GROWING CROPS FOR BIOFUELS: IMPLICATIONS FOR WATER RESOURCES

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ABSTRACT

Biofuel production has increased in the United States due to government policy of energy independence and security. Ethanol can be produced from a variety of crops including grain, sugar, cellulose, and oil seed crops. The primary biofuel crop in the US, corn, uses less water than some crops but more than others. Producing corn for biofuels in the US has resulted in less irrigation water application to crops, since corn is irrigated with less water than the crops it has replaced, such as cotton. By 2030, water withdrawals for biofuel crops are projected at 4% of the total worldwide, but will be 22% of the total in the US, or 2-3 times that amount depending on irrigation water application to cellulosic ethanol crops. Growing corn for biofuel in the US has displaced some soybean production to Brazil, and increased corn production in other parts of the world to meet increasing demand. By 2030, 20% of the developing countries will be facing water shortages, but the only country in this category that has significant plans for biofuel production is India. Despite the relatively minor impact of biofuels on water requirements worldwide, growing biofuels has an impact that was not previously present. However, devoting a portion of our land area and water resources toward growing crops for biofuels may be worth the cost of energy independence and security.

INTRODUCTION

Production of biofuels is increasing in the United States for several reasons. In 2006, a number of petroleum companies decided to start using ethanol instead of methyl tertiary- butyl ether (MTBE) as an oxygenate and octane enhancer in gasoline. MTBE had been found in the groundwater earlier and was banned by some states. The Federal government decided to no longer protect the petroleum industry from lawsuits related to MTBE, and this liability exposure hastened the move to substitute ethanol for MTBE. The Energy Independence and Security Act of 2007 established a renewable fuel standard (RFS) requiring fuel producers to use 36 billion gallons of biofuel by 2022, and established minimum biofuel requirements for each year up to 2022.

Ethanol can be produced from a variety of crops or feedstocks including grain, sugar, cellulose, and oil seed crops. Corn is the primary feedstock that is used in the United States to produce biofuel, and examples of other grain crops used for this purpose are sorghum and wheat. Brazil produces ethanol from sugarcane, but sugar beets and sweet sorghum are examples of other sugar crops that can be used as feedstocks for ethanol. Ethanol can be produced from the cellulose in a variety of crops or waste materials, the most commonly mentioned are switchgrass

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and miscanthus. Biodiesel can be produced from soybean or other oilseed crops such as rapeseed. Algae can also be used to produce ethanol or biodiesel.

DO BIOFUEL CROPS USE MORE WATER THAN CONVENTIONAL CROPS?

Crops currently used for biofuels are not dedicated energy crops and are used for other purposes besides fuel ethanol. Corn, for example, is used as a cattle feed and to produce products such as corn syrup and starch. The peak water use relative to a well-watered grass (or crop coefficient, Kc) of most crops do not vary greatly. Many major crops have a Kc between 1.15 and 1.20. Sugarcane has relatively high Kc of 1.25 due to its height, and sorghum has a relatively low Kc of 1.05 due to the waxiness of its leaves. The length of the growing season and the time of year the crop is grown have more to do with total water use than peak water use. Perennial crops like alfalfa tend to have higher water use due to their longer growing season than annual crops like corn (Table 1). The water use of the major biofuel crop, corn, is intermediate between higher use crops such as alfalfa and sugarcane and lower water use crops such as sorghum and wheat. The water use efficiency, that is, the yield produced per unit water used, is remarkably similar amongst all these crops. So, even though sorghum uses less water than corn, because it has a lower yield than corn, the water use efficiencies of these crops are similar or even slightly lower for sorghum.

HAS BIOFUEL CROP PRODUCTION IN THE US CHANGED IRRIGATION WATER APPLICATION?

Ethanol production in the US in 2007 is about four times the amount it was in the year 2000 (Fig. 1). Corn is the primary crop used as a feedstock for ethanol production in the US, although some sorghum is also used, so the amount of corn used in ethanol production is directly related to ethanol production itself. Increased acreage of corn between 2000 and 2007 has come at the expense of soybean primarily, but also cotton, wheat, barley, and other crops. Increased acreage of irrigated corn has come at the expense of cotton, primarily, but also barley, dry beans, soybeans, and other crops (Fig 2). If more corn is grown than cotton, then less irrigation water is applied since water application is less for corn than cotton as well as barley and dry beans, but not for soybean (Fig 3). So, about 10% less water is applied to corn than the average of water application to cotton, dry beans, barley, and soybean, crops that have decreased in acreage this decade. Based on acreage change and average water application, the increased in water applied to corn has been offset by the decrease in water application to cotton (Fig. 4). There are both increases and decreases in water application to other crops attributed to acreage change between 2000 and 2007, but the net effect is less water application due to land being taken out of production.

HOW MUCH IRRIGATION WATER IS COMMITTED TO FUTURE BIOFUEL CROP PRODUCTION?

As mandated by the 2007 Energy Independence and Security Act, biofuel production in the US will increase each year steadily until 2022 when production reaches 36 billion gallons per year (Fig. 5). Ethanol production from corn will level off at 15 billion gallons per year, about 16 gallons per year will be produced from cellulose, and the remainder from other feedstocks. In

2007, about 23% of the US corn crop was used to produce ethanol that comprised about 2% of the energy equivalents in the transportation sector (EIA, 2008). To put this in perspective, if we wanted to produce all the fuel we needed for transportation in the US from corn, we would need to produce this corn from an area equal to about 14 times the area of all the current cropland in the US. More realistically, the goal of our energy policy is to produce biofuels equal to about 11% of the energy demand (or 16% of the volume) of the transportation sector.

Another goal of our energy policy is to reduce our dependence on petroleum imported from politically volatile regions of the world. About 40% of our energy consumption is oil, and most of our energy from natural gas, coal, nuclear, and renewable sources is domestically produced (Fig. 6). We produce 42% of our petroleum domestically, and 58% is imported. Of the petroleum that is imported, 49% is from the Western Hemisphere, and the remainder is from the Middle East, Africa, and other regions. So, 29% of the petroleum we consume is from areas that may be considered politically volatile, representing 11% of our energy consumption from all sources. The 2007 Energy Bill mentions reducing our consumption of petroleum by 20% in 10 years by a combination of vehicle fuel economy (ca. 12%) and substitution of biofuels (ca. 8%).

The amount of land dedicated to biofuels and irrigation withdrawals for these crops is relatively small worldwide. The US and Brazil are currently the two largest biofuel producers, and will be in the future along with China, India, and the EU (de Fraiture, 2008). In 2030, about 3% of the cropped area and 4% of the irrigation withdrawals worldwide are projected for biofuel production. The US is the only country with projected irrigation withdrawals in 2030 greater than 8%. The study of de Fraiture (2008) did not consider land and irrigation withdrawals for cellulosic ethanol in the US, which is projected at 16 BGY in 2030 along with corn ethanol at 15 BGY. If we assume that the cellulosic ethanol will be produced primarily from perennial grasses such as switchgrass and that the ethanol yield from switchgrass is equivalent to corn on a per acre basis, then the total cropped area for biofuels in the US will be 21% in 2030. If we assume that the proportion of irrigated switchgrass is similar to corn, and that the water application to switchgrass is 2.1 acre-feet per acre compared to 1.2 acre-ft per acre for corn, then the total irrigation withdrawals for biofuels in the US (excluding biodiesel) is projected at 63% in 2030.

WHAT "GIVES" BY GROWING BIOFUELS?

Growing crops for biofuels uses land, water, resources, and agricultural commodities for a purpose not common in the past. The amount of US corn for feed, food, seed, industrial, and export uses has been fairly flat this decade, but corn used for fuel ethanol has experienced exponential growth. The growth in US corn production between 2000 and 2007 has been about 3 billion bushels, roughly equivalent to the amount of corn used in 2007 to produce ethanol. Acreage increase is responsible for about 2/3 of the production increase, and the remaining 1/3 is due to yield increase. Thus, it would appear that the increase in corn use for fuel ethanol has no net effect, but this is not the case. World demand for corn has increased steadily since 2000, yet our exports are flat, indicating that our share of the world corn market has decreased and that the increased demand for corn is being met by production in other regions. Corn production for ethanol in the US has been accompanied by decreases in acreage of soybean, so soybean production has increased in other regions of the world such as Brazil.

According to the FAO, there is no shortage of land or water resources for agriculture worldwide, but there are problems in certain countries (FAO, 2002). At present, about 11% of the world's land area is in cropland, but an area twice this amount that is suitable for rainfed agriculture is not being used. The problem is that unused suitable cropland is unevenly distributed: Countries in the Near East, North Africa, and South Asia are using 87% or more of their suitable cropland. In 1997-99, irrigated land in developing countries made up about 20% of the cropland, 40% of crop production, and 60% of cereal production. Developing countries are expected to expand their irrigation capacity by 20% from 2000 to 2030, but this is only a third of the increase that was achieved the previous 30 years. Most of this increase in irrigation capacity will occur in the areas mentioned above already using a high proportion of suitable cropland. One in five developing countries will be facing water shortages in 2030. Of the countries with major plans for biofuels, only India may experience water shortages by 2030.

Despite the relatively minor impact of biofuels on land area and water requirements worldwide, growing biofuels has an impact that was not previously present. Growing biofuels displaces resources that could have been used for food, feed, exports, municipal or industrial use. However, devoting a portion of our land area and water resources toward growing crops for biofuels may be worth the cost of energy independence and security.

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Table 1. Water use of various crops in Mesa, AZ near Phoenix (Erie et al., 1982) and Imperial Valley for sugarcane (Bali et al., 2007), yield in 2007 for these crops in Maricopa County (NASS, 2008) and estimated for sugar cane, and water use efficiency or yield per unit water used.

Crop	Water Use	Yield	Water Use Efficiency
	inches	lbs/acre	lbs/acre/inch
Sugar cane (Imperial Valley)	78	25,600	328
Alfalfa	74	17,400	235
Blue panic grass	52	---	---
Cotton	41	---	---
Corn	40	9,408	235
Sorghum	25	4,800	192
Wheat	24	5,970	248

Table 2. Biofuels production, cropped area, and irrigation withdrawals, 2005 and 2030 (de Fraiture, 2008).

Country	Crop	Biofuel Production		Area used for biofuels		Irrigation for biofuels	
		2005	2030	2005	2030	2005	2030
		Billion gallons		% total crop area		% total irrigation	
USA	Corn	4.0	15.0	5.0	10	3.5	22
Brazil	Sugarcane	3.4	9.1	3.5	7	2.7	8
China	Corn	0.9	4.7	1.1	4	2.2	7
India	Sugarcane	0.5	2.4	0.2	1	1.2	5
World		9.7	37.3	0.8	3	2.0	4

Fig. 1. Historic US fuel ethanol production (USDA-ERS, 2008).

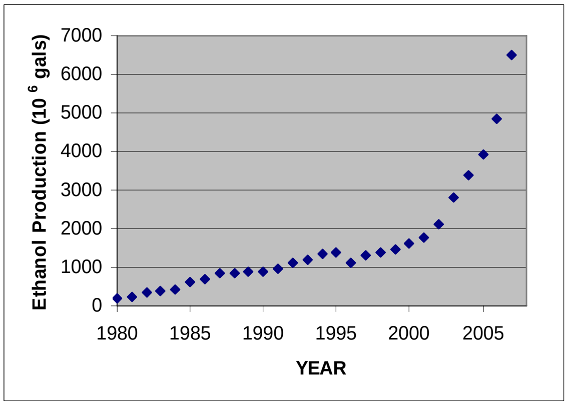

Fig. 2. Acreage change of irrigated crops in the US between 2000 and 2007 (USDA-NASS, 2008).

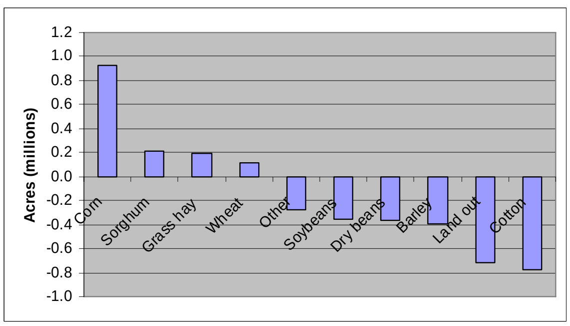

Fig. 3. Average irrigation water application to crops in the US (USDA-NASS, 2008).

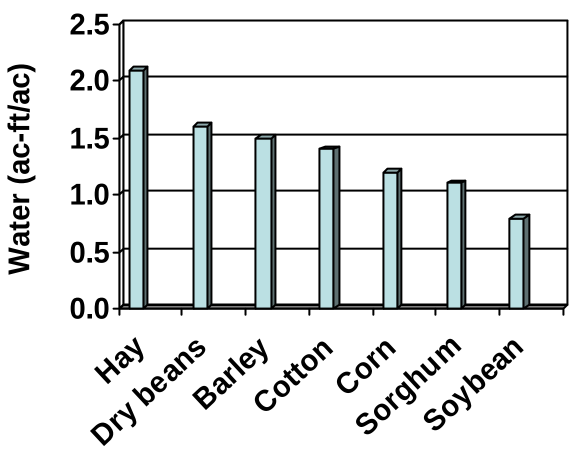

Fig. 4. Change in irrigation water application to crops in the US between 2000 and 2007 (USDA-NASS, 2008).

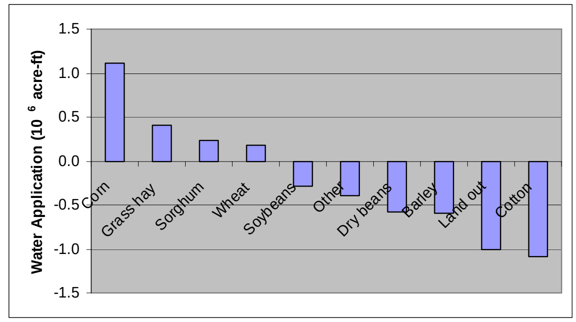

Fig. 5. Biofuel production by feedstock as mandated by the 2007 Energy Bill.

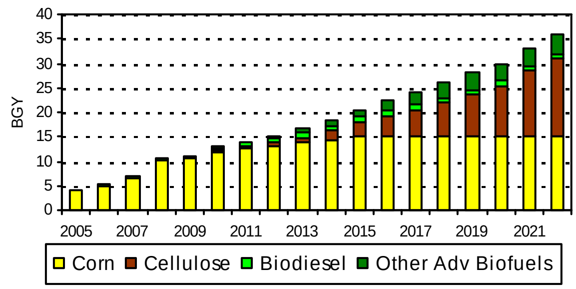

Fig. 6. US energy consumption by source, 2007 (EIA, 2008).