Biofuel and Global Biodiversity

Institute for Agriculture and Trade Policy

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EXECUTIVE SUMMARY

The reduction in global biodiversity has emerged as one of the greatest environmental threats of the 21st century. Urban and agricultural development have traditionally been primary drivers of encroachment on important, biodiversity-sustaining ecosystems. But a new agricultural trend, the use of plant biomass to provide liquid fuels, is exacerbating agriculture's impact on biodiversity. These fuels, called biofuels, are changing land-use patterns in many regions around the world, including some of the most diverse and sensitive regions on the planet.

This new industry has expanded due to two complementary drivers: the increase in crude oil prices, and national policies and incentives directed toward the production and use of biofuel. The U.S. has established federal subsidies and tax advantages for biofuel production, plant construction and the acceleration of research. Many U.S. states have provided additional incentives. Renewable fuels standards, which mandate particular volumes of renewable fuel consumption by certain dates, have also been key to the industry's growth in the U.S. and Brazil. The European Union and other countries that have limited ability to grow biofuel feedstocks themselves have followed suit. The result has been an accelerated expansion of the biofuel industry, with many implications for biodiversity that are unclear.

Due to policy, available infrastructure and knowledge, the feedstocks of choice for the biofuel industry thus far have been "conventional" crops such as corn, soybeans, sugarcane, canola and palm. The use of these crops for biofuel has already had significant impacts on biodiversity. In the U.S., the tremendous increase in land planted in corn is further reducing the diversity in crop rotations and threatening wetlands and acreage set aside for conservation. In Brazil, sugarcane is moving into the fragile, diverse Cerrado region, and other crops such as soy are contributing to significant destruction of the Amazon rainforest. Yet perhaps the largest loss of biodiversity is occurring in the rainforests of Malaysia and Indonesia, where palm oil plantations are rapidly being established to feed the growing demand for biodiesel in Europe and elsewhere.

Given current trends in the biofuel industry, regional and global biodiversity could be substantially harmed, particularly in developing countries. But this does not need to be the case. Many of the biodiversity impacts of biofuel feedstock production are not inherent to biofuel, but are more symptomatic of inappropriate agricultural production systems and policies.

Simply put, a key issue for global biofuel production is the growing volatility of agricultural commodity prices that has resulted from an increased demand for food, industrial products and energy from agricultural land. It matters little for biodiversity whether a bushel of corn, for example, gets processed through an animal or a distillery. The issue is that growing demand for agricultural commodities changes the behavior of farmers and the agribusiness industry. Skyrocketing prices, whether induced by a new demand like biofuel, weather-related crop losses or government policies, can lead to the reckless clearing of native vegetation to take advantage of the increased profit potential.

On the other hand, keeping commodity prices low is not an environmental solution either. For much of the past 30 years, commodity prices have been in collapse and have rarely provided farmers with an income that covers production costs. The low price of corn, in particular, created an economic climate that facilitated research and development into industries such as corn-based ethanol and industrial livestock production.

Environmental groups in the U.S. and throughout the world have struggled to get policies enforced that can mitigate the environmental damage from the monocultural production systems that thrive in times of low prices. Family farm groups in the U.S. have advocated for policies that would better manage production to set fair prices, protecting against volatility that sends prices too high or too low, and ultimately remove disincentives to expand production into biodiverse areas.

In many ways, the biofuel industry juggernaut has already gained substantial momentum and will be difficult to manage. But we have identified opportunities in four policy arenas that can help mitigate the impact of biofuel production on biodiversity:

1 Protect native ecosystems and indigenous lands. The most significant biodiversity threat is the potential for biofuel feedstock production to extend agriculture's encroachment on native vegetation. Lax enforcement of land protection laws in Malaysia, Indonesia and Brazil have all contributed to the proliferation of industrial agricultural production. In the United States, higher commodity prices are encouraging farmers to take land out of conservation reserve programs and into production. Land-use policies must be strengthened and enforced, and conservation programs adequately funded, so that these lands are protected.

2 Make sustainability a priority for all biofuel production. One of the main reasons for broad public and policy support of biofuel has been perceived environmental and rural development benefits. From a biodiversity perspective, biofuel feedstock production provides an opportunity to diversify agricultural cropping systems and generate more environmental benefits from agricultural land, while keeping farmers on the land. But a more sustainable biofuel production system simply cannot get off the ground if it is competing on the same economic terms as the fossil fuel industry on one side and industrial agriculture on the other. For biofuel to really succeed, policies need to assure that sustainability is a priority for all biofuel production. To that end, policies should encourage more sustainable production of biofuel feedstocks, which could potentially include economic incentives for meeting sustainability criteria, procurement preferences for sustainable biofuel, and greater research and investment in more environmentally beneficial biofuel feedstocks to accelerate the transition to the next generation of biofuel.

3 Moderate the environmental damage that results from the dramatic price volatility in agricultural commodities. Corn dominates the U.S. biofuel feedstock industry as well as the industrial livestock feed industry because, traditionally, no other feedstock could compete against low corn prices. Billions of private, state and federal dollars were invested in using up cheap corn. Now, even though corn prices have risen substantially, the ethanol and livestock industries remain just as corn-dependent because there has not been adequate research on other, environmentally beneficial feedstocks.

These price fluctuations in agriculture are devastating for farmers and destructive to the environment, and they even have harmful implications for the diet of consumers. Yet since much of the agribusiness industry thrives on market volatility, policies that traditionally ensured stable, well-functioning commodity markets have been dismantled. The U.S. Farm Bill used to have a series of tools in place to manage supply and prices of primary farm commodities. The University of Tennessee's

Agriculture Policy Analysis Center has documented how an updated supply management system would work to stabilize market prices.[1] Maintaining functional markets is critical for growing and developing diversified agricultural systems.

4 Redesign the agricultural and energy sectors. A number of factors—from high gasoline prices to Mideast conflicts to E. coli and Mad Cow outbreaks—have converged to create an overall sense of concern about the direction of agriculture and energy production. In response, there has been explosive growth in local foods, hybrid cars and small wind turbines as consumers seek positive alternatives.

As biofuel can be produced from a variety of plant materials in nearly every inhabited part of the world, the industry is well-suited for local production, thereby reducing the environmental costs of transportation and allowing local communities to benefit from the sustainable production of biofuel feedstocks and the economic development that can accompany this approach. Unfortunately, the environmental and economic benefits of local production and ownership have largely been abandoned in favor of huge production facilities focused on export to other regions and countries. In Minnesota, state policies initiated in the 1980s contributed to an ethanol industry that was truly homegrown; state incentives favored ethanol plants that were small and cooperatively owned by farmers. These plants had minimal impact on cropping systems and water supplies. Now, however, ethanol plants are most likely not locally owned, production capacity is several times larger, and water availability, air and water contamination, and the growth in monocultural corn production has become much more of a concern.

Rather than exacerbate industrial agriculture's negative impacts on biodiversity, the emergence of the biofuel industry offers a chance to reorient our energy and agricultural policies to prioritize local production and use. A biofuel industry built in conjunction with these policy priorities could protect native ecosystems while providing an opportunity to diversify cropping systems and land use, and benefit rural communities. Public policy has been a major driver in the development of the biofuel industry. In moving forward, smarter policy is crucial if biofuel is going to protect and enhance—rather than decimate—global biodiversity.

INTRODUCTION

"The current massive degradation of habitat and extinction of species is taking place on a catastrophically short timescale, and their effects will fundamentally reset the future evolution of the planet's biota."[2] Michael Novacek and Elsa E. Cleland, National Academy of Sciences proceedings.

The accelerated loss of global biodiversity is of great concern to ecological researchers.[3] Up to one third of the plant and animal species in the U.S. are now at risk of extinction,[4] and major economic and land-use forces at work worldwide are enhancing this loss.

In general, greater diversity leads to greater plant productivity, more nutrient retention and more stable ecosystems.[5] For example, experiments with grasslands have shown that halving the number of plant species within a research plot leads to a 10-20 percent loss of productivity.[6] Numerous other studies indicate that lower plant diversity leads to greater loss of nutrients from the soil through leaching, and subjects ecosystems to loss of productivity through drought, disease and insects.[7] Animal ecology also is subject to major disruptions. An example is the emergence of capybara (a large rat-like mammal) and other small rodents typical of degraded areas that have proliferated in sugarcane areas of Brazil.[8]

Major contributors to declining biodiversity include agricultural expansion, urbanization, land degradation, deforestation, land and water pollution, invasive species and, increasingly, climate change.[9] The global dependence on fossil fuels has indirectly driven much of the loss of biodiversity. As the price of petroleum increases—and if the dependence on low-cost energy does not subside—many of the environmental issues associated with petroleum could be transposed onto production of biofuel feedstocks.

From an environmental perspective, the growth in biofuel production presents great opportunity and challenge. The diversity of potential biofuel feedstocks creates the opportunity—ecosystems such as native prairie could someday become the most efficient source of materials for biofuel. This industry provides one of the only economically viable methods of large-scale conversion away from monocultural production systems.

The current situation in agricultural commodity markets is unique; rarely in recent decades has the agricultural industry experienced sustained high prices for commodities. This creates a new set of environmental concerns, makes industrial agricultural production economically viable in places that it was not previously and exposes inadequate land-use policies in the U.S. and throughout the world.

These and many other drivers have contributed to the complex relationship between agricultural production and biodiversity, which has changed dramatically in large part because of the widespread shift from small-scale, locally based agriculture to large-scale, industrialized agriculture over the past half a century. Modern industrial methods of farming are almost entirely dependent on fossil fuels. And the shift toward industrial agriculture has also diminished the genetic diversity of domesticated plants and animals, as well as biodiversity in ecosystems.[10]

Growth in the biofuel market provides a unique opportunity to develop new agricultural cropping systems, while it also creates new challenges to limiting the encroachment of agricultural production systems on ecosystems that maintain much of the world's biodiversity.

This paper explores the impact of current biofuel production systems on biodiversity and provides recommendations for moving biofuel production toward more sustainable systems that enhance, rather than damage, biodiversity.

CHAPTER 1: BIOFUEL PRODUCTION AND THE GLOBAL BIOFUEL INDUSTRY

With the development of motorized vehicles in the beginning of the 20th century, visionaries such as Henry Ford and Rudolf Diesel advocated for producing liquid transportation fuels from biological materials. But because public policy and extensive research and development supported cheap fossil fuels, these bio-based industries never came to fruition. The oil shocks of the 1970s, however, once again brought both alcohol (ethanol) and combustible oil seed extracts (biodiesel) to the public's attention. Brazil capitalized on its large sugarcane industry in the 1980s and began producing sugar-based alcohol for automobile use. At the same time in the United States, corn-based alcohol was blended with gasoline to produce "gasohol" (10 percent ethanol) for cars.

Political and industrial support for alternative fuels increased modestly until recently. Governments around the world have now created financial incentives for biofuel due to factors including industry lobbying, increased fossil fuel prices, climate change concerns and the desire for energy independence.

BIOFUEL FEEDSTOCKS

Biofuel currently falls into two categories: ethanol, which is compatible with gasoline engines, and biodiesel, which is compatible with petroleum-based diesel engines.

Many plant species can provide suitable biofuel yields. Ethanol is currently made from two basic feedstocks: starch-based feedstocks, such as corn, grain, wheat, barley and grain sorghum; and sugar-based feedstocks, such as sugarcane, sugar beets, fruits, citrus molasses and cane (sweet) sorghum. Biodiesel has more diverse feedstocks than ethanol. It is derived from oilseeds, primarily rapeseed (canola), sunflower, soy and palm oil, as well as animal fat and vegetable waste products.[11]

While these feedstocks currently dominate biofuel production, feedstocks will likely expand into more environmentally beneficial cropping systems in the near future. For example, pilot plants are being developed for cellulosic ethanol production, which uses cellulose rather than plant starches. Potential feedstocks for cellulosic ethanol include dedicated energy crops such as grasses and trees, as well as residues from agriculture (wheat straw, corn stover, sugarcane begasse), industry (paper pulp, sawdust) and forestry. Scientists are also researching other liquid biofuel and feedstock options.

NEW FEEDSTOCKS

A number of new biofuel feedstocks are currently being investigated or already cultivated, some of which are described below. Many of these crops are attractive because they provide more environmental benefits than traditional biofuel crops such as corn, soybean and palm oil. But any feedstock, if cropped in large-scale, monoculture operations and/or if it destroys additional biodiverse regions, creates environmental concerns.

MIXED PRAIRIE GRASSES

Cellulosic feedstocks are the most abundant source of biomass worldwide and are expected to become economically viable in the future, although opinions on when range from a couple of years to well over a decade. In contrast to cultivating cellulosic materials in plantations or unsustainably harvesting them from forests, a diverse mix of perennial crops could offer tremendous biodiversity benefits, higher biomass yields and a significantly improved energy balance.

David Tilman and his colleagues at the University of Minnesota conducted research over the course of a decade with mixed prairie grasses.[12] They compared the energy yields of 172 different patches of grass species grown in a mix of between one and 19 plant species. The research revealed that on formerly highly degraded agricultural land, the mixture of 18 species yielded 238 percent more energy than monocultural systems. The highly diverse plots are more productive because of a more efficient utilization of water and nutrients, better pest control and better resilience to weather perturbations. They also provide the additional benefit of reducing atmospheric greenhouse gas emissions by sequestering carbon in the soil.

JATROPHA

Jatropha has received considerable attention recently as an oil-rich feedstock for biodiesel. Jatropha curcas, a hardy deciduous perennial plant species, is able to survive extreme droughts and can be grown in the poorest, rockiest soils with little maintenance.[13] The oil of the jatropha tree is easily processed and only needs to be modified slightly to produce biodiesel. It also provides an opportunity to produce an economically viable crop in poor growing conditions, and possibly even mitigate desertification.

Jatropha also presents some challenges. The crop consumes considerable water, and is invasive outside of Mexico. The toxicity of jatropha reduces its proliferation, but it could still replace native vegetation and reduce biodiversity. These concerns prompted a ban on jatropha cultivation in Western Australia in 2006.[14]

Investments in jatropha plantations are increasing rapidly in Africa, India, Indonesia and China. India's goal of 20 percent biofuel by 2011 would require 13 million hectares (around 32 million acres) of jatropha plantations.[15] Indonesia is planning to plant 1.5 million hectares of jatropha by 2010, an area the size of its current palm oil plantations.[16] In March 2007, the Chinese forestry administration publicized its goal to develop 13 million hectares of trees high in oil-content, including jatropha.[17] The energy industry is also interested in jatropha: BP is funding a $9.4 million project in India to investigate its utilization.[18] And Archer Daniels Midland, Bayer CropSciences and Daimler recently announced a joint effort to develop jatropha as biodiesel.[19]

SWEET SORGHUM

Sweet sorghum has significant potential as an ethanol feedstock, especially in countries such as India, China and the Philippines. Sweet sorghum does not require the conversion of starch into sugar before the ethanol is produced. Additionally, sweet sorghum can produce both food and fuel, as ethanol can be produced from the stalk juices and humans can consume the grain.

The production of ethanol from sweet sorghum is not yet economically feasible. A disadvantage of sweet sorghum is that its simple sugars cannot be stored as long as starches such as corn, and therefore the ethanol needs to be produced shortly after harvest.[20] In India, ICRISAT (International Crops Research Institute for the Semi-Arid Tropics) is developing hybrids to improve the performance of sweet sorghum, which could make it competitive with other biofuel crops.[21]

ALGAE

The high lipid content of many algae species has spurred interest in commercializing algae production as a biodiesel feedstock. Most algae have an oil content of 15-40 percent[22] and provide a high yield of biomass in a small footprint. From 1978 to 1996, the U.S. Department of Energy's Office of Fuels Development funded a program to develop renewable transportation fuels from algae, the main focus of which was the production of biodiesel from high-lipid-content algae grown in ponds, utilizing waste CO2 from coal-fired power plants. Over the course of this program, tremendous advances were made in the science of manipulating the metabolism of algae and the engineering of microalgae production systems.[23]

Many challenges remain and more research needs to be done before it will be known whether algae can be used on a large scale for biofuel production. Algal farms would be very input-intensive and require considerable nitrogen and phosphorus to maintain growth.[24] Additionally, algae production is management-intensive and requires light throughout the water profile, not just on the surface, to grow productively.

OTHER

Cassava (also known as yucca or manioc), a thick-rooted shrub that is an important food source for millions of people in Africa and South America, is becoming a popular ethanol feedstock, especially in China, where 13.3 million tons of cassava are already cultivated to produce ethanol.[25] Small grains such as barley and wheat are also excellent feedstocks for ethanol production. A challenge with the use of cassava or small grains is the potential for competition with food production.

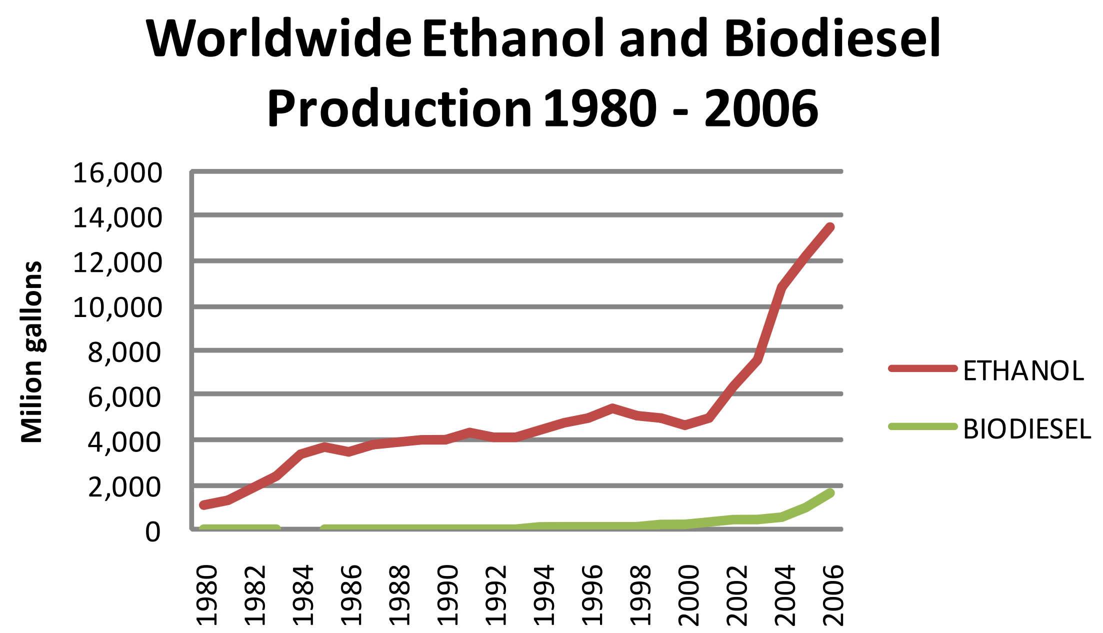
BIOFUEL PRODUCTION TRENDS

The global biofuel industry is expanding rapidly. Ethanol continues to dominate in sheer volume.[26]

Figure 1

World Ethanol and Biodiesel Production 1980-2006: Million Gallons per year

Sources: ▪ www.earthpolicy.org/Updates/2005/Update49_data.htm ▪ www.jechura.com/ChEN409/14_Biofuels.pdf ▪ http://www.ers.usda.gov/AmberWaves/November07/Features/Biofuels.htm



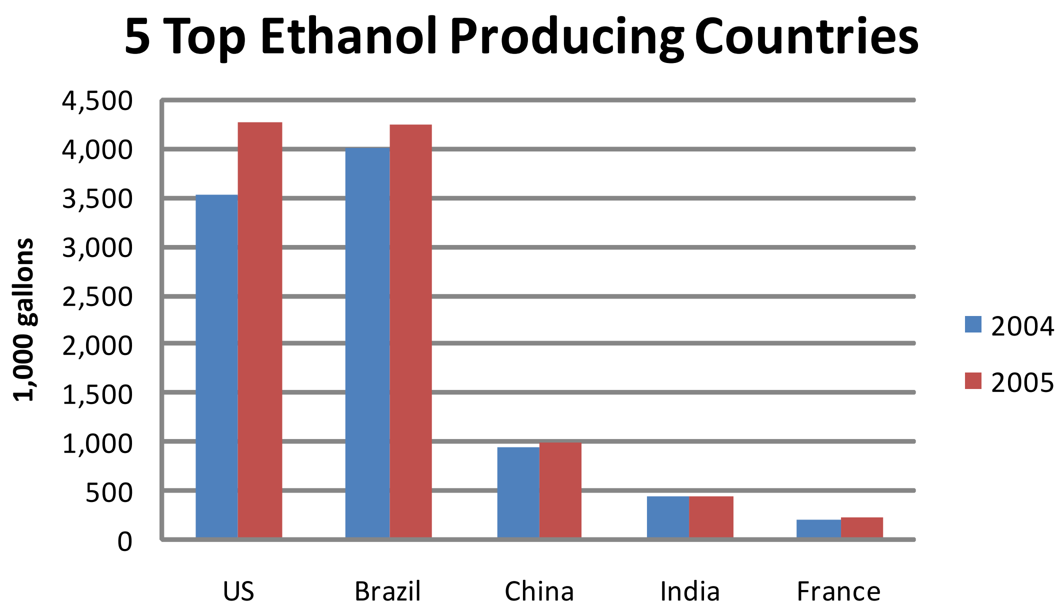
Ethanol

Currently, the five top ethanol-producing countries are Brazil, the United States, China, India and France.[27] Brazil and the U.S. heavily dominate the market, using sugarcane and corn, respectively, to produce three-quarters of the world ethanol supply.[28] China, the world's third-largest ethanol producer, has embarked on a National Fuel Ethanol Program and, as of 2007, 10 Chinese provinces already have a mandatory 10 percent ethanol blend.[29] India, which produces ethanol from cane molasses,[30] has mandated a five percent ethanol blend, although it has thus far been unable to reach that goal.[31] The majority of ethanol is consumed in the countries where it is produced.[32]

Figure 2

5 Top Ethanol Producing Countries 2006

Sources: http://www.epa.gov/reg3wcmd/Ethanol_Workshop/Bauman_Ethanol_workshop.pdf



Biodiesel

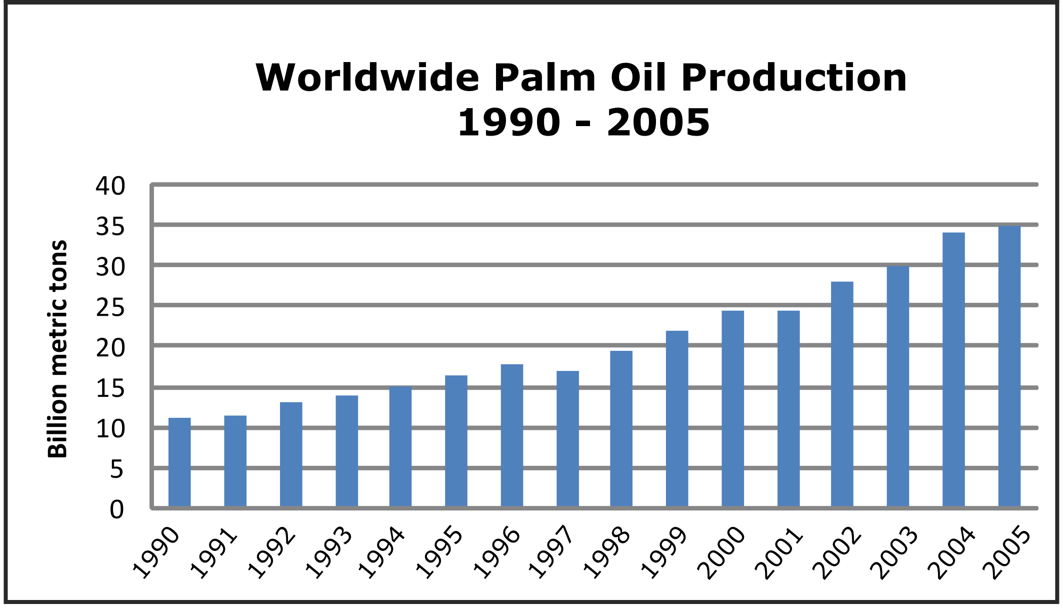
The EU currently dominates world biodiesel production, led by Germany, France and Italy.[33] Around 80 percent of EU biodiesel is produced with rapeseed (canola or mustard) oil.[34] The U.S., producing biodiesel primarily from soybeans, is the world's second-largest biodiesel producer.[35] Brazil, while still a relatively small player in the biodiesel market, is expected to surpass the U.S. and EU in biodiesel production by 2015.[36]

While biodiesel production in both the U.S. and the EU continues to grow, the highest rate of expansion is occurring in palm oil production in Malaysia and Indonesia, as these two countries produce 85 percent of the world's palm oil.[37] World production of palm oil more than tripled between 1990 and 2005.[38] Currently, about one-quarter of the world's palm oil goes to industrial uses, largely biodiesel.[39]

Figure 3

Worldwide Palm Oil Production

Source: Index Mundi; http://www.indexmundi.com/en/commodities/agricultural/oil-palm/

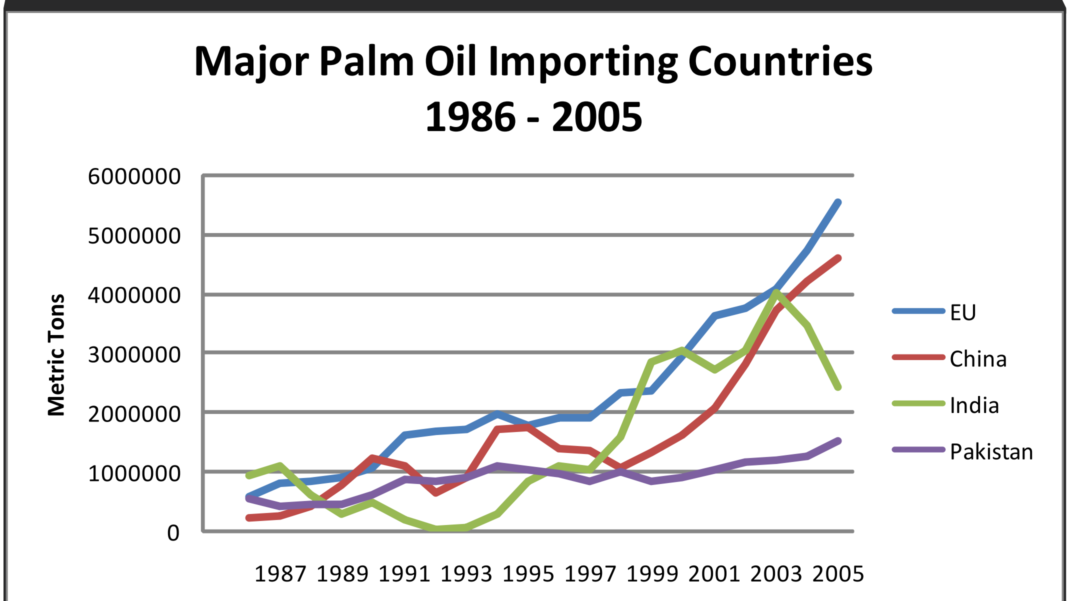


Malaysia and Indonesia are also the largest exporters of palm oil, exporting primarily to the EU. Although it produces biodiesel itself, the EU is limited in cropland for feedstock expansion and has set aggressive targets for biofuel use. Other major palm oil-importing countries, though not necessarily for biodiesel, include China, India and Pakistan, with the U.S. holding only a minor share.[40]

Figure 4

Major Palm Oil Importing

Source: http://faostat.fao.org/site/535/default.aspx



CONTRIBUTING FACTORS: DOMESTIC POLICY INCENTIVES AND INTERNATIONAL TRADE RULES

The use of biofuel has been and continues to be motivated by a complex web of supports and incentives. Renewable fuels standards—government policies designed to carve out a share of the transportation fuel market for biofuel—have been adopted by several countries. Other major policy drivers include government support for research and development of refineries and crops, subsidies directed to fuel blenders, low feedstock prices driven by agricultural overproduction, tax rebates and tariffs. Funding from international monetary organizations such as the World Bank has also been significant in many countries.[41]

Figure 5

Per Country Biofuel Targets

Source: U.S. Department of Agriculture[42]

Country	Target 1	Target 2
Brazil	20-25% ethanol in 2007	5% biodiesel by 2013
China	5 provinces use 10% ethanol blend	Five more provinces targeted for 10% ethanol blend
EU 27	5.75% biofuel share of transportation fuel by 2010	10% biofuel share by 2020
India	10% blending of ethanol in gasoline by 2008	5% biodiesel share by 2012
United States	36 billion gallons of biofuels by 2022	15 billion gallons of corn-based ethanol by 2015; 5.5 billion gallons of non-corn ethanol by 2015; 21 billion gallons of non-corn by 2022; 1 billion gallons of biodiesel by 2012.
Indonesia	10% biofuel by 2010	
Malaysia	5% biodiesel on public vehicles	

TRADE RULES AND BIOFUEL

International trade rules will influence how and where the global biofuel industry matures. While some countries seek to export biofuel feedstocks, other countries have created biofuel consumption targets that are not feasible using internally produced feedstocks, creating a substantial driver for biofuel trade.

Trade in biofuel remains small. In 2004, about 3 billion litres of ethanol were traded internationally, compared to 920 billion litres of crude oil.[43] In 2005, about 10 percent of total biofuel consumption was traded internationally.[44] This trade will expand, probably rapidly, as a result of the various targets created in several industrialized countries to create a minimum use for biofuels. The EU target of 10 percent biofuel by 2020 has drawn particular attention. Many governments in Europe are revising incentives for biofuel to protect the environment, and the EU is proposing to restrict imports of biofuel that has not been produced in a sustainable manner.[45] In the United States there is strong support for domestic fuel production, motivated by both agricultural interests (new markets for domestic producers) and a bid for energy-security (reducing imports of energy).

There is no separate framework of rules governing trade in biofuel. Following the designation made by the World Customs Union, the World Trade Organization (WTO) treats ethanol as an agricultural product, subject to the Agreement on Agriculture. Biodiesel, however, is considered an industrial product, and is therefore subject to the Agreement on Subsidies and Countervailing Measures.[46]

Agriculture has been disciplined by multilateral trade rules only since the signing of the Uruguay Round in 1994. Trade in agricultural goods remains full of exceptions to the rules that govern trade in other goods; agriculture rules allow relatively high levels of domestic support, some extremely high tariffs and, for now, the continued, if constrained, use of export subsidies by those WTO members that were using them when the Uruguay Round Agreements were signed. Subsidies in the energy sector (such as U.S. tax breaks for the domestic petroleum industry) are likely WTO-illegal but have not been challenged, perhaps in part because a number of the world's major oil exporters are not WTO members (e.g., Russia) or have only recently acceded (e.g., Saudi Arabia).

As an industrial product, biodiesel faces low tariffs in industrialized countries. Biodiesel feedstocks, however, as agricultural commodities, are generally protected through agricultural support payments and tariffs. Oilseeds, many of which can be used to generate biodiesel, are an exception for the EU, which has an agreement in place to accept oilseeds duty-free. Given WTO norms and rules, it would be very difficult for members to introduce new, higher tariffs on biofuel, although other market access barriers exist or could arise related to standards.

CHAPTER 2: CASE STUDIES

Current biofuel production based on corn, soybean, sugarcane and palm oil has direct and indirect impacts on biodiversity in all stages of its life-cycle: feedstock production, biofuel production and biofuel combustion. Perhaps the most effective way to explore the impacts of biofuel on biodiversity is to look at case studies where the industry is developing the fastest: Indonesia and Malaysia, Brazil and the United States.

I. INDONESIA AND MALAYSIA

Figure 6

Indonesia and Malaysia

Biodiversity

The tropical forests of Indonesia, which cover around 48 percent of the country's land area,[48] are among the most diverse on the planet. Even though the country is very small, Indonesia hosts 10 percent of all plant species, 16 percent of all reptiles and amphibians, 12 percent of all mammal species and 17 percent of all bird species.[49] Like Indonesia, Malaysia's tropical forests are also among the most diverse on the planet.

Indonesian Wildlife in 2002:[50]

- Breeding Birds: 929 species, 114 threatened
- Mammals: 515 species, 147 threatened
- Higher plants: 29,375 species, 384 threatened
- Fish: 4,080 species, 68 threatened
- Amphibians: 278 species
- Reptiles: 745 species, 28 threatened

Malaysian Wildlife in 2002:[51]

- Breeding Birds: 245 species, 37 threatened
- Mammals: 300 species, 50 threatened
- Higher Plants: 15,500 species, 681 threatened
- Fish: 368 species, 20 threatened
- Amphibians: 198 species
- Reptiles: 379 species, 21 threatened

Nearly all of Malaysia and the largest part of Indonesia, including Sumatra and Borneo, are part of the Conservation International Sundaland Hotspot. The hotspot is unique in its diversity and hosts 15,000 endemic plant species and more than 160 endemic animal species. [52]

Altogether, Indonesia has around 2,500 known animal species (excluding around 4,000 species of fish)[53] and Malaysia has around 1,500 known species of animals (including fish). It is estimated that thousands of species in both countries are still undetected. Key species include the Sumatran tiger, the Sumatran rhinoceros, the gibbon, the clouded leopard and human's closest relative: the Bornean and the Sumatran orangutan.

Biofuel trends

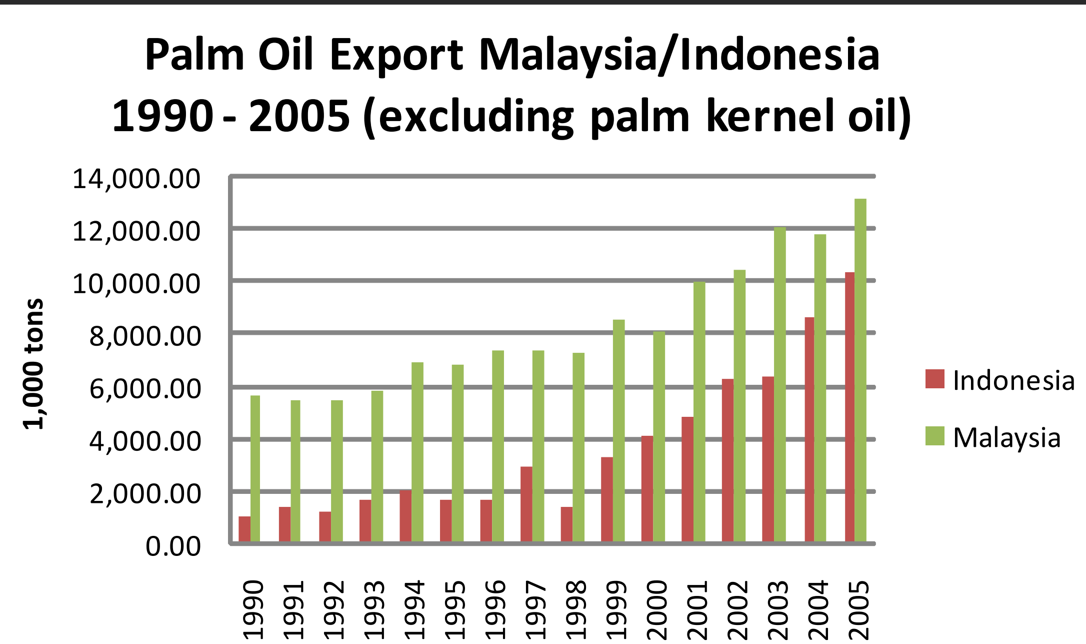
Although the majority of palm oil is produced in Malaysia and Indonesia, the crop originated in central Africa where it remains an important commodity. It was introduced to Southeast Asia in the 19th century, but it was not until the 1960s that a vast monoculture of palm was established in Malaysia and only in the 1980s in Indonesia.[54]

Since the 1960s, Indonesia's palm oil plantations have grown 30-fold, and in 2003 they covered 12,000 square miles. Palm oil plantations in Indonesia increased from 150,000 acres to 1,000,000 acres between 1985 and 2006, an increase of around 660 percent.[55] In Malaysia, plantations in 2003 covered 13,500 square miles, consuming 11 percent of Malaysia's total area and 62 percent of the country's cultivated agricultural land.[56] Between 2000 and 2005, palm oil exports from Indonesia rose from 4.1 million tons to 10.4 million tons annually, while in Malaysia exports rose from 8.1 million tons to 13.2 million tons annually.[57]

Figure 7

Palm Oil Export

Source: http://www.epa.gov/reg3wcmd/Ethanol_Workshop/Bauman_Ethanol_workshop.pdf



Threats to biodiversity

The rich and diverse forests of both Malaysia and Indonesia are threatened by the clearing of land for commercial pulp, rubber and palm oil. According to a paper issued by Friends of the Earth, industry data indicate that by 2002, around 48 percent of all palm oil plantations in Indonesia and Malaysia involved forest destruction.[58] In Malaysia, 87 percent of forest destruction between 1985 and 2000 was connected to the increase of palm tree plantations.[59]

Between 1990 and 2000, Indonesia lost an average of 0.5 million acres of rainforest annually, with an annual 1.6 percent loss in forest cover.[60] Between 2000 and 2005, the average annual loss increased to around two percent of forests, resulting in an average annual loss of around seven million acres.[61] It is estimated that if logging continues at the current rate, no lowland tropical forest will exist in Indonesia's Kalimantan province by 2010.[62]

Malaysia lost around 19,500 acres of forests annually between 1990 and 2000, an average deforestation rate of 0.35 percent per year.[63] The annual deforestation rate jumped to 0.65 percent between 2000 and 2005, an increase of more than 85 percent. In just 15 years, Malaysia lost 6.6 percent of its forest cover, or 375,000 hectares (around 930,000 acres).[64]

The islands of Borneo (split by Indonesia and Malaysia) and Sumatra (Indonesia) have already lost 50 percent and 70 percent of their original forest cover, respectively, and most of the loss has been attributed to logging companies and, more recently, palm oil companies.[65]

Deforestation, habitat fragmentation and development threaten the survival of many species in the two countries. Many of the threatened species are clustered together in small patches of remaining forest stands. It is estimated that nearly 50 percent of Indonesia's forests are fragmented.[66] Fragmentation not only destroys corridors but also exposes wildlife to illegal hunting and poaching. In addition, animals in search for food often collide with poor plantation farmers, who in many cases are legally allowed to shoot the animals in defense of their palm trees. Hundreds of orangutans have lost their lives in Lower Kinabantangan (Malaysia) in the past decade, and conflicts with angry and frustrated elephants are common as well.[67]

Biodiversity is also drastically reduced in monoculture palm oil plantations. Studies have shown that palm oil plantations can support no more than 20 percent of the original rainforest diversity, and often less.[68]

Current economies of scale demand that palm oil plantations must be at least 4,000 hectares (about 9,900 acres) in size for the operation of a crude palm oil mill on-site to be economically viable.[69] In Southeast Asia, the average size of a plantation managed by an individual plantation company is 10,000-25,000 hectares (25,000-60,000 acres), and many of these companies belong to even larger agribusiness holdings themselves.[70]

Slash and burn practices, deforestation and drying and burning of peatland also release large amounts of carbon dioxide and contribute to Indonesia's status as the third largest CO2 emitter worldwide.[71] Not only does this enhance global warming, it destroys precious ecosystems.

Leaching agrochemicals and sediments are also causing severe water pollution, leading to fish and coral kills. Paraquat dichloride, a toxic herbicide banned in several countries, is commonly used on palm oil plantations.[72] Water consumption is also a concern, as the drying of peat lands and deforestation have sharply reduced the water-retaining capacity of the soil, thereby increasing runoff and disturbing hydrologic cycles in Indonesia and Malaysia.

Policy supports

Corruption and cronyism have certainly played a role and have often been responsible for unenforced logging bans, ignored environmental standards, lost forest fire battles and other problems.[73] For instance, in its five-year plan, Indonesia allocates forest land, prioritizing degraded lands. Timber companies often purposely leave forests in poor condition so that conversion to palm plantations can be justified. In addition, the government readily provides permits for forestland, even though large tracts of former agricultural land are set aside for that purpose. Forested land is more attractive than agricultural land because companies can first log the trees and then sell the timber.

What's being done

Several initiatives are trying to address the negative impacts of palm oil production in Indonesia and Malaysia. To deal with unsustainable practices, the Roundtable on Sustainable Palm Oil (RSPO) was established in 2003 in Kuala Lumpur, Malaysia. Companies and environmental organizations, such as World Wildlife Fund, develop voluntary standards and guidelines for plantation managers. RSPO offers trainings for plantation managers and monitors the performance. The RSPO has received increasing industry support from companies like Unilever, Johnson & Johnson, Nestle SA, H.J. Heinz Co. and Cargill. While the RSPO hopes to independently certify palm oil refiners in 2008, it has yet to certify any operation in Malaysia or Indonesia.[74] Operations will have to prove they have not harmed the environment, and plantations on forested areas destroyed after November 2005 will not be eligible for certification.[75] The RSPO has been criticized by many NGOs for being dominated by industry and for not having sufficient representation from indigenous peoples, farmers, small land holders and workers, among other issues. Furthermore, questions remain about the RSPO's willingness to address larger sustainability issues around genetically modified organisms (GMOs), mono-cropping and the effectiveness of the voluntary (as opposed to regulatory) nature of the standards.[76]

The ecologically destructive practices associated with palm oil production have led the European parliamentary committee to recommend a total ban on palm oil imports until sustainable production practices are utilized.[77] But at the same time, the EU has set a goal of 10 percent biofuel blends in all new vehicles by 2020. If palm oil imports are banned, this would create a huge market for other biofuel feedstocks. Whether an EU ban will have a strong influence on the export markets in Indonesia and Malaysia is questionable, because many other global markets, including China and India, exist for palm oil.

Golden Hope Plantations, Berhad, Malaysia

Golden Hope Plantations is often used as an example of a plantation using more sustainable methods. These include the following:[78]

- **No deforestation:** Establishment of plantations only on agricultural land or formerly deforested land, not on new forest and peat land.
- **Zero burning techniques:** Instead of burning the vegetation, the company shreds the material and allows it to compost, which reduces greenhouse gas emissions, controls erosion and adds nutrients to the soil, thereby reducing fertilizer requirements.
- **Strongly restricted use of pesticides:** The farm frequently uses biological controls, such as beneficial insects and owls for rodent control.
- **Use of Palm Oil Mill Effluent:** The effluent is treated through anaerobic digestion, the methane captured and the residues used as fertilizers.
- **Water usage:** The water used in irrigation systems is carefully managed.
- **Biodiversity:** Natural forest lands are restored and sustainably harvested for food and medicinal plants.

II. BRAZIL

Biodiversity

Brazil has some of the most diverse bioregions in the world, including six unique ecoregions: Mata Alantica, Cerrado, Amazonia, Pantanal, Caatinga and Pampa.[79]

Species in Brazil:[80]
- Higher Plants: 56,215 species, 381 threatened
- Mammals: 394 species, 81 threatened
- Breeding Birds: 686 species, 114 threatened
- Reptiles: 648 species, 22 threatened
- Amphibians: 681 species, 6 threatened
- Fish: 471 species, 17 threatened

Figure 8

Unique Species per 10,000 km2 Brazil

Source: http://earthtrends.wri.org/pdf_library/country_profiles/bio_cou_076.pdf

Number of species	
Mammals	0.42
Breeding Birds	0.8
Reptiles	0.78
Amphibians	0.79

The Atlantic Rain Forest (Mata Atlantica) (including the Pampa, which is largely located in Argentina and Uruguay) is among the top five biodiversity hotspots on Earth.[81] It contains more than 260 species of mammals, 450 amphibians, 930 birds, and 20,000 plants and is home to numerous endangered species, including the marmoset and golden lion tamarin.[82] The region also contains 55 endemic threatened birds, 21 mammals and 14 endemic threatened amphibians. The floral biodiversity is actually greater than that of the Amazon.[83]

The Cerrado biome, often referred to as a woodland-savannah, is the second largest of the country's biomes after the Amazon.[84] It consists largely of woodland-savannah and dry forest ecosystems and has an estimated 160,000 species of plants, fungi and animals, 800 species of trees and large shrubs and a large amount of ground shrubs. It is home to the marsh and pampas deer, the giant anteater, the puma and the giant armadillo. There are about 300 other mammals and 935 species of birds as well.[85]

The Amazon is the most widely known biome in all of South America. It represents more than half of the world's remaining rainforest and is the most species-rich rainforest in the world. About 2.5 million insect species, more than 40,000 plant species, 3,000 fish, 1,294 birds, 427 mammals and 378 reptiles have been scientifically described in the Amazon.[86]

The Pantanal is the world's largest freshwater wetland, measuring almost ten times the size of the Everglades.[87] There is an incredible diversity of flora and fauna that have adapted to the area's seasonal flooding, including 260 species of fish and 650 species of birds. Many North American birds also over-winter in the Pantanal.

The Caatinga of the Brazilian Northeast is one of the richest dry forests in the world.[88] It has at least 1,200 plants, nearly 600 arboreal and shrubs, and many fish and amphibians. Two macaws, the indigo and the little blue, are among the 10 most endangered birds in the world.[89]

Biofuel trends

Currently, more than 300 sugar ethanol mills operate in Brazil[90] with nearly 90 new mills planned by 2014.[91] In 2006, Brazil produced nearly 4.5 billion gallons of ethanol.[93] Ethanol plants are currently concentrated in the state of Sao Paulo, in the Atlantic Forest biome. About 14 million acres are currently planted to sugarcane in Brazil, half of which are used for ethanol production and half for sugar production.[94]

As of August 2006, Brazil also had five biodiesel plants in operation, with a total production capacity of nearly 13 million gallons per year (MMgy) and another five plants representing an additional 16 MMgy under development and/or construction. There are plans for another 24 plants with 264 million gallons of capacity in the future.[95] Currently, Brazil uses primarily soybean in its biodiesel production, along with some palm oil and castor oil, but is researching additional feedstocks.[96] One biofuel plant in Mato Grosso, in the heart of Brazil's center-west soybean region, integrates both ethanol and biodiesel production, with resulting energy and cost savings.[97]

Brazil's ethanol production currently accounts for more than 40 percent of the fuel needs of its gasoline-powered motor vehicles.[98] Considering the diesel mix in Brazil's fleet, this works out to about 12 percent of all its transportation fuels.[99] As the global demand for biofuel grows, Brazil plans to further position itself as an exporter of biofuels.[100]

Threats to biodiversity

As in Malaysia and Indonesia, deforestation—and its impact on biodiversity—has been one of the primary results of the biofuel boom in Brazil. The country's Atlantic Rainforest (Mata Atlantica) once covered more than a half million square miles, but today only about seven percent remains,[101] and much of that is severely fragmented.[102] The Mata Atlantica is also one of the most intensely farmed areas in Brazil, home to more than 60 percent of the country's sugarcane[103] and 85 percent of its ethanol production.[104]

The Cerrado has been extensively developed recently for soybean production as well as corn, rice, cotton, coffee and ranching. It is estimated that nearly 60 percent of the Cerrado's original vegetation has now been completely destroyed, and Conservation International predicts that the Cerrado could disappear by 2030.[105] While the demand for beef and soy protein has fueled the clearing of the Cerrado in the past, the demand for both sugarcane and soybean for biofuel likely will accelerate the loss of biodiversity in this region.

Since 1990, the area planted to soybean in Amazonian states has expanded at the rate of 14 percent per year.[106] Soybean, used for animal feed and increasingly for biodiesel, has become a major driver of deforestation. About 20 percent of the Amazon rainforest has been cleared in the past 40 years.[107]

As Brazil's ethanol demand increases, sugarcane plantings are expected to expand.[108] Western Bahia, which historically has had soybean, cotton, coffee and corn, now plans to expand into sugarcane. Between 20,000 and 30,000 hectares of sugarcane could be planted in the region by 2010.[109]

The expansion of sugarcane will likely displace other crops, including soybean, pushing soybean production to the north and into the Cerrado and the Amazon.[110] It is also possible that growing biofuel demand will push sugarcane into the Amazon itself unless the country devises sufficient safeguards.[111]

Water pollution from farming and sugarcane refineries has affected Brazil's rivers, particularly in the Pantanal.[112] As soybean cultivation increased in the neighboring Cerrado, water draining from these fields has further decreased water quality. The Pantanal earned the dubious distinction of being named the "Threatened Lake of the Year 2007" by the Global Nature Fund.[113]

If petroleum prices remain high, and if the U.S. removes its ethanol tariff of 54 cents per gallon, then enormous growth in Brazilian ethanol exports can be expected. This will put large pressures on the Amazon, even if it only intensifies the use of land that has already been cleared. The recent meeting of U.S. President Bush and Brazilian President Lula, during which cooperation in the biofuel sector between the U.S. and Brazil was discussed,[114] highlighted the potentially dramatic new demand for Amazonian land.

Policy support

Brazil emerged as an international leader in biofuel production through a combination of public policy, strong research programs, its excellent climate, and the low cost of land and labor in Brazil.

After the global oil crisis in 1973, the Brazilian government decided to develop the ethanol industry.[115] In 1975, a program known as "Proalcool" was initiated to accelerate ethanol research and development. The program also provided subsidies for sales of ethanol as well as flex fuel vehicles. This program faltered when global oil prices dropped, but demand rebounded with higher petroleum prices. Most recently, the government has passed legislation that mandates a two percent blend of biodiesel in all commercial sales of petroleum diesel by 2008, rising to five percent by 2013.[116]

What's being done

An attempt to help meet the European Union's renewable fuel mandate of 10 percent by 2020 is driving some of the biofuel expansion in the country. But the damage to biodiversity from growing more biofuel feedstock has drawn criticism from the EU, with proposals to restrict import of biofuel that has damaged the environment. Additionally, EU officials have expressed concern that ethanol makers were breaking local environmental and labor laws, in particular the use of slave labor in sugarcane harvest and the destruction of tropical forests.[117] In response, the Brazilian government is taking steps to require ethanol companies to obtain a new environmental and industrial standards certificate before ethanol can be exported in 2008.[118]

III. UNITED STATES

Biodiversity

The U.S. "corn belt," where biofuel production is currently concentrated, has a number of different bioregions. The Upper Midwest Forest-Savanna Transition, which is between the eastern forests and the northern edge of the Great Plains, contains a mosaic of forests, savannas and largely oak, maple and basswood woodlands. The oak savannah is one of the world's most endangered ecosystems. Riparian areas are important to migratory birds, yet less than five percent of the ecoregion is intact, and the remaining habitat is highly fragmented.

The Northern Tall Grasslands region is the northern-most extension of the tall grass prairie, extending from Lake Manitoba south along the Red River Valley to central Minnesota. The dominant grasses are big bluestem, switchgrass and Indian grass, which are often mixed with quaking aspen and oak groves, along with rough fescue grasslands.

The long growing season and abundant rainfall in the Central Tall Grasslands, which covers southern Minnesota, most of Iowa and small areas of eastern South Dakota, Nebraska and Kansas, has given it one of the most productive ecoregions on earth. Prior to agricultural development, bison and likely elk dominated the large animals, but the wolf also was important to the ecosystem. There is a high level of fragmentation, and virtually no significant blocks of intact habitat remain.[119]

The Central Forest-Grasslands Transition extends through northern Illinois, Missouri, eastern Kansas, Oklahoma and Texas and has a mixture of savanna, prairie and woodlands. It was one of the richer ecoregions in North America with a large number of species of reptiles, birds, butterflies and tree species, dominated by oak and hickory. As with the other central U.S. ecoregions, almost all of the area is now cultivated for corn and soybeans. Less than one percent of the native habitat is considered to be intact, and the degree of fragmentation is extremely high.[120]

The western-most part of the U.S. grain producing regions, the Central and Southern Mixed Grasslands, runs north-south from central Kansas through western Oklahoma and north-central Texas. It is a mixture of tall and short grass prairies and has a high floral complexity. Today only about five percent of the remaining habitat is intact, and 90 percent of the area has been converted to cropland and pasture. High wheat prices led to conversion of much of the area in the 1990s, accelerated by use of center pivot irrigation.[121]

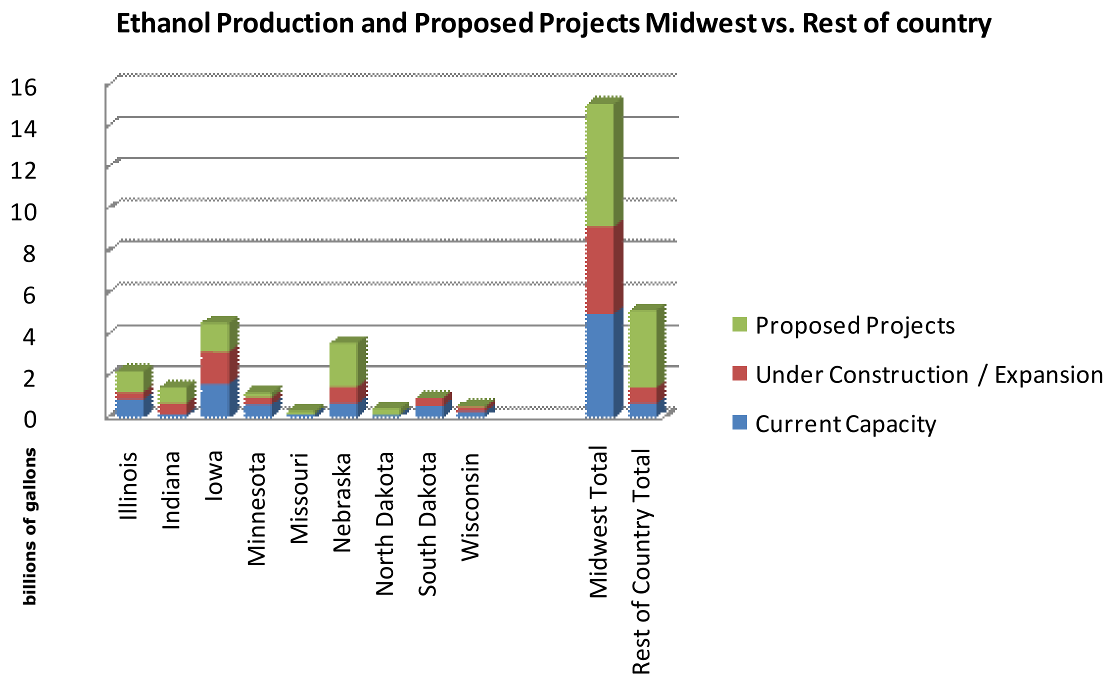
Biofuel trends

The corn-based ethanol industry in the U.S. is growing rapidly. U.S. ethanol production doubled between 2001 and 2005, and it will likely double again within the next few years.[122] According to the Renewable Fuels Association, as of December 18, 2007, the U.S. had 135 active ethanol plants capable of producing more than seven billion gallons of ethanol per year.[123] An additional 65 plants under construction and nine plant expansions will add more than six billion more gallons of capacity, bringing total capacity to more than 13 billion gallons annually. Construction is expected to continue following the passage of a stronger renewable fuel standard by Congress in December 2007, which requires 36 billion gallons of renewable fuel by 2022.[124]

Figure 9

U.S. Ethanol Production and Proposed Projects

Source: IATP data from the Renewable Fuels Association, Ethanol Producer, and various sources. April 2007.



The amount of U.S. corn going into ethanol has also expanded rapidly, from about five percent per year from 1990 to the early 2000s to almost 20 percent in 2006.[125] U.S. farmers planted more than 90 million acres of corn in 2007, up from nearly 79 million acres in 2006 and the most since the 1940s.[126]

Soybean biodiesel production is also significant. In 2007, it reached 250 million gallons, requiring 5.6 percent of U.S. soy production. If all proposed soybean biodiesel plants came online, about 1.7 billion gallons could be produced, or about 42 percent of U.S. soybean production.[127]

While biofuel production has thus far been concentrated in the traditional Midwest "Corn Belt," the agricultural region is expanding as increasing demand for corn and improved genetics and management have adapted corn to more extreme climates and poorer soils. Corn has begun to displace wheat and sugar beets in the Dakotas and cotton in the southern part of the U.S.[128] Corn production has also intensified in the Midwest, in some cases replacing soybeans in the traditional corn-soybean rotation. Ethanol plants are being constructed around the country, including in states that produce little or no corn.[129]

Although the past few years have been extremely profitable for ethanol producers and investors, a number of uncertainties may slow the market, including fluctuations in petroleum prices, higher corn prices and pest pressures that may increase the costs of monocultural corn and soybean production.

Biodiversity impacts

Overall, the native U.S. ecosystems have been so highly altered that native biodiversity has been largely eliminated, except for fragmented remnants and protected areas. While many of these areas were significantly altered before biofuel production began, some of this alteration is due to the production of the same crops that are now being used for biofuel—corn and soybeans. It is critical that these few protected areas be maintained.

The contiguous United States uses about half of its land for production of food, feed and fiber. While much is grasslands and forests, 17 percent is devoted to annual commodity grain crops, including corn, soybean and wheat.[130] These crops dominate in part because of the development of efficient production systems, including machinery, hybrid seed, fertilizers and pesticides, as well as irrigation and drainage.

When humans manage an ecosystem for the purpose of food, fiber and fuel production, they often limit the biodiversity of that land area. However, the degree to which they limit biodiversity depends upon the type of agriculture that is practiced. For example, the state of Iowa has 32,000 square miles of corn and soybeans, representing 92 percent of all its farm acreage.[131] By contrast, researchers have found more than 50 species per garden in home gardens in Mexico, and a combined 404 species across the home gardens in just one Mexican community.[132]

Expansion of grains and oilseeds for biofuel and other uses may well continue to lower biodiversity and, importantly, limit the fledgling efforts at restoring habitat fragments. Examples include the possible loss of conservation reserve land. Nebraska has already seen a decline in conservation reserve land by about 6.5 percent between September and November 2007, from 1.34 million acres to about 1.25 million.[133]

Wetlands are one of the most important ecosystems in the U.S.[134] Wetlands have been disappearing for decades because of drainage for agricultural and development purposes, and they continue to lose their ability to provide ecosystem services, including biodiversity. The Prairie Pothole Region, which extends from northwest Iowa through western Minnesota, the Dakotas, Montana and into western Canada, has seen a major loss in wetlands. These shallow wetlands were formed from depressions left after the last glaciations and are critical to the migration of many wild birds. Many have been protected by federal land preservation agreements, and the U.S. Fish and Wildlife Service (FWS) has been buying these wetlands for preservation as rapidly as funds permit. However, land prices have increased, stretching the FWS funds thin, and farmers are not renewing government contracts because of the high price of corn and soybeans.[135] The economic pressure coupled with loss of refuges due to global warming[136] indicates that this critical ecosystem may suffer even further loss.

High-nutrient (fertilizer) and pesticide inputs, as well as accelerated soil erosion, also impact water supplies and lower soil quality. The nutrient-driven hypoxic zone (dead zone) in the Gulf of Mexico reached a record 7,900 square miles in 2007, one of the largest on record.[137] In addition, consecutive plantings of corn require more nitrogen fertilizer than when corn is alternated with soybeans.[138] If corn production continues to expand in the U.S., so too will the impacts on the environment.

Policy supports

In the U.S., biofuel policies were initiated in the 1970s and have been reinforced with subsidies and renewable fuel standards in the past few years.

U.S. farm policy also plays a significant role. While farm policies initiated in the 1930s were devised to maintain a fair market price for commodity farmers, these policies have largely been abandoned in favor of policies that drive down prices, often well below the cost of production. The very low price of corn over the past 30 years has been an underlying driver behind the crop's rapid expansion. The livestock industry, the sweetener industry and now the ethanol industry have taken advantage of these low prices by making corn their primary feedstock.

What's being done?

Two major pieces of federal legislation will create incentives for non-corn based biofuel in the U.S. First, the Energy Independence and Security Act of 2007, passed Congress in December 2007, sets a renewable fuel standard of 36 billion gallons by 2022, of which 15 billion gallons can be corn-based ethanol with the remaining coming from so-called "advanced biofuel," which includes cellulosic biofuel and biomass-based biodiesel. Second, a new Farm Bill was scheduled to be completed in 2007, but has been pushed back to at least early 2008. Both the House and Senate versions of the Farm Bill contain a "Bioenergy Crop Transition Assistance Program" to create economic incentives for farmers to begin growing cellulosic biofuel feedstocks; a bioenergy re-powering program to provide federal loans and grants for promoting more public and private investment in the construction of cellulosic biorefineries; and another program to encourage more production of on-farm energy, including biodiesel.

States have also taken a leadership role in pushing for more environmentally friendly biofuel feedstocks. For example, a Minnesota working lands bioenergy program allows perennial crops to be grown under long-term easements for the bioenergy market.[139] Other states with advanced biofuels legislation include Washington, Oregon and Massachusetts.

CHAPTER 3: Indirect Impacts on Biodiversity

The previous chapter describes the destruction of natural ecosystems and the threat to global biodiversity caused by current biofuel production systems, but the production of biofuel also has other effects with indirect consequences for biodiversity. This chapter focuses on the biofuel impact on two global issues that will have a profound impact on biodiversity—climate change and the availability of clean water.

Energy use and climate change

Current global biofuel development, supported by governments around the world, is justified in part by the idea that biofuels are carbon-neutral—i.e., that they emit as much carbon dioxide as they take up during plant growth while emitting less carbon dioxide than comparable fossil fuels. But this simplified perception often fails to take into account both the whole life-cycle of biofuels and carbon dioxide (CO2) emissions due to land-use change. Well-managed biofuel production, incorporated into current agricultural production systems, can reduce greenhouse gas emissions. However, if biofuel production encroaches on native vegetation, it is unlikely that even the most energy-efficient cropping system could offset the load of greenhouse gases emitted during the clearing of land.

Global warming will profoundly affect biodiversity worldwide. Habitats for animals and plants change as temperatures increase and as rainfall patterns change. Scientists have estimated that up to 60 percent of northern latitude habitats could be affected by global warming.[140] Examples abound, such as the extinction of a frog species by a climate-induced fungal disease documented in the Monteverde Cloud Forest Preserve in Costa Rica.[141] Other species will not be able to move fast enough to adapt to changing habitat and climate.

Biofuel production involves the use of fossil fuel energy on the farm, in transport and in the conversion process. Energy is needed for land tillage, pest control, harvesting, drying and storage, as well as to operate the fermentation plant.

Land-use change also contributes significant CO2 emissions. In Brazil, for instance, 80 percent of greenhouse gas emissions in the country come from deforestation,[142] and this is at least in part a consequence of the expansion of sugarcane for biofuel, which replaces soya fields and pushes them into the forests.[143]

In Indonesia, CO2 emissions from deforestation account for 83 percent of the country's annual greenhouse gas emissions.[144] In addition, with most of the highland forests destroyed, many palm oil companies are now moving into Indonesia's lowland tropical forests growing on peaty soils. Because the soils are very wet and poor in oxygen, decomposition is usually very slow, but draining the soils for palm oil plantations is accelerating this decomposition, and carbon that has accumulated for thousands of years is being released. As mentioned earlier, Indonesia recently became the third largest emitter of CO2 worldwide.[145]

The effects of deforestation on the world's climate could be disastrous: not only will massive amounts of carbon dioxide be released, but also any hope of major carbon storage in this unique ecosystem will be lost. The Amazon is a major driver of climate in South America and perhaps worldwide.[146] Costa et al., using the climate change model CCM3, investigated the role of soybean expansion in the onset of Amazon drought, as compared to pastureland extension.[147] Their results indicated that due to the very high albedo (reflectivity) of the soybean, precipitation was significantly decreased compared to pastureland. This has reduced rainfall by a factor of four compared to the time before clearing.

Nitrogen also plays a role in accelerating global warming. Some of the fertilizer in the form of nitrogen will eventually be released into the atmosphere as nitrous oxide (N2O), a greenhouse gas 296 times more potent than CO2.[148] Excess nitrogen also has direct negative impacts on the biodiversity of terrestrial, marine and freshwater ecosystems. Terrestrial plant species such as prairie grasses adapted to low nitrogen levels are endangered[149] and eutrophication in fresh water is common, with hypoxic zones developing around the world. A recent study by the National Academy of Sciences also suggests that nitrogen in rain is accelerating emissions of CO2 from peat bogs, rendering them carbon sources instead of sinks.[150]

Water use and water quality

The depletion of water supplies is a global challenge to biodiversity, and biofuel production has contributed to additional agricultural water consumption.[151] The growing, harvesting and processing of biofuel feedstocks in most cases withdraws considerable water. For example, counting only the water used in refining, corn-based ethanol refineries in the U.S. use about four gallons of water for every gallon of ethanol produced.[152]

A typical 100 million gallon per year ethanol plant which is currently the norm in the Midwest U.S., would use about 400 million gallons of water annually—more than a million gallons per day. This is equivalent to the water needs of a community of 10,000.[153]

Figure 10 - A

Water Consumption by Biofuel for Transportation
Source: National Research Council. 2008. Water Implications of Biofuels Production in the United States. Committee on Water Implications of Biofuels Production in the United States. The National Academies Press. Washington, D. C.

Fuel type/process	Water use per unit energy [gal/MMBTU]	Water consumption per unit fuel Gal water/gal fuel
Conventional oil and gas refining	7-20	~1.5
Grain ethanol processing	12-160	~4
Corn irrigation EtOH	2500-31600	~980
Biodiesel processing	4-5	~1
Soybean irrigation biodiesel	13800-60000	~6500
Lignocellulose EtOH	24-150	~2-6
Lignocellulose diesel	14-90	~2-6

Figure 10 - B

Biofuel Water Use Intensity for Selected Feedstocks and Processes.
Source: Pate, R., M. Hightower, C. Cameron, and W. Einfeld. 2007. Overview of Energy-Water Interdependencies and the Emerging Energy Demands on Water Resources. SAND 2007-1349C. Sandia National Laboratories. Albuquerque, NM.

Fuel Type and Conversion Process	**Feedstock**	**Process Water Use** gal water/gal fuel	**Process Water Consumption** gal water/gal fuel	**Feedstock Water Demand** acre-ft/acre	**Feedstock Water Consumption (irrigated)** gal water/gal fuel	**Biofuel Yield** gal fuel/acre
Ethanol	**Corn**	2-6	4	1.2	980	400
Starch	**Sorghum**	2-6	4	1.0	1900	170
Sugar	**Sugar cane**	2-6	4	2.0	1160	560
Sugar	**Sugar beets**	2-6	4	2.3	1360	550
Ethanol	**Switchgrass**	~3-12	~2-6	~2,3	Rain fed	500-800
Cellulose	**Woody biomass**	~3-12	~2-6	~2,5	Rain fed	500-800
Biodiesel from oil extraction	**Soybeans**	0.3-3	~1	~0.8	6500	40
Trans-esterification	**Sunflower**	0.3-3	1	~1.5	6100	80
Trans-esterification	**Oil Palm**	0.3-3	~1	2,5	Rain fed	510
Trans-esterification	**Algae**	0.3-3	~1	Unknown	Unknown	3,000-15,000

Water supplies may also be contaminated by pesticides, nutrients and sediment during crop growth, as well as by byproducts of biofuel processing. For example, Palm Oil Mill Effluent (POME), the residue that remains when palms are crushed, contains water, fat residues and fibrous material from the palm, and is high in carbon and low in nitrogen. When it runs off into water bodies, its high organic carbon content and turbidity can cause organic pollution and reduce the oxygen available for aquatic life.[154] For every ton of fresh palm fruit that is processed, approximately 0.65 tons of POME are produced.[155] Currently in Malaysia POME is the largest pollutant discharge into rivers.[156] Corn ethanol production also produces significant organic waste, which must be treated before the waste water is released into the environment.

Indirect Land Use Change

A potentially significant, but difficult to quantify, effect of biofuel production on biodiversity arises as the price of corn increases and more acreage is switched from other crops to corn. In the Midwestern U.S., where much of the country's corn is grown, sown acreage of soy has decreased as farmers have expanded corn plantings, and this has contributed to a near doubling in the price of soy. This in turn has helped spur more rapid expansion of soy plantation in Brazil, much of it on formerly forested areas of Amazonia and the wooded savannahs of the Cerrado region.[157] It would be too simplistic to suggest a one to one correspondence between land taken out of soy production in the U.S. and rainforest converted to soy in Brazil. Several other factors have contributed to the rising demand for soy worldwide, including changing diets in the developing world and the high price of oil. And the phenomenon of tropical forest conversion being driven by international demand for farm products is nothing new. Nevertheless, it is a cruel irony that even the promotion of more sustainable land uses in the North for biofuel feedstocks (such as restoration of mixed perennial grasses in the Corn Belt) may indirectly contribute to biodiversity loss half a world away.

FUTURE OPPORTUNITIES: CELLULOSIC ETHANOL

The impact of current biofuel production systems on biodiversity is significant. However, if done sustainably, and if combined with a larger strategy of energy conservation and a diversity of renewable energy sources, biofuel does provide an opportunity to diversify cropping systems and land use, and benefit biodiversity.

One of the most promising directions for biofuel production is the potential of cellulosic ethanol. Cellulosic ethanol can be produced from hemicelluloses and cellulose in plants and plant residues, and feedstocks can include both dedicated energy crops and wastes from agriculture, industry or forestry. Cellulosic ethanol is chemically comparable to ethanol produced from starches and sugars.

A recent life-cycle analysis revealed that ethanol from switchgrass generally has a slightly better net energy value than corn ethanol and produces significantly lower emissions of greenhouse gases.[158] Another recent study found that switchgrass produced 540 percent more energy than needed to grow, harvest and process it into cellulosic ethanol.[159] Because cellulosic ethanol production allows the use of the entire plant rather than just the starch or sugar, dedicated energy crops offer considerably higher yields. They also require fewer fossil fuel-derived inputs, such as fertilizer and pesticides, and sequester carbon through a deep root system.

Besides the energy-efficiency and greenhouse gas benefits, cellulosic ethanol production also provides farmers with an opportunity to diversify cropping systems. Growing a mix of perennial grasses and shrubs additionally offers environmental advantages over monoculture crop production, as their large root systems stabilize the soils, sequester carbon, regulate water runoff, attract wildlife and support biodiversity.

As a recent report by Blann[160] points out, properly managed agricultural lands can serve as buffers for wildlife, providing habitat that is more compatible with biodiversity. These working lands would be compatible with the conservation of natural communities and as much as possible recognize the structure and function of ecosystems that had initially been displaced by intensive agriculture. If grasses, particularly native swards, become a major feedstock for ethanol plants, there is a strong possibility of developing landscapes that will support higher levels of biodiversity than at present.

The challenge of cellulosic ethanol production lies in efficiently fermenting the sugars found in hemicelluloses and cellulose. This depends on the right types of yeasts and enzymes, and it is estimated that it will still be at least several years before the enzymes will be available on a commercial scale.[161] However, some demonstration cellulosic ethanol plants are currently under construction in the U.S. and elsewhere.

If cellulosic ethanol becomes commercially viable, it has the potential to bring dramatic changes to the agricultural landscape. It could open new lands to production that were previously unsuitable for traditional row crop farming,[162] leading to diverse income sources for some farmers and ranchers.

There are other questions that have been raised in connection to cellulosic ethanol development. For example, is there sufficient land available to support cellulosic ethanol production on a large scale? How will cellulosic feedstocks compete with other feedstocks and what will be the consequences for family farmers? Will the cultivation of perennial non-edible feedstocks compete with edible feedstocks? Who will control the patents for all aspects of cellulosic ethanol production and will the benefits be limited to the corporate patent holders?[163] Can cellulosic ethanol development be kept from following the industrial model dictated by much of the current research and development? It is difficult at this point to answer all these questions, but it is important to recognize that there are many solutions available, including local production of feedstocks, the local ownership of processing plants and sustainable production practices. And national and international policies will play a large role in the industry's future development.

CHAPTER 4: RECOMMENDATIONS

Developing policy recommendations for addressing the impact of biofuel on biodiversity is complicated by the variety of conditions under which biofuel feedstocks are grown, as well as the impact that this industry has on the larger agricultural and energy economies.

Little doubt remains that the biofuel industry is now well-established and will maintain a strong presence worldwide for the foreseeable future. But it is early in the industry's development—the petroleum and coal industries have taken over a century to reach their current level of infrastructure—and there is still time to influence the direction of biofuel development.

Ethanol and biodiesel are currently being overlaid on a broken agricultural production system. Many of the biodiversity impacts of biofuel feedstock production are not inherent to biofuel, but are more a symptom of damaging agricultural production systems and policies. These production systems and policies will need to be changed to create a more sustainable biofuel environment. Importantly, the enormous new demand for biofuel, coupled with the diversity of potential feedstocks, creates a unique opportunity to restructure agricultural production systems.

The good news is that a growing number of governments, non-profit organizations and companies are recognizing the need to ensure that global biofuel markets develop in a sustainable manner. As mentioned earlier in the case studies, the Roundtable on Sustainable Palm Oil is trying to develop standards and guidelines for plantation managers in Malaysia and Indonesia and hopes to have "sustainable" palm oil on the market by the end of 2008. Brazil is attempting to respond to criticism from Europe by establishing environmental and industrial standards certificates for exported ethanol. Europe itself is re-thinking its mandate for biofuel and considering strong environmental criteria for biofuel production. And the U.S. Energy and Farm Bills include greenhouse gas criteria in the incentives created to help meet a new mandate of 21 billion gallons of non-corn ethanol by 2022.

The bad news is that these efforts are thus far very small in the context of the global agricultural system, very late from a biodiversity standpoint, and even if implemented, may by their design have a limited impact. Urgent action is needed. From a biodiversity perspective, we have identified three components of the biofuel industry with major ecological implications that must be addressed immediately:

- **Land-Use.** The conversion of native vegetation to agricultural uses is without question the greatest concern with the growth of biofuel production. As documented in the case studies, the decimation of critical ecosystems in Malaysia, Indonesia and Brazil is an ecological disaster that has been exacerbated by new biofuel demand. Any benefits that accrue from sound biofuel production in other parts of the world are more than offset by the loss of these ecosystems.

  The challenge, of course, is that stopping biofuel production does not bring this ecological destruction to a halt. Products like palm oil, sugar and soybean have multiple uses, and high petroleum prices create an even greater incentive to find new industrial uses for these products. Additionally, as biomass itself is becoming increasingly valuable, even crop-specific criteria or limits may not have the desired effect on land clearing for agricultural or forest production. Unless land use policies are strengthened and enforced—or the ecological services that these ecosystems provide are more significantly valued—this land-use conversion will continue.

- **The Sustainability of Agricultural Systems.** Agricultural production is not a monolith, and the ecological services produced from different production systems can vary enormously. The trend in biofuel feedstock use over the past decade has been to expand the use of already abundant agricultural commodities, which generally results in diminished habitat. However, biofuels are not feedstock-specific, so there is an increasing opportunity to introduce new and more sustainable crops and cropping systems to meet some of the need. If sustainability can be incorporated into this emerging industry, whether through a certification system, policy incentives, or research and development into beneficial and diverse cropping systems, it provides a unique opportunity to get more benefits out of large-scale agricultural production systems.

- **Commodity Prices.** One of the most contentious issues around the growth in biofuel production is the impact that it has had on commodity prices. Many critics quickly blamed biofuel production for rising food prices, despite the fact that many other factors, from rising petroleum prices to corporate consolidation to climate change, contribute to the rise in global food prices.[164] Biofuel demand certainly has contributed to the expansion of sugarcane and soybean in Brazil and palm oil in southeast Asia. But these higher prices also create the window of opportunity for the development of preferable feedstocks. This is perhaps most notable in the U.S., where high corn prices have instigated tremendous public and private investment into cellulosic ethanol research and development around perennial grasses that offer multiple ecological benefits.

  Biodiversity appears to suffer the most when commodity prices are excessively high or low. When prices are high, agricultural production expands at a frenzied pace. On the flip side, when prices are low, agricultural land rarely goes out of production, but instead the agribusiness industry takes advantage by pumping cheap grains through industrial uses such as livestock factory farms. Moderating these price distortions, which was an integral part of agricultural policy until the mid-1990s, is not a solution by itself, but it does help to alleviate some of these drivers of agricultural expansion.

The complexity of the situation works against any silver bullet solution. Changing inappropriate policies in any particular country is helpful, but could very well result in simply pushing the industry to a different location. To address the multiple drivers in this issue, we provide the following recommendations.

1 Protect native ecosystems and indigenous lands. The most significant biodiversity threat is the potential for biofuel production to extend agriculture's encroachment on native vegetation. Biofuel feedstocks are simply the latest in a long line of commercial crops that have driven forest conversion in the tropics. Lax enforcement of land protection laws in Malaysia, Indonesia and Brazil have all contributed to the proliferation of industrial agricultural production. In the United States, higher commodity prices are convincing farmers to take land out of reserve programs and into production.

Demand for biofuels has increased economic incentives to produce agricultural commodities, while the ecosystem services provided by native vegetation, including protection of genetic resources, are not appropriately valued. Without effective protection of native ecosystems, in combination with incentive programs or other mechanisms that more accurately express the full value of ecosystem services, the biofuel boom will accelerate the encroachment of agriculture onto native lands.

Where markets and national governments both fail to protect natural ecosystems from encroachment, indigenous peoples sometimes succeed. Nepstad, et al have shown that the rate of forest conversion in the Brazilian Amazon is dramatically lower in areas controlled by indigenous peoples, referring to indigenous lands as, "currently the most important barrier to Amazon deforestation."[165] Recognizing and supporting the rights of indigenous peoples is therefore not only a matter of social justice, but also essential to stemming the tide of tropical forest destruction, whether spurred by biofuel markets or other forces.

The growing demand for biofuel, particularly from the EU, has created an economic predicament for many less-developed countries. Developed countries and transnational corporations are willing to invest substantially in biofuel feedstock production, but the market for ecological services has languished. We are still a long way from valuing the benefits of tropical rainforests, which include genetic diversity, habitat, carbon sequestration, water cycling and purification, and countless products of value that are uniquely produced in a rainforest environment.

Specific policies, such as the EU's requirement for the use of biodiesel, have contributed significantly to the destruction of rainforest in Southeast Asia. Hopefully, the EU's promising new steps for environmental protection in the production of biofuel will have a positive effect. Ultimately, it is critical that when the EU and the U.S. use policy to drive the growth of the biofuel industry, the destruction of native ecosystems is discouraged.

2 Make sustainability a priority for all biofuel production. One of the main reasons for broad policy and public support of biofuel has been perceived environmental and rural development benefits. From a biodiversity perspective, biofuel feedstock production provides an opportunity to diversify agricultural cropping systems and generate more environmental benefits from agricultural land, while keeping farmers on the land. But a more sustainable biofuel production system simply cannot get off the ground if it is competing on the same economic terms as the fossil fuel industry on one side and industrial agriculture on the other. For biofuel to succeed, policies need to assure that sustainability is a priority for all biofuel production. To that end, policies are needed to encourage more sustainable production of biofuel feedstocks, which could potentially include economic incentives for meeting sustainability criteria, procurement preferences for sustainable biofuel, and greater research and investment in more environmentally beneficial biofuel feedstocks to accelerate the transition to the next generation of biofuel.

Sustainability criteria can take many different paths. Organic foods certification provides an example of the differentiation of a small but growing niche in the food production industry. Standard systems for biofuel that have been initiated include the Roundtable for Sustainable Palm Oil, the Roundtable for Sustainable Soy and the Roundtable for Sustainable Biofuels. While these approaches may certainly result in better environmental and social practices associated with biofuel feedstock production, there are many concerns about the overall goals, stakeholder participation and effectiveness of such voluntary "market" based approaches. Considering that the expansion of biofuel is largely a result of mandates and targets set at the state, national and international levels, it seems clear that standards and certification will need policy-level support to be effective. Only in this manner will such standards actually be able to influence feedstock production in a meaningful way.

3 Moderate the environmental damage that results from the dramatic price volatility in agricultural commodities. Corn dominates the U.S. biofuel feedstock industry, as well as the industrial livestock feed industry, because no other feedstock could compete against low corn prices. Billions of private, state and federal dollars were invested in using up cheap corn. Now, even though corn prices have risen substantially, the ethanol and livestock industries remain just as corn-dependent because there has not been adequate research on other environmentally beneficial feedstocks. These price fluctuations in agriculture are devastating for farmers, environmentally destructive and even have harmful implications on the diet of consumers. Yet since much of the agribusiness industry thrives on market volatility, policies that traditionally assured well-functioning commodity markets have been dismantled.

As stated earlier in this paper, the most productive agricultural systems are well-diversified cropping systems with long crop rotations and several intermixed crops. Industrial production, on the other hand, tends to prefer one crop in the manufacturing process. This preference for a single crop tends to create enormous markets for particular crops like corn, soybean and palm oil at the expense of other crops that work well in these agricultural systems. This industrial model of agriculture often leaves farmers with little choice but to grow these primary commodities, no matter what happens to commodity prices.

The price variability in agricultural commodity markets is intrinsic to a system that is so dependent on uncontrollable factors such as weather and pest management. But these vagaries have been exacerbated by an agribusiness industry that thrives on price fluctuations, and has contributed to agriculture's continued encroachment on native lands. Extreme price volatility makes it more challenging for new feedstocks to enter an unstable biofuel market. The U.S. Farm Bill used to have a series of tools in place to manage supply and prices of primary farm commodities. The University of Tennessee's Agriculture Policy Analysis Center has documented how an updated supply management would work to stabilize market prices.[166] Maintaining functional markets is critical not only for limiting this encroachment but also for creating diversified agricultural systems on land that is farmed.

4 Take advantage of this rare opportunity to redesign the agricultural and energy sectors. A number of factors—from high gasoline prices to Mideast conflicts to E. coli and Mad Cow outbreaks—have converged to create an overall sense of concern about the direction of agriculture and energy production. This disgruntlement has resulted in explosive growth in local foods, hybrid cars and small wind turbines as consumers seek positive alternatives.

Because biofuel can be produced from a variety of plant materials in nearly every inhabited part of the world, the industry is well-suited for local production, thereby reducing the environmental costs of transportation and allowing local communities to benefit from the sustainable production of biofuel feedstocks. Unfortunately, the environmental and economic benefits of local production and ownership have largely been abandoned in favor of huge production facilities focused on export to other regions and countries.

In the Midwestern U.S. state of Minnesota, policies initiated in the 1980s contributed to development of an ethanol industry that was truly homegrown; state incentives favored ethanol plants that were small and cooperatively owned by farmers. These plants had minimal impact on cropping systems and water supplies. Now, on the other hand, ethanol plants are most likely not locally owned, the production capacity is several times larger, and water availability, air and water contamination, and growth in monocultural corn production has become much more of a concern.

Biofuel presents an interesting dichotomy for those concerned about the environmental performance of agriculture; while the current industry has contributed to harmful, monocultural production practices, a future biofuel industry based on perennial feedstocks provides one of the only large-scale opportunities to diversify agricultural production practices. While many environmental groups have correctly pointed out the looming ecological catastrophe from unchecked growth in palm oil and soy plantations, they often unfairly paint the entire concept of biofuel as inherently unsustainable. Admittedly, creating a truly sustainable biofuel industry is no easy task. This once-in-a-generation opportunity to create a renewable fuel industry that is not in the pocket of the fossil fuel or corporate agribusiness industries will become increasingly difficult as investments are made in the wrong kind of biofuel.

Finally, the environmental risks and opportunities associated with biofuel demonstrate the crucial role that federal and international policy must play in this arena. With a fossil fuel industry that has thrived for decades on outrageous subsidies, tax breaks and military interventions, liquid fuels simply do not have a functional market for “free market” solutions to work. And with the enormous investment from the agribusiness industry on the production and use of a very few energy-intensive crops, agricultural commodity markets are also severely distorted at the expense of environmentally beneficial cropping systems.

Some biofuel policies, most notably the EU’s incentive for biodiesel consumption, were likely crafted with good intentions but have backfired and exacerbated environmental issues in other parts of the world. Reforming this incentive would provide some immediate environmental benefit, but is unlikely to slow the long-term investment in industrially produced biofuel. A biofuel industry that supports an ecologically beneficial agriculture will flounder without public investment in appropriately targeted incentives and research and development. In other words, simply stopping bad policies is not enough; instead, a specific vision, coupled with strategic policy development, is needed to craft a biodiversity-supporting biofuel industry.

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