)[11] assessed the global consequences of implementing first- and second-generation bioenergy production in the coming five decades, while also focusing on the nitrogen cycle and utilizing "a climate mitigation scenario from the Organization for Economic Cooperation and Development's (OECD's) Environmental Outlook, in which a carbon tax is introduced to stimulate production of biofuels from energy crops." They calculate "the area of energy crops will increase from 8 Mha in the year 2000 to 270 Mha (14% of total cropland), producing 5.6 Pg dry matter per year (12% of energy use) in 2050." They also report "this production requires an additional annual 19 Tg of N fertilizer in 2050 (15% of total), and this causes a global emission of 0.7 Tg of $N_2O$-N (8% of agricultural emissions), 0.2 Tg NO-N (6%), and 2.2 Tg of $NH_3$-N (5%)." In addition, they say "2.6 Tg of $NO_3$-N will leach from fields under energy crops."

However, Bouwman *et al*. note there are some less-than-favorable impacts of these several consequences of carbon-tax-supported biofuel production. For starters, the three Dutch researchers note the greenhouse gas emissions supposed to be reduced by using biofuels instead of fossil fuels "are offset by 20% in 2030 and 15% in 2050 if $N_2O$ emission from the cultivation of energy crops is accounted for." Yet even this blowback is but a fraction-30-60% for maize and sugar cane, according to Bouwman *et al*.-"of total emissions from the cultivation, processing, and transportation of biofuels." In addition, they write that "on a regional scale, increased N leaching, groundwater pollution, eutrophication of aquatic and terrestrial ecosystems, $N_2O$ and $NH_3$ emissions from energy crop production, and $NO_X$ emissions from combustion of biofuels may cause relevant loss of human and ecosystem health."

On this latter point, Revell *et al*. (2012)[12] have also noted the nitrogen-based fertilizers used in growing the crops from which biofuels are produced lead to excessive $N_2O$ emissions, citing Crutzen *et al*. (2008) and Smeets *et al*. (2009), after which they point out "$N_2O$ is a greenhouse gas with a 100-year global warming potential of ~298, and a lifetime of ~114 years," citing

11 http://www.co2science.org/articles/V13/N33/EDIT.php.
12 http://www.co2science.org/articles/V15/N41/B2.php.

Forster *et al*. (2007). In a somewhat different twist on the subject, Revell *et al*. go on to analyze the potential negative consequences of the fact that "$N_2O$ leads to stratospheric ozone destruction," as noted over four decades ago by Crutzen (1970).

In analyzing "the potential effects on the ozone layer of a large-scale shift away from fossil fuel use to biofuels consumption over the 21st century," the four New Zealand researchers find "global-mean column ozone decreases by 2.6 DU between 2010 and 2100," due to the fact "(1) large $N_2O$ emissions lead to faster rates of the ozone-depleting $NO_x$ cycles and; (2) reduced $CO_2$ emissions (due to less fossil fuel burning) lead to relatively less stratospheric cooling over the 21st century, which decreases ozone abundances." And in light of such findings, Revell *et al*. state in the concluding sentence of their report, "increased biofuels production and consumption could therefore be damaging to the ozone layer," which would be detrimental to the biosphere because the stratospheric ozone layer filters out much of the harmful UV-B radiation coming from the Sun, which otherwise could do much damage to Earth's terrestrial plants.

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Working at the Kessler Farm Field Laboratory in McClain County, Oklahoma, "in a long-term field experiment," Xue *et al*. (2011) "explored how annual clipping for biofuel feedstock production and warming caused soil erosion and accompanying carbon and nitrogen losses in tallgrass prairie," where warming was provided by infrared heaters suspended 1.5 m above the ground, as described by Kimball (2005), leading to air temperatures being raised by an average of 1.47°C and soil temperatures in the clipping plots by 1.98°C. With respect to carbon and nitrogen, results of the experiment revealed the soil organic carbon was lost at a rate of 69.6 g/$m^2$/year in the warmed plots and 22.5 g/$m^2$/year in the control plots, while total nitrogen was lost at a rate of 4.6 g/$m^2$/year in the warmed plots and 1.4 g/$m^2$/year in the control plots. Xue *et al*. make a point of noting, in this regard, that "the amount of carbon and nitrogen loss caused by clipping is equivalent to, or even larger than, changes caused by global change factors."

"Aside from the necessity to account for the impact of land use change," Lisboa *et al*. (2011)[13] state "soil $N_2O$ emissions during sugarcane production and emissions of GHG due to pre-harvest burning may significantly impact the GHG balance." Based on "a thorough literature review," as they describe it, the four German researchers report "direct $N_2O$ emissions from sugarcane fields due to nitrogen (N) fertilization result in an emission factor of 3.87 ± 1.16%," which is "much higher than suggested by the IPCC (1%)." They also say "$N_2O$ emissions from N fertilization accounted for 40% of the total GHG emissions from ethanol-sugarcane production, with an additional 17% from trash burning." Thus, "if land use change-related GHG emissions are considered," they say that "the total GHG balance turns negative mainly due to vegetation carbon losses." In addition, they note their study shows "major gaps in knowledge still exist about GHG sources related to agricultural management during sugarcane production," such as "effects of irrigation, vinasse [the liquid residue that remains after the distillation of ethanol from sugar] and filter cake [the substance that remains on a filter after filtration designed to purify a desired substance] applications."

All things considered, it is by no means certain there is any benefit to be accrued from the substitution of bioethanol from sugarcane for fossil fuels. In fact, it could even prove to be counter-productive, as production of ethanol from any crop "may directly compete with food and feed production and requires higher rates of nitrogen fertilizers, contributing to local and regional eutrophication and resulting in increased soil $N_2O$ emissions," as Lisboa *et al*. indicate has been found to be the case with ethanol derived from corn, citing Crutzen *et al*. (2008) and Fargione *et al*. (2008). Clearly, therefore (and as they conclude), "more studies are needed to assess if bioethanol from sugarcane is a viable option to reduce energy-related GHG emissions." In fact, such studies are overdue, as Lisboa *et al*. report "54.6% of the sugarcane production in Brazil and 39% in India is used for bioethanol production."

In an invited editorial in the journal *Global Change Biology Bioenergy*, Schulze *et al*. (2012)[14] analyze the question of whether or not bioenergy from forest products can significantly and sustainably reduce fossil fuel use, either by direct combustion of wood or its conversion to cellulosic ethanol., noting "there are important questions about GHG reduction, economic viability, sustainability and environmental consequences" associated with this strategy; and they go on to discuss them in some detail.

First of all, the five scientists-hailing from Austria, France, Germany, Switzerland and the United States-argue that "such an increase in biomass harvest would result in younger forests, lower biomass pools, depleted soil nutrient stocks and a loss of other ecosystem functions," such that "the proposed strategy is likely to miss its main objective, i.e. to reduce GHG emissions, because it would result in a reduction of biomass pools that may take decades to centuries to be paid back by fossil fuel substitution, if paid back at all." In the long run, therefore, they feel

[13] http://www.co2science.org/articles/V14/N35/B3.php.
[14] http://www.co2science.org/articles/V15/N34/EDIT.php.

that "depleted soil fertility will make the production unsustainable and require fertilization, which in turn increases GHG emissions due to $N_2O$ emissions," which ultimately makes the large-scale production of bioenergy from forest biomass, in their opinion, "neither sustainable nor GHG neutral."

A reasonable alternative, in Schulze *et al*.'s opinion, would be the "afforestation of lands that once carried forests," which they say would allow existing forests to continue to provide a range of ecosystem services. Yet, "on arable or pasture land," as they continue, "such a strategy would compete with food and fodder production." And, hence, they caution society should fully quantify direct and indirect GHG emissions associated with energy alternatives and associated consequences prior to making policy commitments that have long-term effects on global forests; for they caution "there is a substantial risk of sacrificing forest integrity and sustainability for maintaining or even increasing energy production with no guarantee to mitigate climate change."

*Short-term economic gains from using crop residues for biofuel must be objectively assessed in relation to adverse changes in soil quality, negative nutrients and carbon budget, accelerated erosion, increase in non-point source pollution, reduction in agronomic production, and decline in biodiversity.*

*And when all of the many benefits of soil organic carbon are tallied, the depleted soil organic carbon pool must be restored, come what may.*

Finally, because of the many concerns associated with biofuel production discussed in this and related subsections, it has been suggested that biofuels should be produced from crop residues, as this approach does not involve the use of additional land and it focuses on an agricultural "waste product." However, according to Lal (2007)[15], crop residues are not exactly unwanted by-products of farming, as they perform many vital functions. He reports, for example, "there are severe adverse impacts of residue removal on soil and environmental degradation, and negative carbon sequestration as is documented by the dwindling soil organic carbon reserves," (he reports most agricultural soils have lost 25-75% of their antecedent pools of soil organic carbon). And he further notes "the severe and widespread problem of soil degradation, and the attendant agrarian stagnation/deceleration, are caused by indiscriminate removal of crop residues."

[15] http://www.co2science.org/articles/V11/N12/EDIT.php.

Clearly, as Lal continues, "short-term economic gains from using crop residues for biofuel must be objectively assessed in relation to adverse changes in soil quality, negative nutrients and carbon budget, accelerated erosion, increase in non-point source pollution, reduction in agronomic production, and decline in biodiversity." And when all of the many benefits of soil organic carbon are tallied, he concludes "the depleted soil organic carbon pool must be restored, come what may."

We agree. We cannot afford to destroy the productive potential of the soil that sustains all of humanity and nature as well (by enabling us to grow most of our own food and thereby not taking what the rest of the biosphere needs in terms of land and water to sustain itself). Truly, Scharlemann and Laurance (2008) have appropriately labeled multibillion-dollar U.S. subsidies for certain biofuel enterprises a "perverse incentive" that will only add to mankind's and nature's many overwhelming problems.

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