Lifecycle Water Consumption and Withdrawal Requirements of Ethanol from Corn Grain and Residues

Supporting Information – II:

Literature review, summary of key inputs, and detailed results

By
Gouri Shankar Mishra (gouri.mishra@gmail.com)
Sonia Yeh (slyeh@ucdavis.edu)

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1 Introduction

1.1 Literature review

Table SII 1.1: Estimates of water consumption intensity of corn ethanol (Liters / VKT)(1)

	Wu, Mintz et al. (2009) (2)	Chiu, Walseth et al. (2009)	Gerbens-Leenes, Hoekstra et al. (2009) & Gerbens-Leenes, Hoekstra et al. (2008)	Mubako & Lant (2008)	Fingerman, Torn et al. (2010)	This study - Weighted average from rainfed & irrigated corn	
	BW	BW	BW+GW	BW+GW	BW+GW	BW intensity	GW intensity
Iowa	1.84	1.09	334.93	271.94		0.56	81.10
Nebraska	59.00	91.32		213.98		32.68	74.47
California		389.68			280.07	146.29	1.15

Table SII 1.2: Estimates of water consumption intensity of corn ethanol (Liters / Liters of ethanol)(3)

	Wu, Mintz et al. (2009) (2)	Chiu, Walseth et al. (2009)	Gerbens-Leenes, Hoekstra et al. (2009) & Gerbens-Leenes, Hoekstra et al. (2008)	Mubako & Lant (2008)	Fingerman, Torn et al. (2010)	This study - Weighted average from rainfed & irrigated corn	
	BW	BW	BW+GW	BW+GW	BW+GW	BW intensity	GW intensity
Iowa	10.1	6.0	1837.5	1,492.0		3.1	444.9
Nebraska	323.7	501.0		1,174.0		182.0	420.3
California		2,138.0			1,536.6	802.6	6.3

Notes:

(1) Assumes a vehicle efficiency of 3877.59 kJ/VKT (5,914.75 BTU / VMT). See SI-I Chapter 2.

(2) Wu, Mintz et al. and Wu, Mintz et al. provide estimates for USDA region 5 (Iowa, Missouri, Illinois, Indiana, and Ohio); and USDA Region 7 (North Dakota, South Dakota, Nebraska, and Kansas). State-wide averages not provided.

(3) This study resports water intensity in form of liters of water / liter of un-denatured ethanol. It is not clear whether the other studies are based on denatured or un-denatured ethanol, and the volume of denaturant in case of denatured ethanol.

2 System boundary and water requirements

The following table summarizes the differences in system boundary and adopted methodology to estimate water requirements of ethanol from corn grain.

Table SII 2.1: Comparison of system boundary

	Wu, Mintz et al. (2009)	Chiu, Walseth et al. (2009)	Gerbens-Leenes, Hoekstra et al. (2009) & Gerbens-Leenes, Hoekstra et al. (2008)	Mubako & Lant (2008)	Fingerman, Torn et al. (2010)	This study - Weighted average from rainfed & irrigated corn
GW consumptive use (P_s+P_{os})	Not considered	Not considered	Included. Results from CROPWAT model. Meteorological data is for Des Moines, IA	Included. Results from CROPWAT	Included. Results from CUP model. Average of multiple stations	Reported separately. Results from CROPWAT. Weighted average of multiple stations.
ET_a (1) - ET_a calculated, ideal conditions			Results from CROPWAT model		Results from CUP model	
- ET_a actual, empirical	Yes. Based on 2003 FRIS and approximated for USDA Regions 5 (IA) and 7 (NE). Adjusted for non-consumptive application losses	Yes. Based on 1997 & 2003 FRIS. Entire water applied is assumed consumptive.		Yes. Based on 1992, 1997 & 2003 FRIS. Adjusted for application losses.		Yes. Based on 2003 FRIS Adjusted for application losses
L_a	Non-consumptive application losses are assumed at 29% of applied water	See above	Not included	Non-consumptive application losses are 40% and 15% for surface and sprinkler systems respectively	Not included	Application losses divided into consumptive and non-consumptive
L_c	Not included	Not included	Not included	Not included	Not included	Included. Divided into consumptive and non-consumptive losses
BR	Included	Included	Included	Included	Included	Included
E_e	Not included	Not included	Not included	Not included	Not included	Included
Storage losses	Not accounted for	Not accounted for	Not accounted for	Not accounted for	Not accounted for	Accounted for.

(1) Estimates of ET_a are either calculated and applicable under ideal conditions, or are based on survey estimates.

Estimates by Gerbens-Leenes, Hoekstra et al. (2009) and Fingerman, Torn et al. (2010) are based on "ideal" ET_a requirements which assumes standard conditions i.e. disease-free, well-fertilized crops, grown in large fields, under optimum soil water conditions, and achieving full production under the given climatic conditions (FAO 1998). In actual practice, presence of pests and diseases, soil salinity, low soil fertility, and water shortage or water-logging may reduce crop yields and the evapotranspiration rate below ETc. To account for this, and the fact the crop yields are based on actual observation, the first two studies use ET_a based on prevalent practice as estimated by USDA's Farm and Ranch Irrigation Survey (FRIS) conducted every 5 years, the last one being in 2008.

3 Methodology

In the section below, we summarize the assumptions and values of the key parameters for the 17 meteorological stations analyzed in this paper (Table S3.1). The spatial (e.g. state vs. county data) and temporal (e.g monthly vs. annual averages) coverage of key input parameters are briefly discussed in the main text and summarized in SI-I Table A1.1.

Table SII 3.1: Summary of location-specific input parameters

	State	**California**	**Illinois**	**Illinois**	**Illinois**	**Illinois**
	Station	Fresno	Peoria	Moline	Chicago	Springfield
	Agricultural District	SJ Valley	Central	North West	North East	West Southwest
Step	**Crop type**	Irrigated	Rainfed	Rainfed	Rainfed	Rainfed
1						
1.1	ET_a (FRIS) (cm)	60.96	0.00	0.00	0.00	0.00
1.2	P_s (cm)	1.96	32.26	39.01	32.13	30.15
1.3	P_{os} (cm)	10.19	4.78	8.41	7.14	9.78
1.4	Ground water share	33%	8%	8%	8%	8%
1.5	SL (cm)	0	0	0	0	0
2						
2.1	Irrigation Method	**SURFACE** - Furrow irrigation	SPRINKLER - Central pivot & Linear move			
3						
3.1	Conveyance losses	3.23%				
3.2	Consumptive portion	2.36%				
4						
4.1	Partition method	Sys Expansion /Displacement				
4.2	Corn Yield (bu/acre)	178.5	178	167.8	172.2	164.8
4.3	Storage loss grain	1%	1%	1%	1%	1%
4.4	Storage loss cob	1%	1%	1%	1%	1%
5A						
5.1	Co-product crediting	Displacement method				
5.2	Conversion Technology	Dry Mill				
5.3a	SB ET_a (FRIS) (cm)	18.3	0.0	0.0	0.0	0.0
5.3b	SB P_s (cm)	19.0	24.0	28.4	23.1	22.8
5.3c	SB P_{os} (cm)	11.5	8.7	4.4	10.8	12.0
5.3d	SB SL (cm)	0.0	0.0	0.0	0.0	0.0
5.3e	SB yield (bu/acre)	56.4	51.4	46.8	49	45.6
5B						
5b.1	Co-product crediting	Displacement (of electricity)				
5b.2	Conversion Technology	Biochemical Conversion				

Table SII3.1 – continued

Step	State Station Agricultural District Crop type	Indiana Evansville Southwest Rainfed	Indiana Indianapolis Central Rainfed	Indiana Fort Wayne North East Rainfed	Indiana Jeffersonville South East Rainfed
1					
1.1	ET_a (FRIS) (cm)	0.00	0.00	0.00	0.00
1.2	P_s (cm)	30.63	31.85	29.54	34.04
1.3	P_{os} (cm)	7.87	2.44	7.98	10.39
1.4	Ground water share	8%	8%	8%	8%
1.5	SL (cm)	0	0	0	0
2					
2.1	Irrigation Method	SPRINKLER - Central pivot & Linear move			
3					
3.1	Conveyance losses				
3.2	Consumptive portion				
4					
4.1	Partition method	Sys Expansion /Displacement			
4.2	Corn Yield (bu/acre)	162.5	158.7	149.9	141.34
4.3	Storage loss grain	1%	1%	1%	1%
4.4	Storage loss cob	1%	1%	1%	1%
5A					
5.1	Co-product crediting	Displacement method			
5.2	Conversion Technology	Dry Mill			
5.3a	SB ET_a (FRIS) (cm)	0.0	0.0	0.0	0.0
5.3b	SB P_s (cm)	21.4	23.3	20.32	23.50
5.3c	SB P_{os} (cm)	11.8	7.3	2.39	7.29
5.3d	SB SL (cm)	0.0	0.0	0.0	0.0
5.3e	SB yield (bu/acre)	50.9	45.3	45.3	41.3
5B					
5b.1	Co-product crediting	Displacement (of electricity)			
5b.2	Conversion Technology	Biochemical Conversion			

Table SII3.1 – continued

Step	State Station Agricultural District Crop type	Iowa Davenport East Central Rainfed	Iowa Des Moines South Central Rainfed	Iowa Des Moines Central Rainfed	Iowa Sioux City West Central Rainfed
1					
1.1	ET_a (FRIS) (cm)	0.00	0.00	0.00	0.00
1.2	P_s (cm)	39.01	36.40	36.40	29.21
1.3	P_{os} (cm)	8.41	3.33	3.33	0.56
1.4	Ground water share	20%	20%	20%	20%
1.5	SL (cm)	0	0	0	0
2					
2.1	Irrigation Method	SPRINKLER - Central pivot & Linear move			
3					
3.1	Conveyance losses				
3.2	Consumptive portion				
4					
4.1	Partition method	Sys Expansion /Displacement			
4.2	Corn Yield (bu/acre)	171.04	151	178.5	171.5
4.3	Storage loss grain	1%	1%	1%	1%
4.4	Storage loss cob	1%	1%	1%	1%
5A					
5.1	Co-product crediting	Displacement method			
5.2	Conversion Technology	Dry Mill			
5.3a	SB ET_a (FRIS) (cm)	0.0	0.0	0.0	0.0
5.3b	SB P_s (cm)	28.45	24.13	24.1	21.0
5.3c	SB P_{os} (cm)	4.39	10.1	10.1	3.8
5.3d	SB SL (cm)	0.0	0.0	0.0	0.0
5.3e	SB yield (bu/acre)	50.5	45.5	52.8	49.9
5B					
5b.1	Co-product crediting	Displacement (of electricity)			
5b.2	Conversion Technology	Biochemical Conversion			

Table SII3.1 – continued

Step	State	Kansas	Kansas	Kansas	Kansas	Kansas	Kansas
	Station	Concordia Blosser	Concordia Blosser	Dodge City	Kansas City	Topeka	Topeka
	Agricultural District	North Central	North Central	Southwest	Northeast	East Central	East Central
Step	**Crop type**	Irrigated	Rainfed	Irrigated	Rainfed	Irrigated	Rainfed
1							
1.1	ET_a (FRIS) (cm)	39.62	0.00	39.62	0.00	39.62	0.00
1.2	P_s (cm)	31.75	31.75	25.28	37.43	34.45	34.45
1.3	P_{os} (cm)	4.88	4.88	3.21	6.29	6.54	6.54
1.4	Ground water share	77.80%	77.80%	77.80%	77.80%	77.80%	77.80%
1.5	SL (cm)	0	0	0	0	0	0
2							
2.1	Irrigation Method	SPRINKLER - Central pivot & Linear move					
3							
3.1	Conveyance losses	4.23%	4.23%	4.23%	4.23%	4.23%	4.23%
3.2	Consumptive portion	1%	1%	1%	1%	1%	1%
4							
4.1	Partition method	Sys Expansion / Displacement					
4.2	Corn Yield (bu/acre)	178.4	101	196.4	130.3	169	103.5
4.3	Storage loss grain	1%	1%	1%	1%	1%	1%
4.4	Storage loss cob	1%	1%	1%	1%	1%	1%
5A							
5.1	Co-product crediting	Displacement method					
5.2	Conversion Technology	Dry Mill					
5.3a	SB ET_a (FRIS) (cm)	30.5	0.0	30.5	0.0	30.5	0.0
5.3b	SB P_s (cm)	24.8	24.8	20.0	28.6	26.5	26.5
5.3c	SB P_{os} (cm)	10.3	10.3	13.9	7.8	8.0	8.0
5.3d	SB SL (cm)	0.0	0.0	0.0	0.0	0.0	0.0
5.3e	SB yield (bu/acre)	55.6	38.8	54.3	43.0	50.0	31.3
5B							
5b.1	Co-product crediting	Displacement (of electricity)					
5b.2	Conversion Technology	Biochemical Conversion					

Table SII 3.1 – continued

Step	State	Nebraska	Nebraska	Nebraska	Nebraska	Nebraska	Nebraska
	Station	Lincoln	Lincoln	Valentine	Valentine	North Platte	North Platte
	Agricultural District	East	East	North	North	Southwest	Southwest
Step	**Crop type**	Irrigated	Rainfed	Irrigated	Rainfed	Irrigated	Rainfed
1							
1.10	ET_a (FRIS) (cm)	24.38	0.00	24.38	0.00	24.38	0.00
1.2	P_s (cm)	29.59	29.59	25.70	25.70	23.37	23.37
1.3	P_{os} (cm)	5.79	5.79	0.56	0.56	6.53	6.53
1.4	Ground water share	61%	61%	61%	61%	61%	61%
1.5	SL (cm)	0	0	0	0	0	0
2							
2.1	Irrigation Method	SPRINKLER - Central pivot and Linear move					
3							
3.1	Conveyance losses	12%	12%	12%	12%	12%	12%
3.2	Consumptive portion	1%	1%	1%	1%	1%	1%
4							
4.1	Partition method	Sys Expansion / Displacement					
4.2	Corn Yield (bu/acre)	186.9	134.9	181.4	78.8	184.3	76.4
4.3	Storage loss grain	1%	1%	1%	1%	1%	1%
4.4	Storage loss cob	1%	1%	1%	1%	1%	1%
5A							
5.1	Co-product crediting	Displacement method					
5.2	Conversion Technology	Dry Mill					
5.3a	SB ET_a (FRIS) (cm)	18.3	0.0	18.3	0.0	18.3	0.0
5.3b	SB P_s (cm)	20.6	20.6	18.1	18.1	18.3	18.3
5.3c	SB P_{os} (cm)	9.3	9.3	11.2	11.2	13.9	13.9
5.3d	SB SL (cm)	0.0	0.0	0.0	0.0	0.0	0.0
5.3e	SB yield (bu/acre)	58.8	46	53	32.1	57.3	27.4
5B							
5b.1	Co-product crediting	Displacement (of electricity)					
5b.2	Conversion Technology	Biochemical Conversion					

Table SII 3.1 – continued

Step	State Station Agricultural District Crop type	Nebraska South Sioux City East Central Irrigated	Nebraska South Sioux City East Central Rainfed
1			
1.10	ET_a (FRIS) (cm)	24.38	0.00
1.2	P_s (cm)	29.21	29.21
1.3	P_{os} (cm)	0.56	0.56
1.4	Ground water share	61%	61%
1.5	SL (cm)	0	0
2			
2.1	Irrigation Method	SPRINKLER - Central pivot & Linear	
3			
3.1	Conveyance losses	12%	12%
3.2	Consumptive portion	1%	1%
4			
4.1	Partition method	Sys Expansion / Displacement	
4.2	Corn Yield (bu/acre)	191.30	137.34
4.3	Storage loss grain	1%	1%
4.4	Storage loss cob	1%	1%
5A			
5.1	Co-product crediting	Displacement method	
5.2	Conversion Technology	Dry Mill	
5.3a	SB ET_a (FRIS) (cm)	18.3	0.0
5.3b	SB P_s (cm)	21.0	21.0
5.3c	SB P_{os} (cm)	3.8	3.8
5.3d	SB SL (cm)	0.0	0.0
5.3e	SB yield (bu/acre)	55.26	44.74
5B			
5b.1	Co-product crediting	Displacement (of electricity)	
5b.2	Conversion technology	Biochemical Conversion	

The agricultural districts in which these stations are located represent 45-65% of the corresponding state's corn production in 2009. Each district's share of corn production in 2009 is detailed in SI-I, Appendix A2.

4 Results

4.1 Water requirements of corn harvested

The following table details the data for Figure 2 in the article

Table SII 4.1: Average water requirements of corn cultivation in various states (liters / bushel harvested)

	GW consumed	Blue Water consumed		Blue water released	
		Ground	Surface	Ground	Surface
Rainfed cultivation					
IL	9,911				
IN	9,575				
IA	9,243				
KS (rainfed)	14,838				
NE (rainfed)	10,319				
Irrigated cultivation					
CA	2,780	3,966	8,229	721	1,495
KS (irrigated)	6,818	6,367	1,817	546	156
NE (irrigated)	7,230	3,127	1,984	522	330

Source: Our analysis

4.2 Water intensity of ethanol

The following table details the data for Figure 3 in the article.

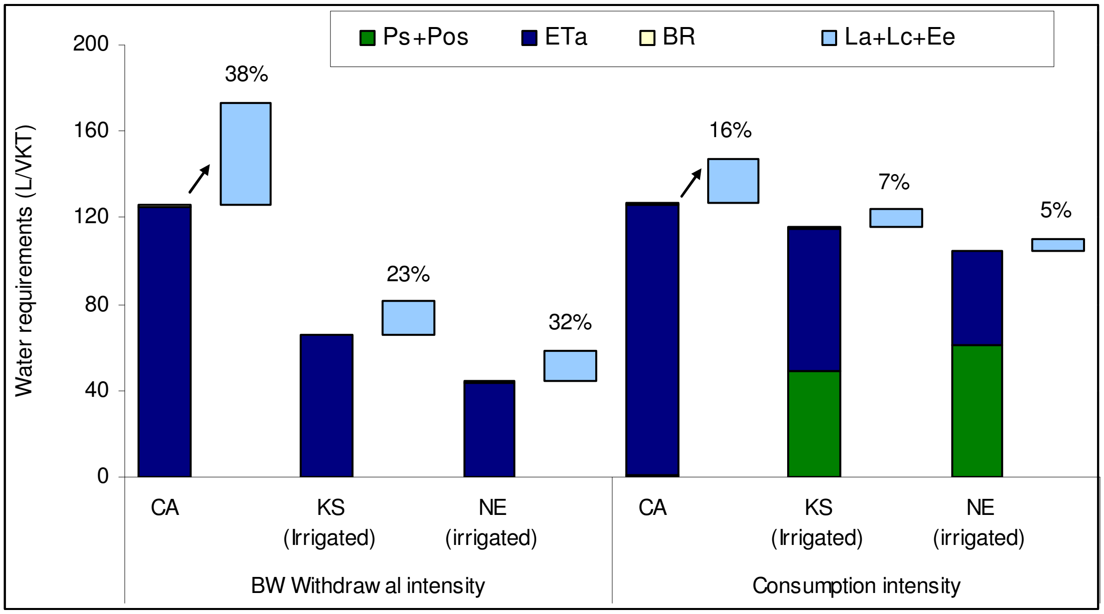
Table SII 4.2: Average water intensity of ethanol (L/VKT) for ethanol from corn grain, corn grain & cob, and co-products.

State Crop type	**IL** Rainfed	**IN** Rainfed	**IA** Rainfed	**KS** Rainfed	**NE** Rainfed	**CA** Irrigated	**KS** Irrigated	**NE** Irrigated
Ethanol from corn grain								
GW	87.0	86.6	81.1	136.9	95.8	1.2	49.3	63.6
BW Ground	0.0	0.0	0.1	0.4	0.3	47.6	58.1	29.9
BW Surface	0.5	0.5	0.5	0.2	0.3	98.7	16.6	19.1
Ethanol from grain & cob								
GW	75.4	75.2	70.4	118.8	83.1	1.0	42.8	55.2
BW Ground	0.0	0.0	0.1	0.4	0.4	41.3	50.5	26.1
BW Surface	0.6	0.6	0.5	0.2	0.2	85.7	14.4	16.6
Co-products (DGS & Electricity)								
GW	73.7	73.4	68.7	103.0	76.8	40.6	61.6	60.0
BW Ground	0.0	0.0	0.0	0.0	0.0	18.3	45.4	20.8
BW Surface	0.0	0.0	0.0	0.0	0.0	37.9	13.0	13.2

Source: Our analysis

The following figure divides the water intensity of ethanol from irrigated corn based on various components of the system boundary (water requirements). It also highlights the impact on withdrawal and consumption intensity as a result of extension of system boundary.

Figure SII 4.3: Detailed breakdown of water requirements of ethanol from irrigated corn



The detailed breakdown of water requirements for ethanol (in L/VKT) from irrigated corn are given below:

Table SII 4.4: Detailed breakdown of water requirements of ethanol from irrigated corn

	CA	KS (irrigated)	NE (irrigated)
Consumed			
Green Water	**1.2**	**49.29**	**63.60**
Blue Water	**146.3**	**74.69**	**49.00**
- ET_a	125.1	65.63	43.06
- SL	-	-	-
- L_a	16.7	7.72	5.12
- L_c	3.9	0.77	0.51
- BR	0.5	0.50	0.50
- E_e	0.1	0.07	0.07
Withdrawn			
Blue Water	**172.8**	**81.04**	**57.08**
- ET_a	125.1	65.63	43.06
- SL	-	-	-
- L_a	41.7	11.58	7.69
- L_c	5.4	3.27	6.15
- BR	0.5	0.50	0.50
- E_e	0.1	0.07	0.07

Source: Our analysis

4.3 Impact on state-wide water demand

Table SII 4.5: Calculation of the total water requirement at each state

		IL	IN	IA	KS	NE	All US
Ethanol production in 2009							
Operating Capacity (1)	(million L)	5,110	2,673	12,049	1,652	5,504	44,961
Production (2)	(million L)						
- Dry Mill		4,013	2,099	9,463	1,298	4,323	35,310
- Wet Mill		547	286	1,290	177	589	4,815
Corn required (3)	(million bu)						
- Irrigated					70	299	626
- Rainfed		418	219	987	65	152	3,056
Total corn produced in 2009		2,053	934	2,439	598	1,575	13,110
Percentage corn used for EtOH		20%	23%	40%	23%	29%	28%
		IL	**IN**	**IA**	**KS**	**NE**	**All US**
Water Consumption (without co-product water credit)							
Corn cultivation	(billion L)						
- Green water (4)		4,147	2,095	9,120	1,446	3,728	
- Blue water (4)					574	1,527	
- % of State total irrigation water (5)					14.8%	14%	
Ethanol conversion	(billion L)						
- Blue water (6)		13	7	31	4	14	
- % of State total industrial + public supply water (7)		0.5%	0.0%	0.1%	0.8%	1.6%	
BW used for ethanol as % of total state-wide BW use (8)		0.06%	0.05%	0.66%	10.84%	11.14%	
Water Consumption (with co-product water credit)							
Corn cultivation	(billion L)						
- Green water (9)		2,097	1,060	4,613	714	1,849	
- Blue water (9)					301	855	
- % of State total irrigation water (5)					8.0%	7.3%	
Ethanol conversion	(billion L)						
- Blue water		13.2	6.9	31.0	3.2	10.0	
- % of State total industrial + public supply water (7)		0.46%	0.03%	0.15%	0.64%	1.15%	
BW used for ethanol as % of total state-wide BW use (8)		0.06%	0.05%	0.66%	5.72%	6.19%	

Notes

(1) Based on (RFA 2010) which gives operating capacity as of January 2010
(2) Based on share of Dry Mills in total ethanol production in 2009 (88%) from RFA website
(3) Corn required is based on assumed ethanol yield for dry mill and wet mill plants (See SI-I). Share of irrigated and rainfed corn is based on (USDA 2010)
(4) GW and BW requirements for corn cultivation are based on results of our model
(5) Total irrigation water are from 2008 FRIS ((USDA 2010)

(6) BW requirements for ethanol conversion are based on our model and assumptions of process and cooling water use in dry and wet mills (See SI-I)
(7) Data for 2005 (latest available) from (USGS 2009).
(8) Total BW water use in state is based on irrigation water use in 2008 from (USDA 2010) and all other water use (industrial, mining, domestic, livestock, thermoelectric) in 2005 from (USGS 2009)
(9) Co-product credits are based on our model. Co-products for ethanol from corn grain using both dry mill and wet mill conversions.

4.4 "Average" versus "marginal" analysis

Table SII 4.5: Changes in corn and soybean production between

	All crops		**Corn grain**					**Soybean**	
	Change in acreage between 2003 & 2007		Change in corn acreage between 2003 & 2007			Corn grain yield (2007)(bu/acre)		Change in soybean acreage between 2003 & 2007	
	Total harvested cropland	Total irrigated cropland	Total acres harvested	Irrigated corn acres	Irrigated acreage as % of total (2007)	Irrigated yield:	Non-irrigated yield	Total acres harvested	Irrigated SB acres
IL	0%	21%	22%	57%	2%	172.9	171.8	-21%	-39%
IN	1%	27%	24%	49%	3%	146	150.1	-17%	-3%
IA	-1%	33%	18%	46%	1%	114	166	-17%	7%
KS	5%	3%	48%	12%	14%	192	103.1	2%	-16%
NE	5%	12%	25%	30%	47%	174.1	119.3	-16%	-18%

Source: 2002 and 2007 Census of Agriculture (USDA 2009)

4.5 Comparison with fossil fuels

Table SII 4.6: Summary of water intensity of gasoline from various sources of crude oil

Source of gasoline	L of water / L of gasoline	L of water / VKT
US conventional crude oil	3.4 - 6.5	0.41 - 0.78
Canadian Oil Sands (surface)	5.2	0.62
Canadian Oil Sands (in-situ)	2.4	0.29
US Oil Shale (surface)	3.3 - 5.2	0.4 - 0.62
US Oil Shale (in-situ)	2.4 - 8.4	0.29 - 1.01

Notes: Assumes vehicle efficiency of 3.88 MJ/VKT (5,914.75 BTU/VMT; Section 2.4 SI-I).
Source: (Wu, Mintz et al. 2009)

Table SII 4.6: Water intensity of crude oil and gasoline: detailed information

Source	Water Intensity	Source	Notes
Crude oil production	L water / L of crude oil produced		
US conventional crude oil	2.1 - 5.4	Wu and Wang 2009	Estimates for on-shore production which accounts for 67% of US crude production in 2005. Accounts for reinjection of produced water. Weighted average of various recovery technologies - conventional (4.5%), secondary (50%), and tertiary or enhanced recovery (12.5%)

Canadian Oil Sands (surface)	4.0	Wu and Wang 2009	59% of Canadian oil-sands-based crude oil production in 2005. Accounts for recycling of water from tailing ponds
Canadian Oil Sands (in-situ)	1.0	Wu and Wang 2009	Assumes recycling of 80% of the steam used for oil extraction and processing
US Oil Shale (surface)	2 - 4	GAO 2010	Data is based on limited experience from demonstration projects. No commercial production yet
US Oil Shale (in-situ)	1 - 12	GAO 2010	As above. Average water intensity of 5 L/L
Refining	L/L of crude oil refined		
Conventional crude	1.53	Wu and Wang 2009	1 L of crude oil generates 1.062 L of gasoline
Synthetic crude from oil sands	As above	Wu and Wang 2009	

Source: (Wu, Mintz et al. 2009)

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