LETTERS

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Biofuels: Social Benefits

IN THEIR POLICY FORUM "BENEFICIAL BIOFUELS—THE FOOD, energy, and environment trilemma" (17 July, p. 270), D. Tilman *et al.* argue that the search for beneficial biofuels should focus on feedstocks that (i) do not compete with food crops, (ii) do not lead to land-clearing, and (iii) offer real greenhouse-gas reductions. We suggest a fourth criterion: the maximization of social benefits.

Indonesia's oil palm industry provides employment for 4.5 million people (*1*). Many smallholder producers also derive significant economic benefits (*2*, *3*). However, the negative impacts of oil palm development are also widely reported and include poor wages and labor standards, impacts on health and local culture, "land grabbing," and the loss of environmental goods and services (*4*, *5*). Although the cultivation of biofuel feedstocks may represent an opportunity for rural development (*6*, *7*), the social impacts need to be carefully assessed.

Oil palm fruit. The social impacts of the oil palm industry must be assessed.

Four of the five biomass sources outlined by Tilman *et al*. may be of less merit upon inclusion of this criterion. Cultivation on degraded or abandoned lands may indeed minimize competition with food production. However, if such lands support the subsistence of rural communities, biofuel development will likely result in social costs, especially given that the rights of these communities are often poorly protected (*8*, *9*). Furthermore, the potential use of crop and forestry residues or municipal and industrial wastes in developed nations to produce next-generation biofuels may undermine demand for feedstocks from tropical developing countries that currently supply international markets.

Coherent biofuels policies must also address the social context of agricultural production if biofuels are to make a sustainable contribution toward reducing climate change and safeguarding food security. Tilman *et al.*'s selection criteria are valuable but should include the potential opportunities and risks to rural communities afforded by biofuel feedstock cultivation.

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Biofuels: By-Products

IN THE POLICY FORUM "BENEFICIAL BIOFUELS—the food, energy, and environment trilemma" (17 July, p. 270), D. Tilman *et al.* emphasized the importance of a life-cycle assessment that includes the impact of biofuels production on future food supplies, greenhouse gas emissions, and environmental consequences of clearing virgin land and potential reduction in biodiversity. We agree that these potential impacts are crucial and add a fourth component: environmental and health impacts of the co-products or by-products that arise during generation of biofuels from feedstocks.

For example, maize-based ethanol production results in the production of dried distillers' grain plus solubles or wet distillers' grains, which are sold primarily as livestock and poultry feed (*1*). Unfortunately, any mycotoxins in the original maize become up to three times as concentrated in these co-products (*2*–*4*). Hence, including the co-products in livestock and poultry diets can cause adverse health effects in animals, resulting in potential economic losses to livestock and poultry industries (*1*). Although the next-generation feedstocks proposed by Tilman *et al.* do not include maize grain, similar environmental and health risks of by-products and co-products and their potential uses should be considered in any life-cycle assessment used to drive national biofuels policy.

Converting municipal and industrial waste to liquid fuels, as proposed by Tilman *et al.*, would provide a potentially sustainable pathway for this waste to replace current treatment and disposal approaches. This use of an industrial waste stream has the potential to eliminate a costly expense for industries and turn it into a new profit center. One example is paper sludge, a waste material that currently goes

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into landfills at a cost of $60 to $100 per dry ton (*5*). However, production of biofuels from waste materials may release chemicals such as dioxins and heavy metals that could result in unintended environmental and public health exposures. Industrial market research should explore whether suitable sustainable pathways exist for co-products that will simultaneously generate revenue streams and reduce the potential for adverse exposures.

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Biofuels: Algae

IN THE POLICY FORUM "BENEFICIAL BIOFUELS—the food, energy, and environment trilemma" (17 July, p. 270), D. Tilman *et al.* concisely summarize the Gordian knot entangling the food and environmental implications of biofuel development. However, they overlook algae as a solution. Others have concluded that microalgae are the only source of renewable biodiesel that can meet global demand for transport fuels (*1*, *2*).

Tilman *et al*. argue cogently that "biofuels done right" must derive from feedstocks with low greenhouse gas emissions and little or no competition with food production. Algae are likely to win on both counts. For example, had the 67 million acres of soybeans cultivated in 2007 gone entirely to biodiesel, they would have displaced 6% of the United States' on-road petroleum diesel use; the same acreage used for algal culture would yield more than 100% of the petroleum diesel usage, even assuming modest algal productivity (*3*).

Microalgae are typically at least an order of magnitude more productive than even the fastest growing terrestrial feedstock crops, require no soil, and can be grown in eutrophied water (fresh or saline), which is unsuitable for agriculture or human consumption. Thus, algal production does not compete for scarce arable land and can remove nutrients and contaminants from waterways. Although rigorous life-cycle analyses are not yet available, the prospects for carbon-neutral or negative production of algal fuels on commercial scales appear bright (*3*).

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Biofuels: Forests and Carbon

IN THE POLICY FORUM "BENEFICIAL BIOFUELS—the food, energy, and environment trilemma" (17 July, p. 270), D. Tilman *et al.* neglected to mention the role of forests and carbon capture and storage. Trees offer promise as an energy crop in areas where they grow well on degraded lands. A new and permanent reservoir of carbon is created as planted forest develops toward a steady state where mature trees mix with young saplings. Furthermore, forests offer a great variety of ecosystem services such as biodiversity promotion, nutrient retention, and flood protection. Timber crops can be harvested at any time during the year, and the durable wood serves as an interim energy storage—two assets for energy transport logistics. The carbon budget of wood is competitive against other materials in end uses such as construction (*1*).

Opportunities to use side-products from wood-processing industries in electricity production should be fully explored. Biopower in any case deserves attention. Greenhouse gas benefits are better achieved making electricity than fuels (*2*–*4*).

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Biofuels: Beware Crop Residues

IN THE POLICY FORUM "BENEFICIAL BIOFUELS—the food, energy, and environment trilemma" (17 July, p. 270), D. Tilman *et al.* propose using crop residues and harvesting biomass from double crops and mixed cropping systems. We point out the potential risks of doing so.

Retention of crop residues on soils, including the biomass produced from cover crops, is essential to numerous ecosystem services such as carbon sequestration, conservation of soil and water, and high use-efficiency of inputs for increasing and sustaining agronomic productivity. The agrarian stagnation and perpetual food deficit in sub-Saharan Africa is attributed to severe soil degradation (*1*, *2*), caused by extractive farming practices that involve continuous removal of crop residues for use as traditional biofuels and cattle feed. This has created a negative nutrient budget. Soils are a source of greenhouse gases (CO_2, CH_4, and N_2O) when prone to accelerated erosion and when under management that creates negative carbon and nutrient budgets. Crop residues and other biosolids are essential to maintain activity and species diversity of soil biota (micro-

Letters to the Editor

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and macroorganisms) and to improve soil structure and tilth (*3–5*). Indiscriminate removal of crop residues and harvesting of biomass from cropland soils is supported neither by science nor by conventional wisdom.

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Biofuels: Steer Clear of Degraded Land

WE DISAGREE WITH D. TILMAN *ET AL*. ("Beneficial biofuels—the food, energy, and environment trilemma" Policy Forum, 17 July, p. 270) that perennial plants should be grown on degraded lands that can no longer be used for agriculture. If land is fertile enough to grow plants that offer substantial yields for biofuels, it should be suitable for agriculture as well. Even if not used today, this land could be kept as a productive reserve and used later to combat the foreseeable problems in feeding the world in the future (*1*). If the land is not fertile enough for that purpose, the perennial energy plants will probably be dependent on anthropogenic inputs such as fertilizers and, in some regions, irrigation. These are the factors disrupting the energy balance; nitrogen fertilization is the basis for N_2O emissions with the potential to overcompensate all greenhouse gains (*2*). Economically, such plantations would not be viable without intensive farming practices, raising doubts regarding the expected benefits for biodiversity and wildlife.

Given that currently only about 10% of the global primary energy demand is covered by renewable resources and that humans already appropriate large percentages of the potentially available biomass (20 to 40% globally, 50% in some industrialized countries, up to 90% in intensively farmed regions) (*3*), we are skeptical about the potential of biofuels. We join Tilman *et al*. in urgently requesting additional research, but we cannot support their demand that "a robust biofuels industry should be enabled" now. We'd better look before we leap.

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Response

THE LETTERS ABOUT OUR COMMENTARY RAISE issues with which, for the most part, we agree. They amplify our assertion that each biofuel should be evaluated on its net benefit to society based on a full life-cycle analysis that includes, among other factors, its effects on net energy supply, the global food system, greenhouse-gas emissions, soil carbon and soil fertility, water and air quality, and biodiversity. We agree with Rist *et al*. that the social context and international equity issues associated with food and biofuel merit inclusion in such analyses. We support the suggestion by Biksey and Wu that health and environmental impacts of biofuels and their co-products should be included. Other biomass sources, such as algae (Duffy *et al*.) and other technologies, such as biomass combined with carbon capture and storage (Kauppi and Saikku), merit evaluation and consideration. We agree with Lal and Pimentel that biomass should be grown so as to maintain or increase soil fertility. Contrary to Spangenberg and Settele, we believe that appropriate perennials can give reasonable yields and increase soil carbon stores when grown with low inputs on degraded soils (*1*). In a world that is increasingly rich and energy-hungry, solutions are more likely to be wise tradeoffs than miracles. Because substantial components of the global transportation system have no viable substitutes for liquid fuels, it is important and timely, as we asserted, to support the emergence of an industry that produces biofuels that offer significant net benefits relative to petroleum. At the same time, we need comprehensive, science-based policies that protect wild lands and make managed lands—including but not limited to land used for biofuels—part of the solution to reducing atmospheric carbon.

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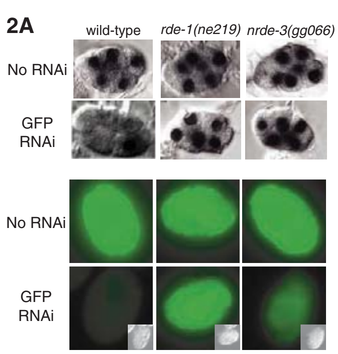
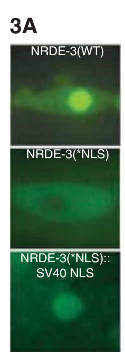
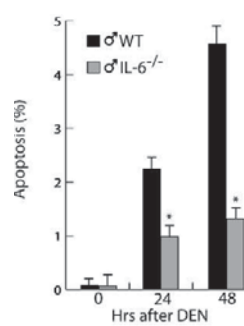
CORRECTIONS AND CLARIFICATIONS

Research Article: "An Argonaute transports siRNAs from the cytoplasm to the nucleus" by S. Guang *et al*. (25 July 2008, p. 537). The rightmost four images in the top panel of Fig. 2A and the top image of Fig. 3A were inadvertently mislabeled and duplicated. Investigators who were not involved in the original experiments have repeated these experiments, which yielded results similar to those originally reported. Our conclusions remain unaltered. The corrected figures are shown below (left).

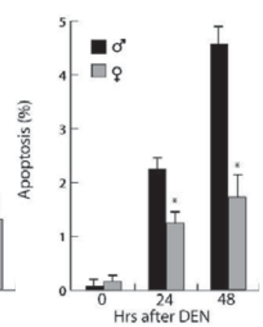
Reports: "Gender disparity in liver cancer due to sex differences in MyD88-dependent IL-6 production" by W. E. Naugler *et al*. (6 July 2007, p. 121). The originally published Fig. 3B inadvertently duplicated Fig. 3E. The corrected 3B, along with originally published 3E, is provided below (right).







Corrected Figure 3B



Original (and correct) Figure 3E