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In Defense of Biofuels, Done Right

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Despite recent claims to the contrary, plant-based fuels developed in economically and environmentally sensible ways can contribute significantly to the nation's—indeed, the world's—energy security while providing a host of benefits for many people worldwide.

Biofuels have been getting bad press, not always for good reasons. Certainly important concerns have been raised, but preliminary studies have been misinterpreted as a definitive condemnation of biofuels. One recent magazine article, for example, illustrated what it called "Ethanol USA" with a photo of a car wreck in a corn field. In particular, many criticisms converge around grain-based biofuel, traditional farming practices, and claims of a causal link between U.S. land use and land-use changes elsewhere, including tropical deforestation.

Focusing only on such issues, however, distracts attention from a promising opportunity to invest in domestic energy production using biowastes, fast-growing trees, and grasses. When biofuel crops are grown in appropriate places and under sustainable conditions, they offer a host of benefits: reduced fossil fuel use; diversified fuel supplies; increased employment; decreased greenhouse gas emissions; enhanced habitat for wildlife; improved soil and water quality; and more stable global land use, thereby reducing pressure to clear new land.

Not only have many criticisms of biofuels been alarmist, many have been simply inaccurate. In 2007 and early 2008, for example, a bumper crop of media articles blamed sharply higher food prices worldwide on the production of biofuels, particularly ethanol from corn, in the United States. Subsequent studies, however, have shown that the increases in food prices were primarily due to many other interacting factors: increased demand in emerging economies, soaring energy prices, drought in food-exporting countries, cutoffs in grain exports by major suppliers, market-distorting subsidies, a tumbling U.S. dollar, and speculation in commodities markets.

Although ethanol production indeed contributes to higher corn prices, it is not a major factor in world food costs. The U.S. Department of Agriculture (USDA) calculated that biofuel production contributed only 5% of the 45% increase in global food costs that occurred between April 2007 and April 2008. A Texas A&M University study concluded that energy prices were the primary cause of food price increases, noting that between January 2006 and January 2008 the prices of fuel and fertilizer, both major inputs to agricultural production, increased by 37% and 45% respectively. And the International Monetary Fund has documented that since their peak in July 2008, oil prices declined by 69% as of December 2008, and global food prices declined by 33% during the same period, while U.S. corn production has remained at 12 billion bushels a month, one-third of which is still used for ethanol production.

In another line of critique, some argue that the potential benefits of biofuel might be offset by indirect effects. But large uncertainties and postulations underlie the debate about indirect land-use effects of biofuels on tropical deforestation, the critical implication being that use of U.S. farmland for energy crops necessarily causes new land clearing elsewhere. Concerns are particularly strong about the loss of tropical forests and natural grasslands. The basic argument is that biofuel production in the United States sets in motion a necessary scenario of deforestation.

According to this argument, if U.S. farm production is used for fuel instead of food, food prices rise and farmers in developing countries respond by growing more food. This response requires clearing new land and burning native vegetation and, hence, releasing carbon. This "induced deforestation" hypothesis is based on questionable data and modeling assumptions about available land and yields, rather than on empirical evidence. The argument assumes that the supply of previously cleared land is inelastic (that is, agricultural land for expansion is unavailable without new deforestation). It also assumes that agricultural commodity prices are a major driving force behind deforestation and that yields decline with expansion. The calculations for carbon emissions assume that land in a stable, natural state is suddenly converted to agriculture as a result of biofuels. Finally, the assertions assume that it is possible to measure with some precision the areas that will be cleared in response to these price signals.

A review of the issues reveals, however, that these assumptions about the availability of land, the role of biofuels in causing deforestation, and the ability to relate crop prices to areas of land clearance are unsound. Among our findings:

First, sufficient suitably productive land is available for multiple uses, including production of biofuels. Assertions that U.S. biofuel production will cause large indirect land-use changes rely on limited data sets and unverified assumptions about global land cover and land use. Calculations of land-use change begin by assuming that global land falls into discrete classes suitable for agriculture—cropland, pastures and grasslands, and forests—and results depend on estimates for the extent, use, and productivity of these lands, as well as presumed future interactions among land-use classes. But several major organizations, including the Food and Agriculture Organization (FAO), a primary data clearinghouse, have documented significant inconsistencies surrounding global land cover estimates. For example, the three most recent FAO Forest Resource Assessments for periods ending in 1990, 2000 and 2005, provide estimates of the world's total forest cover in 1990 that vary by as much as 470 million acres, or 21% of the original estimate.

Cropland data face similar discrepancies, and even more challenging issues arise when pasture areas are considered. Estimates for land used for crop production range from 3.8 billion acres (calculated by FAO) to 9 billion acres (calculated by the Millennium Ecosystem Assessment, an international effort spearheaded by the United Nations). In a recent study attempting to reconcile cropland use circa 2000, scientists at the University of Wisconsin-Madison and McGill University estimated there were 3.7 billion acres of cropland, of which 3.2 billion were actively cropped or harvested. Land-use studies consistently acknowledge serious data limitations and uncertainties, noting that a majority of global crop lands are constantly shifting the location of cultivation, leaving at any time large areas fallow or idle that may not be captured in statistics. Estimates for idle croplands, prone to confusion with pasture and grassland, range from 520 million acres to 4.9 billion acres globally. The differences illustrate one of many uncertainties that hamper global land-use change calculations. To put these numbers in perspective, USDA has estimated that in 2007, about 21 million acres were used worldwide to produce biofuel feedstocks, an area that would occupy somewhere between 0.4% and 4% of the world's estimated idle cropland.

Diverse studies of global land cover and potential productivity suggest that anywhere from 600 million to more than 7 billion additional acres of underutilized rural lands are available for expanding rain-fed crop production around the world, after excluding the 4 billion acres of cropland currently in use, as well as the world's supply of closed forests, nature reserves, and urban lands. Hence, at a global scale, land per se is not an immediate limitation for agriculture and biofuels.

In the United States, the federal government, through the multiagency Biomass Research and Development Initiative (BRDI), has examined the land and market implications for reaching the nation's biofuel target, which calls for producing 36 billion gallons by 2022. BRDI estimated that a slight net reduction in total U.S. active cropland area would result by 2022 in most scenarios, when compared with a scenario developed from USDA's so-called "baseline" projections. BRDI also found that growing biofuel crops efficiently in the United States would require shifts in the intensity of use of about 5% of pasture lands to more intensive hay, forage, and bioenergy crops (25 million out of 456 million acres) in order to accommodate dedicated energy crops, along with using a combination of wastes, forest residues, and crop residues. BRDI's estimate assumes that the total area allocated to USDA's Conservation Reserve Program (CRP) remains constant at about 33 million acres but allows about 3 million acres of the CRP land on high-quality soils in the Midwest to be offset by new CRP additions in other regions. In practice, additional areas of former cropland that are now in CRP could be managed for biofuel feedstock production in a way that maintains positive impacts on wildlife, water, and land conservation goals, but this option was not included among the scenarios considered.

Yields are important. They vary widely from place to place within the United States and around the world. USDA projects that corn yields will rise by 20 bushels per acre by 2017; this represents an increase in corn output equivalent to adding 12.5 million acres compared with 2006, and over triple that area compared with average yields in many less developed nations. And there is the possibility that yields will increase more quickly than projected in the USDA baseline, as seed companies aim to exceed 200 bushels per acre by 2020. The potential to increase yields in developing countries offers tremendous opportunities to improve welfare and expand production while reducing or maintaining the area harvested. These improvements are consistent with U.S. trends during the past half century showing agricultural output growth averaging 2% per year while cropland use fell by an average of 0.7% per year. Even without large yield increases, cropland requirements to meet biofuel production targets may not be nearly as great as assumed.

Concerns over induced deforestation are based on a theory of land displacement that is not supported by data. U.S. ethanol production shot up by more than 3 billion gallons (150%) between 2001 and 2006, and corn production increased 11%, while total U.S. harvested cropland fell by about 2% in the same period. Indeed, the harvested area for "coarse grains" fell by 4% as corn, with an average yield of 150 bushels per acre, replaced other feed grains such as sorghum (averaging 60 bushels per acre). Such statistics defy modeling projections by demonstrating an ability to supply feedstock to a burgeoning ethanol industry while simultaneously maintaining exports and using substantially less land. So although models may assume that increased use of U.S. land for biofuels will lead to more land being cleared for agriculture in other parts of the world, evidence is lacking to support those claims.

Second, there is little evidence that biofuels cause deforestation, and much evidence for alternative causes. Recent scientific papers that blame biofuels for deforestation are based on models that presume new land conversion can be simulated as a predominantly market-driven choice. The models assume land is a privately owned asset managed in response to global price signals within a stable rule-based economy — perhaps a reasonable assumption for developed nations.

However, this scenario is far from the reality in the smoke-filled frontier zones of deforestation in less developed countries, where the models assume biofuel-induced land conversion takes place. The regions of the world that are experiencing first-time land conversion are characterized by market isolation, lawlessness, insecurity, instability, and lack of land tenure. And nearly all of the forests are publicly owned. Indeed, land-clearing is a key step in a long process of trying to stake a claim for eventual tenure. A cycle involving incremental degradation, repeated and extensive fires, and shifting small plots for subsistence tends to occur long before any consideration of crop choices influenced by global market prices.

The causes of deforestation have been extensively studied, and it is clear from the empirical evidence that forces other than biofuel use are responsible for the trends of increasing forest loss in the tropics. Numerous case studies document that the factors driving deforestation are a complex expression of cultural, technological, biophysical, political, economic, and demographic interactions. Solutions and measures to slow deforestation have also been analyzed and tested, and the results show that it is critical to improve governance, land tenure, incomes, and security to slow the pace of new land conversion in these frontier regions.

Selected studies based on interpretations of satellite imagery have been used to support the claims that U.S. biofuels induce deforestation in the Amazon, but satellite images cannot be used to determine causes of land-use change. In practice, deforestation is a site-specific process. How it is perceived will vary greatly by site and also by the temporal and spatial lens through which it is observed. Cause-and-effect relationships are complex, and the many small changes that enable larger future conversion cannot be captured from satellite imagery. Although it is possible to classify an image to show that forest in one period changed to cropland in another, cataloguing changes in discrete classes over time does not explain why these changes occur. Most studies asserting that the production and use of biofuels cause tropical deforestation point to land cover at some point after large-scale forest degradation and clearing have taken place. But the key events leading to primary conversion of forests often proceed for decades before they can be detected by satellite imagery. The imagery does not show how the forest was used to sustain livelihoods prior to conversion, nor the degrees of continual degradation that occurred over time before the classification changed. When remote sensing is supported by a ground-truth process, it typically attempts to narrow the uncertainties of land-cover classifications rather than research the history of occupation, prior and current use, and the forces behind the land-use decisions that led to the current land cover.

First-time conversion is enabled by political, as well as physical, access. Southeast Asia provides one example where forest conversion has been facilitated by political access, which can include such diverse things as government-sponsored development and colonization programs in previously undisturbed areas and the distribution of large timber and mineral concessions and land allotments to friends, families, and sponsors of people in power. Critics have raised valid concerns about high rates of deforestation in the region, and they often point an accusing finger at palm oil and biofuels.

Palm oil has been produced in the region since 1911, and plantation expansion boomed in the 1970s with growth rates of more than 20% per year. Biodiesel represents a tiny fraction of palm oil consumption. In 2008, less than 2% of crude palm oil output was processed for biofuel in Indonesia and Malaysia, the world's largest producers and exporters. Based on land-cover statistics alone, it is impossible to determine the degree of attribution that oil palm may share with other causes of forest conversion in Southeast Asia. What is clear is that oil palm is not the only factor, and that palm plantations are established after a process of degradation and deforestation has transpired. Deforestation data may offer a tool for estimating the ceiling for attribution, however. In Indonesia, for example, 28.1 million hectares were deforested between 1990 and 2005, and oil palm expansion in those areas was estimated to be between 1.7 million and 3 million hectares, or between 6% and 10% of the forest loss, during the same period.

Initial clearing in the tropics is often driven more by waves of illegitimate land speculation than agricultural production. In many Latin American frontier zones, if there is native forest on the land, it is up for grabs, as there is no legal tenure of the land. The majority of land clearing in the Amazon has been blamed on livestock because, in part, there is no alternative for classifying the recent clearings and, in part, because land holders must keep it "in production" to maintain claims and avoid invasions. The result has been the frequent burning and the creation of extensive cattle ranches. For centuries, disenfranchised groups have been pushed into the forests and marginal lands where they do what they can to survive. This settlement process often includes serving as low-cost labor to clear land for the next wave of better-connected colonists. Unless significant structural changes occur to remove or modify enabling factors, the forest clearing that was occurring before this decade is expected to continue along predictable paths.

Testing the hypothesis that U.S. biofuel policy causes deforestation elsewhere depends on models that can incorporate the processes underlying initial land-use change. Current models attempt to predict future land-use change based on changes in commodity prices. As conceived thus far, the computational general equilibrium models designed for economic trade do not adequately incorporate the processes of land-use change. Although crop prices may influence short-term land-use decisions, they are not a dominant factor in global patterns of first-time conversion, the land clearing of chief concern in relating biofuels to deforestation. The highest deforestation rates observed and estimated globally occurred in the 1990s. During that period, there was a surplus of commodities on world markets and consistently depressed prices.

Third, many studies omit the larger problem of widespread global mismanagement of land. The recent arguments focusing on the possible deforestation attributable to biofuels use idealized representations of crop and land markets, omitting what may be larger issues of concern. Clearly, the causes of global deforestation are complex and are not driven merely by a single crop market. Additionally, land mismanagement, involving both initial clearing and maintaining previously cleared land, is widespread and leads to a process of soil degradation and environmental damage that is especially prevalent in the frontier zones. Reports by the FAO and the Millennium Ecosystem Assessment describe the environmental consequences of repeated fires in these areas. Estimates of global burning vary annually, ranging from 490 million to 980 million acres per year between 2000 and 2004. The vast majority of fires in the tropics occur in Africa and the Amazon in what were previously cleared, nonforest lands. In a detailed study, the Amazon Institute of Environmental Research and Woods Hole Research Center found that 73% of burned area in the Amazon was on previously cleared land, and that was during the 1990s, when overall deforestation rates were high.

Fire is the cheapest and easiest tool supporting shifting subsistence cultivation. Repeated and extensive burning are manifestations of the lack of tenure, lack of access to markets, and severe poverty in these areas. When people or communities have little or no assets to protect from fire and no incentive to invest in more sustainable production, they also have no reason to limit the extent of burning. The repeated fires modify ecosystem structure, penetrate ever deeper into forest margins, affect large areas of understory vegetation (which is not detected by remote sensing), and take an ever greater cumulative toll on soil quality and its ability to sequester carbon. Profitable biofuel markets, by contributing to improved incentives to grow cash crops, could reduce the use of fire and the pressures on the agricultural frontier. Biofuels done right, with attention to best practices for sustained production, can make significant contributions to social and economic development as well as environmental protection.

Furthermore, current literature calculates the impacts from an assumed agricultural expansion by attributing the carbon emissions from clearing intact ecosystems to biofuels. If emission analyses consider empirical data reflecting the progressive degradation that occurs (often over decades) prior to and independent of agriculture market signals for land use, as well as changes in the frequency and extent of fire in areas that biofuels help bring into more stable market economies, then the resulting carbon emission estimates would be worlds apart.

Brazil provides a good case in point, because it holds the globe's largest remaining area of tropical forests, is the world's second-largest producer of biofuel (after the United States), and is the world's leading supplier of biofuel for global trade. Brazil also has relatively low production costs and a growing focus on environmental stewardship. As a matter of policy, the Brazilian government has supported the development of biofuels since launching a National Ethanol Program called Proálcool, in 1975. Brazil's ethanol industry began its current phase of growth after Proálcool was phased-out in 1999 and the government's role shifted from subsidies and regulations toward increased collaboration with the private sector in research and development. The government helps stabilize markets by supporting variable blending rates of ethanol with gasoline and planning for industry expansion, pipelines, ports, and logistics. The government also facilitates access to global markets; develops improved varieties of sugarcane, harvest equipment, and conversion; and supports improvements in environmental performance.

New sugarcane fields in Brazil nearly always replace pasture land or less valuable crops and are concentrated around production facilities in the developed southeastern region, far from the Amazon. Nearly all production is rain-fed and relies on low input rates for fertilizers and agrochemicals, compared with other major crops. New projects are reviewed under the Brazilian legal framework of Environmental Impact Assessment and Environmental Licensing. Together, these policies have contributed to restoration or protection of reserves and riparian areas and increased forest cover, in tandem with an expansion of sugarcane production in the most important producing state, Sao Paulo.

Yet natural forest in Brazil is being lost, with nearly 37 million acres lost between May 2000 and August 2006, and a total of 150 million acres lost since 1970. Some observers have suggested that the increase in U.S. corn production for biofuel led to reduced soybean output and higher soybean prices, and that these changes led, in turn, to new deforestation in Brazil. However, total deforestation rates in Brazil appear to fall in tandem with rising soybean prices. This co-occurrence illustrates a lack of connection between commodity prices and initial land clearing. This phenomenon has been observed around the globe and suggests an alternate hypothesis: Higher global commodity prices focus production and investment where it can be used most efficiently, in the plentiful previously cleared and underutilized lands around the world. In times of falling prices and incomes, people return to forest frontiers, with all of their characteristic tribulations, for lack of better options.

The promise of sustainable biofuels

With the right policy framework, cellulosic biofuel crops could offer an alternative that diversifies and boosts rural incomes based on perennials. Such a scenario would create incentives to reduce intentional burning that currently affects millions of acres worldwide each year. Perennial biofuel crops can help stabilize land cover, enhance soil carbon sequestration, provide habitat to support biodiversity, and improve soil and water quality. Furthermore, pressure to clear new land is reduced via improved incomes and yields. Developing countries have huge opportunities to increase crop yield and thereby grow more food on less land, given that cereal yields in less developed nations are 30% of those in North America. Hence, policies supporting biofuel production may actually help stop the extensive slash-and-burn agricultural cycle that contributes to greenhouse gas emissions, deforestation, land degradation, and a lifestyle that fails to support farmers and their families.

Biofuels alone are not the solution, however. Governments in the United States and elsewhere will have to develop and support a number of programs designed to support sustainable development. The operation and rules of such programs must be transparent, so that everyone can understand them and see that fair play is ensured. Among other attributes, the programs must offer economic incentives for sustainable production, and they must provide for secure land tenure and participatory land-use planning. In this regard, pilot biofuel projects in Africa and Brazil are showing promise in addressing the vexing and difficult challenges of sustainable land use and development. Biofuels also are uniting diverse stakeholders in a global movement to develop sustainability metrics and certification methods applicable to the broader agricultural sector.

Given a priority to protect biodiversity and ecosystem services, it is important to further explore the drivers for conversion of land at the frontier and to consider the effects, positive and negative, that U.S. biofuel policies could have in these areas. This means it is critical to distinguish between valid concerns calling for caution and alarmist criticisms that attribute complex problems solely to biofuels.

Still, based on the analyses that we and others have done, we believe that biofuels, developed in an economically and environmentally sensible way, can contribute significantly to the nation's—indeed, the world's—energy security while providing a host of benefits for many people in many regions.

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Recommended reading

Biomass Research and Development Interagency Board (BRDI-U.S.), (2008). "Increasing feedstock production for biofuels: economic drivers, environmental implications, and the role of research." http://www.brdisolutions.com/default.aspx

A. Contreras-Hermosilla (2007). "The underlying causes of forest decline." (CIFOR Occasional Paper 30, Center for International Forestry Research, Bogor, Indonesia, 2000). http://www.cifor.cgiar.org/publications/pdf_files/OccPapers/OP-030.pdf

S. Fritz and Linda See, (2008). "Identifying and quantifying uncertainty and spatial disagreement in the comparison of Global Land Cover for different applications." Global Change Biology (2008) 14, 1057–1075.

A. Grainger, (2008). Proc. Nat. Acad. Sci. USA; "Difficulties in tracking the long-term global trend in tropical forest area" PNAS 105, 818-823.

K.L. Kline and V.H. Dale, (2008). Biofuels: Effects on land and fire. *Science* 321:199-200.

E. Lambin et al., (2001). "The causes of land-use and land-cover change: Moving beyond the myths" Global Env. Change 11, 261. See also: http://www.eoearth.org/article/Causes_of_land-use_and_land-cover_change

C. Monfreda et al., (2008). "Farming the Planet: 2. Geographic distribution of crop areas, yields, physiological types, and net primary production," Glob. Biogeochemical Cycles 22, GB1022.

P. Zuurbier and J. Van De Vooren (Editors), (2008). *Global impact of sugar cane ethanol.* Wageningen Academic Publishers.

R. Perlack et al., (2005). Biomass as Feedstock for a Bioenergy and Bioproducts industry: The Technical Feasibility of a Billion-Ton Annual supply.

P. Robertson, V.H. Dale, O.C. Doering, S.P. Hamburg, J.M. Melillo, M.M. Wander; W.J. Parton; R. Pouyat; P.R. Adler; J. Barney; R.M. Cruse; C.S. Duke; P.M. Fearnside, R.F. Follett; H.K. Gibbs, J. Goldemberg, D. Mladenoff, D. Ojima, M.W. Palmer, A. Sharpley, L. Wallace, K.C. Weathers, J.A. Wiens, W.W. Wilhelm, (2008). Sustainable biofuels redux. *Science* 322: 49-50.

Key quotes:

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