Agriculture as a Source of Energy: Is it Sustainable?

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Agricultural products have traditionally been used for food, feed and fibre. In the last decade, however, commodities like corn, soybeans, canola and sugarcane are increasingly being diverted into the production of energy for transportation, electricity and heating. The shift of agricultural products to fuel production is being felt in global food and feed markets.

Countries are turning to biofuels for a variety of reasons. Energy security issues, climate change concerns, and a desire for economic activity in rural economies all play a role. Governments have encouraged this shift with domestic mandates for the use of biofuels, tax incentives, import restrictions, as well as production and investment subsidies. This article examines agriculture's role as a source of energy, the impact of biofuel production on land use, and the sustainability of this activity.

Biofuels and Energy Supply and Demand

Global energy demands are growing. In the next 25 years, total energy demands are expected to increase by 25% (1.6 per cent per year).[13] Part of this energy increase is due to a population growth from 6 to 9 billion over the next forty years.[25] Moreover, as countries like China and India increase their prosperity, and enter into their energy-intensive phases of development, their energy needs will grow.[4] For example, while world energy consumption increased by 16% over the period 2000-2005, India and China increased their consumption by 20% and 79%, respectively.

In contrast to the strong growth in energy demand, the global growth rate in supplies of 'easy energy', like oil, is forecasted to decline.[8,11] In fact, Hubbert's Peak (the point at which annual conventional oil production peaks) is expected to occur sometime between now and 2040 (oil production in the United States peaked around 1970).[3,8] Therefore, the expectation is that the price of oil, and oil-derived energy, will increase as demand outpaces supply. This supply-demand imbalance will accelerate the need for alternative energy sources.

One alternative source of energy is biofuels. Since the early 1970s, the United States and Brazil have invested heavily in ethanol production. While it took all of the 1980s for the United States to build its first billion gallons of ethanol capacity, and all of the 1990s to bring the next billion online, the third billion was developed in just two years. U.S. production has since grown from approximately three billion gallons in 2003 to nearly six billion gallons in 2007. Annual production is expected to reach 14 billion gallons by 2010.[19,24] Brazil is doing the same with sugarcane-based ethanol. Germany and France are investing in a renewable alternative for diesel. In 2007, they were the world leaders in the production of biodiesel, produced mainly from rapeseed oil.

High energy costs and concerns about energy security are creating pressure for the land to produce biomass that can be converted to fuel. Photo credit: Guy Lafond

Biofuels In Brief

Biofuels by definition are fuels made from biological materials. There are solid biofuels and liquid biofuels. Solid biofuels are used as substitutes for energy sources such as coal and electricity. Materials such as hybrid poplar, willow, or wood waste are considered good sources of biomass for solid biofuel production. Typically, energy from solid biofuels is obtained either by direct burning or through gasification. Gasification involves mixing the raw material with oxygen at high temperatures to create a fuel (often referred to as syngas) that can then be burned.

Liquid biofuels, including biodiesel and ethanol, are substitutes for gasoline and diesel. Biodiesel is made from the conversion of plant oils, or animal fats, into diesel fuel through the process of transesterification. Biodiesel can either be used in a blend with diesel, or by itself. The primary oil sources for biodiesel are rapeseed (Europe), soybean and sunflower (United States), and canola (Canada). While biodiesel production is increasing, it currently accounts for less than one per cent of global diesel use.[5]

There are at least three methods of producing ethanol. The first one consists of converting starches from corn, wheat, and barley grain into sugar, and then fermenting the sugars into ethanol. The second method consists of using cellulosic technology to convert plant lignocellulosic fibres into sugars using special enzymes, and then fermenting the sugars into ethanol. This second method can utilize feedstocks such as wood chips, switch grass, straw, and other woody materials, like hybrid poplar and willow. The third method involves the use of cane sugar. The stalks are crushed and squeezed and the resulting sugar solution is then fermented directly, thus avoiding the starch conversion step required in the first two methods. The remaining plant material is then burned to supply some or all of the energy requirements for the ethanol production.

Corn is one of the least efficient ethanol feedstocks, second only to wheat and barley (Table 1). The inefficiency of grain-based ethanol stems from the fact that grain yields are relatively small compared to the other feed stocks. Sugarcane, the most energy efficient feedstock, has much higher yields of sugar, and produces 56% fewer greenhouse gas (GHG) emissions than gasoline. Cellulosic feedstocks, such as switchgrass, or miscanthus, produce nearly double the amount of biomass as sugarcane on a unit area basis, and have the potential to reduce GHG emissions by 90% over gasoline.

In 2005, ethanol consumption comprised approximately 1.5% of total world gasoline use. Although renewable fuel use will increase by an estimated 6.6% per year, from 2004 to 2030,[13] it will remain relatively insignificant in terms of total energy use (less than 1%). In the United States, where ethanol production has grown very rapidly, ethanol production (by volume) is only expected to represent about 8% of annual gasoline use in the United States by 2016.[27]

Currently, biofuel production is highly subsidized. Biofuels can become economically sustainable without subsidies only if oil and coal prices continue to increase, and grain prices do not rise too far. Given the small production of biofuels, relative to other fuels, biofuel production will not affect the price of oil and coal. Oil prices are important because oil is used to produce gasoline and diesel. In order for liquid biofuels, such as ethanol and biodiesel, to be both price competitive and profitable, the price of oil has to be relatively high.

Coal prices are important too because coal is used as a solid fuel to heat buildings and generate electricity. Agricultural and forestry biomass can be both profitably produced and profitably used as a solid fuel only if the price of coal is relatively high. With currently low coal prices, solid biofuels are not profitable to produce.

Setting the stage for competition - food versus fuel

There are a number of reasons why countries support and promote renewable fuel industries. One is the rising price of oil and the political pressure put on developed countries to curb their GHG emissions. Another is the need to bolster rural economies, the decline of which is in part due to low world prices for grains and oilseeds over the last 30 years. Countries, especially those that are net importers of oil, are also concerned about their national energy security. There is also a need to respond to societal environmental demands, i.e. more green fuels. All together, these reasons have provided incentives and the rationale for biofuel production around the world.[18]

Governments have introduced numerous policy instruments to support biofuel production. These instruments include: subsidization (acreage payments to grain producers, construction grants to build biofuel distilleries, per gallon payments for ethanol production); tax incentives (excise and sales tax exemptions, corporate tax credits for biofuel facilities, tax deductions on flex-fuel vehicles); mandated use (many countries including the United States, Brazil, Canada and the EU have implemented targets for biofuel as a percentage of total fuel use); and import restrictions to encourage and enhance domestic biofuel production. While these numerous policy instruments have clearly provided a benefit to farmers, they generate large economic efficiency losses. In the United States alone, these losses are estimated to be in the billions of dollars per year.[9]

Agriculture has been significantly affected by these biofuel strategies, as the development of biofuels has fundamentally altered the grain price determination mechanism. For the last 50 years, grain prices have generally followed a downward sloping trend, the slope of which was determined by productivity and yield increases that lowered unit production costs. Prices did not fall below this floor because farmers would build up stocks rather than sell at below cost. Prices would, however, spike occasionally when stocks were not sufficient to meet intermittent short-falls in production resulting from climatic conditions and pests.

With the development of a biofuel industry, this relationship has been altered. As long as ethanol production is economically viable, demand for ethanol production shifts out the demand curve for grain, resulting in higher grain prices, at least in the short to medium term. While input costs and land prices will eventually rise to this new level, the outcome is nevertheless a higher price for grain.

Higher agricultural commodity prices are also being fueled by growth in the economies of countries like China and India, which are growing at approximately 10% per year. Economic growth leads to an increase in purchasing power and increases the demand for items such as meat and fuel. Increased demand for both of those commodities, along with the growth in ethanol demand, increases the demand for grain and hence grain prices.

These higher prices, at least in the short term, are raising the incomes of grain farmers, and affecting land prices and rents. At the same time, higher grain prices mean higher livestock production costs (particularly for hogs and chickens); higher grain prices also result in higher crop input costs as input suppliers ratchet up prices to ration demand. Over the last year, rising energy prices have also pushed up agricultural input prices (particularly fuel and fertilizer).

Rising grain prices will affect land use decisions. In the United States, where most ethanol production is corn-based, annual U.S. corn plantings since 2005 have increased from just under 80.0 million acres to 92.9 million acres in 2007. Although the 2008 plantings are forecasted to decrease to 88 million acres,[12] the expectation is for corn planting areas to increase in subsequent years with 33% of the corn crop being used for ethanol production by 2009/10. This implies that areas devoted to other crops, like wheat and soybean, will decline, at least in the short term. This will drive up the price of these other commodities. For the medium term, land now in forages, or pasture, will likely be brought into grain production as a response to higher grain prices. Over the longer term, expectations are that pressure will be put on natural forests and rangeland for conversion to grain production.[10]

Higher grain prices will also lead to higher food prices, as has been observed over the last 12 to 18 months. Higher prices for both food and energy have become the catalyst for unrest in many countries around the world, and have led a number of countries to impose export restrictions, or export tariffs, on food. Of the 37 nations facing food crises in December 2007, 20 of them, including exporting nations, such as Argentina and Vietnam, had imposed export caps, or taxes, on primary food items in an effort to address domestic inflation.[2]

Is Ethanol to Blame for Soaring Food Prices?

In the early 1970's, a bushel of wheat sold for the same price as a barrel of oil - about $2. While grain prices have risen sharply in the last 18 months, no one is talking about $120 per bushel for wheat or corn.

Suggestions that ethanol production is a huge factor in food shortages are silly. The food versus fuel debate is an important issue, but it's more complicated than some of the simplistic arguments put forth by opponents of ethanol.

No doubt the big increase in American and Brazilian ethanol production has played a role in grain price escalation, but a more important factor is the growing demand for food in Indian and China. Transportation costs caused by $120 per barrel oil are also adding to food prices.

In Western Canada, some estimates suggest that a million tonnes of wheat may be used for ethanol this year. That's about 4% of an average Canadian wheat crop. And that million tonnes of wheat will produce about 400,000 tonnes of distillers' grains, which will go back into the food chain. An early frost or wet harvest weather could create a million tonnes of feed-grade wheat, not suitable for human consumption. Excesses of feed wheat are extremely difficult to market.

Ethanol is being cast as the villain responsible for high grain prices and food shortages. The truth is, Canadians could stop producing ethanol and world grain markets would hardly notice.

Kevin Hursh

It is also important to point out that without an increase in the price of oil, higher grain prices could make ethanol production unprofitable. Recent estimates have shown that U.S. corn-based ethanol can continue to be profitable with oil at $125 per barrel, so long as distillers continue to receive the current $0.51 per gallon (equivalent to $US 1.43 per bushel of corn) government subsidy, and corn prices stay below $5.75 per bushel. However, as the price of oil continues to increase, the distillers' ability to pay for feedstock also rises. In the long run, ethanol production can only be profitably carried out without subsidies if the price of oil is relatively high, and if the demand from ethanol production does not push corn and other grain prices too high.[12]

The Biofuel Future

With the exception of sugarcane-based ethanol produced in Brazil, biofuels are not, in the absence of subsidies, currently competitive with petroleum-based fuel. Yet all indicators point to increasing production of ethanol and biodiesel as alternatives to liquid fuels. Policy provisions from around the world mean that in the short term, countries will continue to produce ethanol and biodiesel with current technologies and continued government support.[18] At the present time in the United States, the Farm Bill continues to subsidize feed grains, such as corn, to ensure availability of feedstock, and also maintains loan guarantees, mandated use levels, direct grants and tax exemptions to new bio refineries. China, the third largest ethanol producer, has continued to subsidize the development of its ethanol industry, providing four new corn-based ethanol plants with $173 per ton subsidies upon reaching stipulated production capacities.[26]

Canada is also subsidizing biofuel production. In addition to a 10 cent per litre excise tax exemption for ethanol use, the Canadian government has introduced numerous production incentives, including capital formation programs, support for business plans, and feasibility studies for facilities that promote producer investment. In addition, the federal government also wants to mandate a renewable content of five percent in gasoline by 2010. Several of the Canadian provinces also offer additional support for the use of biofuels and the development of an industry in their provinces, largely in the form of fuel tax exemptions.[16]

Although investment and support for biofuel continues, the industry faces several constraints. An important concern is that, while the use of renewable fuels can potentially reduce greenhouse gas emissions, the production processes used to manufacture biofuels is nevertheless carbon and energy intensive.[21,30] Another concern is that countries have mandated targets for biofuel use but there is limited ability to meet these targets given current fermentation technologies and the availability of arable land and overall yield potential.

Cellulosic Biofuels - Newer and Better?

Technological developments will be very important in determining the future of biofuels. The expectation is that in the future ethanol will be produced by cellulosic technology.[1,7] Currently, this technology is primarily in the development stage, although Iogen Corporation has announced plans to build the first North American commercial-scale cellulose ethanol plant in Saskatchewan (albeit with considerable subsidization). If the economics of cellulosic ethanol can be improved, it is expected that cellulosic technology will eventually dominate fermentation technology. It is important to note that cellulosic ethanol facilities will require government subsidies to be viable, at least in the short to medium term.

One reason many countries are considering cellulosic ethanol production is the ability to use a wide range of biomass that is cheaper to produce than the current feedstocks used for starch-based ethanol production. Wheat and barley grains are relatively expensive to produce given the low biomass output per acre. In contrast, plants such as hybrid poplar, willow, or switchgrass, can produce a large amount of biomass per acre. While corn may be able to remain a feedstock for starch-based ethanol because of its higher yield per acre, crops such as wheat and barley will almost certainly be replaced by hybrid poplar and willow.

An attractive component of cellulosic ethanol production is that it offers the potential to utilize marginal lands for feedstock production. In the food versus fuel competition for land resources, the ability to retain much of the world's arable land for food production, while minimizing the need to convert rainforests, peatlands, savannas, or grasslands to food-crop or fuel-crop production, is desirable. Estimates suggest that clearing peatlands, rainforests, or grasslands, has the potential to release 17 to 420 times the annual greenhouse gases from fossil fuels that biofuels are intended to displace. In contrast, biofuels produced from perennials grown on marginal lands can offer immediate and sustained GHG advantages.[6] Production of ethanol from cellulosic technologies also offers lower life-cycle greenhouse gas emissions from the production process.[17]

For cellulosic technology to be successful, a secure and reliable supply of feedstock will be crucial. For example, it is estimated that an efficient cellulosic plant will require 5,000 to 10,000 metric tonnes of biomass per day. With an average production of 10 tonnes per acre of biomass, approximately 100,000 acres of land dedicated to energy crop production are required to feed a single plant.[15] These requirements suggest that cellulosic bio-refineries, and gasification plants, need to be located in close proximity to feedstocks.

Biofuels - a sustainable source of energy from agriculture?

To consider the sustainability of biofuels, and its potential outlook for Canada and the prairies, the question of whether biofuels are economically sustainable over the long run needs to be addressed first. With current levels of technology, and current prices for oil and corn, biofuels production currently is only profitable if the industry is subsidized. The question is whether the subsidization model can be sustained on a global basis. There are at least two reasons to think that it may not be. First, biofuel subsidies in the United States alone create economic costs in the billions of dollars each year.[9] Although agriculture and energy lobbies are very strong in the United States, they may be unable to maintain biofuel subsidies at the projected levels. A reduction in biofuel subsidies would lead to a reduction in biofuel production.

The second has to do with global factors. In April 2008, the International Monetary Fund indicated its concerns over the dramatic increase in food prices, which rose 48% from the end of 2006 to the spring of 2008.[14] Increased diversion of grain into biofuels production, in addition to greater food demands from growing economies, and the increase in fuel and fertilizer prices, are creating major social unrest in many developing countries. In the poorest parts of the world, people are experiencing major food shortages as international donor programs struggle to provide grain that is now priced two and three times higher than it was a year ago. This situation is made worse by the actions of a growing number of countries that are attempting to insulate their domestic markets against rising food prices by restricting exports. The question of whether countries (largely those in the developed world) will continue to subsidize biofuel production over the longer term in light of these developments is an open one.

Biofuels can become economically sustainable without subsidies only if oil and coal prices continue to increase beyond their current levels. What is the likely price path for these two energy sources? If oil prices continue to rise, driven upwards by such things as falling reserves (Hubbert's Peak), and geopolitical unrest, then ethanol and biodiesel will likely be profitable to produce - without subsidies, providing the price of grain does not rise sufficiently to offset the oil price increase. If coal prices were to rise, driven upwards by the introduction of limitations on carbon emissions and/or carbon taxes to reduce greenhouse gases, then agricultural biomass could be burned profitably as a fuel.

There are two critical factors that will determine whether biofuel production will take place on the Prairies. First, given the biomass requirements of biofuels, it is unlikely that the arable lands of the Canadian Prairies will be able to produce the quantities required. Instead, if it is to be found at all, the land suitable for the type of high-foliage growth required (i.e., something that will grow fast and plentiful, like a weed) tends to be located in the parkland region of the northern Prairies. These areas have higher annual rainfall, and soil conditions are appropriate for this type of growth. Since land in the southern part of the Prairies does not share these attributes, economical biomass production in this area is unlikely. However, this land can continue to produce high-quality food grain, oilseeds and pulses. Prices for these commodities will likely continue to be high given the worldwide demand for land to produce biomass.

Second, developing a consistent and economically viable biomass supply system will require addressing a number of diverse harvesting, storage, preprocessing, and transportation factors.[28] Much of the infrastructure and rural development that supports agriculture in the Canadian prairies (transport systems, marketing and distribution centres, community support networks) has evolved in the southern prairies, where food grain production has traditionally occurred. Investment in the development of supporting infrastructure, such as transportation networks and biomass storage systems, would be essential to the success of the industry.

Conclusion

The development of biofuels is one of the most important developments in agriculture in the last century. Although land has always been used to produce fuel, the fuel has primarily been wood. Higher energy prices, and growing concerns about energy security, mean that there will be new pressures to use land to produce various forms of biomass that can be converted into fuel. In the short turn, ethanol produced from grain will remain the most important biofuel for North America, since the United States is expected to maintain its support for ethanol production.

Considerable uncertainty, however, exists as to whether a viable biofuels industry will emerge in Canada. It is also unclear which form it might take. In addition to questions about the nature of the technology that might exist (e.g., will cellulosics technology develop sufficiently to become economically viable?), questions also abound about the environmental costs associated with the industry and the willingness of governments to invest taxpayer money in a sector that will be increasingly linked to global issues and conflicts. While biofuels seemed like a fairly sure bet in Canada a few years ago, this is no longer the case today.

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