UNDERSTANDING LAND USE CHANGE AND U.S. ETHANOL EXPANSION

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EXECUTIVE SUMMARY:
UNDERSTANDING LAND USE CHANGE AND U.S. ETHANOL EXPANSION

Understanding changes in land use—such as deforestation, urbanization and agriculture expansion—is important if society is to properly address the challenges of climate change, utilization of natural resources, and energy production and consumption. However, the intensifying debate over potential indirect land use changes resulting from biofuels expansion is nebulous at best. At worst, it is tainted by ideological or political agendas.

Using unsupported assumptions, imprecise economic models, and questionable logic, some have suggested growth in U.S. biofuels like ethanol would indirectly cause significant conversion of forest and grassland to agriculture in the United States and abroad. However, the subject of land use change is much more complicated than some would suggest. Unfortunately, the current state of land use change science is far from conclusive and no consensus exists on how best to analyze the potential indirect land use impacts of expanding biofuels production.

As the U.S. Environmental Protection Agency (EPA), a new administration, and a new Congress attempt to address these exceedingly complex issues, it is critical that the discourse involves multiple disciplines and is informed by clear thinking, reliable data, and transparent analyses.

This report discusses historical agricultural land use and crop utilization trends, explores the role of increased productivity, looks at the contributions of ethanol feed co-products, and examines global agricultural land use projections obtained from Informa Economics. Key findings include:

GROWTH IN ETHANOL PRODUCTION HAS NOT SIGNIFICANTLY DRIVEN LAND USE CHANGES

- Historical trends indicate that increased U.S. ethanol demand has not been a significant driver of global land use change. Increased crop productivity (growing more on the same amount of land) has primarily provided the growth in production necessary to meet heightened demand for crop-based feed, food, and fuel. Moving forward, more pronounced gains in productivity promise to mitigate the need for large amounts of new agricultural lands.

- In 2007/08, just 0.9 percent of world major cropland was needed (on a gross basis) to meet the grain requirements of the U.S. ethanol industry. When the ethanol industry's production of feed co-products are factored in, the net use of global cropland for U.S. ethanol production was 0.6 percent, or an area roughly the size of the state of West Virginia.

- Although U.S. ethanol production is expected to grow in the years ahead, the amount of land needed to support U.S. ethanol demand will continue to be small compared to world agricultural land use. Projections from Informa Economics suggest the land required to produce 15 billion gallons of grain ethanol in the United States in 2015 amounts to less than 1 percent of world cropland.

INCREASED PRODUCTIVITY REDUCES THE AMOUNT OF LAND NEEDED FOR AGRICULTURE

- Heightened demand for crops in the last several decades has been met primarily through increased productivity per unit of land. Higher crop yields relieve pressure on land resources and mitigate the need to expand agricultural land use. Using average global corn yields from 40 years ago (1967), more than 330 million hectares would be required to produce the world corn crop grown on 158 million hectares in 2007. In other words, it would have taken more than twice as much land in 1967 to grow a crop equivalent in size to the 2007 world corn crop.

- Despite increases in the amount of coarse grains used for ethanol, the amount of land dedicated to coarse grains (corn, grain sorghum, barley, oats, rye, and millet) globally has decreased over the past 30 years. Global area for coarse grains has decreased 8 percent since 1980, while world grain ethanol production has increased dramatically. Despite a reduction in land dedicated to coarse grains, annual world coarse grain production has increased nearly 50 percent since 1980.

AGRICULTURAL LAND USE CAN EXPAND WITHOUT JEOPARDIZING FOREST OR OTHER SENSITIVE LANDS

- Recent research has concluded that significant global capacity exists to expand agricultural land use without jeopardizing land used for forest or other sensitive environmental ecosystems. According to experts at Oak Ridge National Laboratory, "Land is available for agricultural expansion without clearing new forest."

- A team of researchers at Stanford University recently found that a significant amount of abandoned agricultural land could potentially be brought back into production. The study found, "the estimated global area of abandoned agriculture is 385-472 million hectares," which is an area equivalent to roughly half of the land area of the continental United States.

- Similarly, a 2002 study by the U.N. Food and Agriculture Organization revealed a tremendous amount of unused land is potentially suitable for agricultural. FAO determined, "There is still potential agricultural land that is as yet unused…" and that an amount of land twice as large as that which is currently farmed "…is to some degree suitable for rainfed (agricultural) production."

MODELS USED TO PREDICT FUTURE AGRICULTURAL LAND USE CHANGES HAVE LIMITATIONS

- There is currently no scientific consensus on what methodologies are most appropriate for analyzing potential land use changes and the carbon emissions that would result from such conversions. In an attempt to forecast the potential global direct and indirect land use changes of expanding U.S. biofuels production in the future, federal and state government agencies are relying on global equilibrium models and other econometric models. These models have numerous limitations and cannot possibly predict with any certainty the extraordinarily complex causal interactions that drive land use change decisions.

- It is virtually impossible for a global equilibrium model or other economic model to predict with any certainty what impact a single event, such as the increase in demand for biofuels in the United States, will have indirectly on global land use patterns. Certainly, tools exist that can assist in empirically quantifying land conversions that have occurred, but these tools do not and cannot positively assign the cause of these land use changes.

ETHANOL FEED CO-PRODUCTS MITIGATE LAND USE CHANGE

- The feed coproducts (commonly known as distillers grains) generated by ethanol biorefineries play an important role in mitigating impacts on land use change. Only a portion of every hectare of grain "dedicated" to ethanol production is actually used for biofuel production. The remaining portion of the hectare is more accurately characterized as producing livestock feed.

- One hectare of corn used for ethanol produces more than 4,000 liters of fuel as well as an amount of feed equivalent to the volume of corn coming from 30 percent of a corn-dedicated hectare and the amount of soybean meal from 50 percent of a soybean-dedicated hectare.

U.S. CORN AND SOYBEAN EXPORTS REMAIN STRONG WHILE BIOFUELS PRODUCTION GROWS

- One of the main arguments waged by those who believe increased biofuels production will lead to significant indirect land use change is the idea that U.S. corn and soybean exports will drop appreciably, inciting cultivation in other countries to account for the lost volume on the world market. Such an export reduction has not occurred. In fact, corn exports reached record levels in 2007/08 and, despite the current global economic slowdown, are projected to be above the 10-year average in 2008/09. Soybean exports also set a new record in 2007/08 and are expected to remain strong in 2008/09.

- Exports of ethanol feed co-products like distillers grains are likely to top 4 million metric tons in 2008 and have increased dramatically in the last three years. These exports are offsetting some demand for corn and soybean exports, an occurrence that is often overlooked.

UNDERSTANDING LAND USE CHANGE AND U.S. ETHANOL EXPANSION

The use of land resources in the United States and around the world is a complex and often contentious issue. While the various uses of global lands have remained relatively stable during the past several decades, the recent surge in world demand for agricultural products and energy has thrust land utilization issues into the environmental, economic and political spotlight.

Historically, a sizable share of the world's land has been used for agriculture. Approximately 11 percent of the world's land surface was considered arable (suitable for farming) in 2005, while about 6.5 percent was engaged in crop production. Another 26 percent of global land area was classified as permanent pasture and meadows.[1] Agricultural land use is affected by many factors, including social, economic, political, and technological forces. Demand for competing land uses (including forest, residential, commercial, industrial, recreational, etc.) greatly affects agricultural land use decisions. The interplay and utility of various land uses is often the source of intense social and political debate.

Recently, the public debate over the potential land use implications of increased demand for biofuels has intensified. Using unsupported assumptions, imprecise economic models, and questionable logic, some have suggested growth in U.S. biofuels like ethanol would indirectly cause significant conversion of forest and grassland to agriculture in the United States and abroad. According to this school of thought, the carbon emissions resulting from indirect conversion of land to biofuel crops would make biofuels worse than gasoline in terms of lifecycle greenhouse gas emissions. Adding urgency to the debate are emerging federal and state regulatory schemes that require the inclusion of emissions resulting from indirect land use change in biofuels greenhouse gas lifecycle assessment.

Understanding land use change and its causes isn't nearly as simple as some would suggest. Experts at the U.S. Department of Energy's Oak Ridge National Laboratory point out global land use change has historically been "largely independent of crop markets." Rather, they say, land use changes are "driven by interactions among cultural, technological, biophysical, political, economic, and demographic forces—not singular events."[2] Further, a recent paper published by the National Academy of Sciences notes that, "…no facet of land change research has been more contested than that of cause." The authors found that the complex factors that drive land use change "…tend to be difficult to connect empirically to land outcomes, typically owing to the number and complexity of the linkages involved."[3]

Historical trends indicate that increased U.S. ethanol demand has not been a significant driver of land use change. Increased crop productivity (growing more on the same amount of land) has primarily provided the growth in production necessary to meet heightened demand. Moving forward, more pronounced gains in productivity promise to mitigate the need for large amounts of new agricultural lands. Although U.S. ethanol production is expected to grow in the years ahead, the amount of land needed to support U.S. ethanol demand will continue to be small compared to total global agricultural land use. Projections from Informa Economics suggest the land required to produce 15 billion gallons of grain ethanol in the United States in 2015 will amount to less than 1 percent of world cropland.

This report discusses historical agricultural land use and crop utilization trends, explores the role of increased productivity, looks at the contributions of ethanol feed co-products, and examines global agricultural land use projections obtained from Informa Economics.

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[1] Food & Agriculture Organization (FAO) of the United Nations. FAOSTAT. http://faostat.fao.org/default.aspx

[2] K. Kline."Global Land Use Issues" Presentation. 5th Annual Forum of the California Biomass Collaborative. May 29, 2008.

[3] B.L. Turner et al. "The emergence of land change science for global environmental change and sustainability." PNAS. December 26, 2007 vol. 104 no. 52: 20666-20671.

HISTORICAL PERSPECTIVE ON GLOBAL AGRICULTURAL LAND USE

The world's total land area is approximately 13.1 billion hectares. Of this amount, 1.4 billion hectares are considered arable, which the U.N. defines as "…land under temporary crops (double-cropped areas are counted only once), temporary meadows for mowing or pasture, land under market and kitchen gardens and land temporarily fallow (less than five years)."[4] The global area required for major crops has averaged about 850 million hectares, or 6.5 percent of the world's land surface, in recent years.[5] Rice, oilseeds, wheat, and coarse grains typically account for approximately 90-95 percent of global cropland.

The various uses of the world's land area have remained relatively stable over the past several decades. For instance, total agricultural land use increased less than 1 percent between 1995 and 2005 (the most recent data available).[6] This includes land used for permanent crops, permanent pasture and meadows, temporary crops, temporary pasture and meadows, and fallow land.

A NOTE ON UNITS OF MEASUREMENT

This report primarily uses metric units of measurement for land and grain volumes. Conversion factors are below:

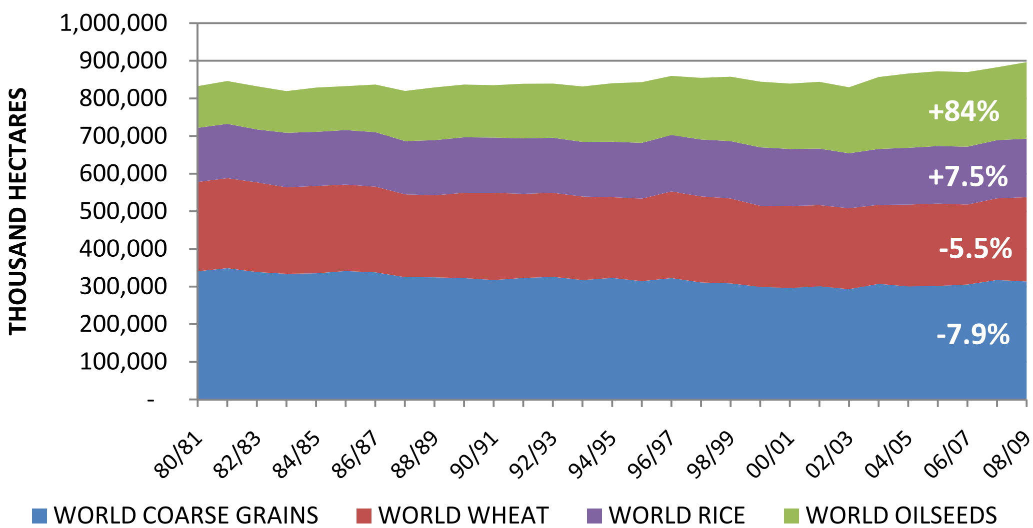
1 Hectare = 2.47 acres, or .004 sq. miles

1 Metric Ton = 2,204 lbs., 39 bushels (corn)

1 Bushel (Corn) = 25 kg., or 56 lbs.

Despite increases in the amount of coarse grains used for ethanol, the amount of land dedicated to coarse grains (corn, grain sorghum, barley, oats, rye, and millet) globally has decreased over the past 30 years (Figure 1). Global area for coarse grains has decreased 8 percent since 1980, while world grain ethanol production has increased dramatically. Global coarse grains area peaked at 349 million hectares in 1981 and is estimated at 313 million hectares in 2008.[7] Global wheat area has experienced a similar decrease since 1980, while land dedicated to rice production has increased slightly. Increases in global cropland in the last 30 years have been driven primarily by expansion of oilseed area in response to higher demand for protein. However, increases in land use for oilseeds have been largely offset by reductions in land use for other agriculture products, such as grains, pasture and forage crops.

FIGURE 1. WORLD CROP AREA: COARSE GRAINS, WHEAT, RICE, OILSEEDS



Source: USDA PSD Online

[4] FAOSTAT. See footnote 1.

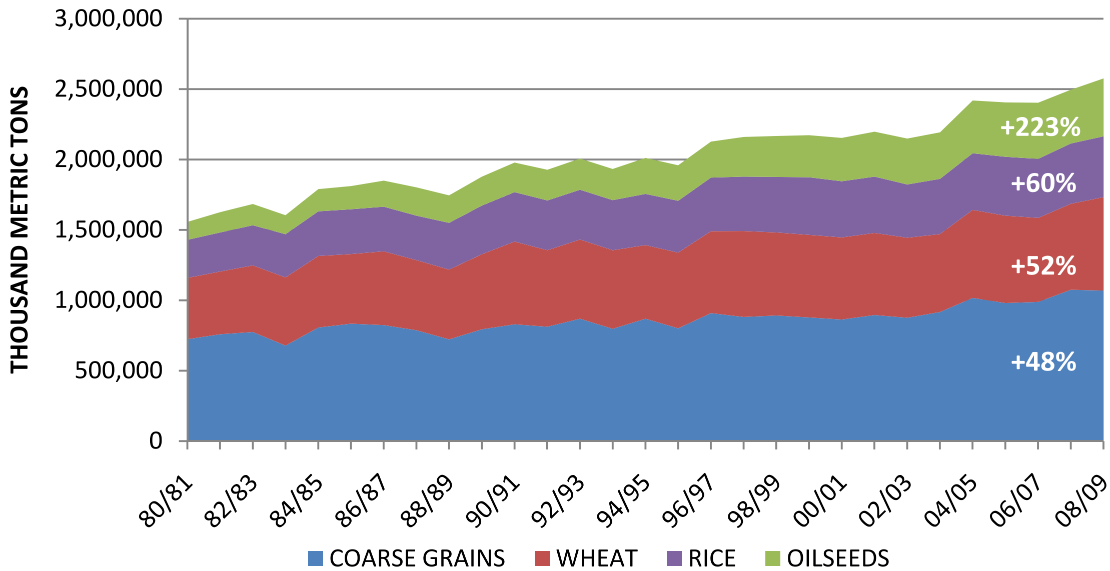
[5] U.S. Department of Agriculture (USDA) Foreign Agriculture Service. Production, Supply, & Distribution (PSD) Database. http://www.fas.usda.gov/psdonline/. Major crops are corn, barley, sorghum, oats, rye, millet, wheat, peanuts, rapeseed, soybeans, sunflower, rice, cotton, and sugar crops.

[6] FAOSTAT. See footnote 1.

[7] PSD. See footnote 5.

Despite a reduction in land dedicated to coarse grains, annual world coarse grain production has increased nearly 50 percent since 1980 (Figure 2).[8] Wheat, rice, and oilseed production has also increased substantially. The vast increases in the production of these agricultural commodities have come about primarily through higher productivity per unit of land, though increased oilseed output has resulted in part from expanded cultivated area, as demonstrated in Figure 1.

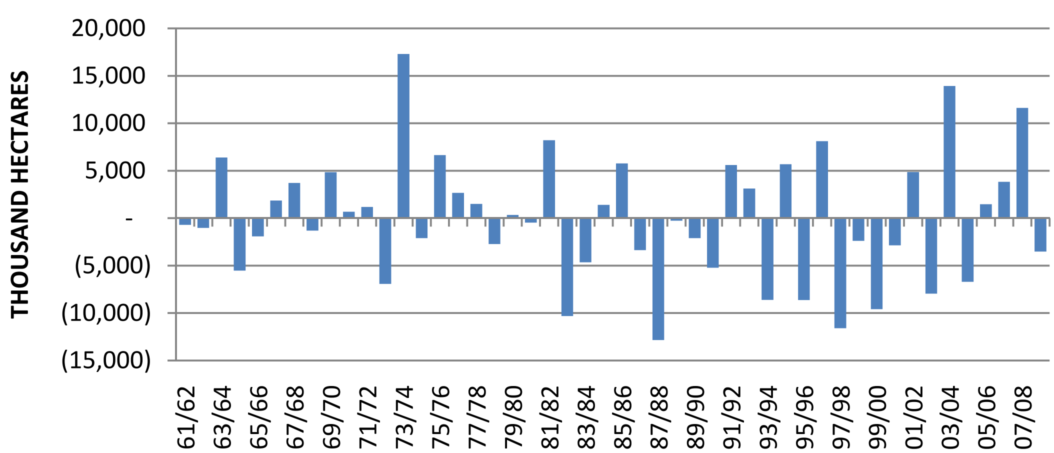
FIGURE 2. WORLD PRODUCTION: COARSE GRAINS, WHEAT, RICE, OILSEEDS



Source: USDA PSD Online; 08-09 is projected

Although the patterns of aggregate global agricultural land use have been relatively stable over time, year to year fluctuations in the crop mix are common. For example, global coarse grains area has deviated widely from year to year in the past 50 years in response to numerous market factors. Since 1960, the average year-to-year fluctuation in coarse grains area has been 5.1 million hectares per year, an area equivalent to 15 percent of the 2008 U.S. corn area. Since 1960, year-to-year losses in coarse grains area have outpaced gains in both frequency and magnitude.

FIGURE 3. YEAR-OVER-YEAR CHANGE IN WORLD COARSE GRAIN AREA



Source: USDA PSD Online

[8] PSD. See footnote 5.

Recent research has concluded that significant global capacity exists to expand agricultural land use without jeopardizing land used for forest or other sensitive environmental ecosystems. According to experts at Oak Ridge National Laboratory, "Land is available for agricultural expansion without clearing new forest."[9] A team of researchers at Stanford University recently found that a significant amount of abandoned agricultural land could potentially be brought back into production. The study found, "the estimated global area of abandoned agriculture is 385-472 million hectares,"[10] which is an area equivalent to roughly half of the land area of the continental United States.

Similarly, a 2002 study by the U.N. Food and Agriculture Organization (FAO) revealed that a tremendous amount of unused land is potentially suitable for agricultural production. According to the report:

> There is still potential agricultural land that is as yet unused. At present some 1.5 billion ha of land is used for arable and permanent crops, around 11 percent of the world's surface area. A new assessment by FAO and the International Institute for Applied Systems Analysis (IIASA) of soils, terrains and climates compared with the needs of and for major crops suggests that a further 2.8 billion ha are to some degree suitable for rainfed production. This is almost twice as much as is currently farmed.[11]

The FAO report also found that, "Fears of an imminent crunch between population growth and land availability are unwarranted…" and that "…there is little evidence to suggest that global land scarcities lie ahead."

Forested area in many major crop producing regions has remained unchanged or actually increased during the last 10-year period for which data is available (1995-2005). Increases in forested area were recorded in the United States, India, and China, while forested areas in Europe and Canada were unchanged.[12] Deforestation of varying degrees did occur in several regions, including South America and Southeast Asia. However, it is interesting to note that the amount of forest land cleared in the Amazon dropped from a peak of 10,000 square miles in 2004 to 4,400 square miles in 2007, the third-straight year of decline and the lowest level since 1991, according to government figures.[13] As noted earlier, determining the causes of land use conversion, including deforestation, is a complex and uncertain task. According to Helmut Geist, one of the world's foremost experts on deforestation, "One of the primary causes of global environmental change is tropical deforestation, but the question of what factors drive deforestation remains largely unanswered."[14]

HISTORICAL PERSPECTIVE ON U.S. AGRICULTURAL LAND USE

The total land area in the United States is approximately 3.5 million square miles, or about 915 million hectares. The various uses of land in the United States have been relatively constant over the last 60 years, though agricultural land has decreased slightly, while urban and special land uses have increased. Every five years, USDA releases data on the major uses of land in the United States.[15] In 2002 (the most

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[9] Kline. See footnote 2.

[10] J.E. Campbell et al. "The Global Potential of Bioenergy on Abandoned Agriculture Lands." Environ. Sci. Technol. *42* (15), 5791–5794, 2008.

[11] FAO. "World Agriculture Towards 2015/2030: Summary Report." Rome, 2002.

[12] FAOSTAT. See footnote 1.

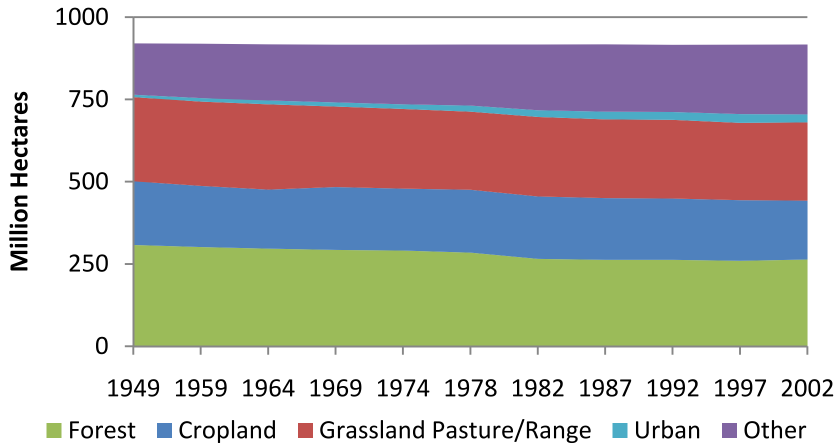
[13] J. Partlow. "Finding Balance in Amazon Tug of War." Washington Post. Nov. 6, 2008; Page A3.

[14] H. J. Geist, E. F. Lambin. "Proximate causes and underlying driving forces of tropical deforestation: Tropical forests are disappearing as the result of many pressures, both local and regional, acting in various combinations in different geographical locations." BioScience. February 1, 2002.

[15] Lubowski et al. USDA "Major Uses of Land in the United States, 2002." EIB-14. May 2006.

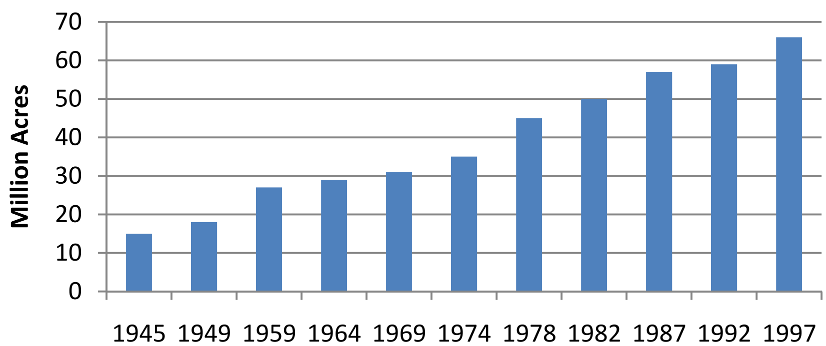
recent year for which data is available), U.S. cropland totaled 179 million hectares. This total includes land used for crops, idle cropland, and cropland pasture. The 2002 total is the lowest since USDA began recording these statistics in 1945 and is the first time cropland use registered under 182 million hectares since 1964. The area used for crops alone was 138 million hectares in 2002 (Figure 6). Cropland used for crops in 2006 declined further to 134 million hectares. It is also notable that the share of cropland constituted by idled cropland has increased since USDA began recording land use data in 1949.

FIGURE 4. MAJOR USES OF U.S. LAND



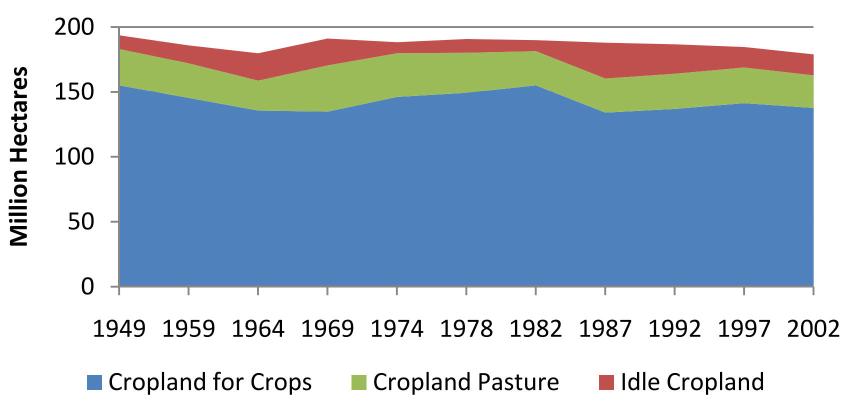
Source: USDA "Major Uses of Land in the United States"

FIGURE 5. U.S. URBAN LAND USE



Source: USDA "Major Uses of Land in the United States"

FIGURE 6. USES OF U.S. CROPLAND



Source: USDA "Major Uses of Land in the United States"

While the amount of urban land in the United States is considerably less than cropland, land used for urban areas increased 340 percent from 1945 to 1997 (Figure 5). Further, more and more agricultural land is being converted to rural residencies. Rural residential land was estimated at 38 million hectares in 2002, up 13 percent from 1997, which was the first year USDA measured rural residential land use. Special use areas (roads, railroads, airports, defense and industrial areas, wildlife areas, state and national parks) increased 249 percent from 34 million hectares in 1945 to 120 million hectares in 2002.

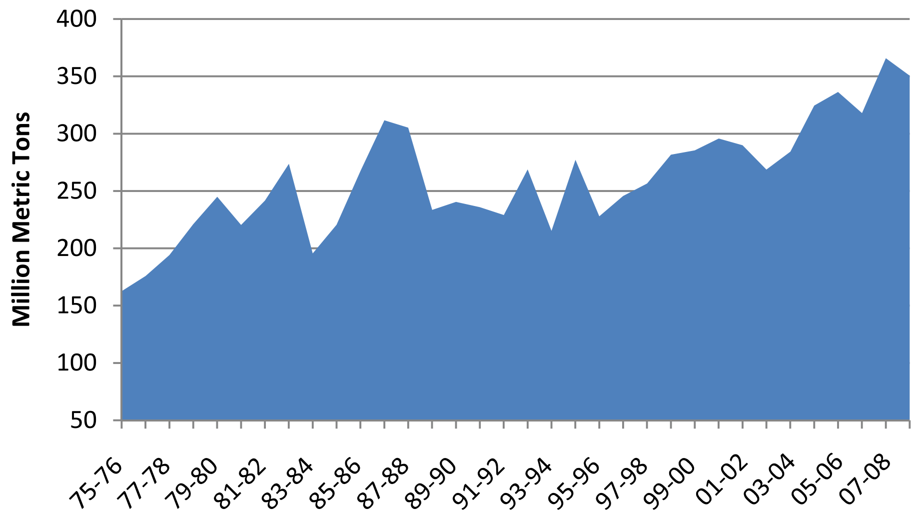
USDA reports that "urban land area has increased at about twice the rate of population growth."[16] Land dedicated to urban use has more than doubled in the states that make up the Corn Belt since 1960. On average, nearly 1 million hectares of farmland per year were converted to urban uses between 1992 and 2001. Urban, rural residential, and special use lands accounted for about 20 percent of total U.S. land use in 2002, slightly more than cropland use.

[16] Lubowski et al. See footnote 14.

UNDERSTANDING THE IMPACT OF U.S. ETHANOL PRODUCTION ON GRAIN USE

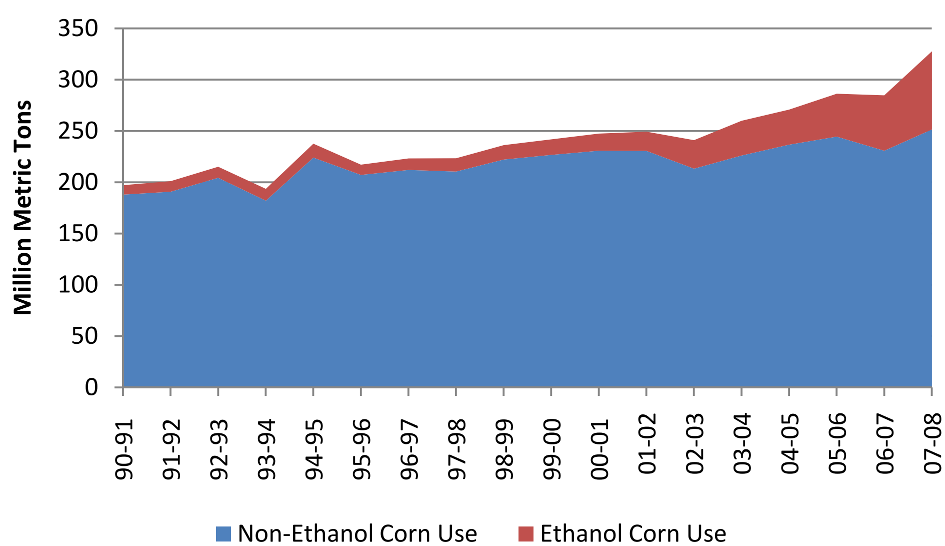
To understand the land use implications associated with U.S. ethanol production, a proper appreciation of the industry's demand for grain is first necessary. The amount of corn processed into ethanol in the United States has grown eight-fold from approximately 9.3 million metric tons in 1990/91 to 76 million metric tons in 2007/08.[17] Corn fed to livestock and poultry has also increased during this period. Corn exports have fluctuated during this period, but generally trended up slightly. To accommodate increased demand for livestock feed, exports, and ethanol use, annual corn production grew from 200.7 million metric tons in 1990/91 to 333 million metric tons in 2007/08. Contrary to statements that ethanol has "diverted" corn from other markets, it is clear that the corn available for uses other than ethanol has continued to grow or remain stable in recent years.

FIGURE 7. U.S. CORN SUPPLY (Production + Stocks)



Source: USDA

FIGURE 8. U.S. CORN USE

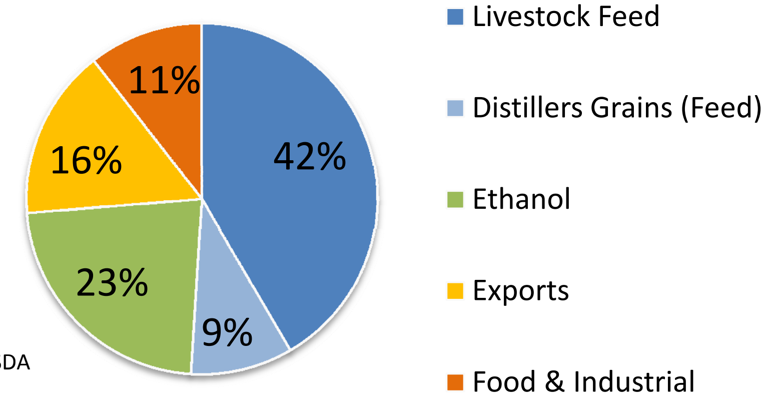


Source: USDA

[17] PSD. See footnote 5.

USDA projects the 2008 corn crop will be 305 million metric tons in size, the second largest ever.[18] On a gross basis, 102 million metric tons are projected to be used for ethanol production in 2008/09. However, since one-third of every ton of corn processed into ethanol returns to the feed market (this process is explained later), net usage of corn for ethanol would be closer to 74 million metric tons. This represents 23 percent of total projected U.S. corn use, which is estimated at 322 million metric tons.

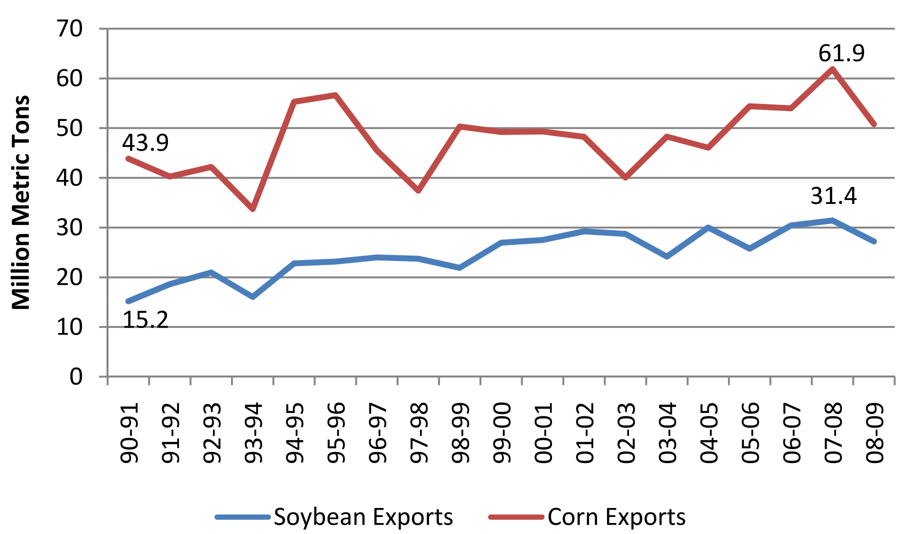
FIGURE 9. PROJECTED 2008/09 U.S. CORN USE



Source: USDA

It is also noteworthy that U.S. exports of corn and soybeans remain strong despite increased domestic use of these crops. One of the main arguments waged by those who believe increased biofuels production will lead to significant indirect land use change is the idea that U.S. exports will drop appreciably, inciting cultivation in other countries to account for the lost volume on the world market. Such an export reduction has not occurred. In fact, corn exports reached record levels in 2007/08 and, despite the current global economic slowdown, are projected to be above the 10-year average in 2008/09. Soybean exports also set a new record in 2007/08 and are expected to remain strong in 2008/09. Exports of ethanol feed co-products like distillers grains have increased dramatically in the last three years and are offsetting some demand for corn and soybean exports.

FIGURE 10. U.S. CORN & SOYBEAN EXPORTS



Source: USDA; 08-09 is projected

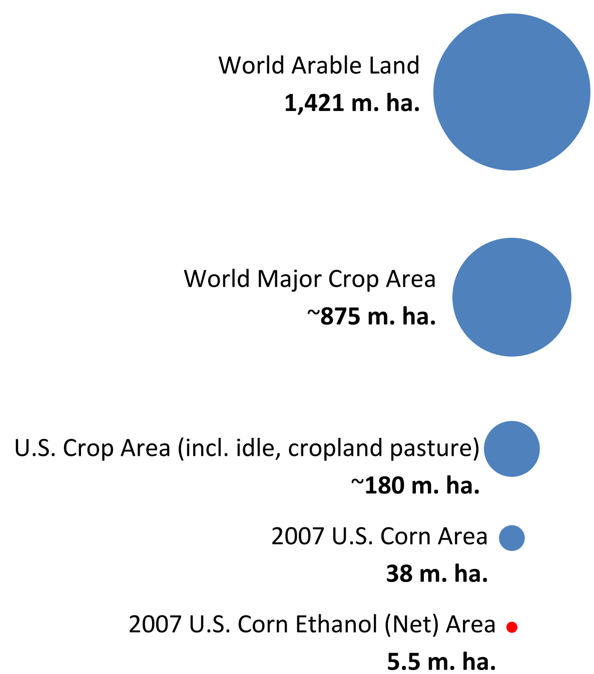
[18] USDA Crop Production Report. October 10, 2008 (revised October 28, 2008)

On a global scale, U.S. ethanol production is expected to consume approximately 6 percent of the 2008/09 world coarse grains supply (corn, grain sorghum, barley, oats, rye, and millet) on a net basis. When all grains are considered (coarse grains, rice and wheat), the U.S. ethanol industry is projected to consume 2.9 percent of the world's grain supply in 2008/09.

Because grains used for ethanol represent a small share of total world grain use, it seems logical that the U.S. ethanol industry is not a significant driver of land use change decisions. In 2007/08, just 0.9 percent of world major cropland was needed (on a gross basis) to meet the grain requirements of the U.S. ethanol industry. When the production of feed co-products are factored in, the net use of global cropland for U.S. ethanol production was 0.6 percent, or an area roughly the size of the state of West Virginia.

Approximately 4.5 percent of U.S. cropland (including idle land and cropland pasture) was used for ethanol in 2007/08. When the production of feed co-products is considered, the net use of U.S. major cropland for ethanol was 3.1 percent. The land use requirement of U.S. ethanol in 2007/08 is put into context in Figure 12.

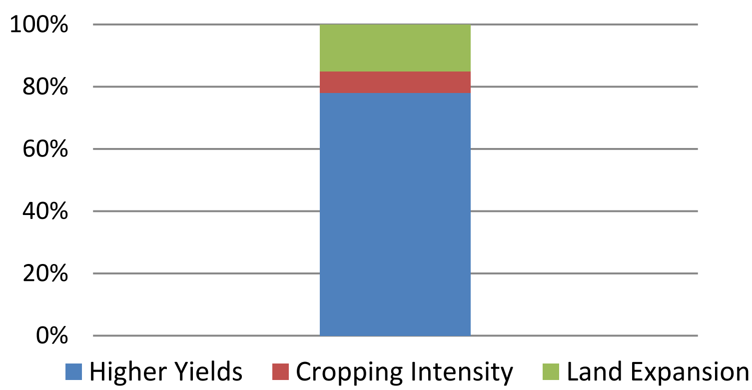
FIGURE 12. U.S. ETHANOL LAND USE IN CONTEXT



THE IMPACT OF HIGHER PRODUCTIVITY ON AGRICULTURAL LAND USE

Heightened demand for crops in the last several decades has been met primarily through increased productivity per unit of land. Higher crop yields relieve pressure on land resources and mitigate the need to expand agricultural land use. According to FAO, yield increases were responsible for about 78 percent of global crop production growth between 1961 and 1999, with about 7 percent from more intense agricultural practices, and just 15 percent coming from agricultural area expansion.[19] The role of higher yields in increased U.S. crop production is even more pronounced, as U.S. agricultural land use has actually decreased in the last several decades. Because global average yield growth for most major crops has occurred more rapidly since 1999, it seems reasonable that the percentage of

FIGURE 13. SOURCES OF GROWTH IN WORLD CROP PRODUCTION, 1961-1999



Source: FAO

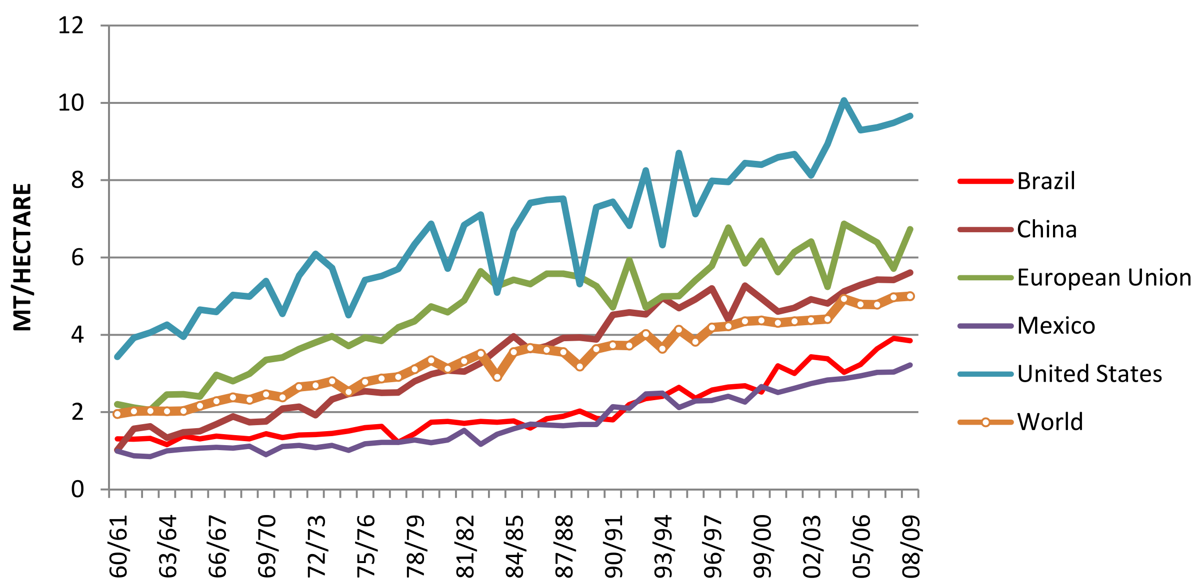
[19] FAO. See footnote 11.

increased world production due to yield increases would be even higher today.

Average corn yields have advanced rapidly in the United States. Improved management practices and seed technology advances are responsible for the dramatic increases in corn yields over the past four decades. During the decade of the 1970s, corn yields averaged 5.7 metric tons per hectare. The average yield in the 1980s was 6.7 metric tons per hectare, while the average yield in the 1990s was 7.8 metric tons per hectare. From 2000 to 2007, yields have averaged 9.1 metric tons per hectare. As demonstrated by the reduction in deviations from the long-term U.S. trend, improved corn genetics have also helped mitigate yield shortages due to weather shocks or other stresses.

Though growth has occurred more slowly in other major corn producing nations and blocs, world average corn yields have more than doubled since 1960. Average yields in the European Union and China have essentially tripled since 1960, while growth has occurred more slowly in Brazil and Mexico. Average yields for the world's top five corn producing nations and blocs is shown in Figure 14.

FIGURE 14. CORN YIELD GROWTH
TOP 5 CORN PRODUCERS & WORLD AVERAGE



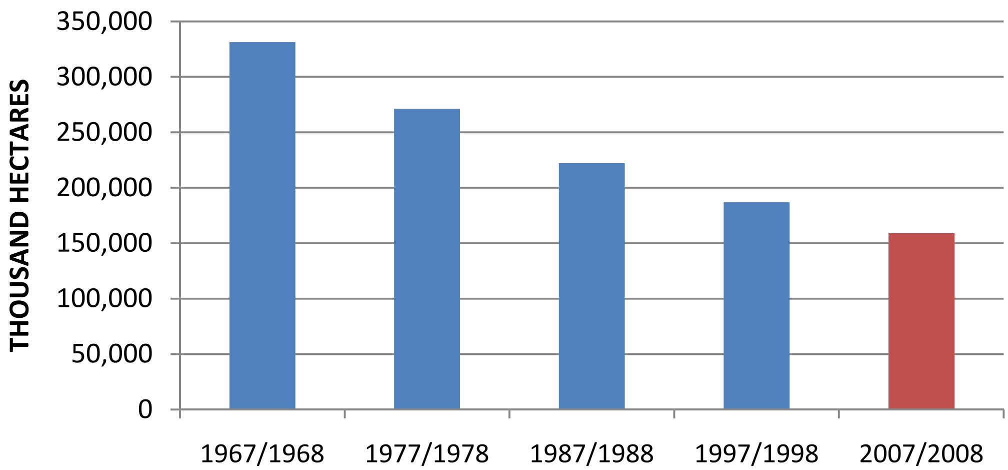
Source: USDA PSD Online; 08-09 is projected

The U.S. average corn yield in 2007 was nearly twice the world average (9.5 versus 5 metric tons per hectare). If the 2007 world average corn yield had been even 75 percent of the U.S. average, world corn production would have been 1.13 billion metric tons rather than the actual 789.2 million metric tons. The theoretical difference of 340.8 million metric tons is four times larger than the amount of corn processed into biofuels globally in 2007/08.

Certainly, a number of important factors influence the ability of producers around the world to increase crop yields. Some of those factors are beyond the control of farmers, while others are manageable. Yield limiting factors such as weather stress and certain soil characteristics are largely uncontrollable. However, farmers have some ability to influence factors such as pest pressure, soil drainage and soil fertility. Farmers have the greatest ability to control certain management decisions, such as hybrid selection, identification of optimal planting and harvest dates, and seeding rates.

Increased productivity has a tremendous impact on agricultural land use. Using average global corn yields from 40 years ago (1967), more than 330 million hectares would be required to produce the world corn crop grown on 158 million hectares in 2007. In other words, it would have taken more than twice as much land in 1967 to grow a corn crop equivalent in size to the 2007 world corn crop.

FIGURE 15. AREA REQUIRED TO PRODUCE 2007 WORLD CORN CROP AT HISTORICAL YIELD RATES



Higher commodity crop prices on the global market serve as an incentive for producers around the world to improve their cropping practices and adopt new, more efficient technologies. Additionally, higher prices and heightened demand for agricultural products serves as an incentive for governments and private industry to increase investments in agricultural technology and education.

Because of new and emerging plant breeding practices and technologies, the prospects for accelerated yield increases appear very promising. Information from seed companies such as Monsanto and DuPont suggest the impact of marker-assisted breeding and molecular breeding practices are likely to accelerate corn yield improvements even more quickly. Monsanto suggests U.S. average corn yields could reach approximately 16.5 metric tons per hectare by 2022 and 19 metric tons per hectare by 2030.[20]

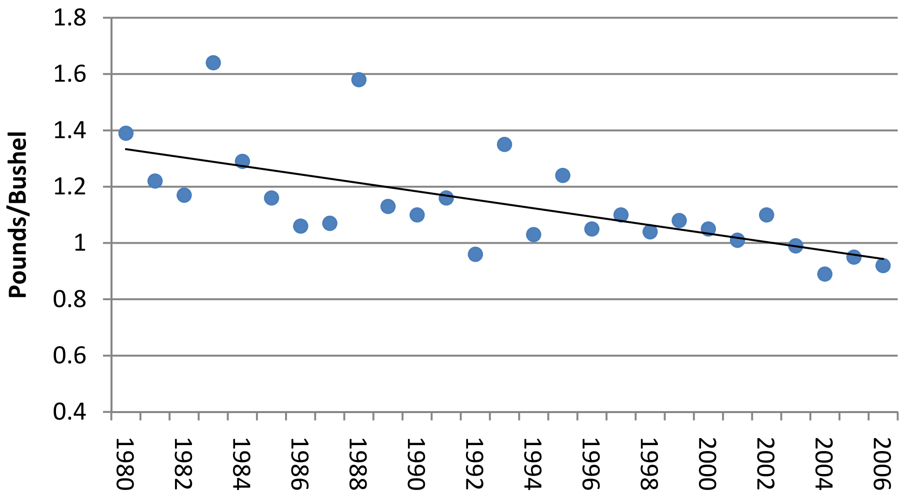
INCREASED GRAIN DEMAND AND ENVIRONMENTAL SUSTAINABILITY

It is often assumed that higher crop yields are achieved at the expense of environmental sustainability. However, analysis of fertilizer application data reveals that farmers are increasingly efficient in their use of fertilizers. Through best management practices and new technologies, farmers have significantly reduced the amount of fertilizer required to produce a bushel of corn. Three macronutrients—nitrogen, phosphorous, and potassium—are primarily used in the fertilization of corn. Data from USDA shows that less of each of these nutrients is necessary to produce a bushel of corn today than in years past.[21] As an example, the reduced amount of nitrogen required to produce one bushel of corn is shown in Figure 16.

[20] Monsanto. "Reducing the Environmental Impact of Agriculture." http://www.monsanto.com/responsibility/our_pledge/healthier_environment/raising_yield_peracre.asp

[21] USDA Agricultural Chemical Usage Report.

FIGURE 16. COMMERCIAL NITROGEN APPLIED PER BUSHEL OF CORN PRODUCED, U.S., 1980-2006



Source: USDA Agricultural Chemical Usage Reports

Data also suggests that nutrient leaching from agricultural lands, the process by which residual nutrients are dissolved and carried away by water, is on the decline. Fertilizer runoff from Midwestern fields has long been believed to be a source of hypoxia in the Gulf of Mexico. Hypoxia is the depletion of dissolved oxygen in water, a condition resulting from an overabundance of nutrients that stimulate the growth of algae, which in turn die and require large amounts of oxygen as the algae decompose.

According to recent data from the Environmental Protection Agency, average annual nitrogen discharges from the Mississippi and Atchafalaya River Basins to the Gulf of Mexico decreased 21 percent from the reference period of 1980-1996 to the period of 2001-2005.[22] According to the International Plant Nutrition Institute (IPNI), this data provides "…reason to believe that declines in discharge of nitrogen and phosphorous to the Gulf of Mexico are proceeding through voluntary actions by farmers, their advisors, and their suppliers."[23] The IPNI report further found that "…farmers and practitioners are increasingly implementing fertilizer best management practices."

Further, an increasing number of farmers are practicing conservation tillage practices, which reduce soil disruption and erosion. According to the Conservation Technology Information Council, nearly 55 percent of reporting cropland was engaged in some form of conservation tillage, up from 34 percent in 1990.[24] Conservation tillage practices also reduce the amount of fossil fuel energy required to conduct field preparation. Perhaps the most important benefit of conservation tillage is that it reduces the release of carbon stored in the soil.

THE ROLE OF FEED COPRODUCTS IN MITIGATING THE LAND USE REQUIREMENTS OF U.S. ETHANOL

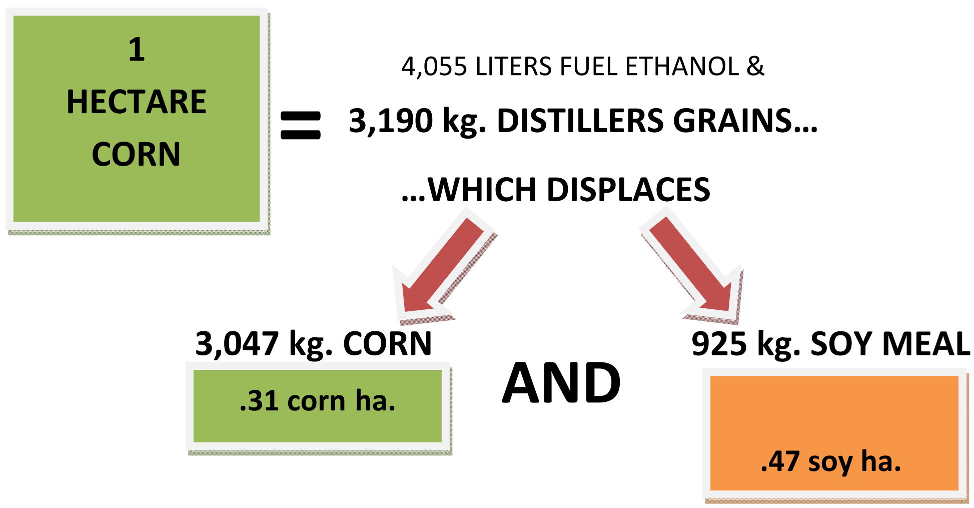
The feed coproducts generated by ethanol biorefineries play an important role in mitigating impacts on land use change. As noted earlier, each metric ton of corn that is processed by a dry mill ethanol biorefinery results in not only 420 liters of renewable fuel, but also 318 kg of residual feed grains (commonly referred to as distillers grains).

[22] EPA SAB. 2008. "Hypoxia in the northern Gulf of Mexico: an update by the EPA Science Advisory Board."
[23] C.S. Synder. "Nutrients and Hypoxia in the Gulf of Mexico—An Update on Progress, 2008." Better Crops. Vol. 92 (2008, No. 2).
[24] Conservation Technology Information Council. National Crop Residue Management Survey. 2006

Ethanol production uses only the starch portion of the corn kernel, while the remaining protein, fat, and other nutrients, vitamins and minerals are passed through the process into the distillers grains. Accordingly, only a portion of every hectare of grain "dedicated" to ethanol production is actually used for biofuel production. The remaining portion of the hectare is more accurately characterized as producing livestock feed. The protein and fat content of distillers grains is typically three times higher than the protein and fat content of the original corn, making distillers grains a nutrient-dense and valuable feed product.

Recent research at Argonne National Laboratory supports the notion that feed co-products provide a significant land use "credit." According to researchers at Argonne, 1 kg of distillers grains replaces .955 kg of corn and .291 kg of soybean meal in animal feed rations.[25] Thus, one hectare of corn used for ethanol produces more than 4,000 liters of fuel as well as an amount of feed equivalent to the volume of corn coming from about 30 percent of a corn-dedicated hectare and the amount of soybean meal coming from approximately 50 percent of a soybean-dedicated hectare (Figure 17).

FIGURE 17. LAND USE "CREDITS" FROM DISTILLERS GRAINS



ASSUMPTIONS:
Corn Yield = 154 bu./acre (USDA)
Soybean Yield = 39.5 bu./acre (USDA)
1 bu. soybeans = 20 kg soybean meal (USB)
1 kg DG replaces .96 kg corn and .29 kg soy meal (Argonne Natl. Lab)

PREDICTING FUTURE AGRICULTURAL LAND USE CHANGES

In an attempt to forecast the potential global direct and indirect land use changes of expanding U.S. biofuels production in the future, federal and state government agencies are relying on global equilibrium models and other econometric models. These models have numerous limitations and cannot possibly predict with any certainty the extraordinarily complex causal interactions that drive land use change decisions. As stated recently by a scientist from Oak Ridge National Laboratory, land use change is "driven by interactions among cultural, technological, biophysical, political, economic, and demographic forces—not singular events."[26]

[25] Arora et al. Argonne National Laboratory. "Update of Distilers Grains Displacement Ratios for Corn Ethanol Life-Cycle Analysis." September 2008.
[26] Kline. See footnote 2.

Further, there is no scientific consensus on what methodologies are most appropriate for analyzing potential land use changes and the carbon emissions that would result from such conversions. A recent report issued by Harvard University's Center for International Development concluded, "There is presently a lack of consistent methodologies for carbon emissions accounting that would allow society to precisely assess the impact of different agricultural and forestry practices."[27]

Additionally, the Roundtable for Sustainable Biofuels, a group comprised of NGOs, government agencies, academia, and industry, recently concluded, "Deforestation and loss of biodiversity had already reached unsustainable levels before the recent surges in biofuel demand, and it is difficult to link direct causality of land use changes in one region or country to biofuel production in another."[28] Further, the Roundtable found, "…there is to date no scientific consensus as to how to quantify the amount of land use change…attributable to biofuel production."

Similarly, a June 2008 letter to the California Air Resources Board signed by nearly 30 prominent biomass and biofuels researchers stated, "…we are convinced that there simply is not enough hard empirical data to base any sound policy regulation in regards to the indirect impacts of renewable biofuels production."[29] The letter concluded that, "Given that our only options for sustainably powering transportation with a significant reduction in transportation related greenhouse gas emissions are biofuels, batteries, and hydrogen, a presumptive policy implementation based on the current understanding of indirect impacts will have a significant chance to hurt real progress on reducing carbon emissions and decreasing our reliance on fossil fuels."

In order to have a more informed and more balanced discourse on potential indirect land use changes, stakeholders need more than results from "black box" models that were fed debatable assumptions. To provide an alternative to the results of land use modeling efforts undertaken by federal and state agencies, the Renewable Fuels Association contracted with Informa Economics, a leading agricultural economic consulting firm, to obtain a market-based perspective on future agricultural land use patterns. Informa Economics' projections on global agricultural land use in the 2015/16 crop year are based not on modeling results, but rather on years of experience in analyzing global agricultural markets and a set of clear social, economic, policy, and technological assumptions.

Informa expects the global area for major crops will increase approximately 30 million hectares between 2007/08 and 2015/16. This would equate to major crop area growth of 3.4 percent in the eight-year period. However, very little of this expansion can be traced to the increase in U.S. ethanol production from 2007/08 levels (approximately 8.5 billion gallons) to 15 billion gallons per year (BGY) in 2015/16. In fact, the incremental requirement of expanding ethanol production from current levels to 15 BGY is just 2.3 million hectares on a net basis between 2007/08 and 2015/16. This estimate is based on Informa's projected average future crop yields and the assumption that distillers grains reduce ethanol land use requirements by one-third; as discussed earlier, distillers grains may reduce the land impact by approximately 80 percent, meaning the land use impact of expanding biofuels production to 15 BGY

[27] Sustainability Science Program, Harvard University Kennedy School of Government; Italian Ministry of Environment, Land & Sea; Venice International University. "Biofuels and Sustainable Development: An Executive Session on Grand Challenges of the Sustainability Transition." Venice, May 2008.

[28] Roundtable on Sustainable Biofuels. "Global principles and criteria for sustainable biofuels production." Version Zero. August 13, 2008.

[29] Letter to Mary D. Nichols, chairman, California Air Resources Board. June 24, 2008. Available at: http://www.arb.ca.gov/lists/lcfs-lifecycle-ws/30-luc_change_letter_from_livermore_et_al.pdf

could be far less than 2.3 million hectares. Further, if crop yields advanced more rapidly than projected by Informa, it seems likely there would be virtually no incremental land use impact from expanding U.S. ethanol production.

Additionally, because the costs of converting wooded lands are high, it seems likely that incremental land needs for grain ethanol production would come from cropland that previously produced crops for which global demand has diminished (e.g. cotton in the Southeast United States), or possibly from ground previously enrolled in the Conservation Reserve Program (nearly 80 percent of the land enrolled in the CRP program is classified by USDA as “grass plantings,” while tree plantings constitute only 6 percent of CRP land). In this scenario, and assuming corn and soybean exports remain relatively constant, expansion of U.S. ethanol production would have no discernable indirect international impact.

According to Informa Economics projections, U.S. grain ethanol expansion would be responsible for just 7.7 percent of total global major crop land expansion from 2007/08 to 2015/16. The remaining 92.3 percent of crop land expansion will be in response to new demands for food and feed and, to a lesser extent, other nations’ demands for biofuels. Informa predicts more than 70 percent of agricultural land expansion between 2007/08 and 2015/16 will be accounted for by expanded oilseed production.

FIGURE 18. SUMMARY OF INFORMA ECONOMICS PROJECTIONS TO 2015/16		**2007/08 Actual**	**2015/16 Projected**	**Change**
World Total Major Crop Area (Corn, Wheat, Oilseed, Other)	*thousand ha.*	873,200	903,200	30,000
World Corn Area	*thousand ha.*	157,600	162,900	5,300
World Wheat Area	*thousand ha.*	216,800	219,700	2,900
World Oilseeds Area	*thousand ha.*	198,200	220,300	22,100
World All Other Major Crop Area	*thousand ha.*	300,600	300,300	-300
U.S. Grain Ethanol Production	*m. gallons*	8,475	15,000	6,525
U.S. Corn Use for Ethanol (Gross)	*m. metric tons*	76.2	130.9	54.7
Land Required for U.S. Grain Ethanol Production (Gross)	*thousand ha.*	8,037	11,417	3,380
Distillers Grains Production	*m. metric tons*	24	41	17
Land Required for U.S. Grain Ethanol Production (Net)	*thousand ha.*	**5,525**	**7,849**	**2,324**
% **of World Major Crop Area Reqd. for U.S. Ethanol**	*%*	**0.63%**	**0.87%**	**0.24%**

***Note**: Informa’s projections assume distillers grains production reduces the land use impact of corn ethanol by one-third. As discussed elsewhere in this paper, it is likely that the land use “credit” from distillers grains is much higher, which would significantly reduce the net land area required for ethanol.*

CONCLUSION

Understanding the factors that cause land use changes in the United States and around the world is no simple task. A number of inter-related social, political, economic, and other factors influence land use decisions—not singular events. It is virtually impossible for a global equilibrium model or other economic model to predict with any certainty what impact a single event, such as the increase in demand for biofuels in the United States, will have indirectly on global land use patterns. Certainly, tools exist that can assist in empirically quantifying land conversions that have occurred, but these tools do not and cannot positively assign the cause of these land use changes.

Though the subject of land use change is complex and multifaceted, one thing is clear: the amount of land required by the expansion of the U.S. grain ethanol industry to 15 billion gallons is immaterial in the context of world agricultural land use and is likely to be mitigated by gains in agricultural productivity and the contribution of feed co-products.