The Water Footprint of Yuma Durum Wheat Production

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Summary

This study estimates the green, blue, grey, and overall water footprint of durum wheat production in Yuma County, Arizona. A product's water footprint is the volume of freshwater used to produce the good. Green water is the consumptive use of rainwater stored in the soil. Blue water is the crop consumptive use of irrigation water. Grey water is the amount of freshwater required to assimilate the load of pollutants based on existing ambient water quality standards. Adding up green, blue, and grey water footprints, the overall water footprint for Yuma durum production, based on local data was 1,090 m^3 / MT. This overall footprint is 22% lower than that reported by the Water Footwork Network. The present study makes use of more accurate, local irrigation and precipitation data not used in other analyses that rely on more aggregate and indirect measurements. Yuma's durum wheat water footprint is among the lowest of areas in the world producing durum wheat.

Introduction

A product's water footprint is the volume of freshwater used to produce the product. One may be interested in the water footprint of a specific process step (e.g. durum wheat cultivation as a first stage in pasta production). Alternatively, one may be interested in the water footprint of a final product, measuring water consumption throughout the entire value chain. Water footprint assessment water use into green water, blue water, and grey water. Green water measures the consumptive use of rainwater stored in the soil (Falkenmark and Rockström, 2004). Green water use is the minimum of effective rainfall and crop water requirement (Chapagain et al., 2006; Aldaya et al., 2010). Effective rainfall is the percentage of rainfall available to plants and crops, subtracting losses from runoff, evaporation, and deep percolation. If effective rainfall is less than crop water requirements, then green water use is effective rainfall. This also means that rainfall alone is insufficient to meet crop requirements. If effective rainfall is in excess of crop water requirements, then green water use equals the crop water requirement. Excess water evaporates, becomes runoff, or percolates into the groundwater table. The definition green water used by a crop in a given area means that effective precipitation will always be an upper bound of green water use. Blue water is the consumptive use of ground and surface water applied to crops through irrigation. Mekonnen and Hoekstra (2011) define grey water as, "the volume of freshwater that is required to assimilate the load of pollutants based on existing ambient water quality standards (p. 1578)."

The Water Footprint Network (WFN) first developed standards for conducting water footprint assessments in 2009 (Hoekstra et al., 2009), with a "final" standard published in 2011 (Hoekstra et al. 2011). The WFN has published additional guidelines addressing measurement of grey water footprints (Franke et al. 2013). The beverage industry published water use guidelines that were generally consistent with WFN standards (BIER 2011). Since then, private companies have increasingly been assessing, measuring and reporting the water footprint of their production processes and final products (Hoekstra, 2015, Ruini et al., 2013; Antonelli and Ruini, 2015; Esposito et al., 2016).

Comparative Water Footprint Calculations for Wheat

Recent studies have attempted to estimate the water footprint for wheat production in general and durum wheat production in particular. The Water Footprint Network (WFN) provides estimates of water footprints for a variety of commodities, including wheat. Their analysis combines production of common wheat and durum wheat. The site reports how much water is used (measured in cubic meters, m^3) to produce one metric ton (MT) of wheat. (http://waterfootprint.org/en/water-footprint/product-water-footprint/) Mekonnen and Hoekstra. (2011) and Hoekstra et al, (2011) describe methods used in WFN assessments to estimate the green, blue and grey water footprint of crops and derived crop products.

Table 1 reports water footprint estimates of wheat production for selected countries. Table 1 also compares WFN estimates with those from other published studies as well as from this author's calculations. In several key cases, there are significant differences between estimates published by the WFN and those of peer-reviewed studies. In part, this is because WFN reports estimates for all wheat (including common wheat) production, while several other studies focus on production in durum-dominated regions.

For the USA, the WFN, Mekonnen and Hoekstra (2010), and Ruini et al. (2013) report values in the 2,100-2,200 m^3 / MT range. Ruini et al. (2013) report separate figures of 1,440 1,403 m^3 / MT for the North USA and 1,403 m^3 / MT for the Southwest USA. Antonelli & Ruini (2015) also use the 1,403 m^3 / MT figure for durum wheat production in Arizona. This total, as well as its components (green, 399 blue, 848 and grey, 156 m^3 /MT) are the same as those reported by the WFN.

The Water Footprint of Yuma County Durum Wheat

Green water footprint

The WFN site reports a green water footprint for wheat production in Arizona of 399 m^3 / MT. Recall first that green water is the consumptive use of rainwater stored in the soil, equal to the minimum of effective rainfall and crop water requirements and second. This means that effective precipitation is the upper bound of green water use, so an upper bound estimate of Yuma's green water footprint (in liters / kg) would be effective precipitation (in liters / ha) divided by yield (in kg / ha). Yet, the 10-year average for yields Yuma durum wheat has been 106.69 bushels per acre based on data from the USDA, National Agricultural Statistical Service (NASS) (http://www.nass.usda.gov/Quick_Stats/),[1] which equals 7,175 kg / ha. For Yuma's green water footprint to equal 399 m^3 / MT, given these yields, effective precipitation would have to be slightly more than 286 mm or more than 11.25 inches during the growing season.

Given Arizona's climate generally, and Yuma's climate in particular, there are obvious problems with applying this green water footprint estimate to Yuma's durum wheat production. First, while 11.25 inches of annual precipitation may be reasonable as a statewide average, it is not for wheat-growing areas of Yuma County where rainfall is far less, on the order of 2.5 to 4 inches annually (see below). Second, the growing season for durum wheat production is relatively short. Planting begins in December, with most acres planted by the end of January. Table 2 shows the share of the Arizona durum wheat planted and harvested at the end of selected weeks. Again, the data are available through the USDA, NASS. Data on acreage planted goes back to 2015, while data on acreage harvested goes back to 2014. More than half the crop is harvested by mid-June with the entire crop usually harvested by the end of July. While some planting begins in December, most of the crop is not planted until January.

Next, we take data from cooperating Yuma weather stations in the Western Regional Climate Center (WRRC) network (http://www.wrcc.dri.edu/). Data were selected from stations that (a) had a long-term, continuous record of recording and (b) were relatively close to the main wheat-growing areas of the county. WRRC reports monthly average precipitation estimates as a long-term average from 1981 to 2010. Data from five stations were selected: Yuma Proving Ground, Yuma Valley, Yuma Quartermaster Depot, Yuma International Airport, and Tacna 3, NE. Long-term (1980 to 2010) average precipitation by month from each of these stations is reported in Table 3. Long-term data from the Yuma stations show that annual precipitation is approximately 3 to 4 inches per year, not 11.25 as implied by the WFN green water footprint. In addition, a significant share of the area's rainfall comes in the form of summer monsoons. About 30-40% of precipitation occurs from August to November, after the durum wheat harvest and well before planting. Table 3 reports total precipitation over the December-to-July durum crop season separately from annual totals. These totals are converted to mm of precipitation, which is then converted to liters per hectare of land area. If one measures only precipitation from the beginning December to the end of July, and takes a simple average of readings from the five Yuma weather stations, then precipitation only averages 54.2 mm) This implies 542,036 liters per hectare. Given 10-year average yields of 7,174.90 kg / ha, this implies an upper bound green water footprint of less than 76 m^3 / MT, not the 399 m^3 / MT reported by the WFN for Arizona.

Even this 76-m^3 / MT figure, however, assumes that the wheat crop takes up 100% of the rain that falls over these months and that 0% is lost to runoff, evaporation, or deep percolation. As such, it overestimates the green water footprint. To the extent that these losses occur, *effective* precipitation would be lower, as would the green water footprint. The US Bureau of Reclamation (BOR) has developed a formula to estimate this effective precipitation defined as the amount of precipitation that infiltrates and remains in the soil and so is available for crop consumptive

[1] USDA did not report Yuma durum wheat yields for 2008. The 10-year average included years 2006-7 and 2009-2018.

use. In other words, this measure green water use. The formula is: Effective Precipitation = Daily Precipitation × Monthly Effective Precipitation Coefficient. Jensen (1993, 1998) reports the documentation for the effective monthly precipitation coefficients used by BOR. These are as follows: 0.4 from October to February, 0.2 for March, and 0.0 for April to September. Table 4 reports estimates of effective precipitation and the resultant green water footprint based on a simple, unweighted average from the five Yuma weather stations. Applying the effective precipitation coefficients from Jensen (1993, 1998) reduces the estimated green water footprint even further, to 21 m^3/ MT.

A second way to estimate the green water footprint is to make use of data from the Lower Colorado River Accounting System (LCRAS) of the US Bureau of Reclamation (BOR), which measures consumptive use of water along the Lower Colorado River. The LCRAS analyses estimated monthly precipitation along different regions based on reading from Arizona Meteorological Network (AZMET) stations. LCRAS is concerned with consumptive use Colorado River water. It therefore seeks to derive estimates of irrigation water (blue water) taken for crops over and above green water supplies that come as effective precipitation.

BOR estimates effective precipitation as the product of recorded precipitation and an effective precipitation coefficient. BOR relies on rain gauge data from CIMIS (California Irrigation Management Information System and AZMET (Arizona Meteorological Network) and (NWS) National Weather Service stations along the Colorado River. Stations in Yuma County include, for the Wellton-Mohawk area, Roll (AZMET), Roll ETo (AZMET), and Tacna 3, NE (NWS). The Wellton-Mohawk Irrigation and Drainage District is among the largest wheat producing areas in the county. For the Yuma Area, stations include Yuma North Gila, Yuma South, Yuma Valley, and Yuma Valley ETo (all AZMET) as well as from Yuma Proving Ground, Yuma Quartermaster, Yuma 9.7 ESE, Yuma 13.8 ESE, and Yuma MCAS (all from the NWS). Table 5 reports precipitation estimates from LCRAS (2013) and separates out precipitation during the crop season for durum wheat from precipitation over the entire year..

LCRAS reports precipitation data separately for the Wellton Mohawk area and the Yuma Area. The Wellton Mohawk area lies in the Gila River Valley, while the Yuma Area is along the Colorado River Mainstem from Davis Dam the Mexican border. Growing-season precipitation is between 50 and 60 mm. Table 5 weights green water usage by each region's share of wheat acreage (as reported by LCRAS, 2013). Based on these data, the green water footprint for durum wheat production is 74 m^3 / MT. Again, however, if one applies Jensen's (1993, 1998) monthly effective precipitation coefficients to the results suggest an even lower green water footprint of 15 m^3 / MT (Table 6). This green water footprint has the advantage of explicitly accounting for effective precipitation and weighting precipitation estimates by crop acreage in different areas. With this more accurate, local-level accounting the green water footprint of 15 m^3 / MT is 96% lower than that reported for Arizona by the WFN.

Blue water footprint

Since 1995, BOR's LCRAS has published a *Lower Colorado River Annual Summary of Evapotranspiration and Evaporation* report. The most recent publically available report was published in 2013 (LCRAS, 2013). BOR (LCRAS, 2013), "administers a number of programs, some of which utilize remote sensing technology to monitor and estimate annual agricultural and riparian vegetation water use, and open water evaporation along the lower Colorado River from Hoover Dam to the Southerly International Border with Mexico (p. ES-1)." BOR estimates evapotranspiration (ET) from irrigated agricultural areas and reports data on types of crops grown and acreages of water users along the Lower Colorado River.

BOR uses Remote Sensing (RS) technologies and Geographic Information Systems (GIS) to identify acreages of different types of crops grown in the program area. BOR uses satellite imagery from Landsat Thematic Mapper sensors, other satellites, and other aerial imaging systems. In addition, BOR "ground truths" remotely sensed assessments of which crops are grown on which fields throughout the year by collecting data from ground reference surveys. BOR conducts a stratified random sample, selecting irrigated fields from a GIS database to ensure that all major crop groups are represented. Additional details of sampling procedures are reported in LCRAS (2013) and Stehman and Milliken (2007). BOR achieves an accuracy of 90 percent or better for crop groups in the program area.

BOR explicitly accounts for the effect of rainfall on crop water use by subtracting effective precipitation (inches) from the ET rate for each crop group. This generates an estimate of blue water use, water directly consumed in the process of taking water to irrigate crops. To calculate ET for selected crops, BOR calculates an ET rate for each crop by multiplying the average daily reference ET values by each group's unique daily ET coefficient, Kc. The *Lower*

Colorado River Accounting System Evapotranspiration and Evaporation Calculations, Calendar Year 2008 (Appendix, Part 2) reports daily Kc values for different crops.

LCRAS (2013) provides the most recent report on crop acreage ET for irrigators in Yuma. Strictly speaking, LCRAS reports ET and acreage for Small Grains Spring, not specifically durum wheat, and which may include barley, oats and millet. This is of little consequence for our blue water footprint calculations. First, historical USDA data suggests durum wheat accounts for 92% or more of small grains acreage in Yuma annually. Second, barley's crop ET is quite similar to that of durum wheat (Husman and Ottman, 2004; Ottman, 2008). Therefore, any biases associated with including barley in data in the overall averages will be small. Production of oats and millet in the county have been so limited that USDA does not record or report acreage. Estimates of blue water use in Yuma durum wheat production were 5,358 / hectare based on LCRAS (2013) data (Table 7).

University of Arizona Cooperative Extension publications have previously reported crop ET for durum wheat in the ranges of 20 inches to 24 inches per acre (Noble, 2015; Husman and Ottman, 2004). LCRAS estimates are in this range, at 21.1 inches. Based on the 10-year average of durum wheat yields of 7.175 MT / ha, the blue water footprint for Yuma durum wheat production is 747 m^3 / MT. This is 12% lower than the WFN estimate for Arizona of 848 m^3 / MT.

Grey water footprint

The WFN reports a global average grey water footprint of 207 m^3 /MT for wheat, with and average U.S. footprint of 229 m^3 /MT. For Arizona, both the WFN and Ruini et al. (2013) report a green water footprint of 156 m^3 /MT. Hoekstra et al. (2011) and Franke et al. (2013) identify a three-tier approach for estimating diffuse pollution loads to water bodies. Tier 1 requires the least amount of data. Moving to Tiers 2 then 3, increases measurement accuracy but require more localized data on soils, climate, and hydrology. To calculate global estimates of the grey water footprint for wheat, Mekonnen and Hoekstra (2010) consider only nitrogen as a pollutant entering water bodies. We follow their approach here using Tier 1 methods to estimate the grey water footprint for wheat. This method calculates the amount of water needed to assimilate the pollutant (nitrogen) as a simple function of fertilizer application rates, a leaching runoff fraction, water quality standards, naturally occurring nitrogen and crop yields. The formula is:

$$\text{Grey WF} = [(\delta * AR) / (c_{max} - c_{nat})] \times (1/Y)$$

Where:

AR	= the nitrogen fertilizer application rate (in kg / ha)
δ	= the leaching runoff fraction (measured as a %)
c_{max}	= the maximum acceptable (or allowable) concentration of nitrogen (in kg / m^3)
c_{nat}	= the natural concentration of nitrogen in the receiving water body (in kg / m^3)
Y	= yield per acre of the crop, in this case durum wheat (in MT / ha)

Mekonnen and Hoekstra (2010) note studies reporting values of nitrogen leaching (δ) of 2% to 13%. Chapagain et al. (2006) and Mekonnen and Hoekstra (2010) and Hoekstra et al. (2011) assume a constant leaching-runoff fraction of 10% ($\delta = 0.1$). Next, lacking data, they assume that the natural level of nitrogen in the receiving water body equals zero. Finally, they assume a maximum acceptable concentration of nitrogen of 10 mg / liter, based on the standard recommended by the U.S. EPA. Below, we follow this approach for the Yuma grey water footprint.

According to the Cooperative Extension publication, *Nitrogen Fertilizer Management in Arizona*, for wheat (and other small grains, "With good management, a total of about 150 to 230 lbs. N per acre is usually needed for optimal production." University of Arizona Crop Enterprise Budgets for Yuma County estimate representative applications rates to be 210 pounds of nitrogen per acre in durum wheat production, which translates to 235 kg / ha. Again, assuming 10-year average yields of 7.175 MT / ha, the grey water footprint becomes:

$$\text{Grey WF} = [(0.1 * 235 \text{ kg / ha}) / (10 \text{ mg/ l})] \times (1/7.175 \text{ MT /ha})$$

$$\text{Grey WF} = 23.5 \text{ kg / ha } / 0.01 \text{ kg / m}^3 \times (1/7.175 \text{ MT /ha}) = 328 \text{ m}^3 \text{ / MT.}$$

Unlike the case with green and blue water footprints, the grey water footprint for Yuma appears to be greater than what the WFN and Ruini et al. (2013) report for Arizona.

Overall water footprint

Based on local production, precipitation, crop ET and nitrogen fertilizer data, the overall water footprint for durum wheat production in Yuma is 1,090 m3 / MT. This is comprised of green water footprint of 15 m^3 / MT, a blue water footprint of 747 m^3 / MT and a grey water footprint of 328 m^3 / MT. This is 22% less than the estimated 1,090-m3 / MT figure reported by the WFN and by Ruini et al. (2013) for Arizona.

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Table 1. Comparative water footprint estimates in m^3 / MT

	Green	Blue	Grey		Total
Water Footprint Network (2019)					
Italy (excluding Sicily)	1,188	16	187		1,391
Turkey	2,074	130	196		2,399
Greece	1,486	29	135		1,650
France	581	1	5		588
Australia	1,998	16	102		2,116
Canada	1,336	5	201		1,542
USA	1,869	92	229		2,191
Arizona	399	848	156		1,403
Mekonnen and Hoekstra (2010)					
USA	1,879	92	230		2,202
Ventrella et al (2015)					
South Italy, rainfed	2,718	0	NR		2,718
South Italy, irrigated			NR		2,193
Aldaya & Hoekstra (2010), Italy	748	525	301		1,574
Zotou & Tsihrintzis (2017)					
Greece (B-C)	991	1,002	951		2,943
Greece (P-M)	1,043	724	951		2,718
Esposito et al. (2016)					
Italy, Puglia	1,372	-	212		1,584
France	581	-	5		586
Australia	1,998	-	102		2,100
USA	1,869	-	229		2,098
Ruini et al. (2013)					
Turkey (irrigated)	2,909	172	265		3,346
Turkey	2,074	-	196		2,270
Bulgaria	1,471	-	373		1,844
Spain	1,394	-	279		1,673
Greece	1,486	-	135		1,621
South Italy	1,372	-	212		1,584
Middle Italy	1,157	-	193		1,350
North Italy	997	-	172		1,169
France	581	-	5		586
Australia	1,998	-	102		2,100
Canada	1,336	-	201		1,537
North USA	1,256	-	184		1,440
Southwest USA	399	848	156		1,403
Mexico	333	558	185		1,076
Kersebaum et al (2016)					
Italy, Fogia low					1,327
Italy, Fogia high					1,694
Antonelli & Ruini (2015)					
Arizona	399	848	156		1,403
Central & Southern Italy	1,200	-	153		1,353
Yuma, author's calculation	15	747	328		1.090

Table 2. Arizona crop progress (% of crop planted and harvested): durum wheat

Season	Date (week ending)	Percent of crop planted		Date (week ending)	Percent of crop harvested
2013/4				6/22/2014	63
				6/29/2014	70
				7/6/2014	84
				7/13/2014	95
				7/20/2014	100
2014/5	1/18/2015	45		6/28/2015	65
	1/25/2015	72		7/5/2015	75
				7/12/2015	85
				7/19/2015	95
				7/26/2015	100
2015/6	12/20/2015	9		6/26/2016	60
	12/27/2015	10		7/3/2016	75
	1/3/2016	15		7/10/2016	80
	1/10/2016	20		7/17/2016	90
	1/17/2016	30		7/24/2016	98
	1/24/2016	40			
	1/31/2016	70			
2016/7	12/25/2016	0		7/2/2017	84
	1/1/2017	22		7/9/2017	89
	1/8/2017	25		7/16/2017	92
	1/15/2017	29		7/23/2017	94
	1/22/2017	53		7/30/2017	96
	1/29/2017	62			
2017/8	12/31/2017	21		6/10/2018	41
	1/28/2018	58		6/17/2018	60
				6/24/2018	75
				7/1/2018	85
				7/8/2018	95

Source: USDA, NASS

Table 3. Precipitation from WRCC stations and upper bound green water footprint estimates (excluding water lost to runoff, evaporation, or deep percolation)

	Yuma Valley		Tacna 3, NE		Yuma Proving Ground		Yuma International Airport		Yuma Quartermaster Depot		Five Station Average
	12 month	Crop Season	12-month	Crop Season	12-month	Crop Season	12-month	Crop Season	12-month	Crop Season	
Jan	0.34	0.34	0.43	0.43	0.52	0.52	0.39	0.39	0.5	0.5	
Feb	0.28	0.28	0.52	0.52	0.51	0.51	0.37	0.37	0.49	0.49	
Mar	0.36	0.36	0.41	0.41	0.36	0.36	0.31	0.31	0.29	0.29	
Apr	0.15	0.15	0.14	0.14	0.13	0.13	0.13	0.13	0.09	0.09	
May	0.01	0.01	0.07	0.07	0.01	0.01	0.04	0.04	0.05	0.05	
Jun	0.01	0.01	0.07	0.07	0.02	0.02	0.05	0.05	0.02	0.02	
Jul	0.31	0.31	0.37	0.37	0.27	0.27	0.34	0.34	0.09		
Aug	0.45		0.6		0.65		0.57		0.24		
Sep	0.17		0.34		0.32		0.29		0.17		
Oct	0.15		0.23		0.22		0.21		0.13		
Nov	0.26		0.32		0.29		0.26		0.25		
Dec	0.57	0.57	0.47	0.47	0.48	0.48	0.43	0.43	0.36	0.36	
Total (in)	3.04	2.03	3.97	2.48	3.76	2.3	3.39	2.06	2.6	1.8	
Total (mm)		51.56		62.99		58.42		52.32		45.72	54.20
Liters (000) / ha		515.6		629.9		584.2		523.2		457.2	542.0
Avg. yield (kg/ha)		7,175		7,175		7,175		7,175		7,175	7,175
Liters / kg		72		88		81		73		64	76

Table 4. The green water footprint for Yuma durum wheat production, based on effective precipitation and simple average precipitation from WRCC stations

	Yuma Valley		Tacna 3, NE		Yuma Proving Ground		Yuma International Airport		Yuma Quartermaster Depot		Five Station Average
	Effective Precipitation in Inches*										
	12-month	Crop Season	12-month	Crop Season	12-month	Crop Season	12-month	Crop Season	12-month	Crop Season	
Jan	0.136	0.136	0.172	0.172	0.208	0.208	0.156	0.156	0.2	0.2	
Feb	0.112	0.112	0.208	0.208	0.204	0.204	0.148	0.148	0.196	0.196	
Mar	0.072	0.072	0.082	0.082	0.072	0.072	0.062	0.062	0.058	0.058	
Apr	0	0	0	0	0	0	0	0	0	0	
May	0	0	0	0	0	0	0	0	0	0	
Jun	0	0	0	0	0	0	0	0	0	0	
Jul	0	0	0	0	0	0	0	0	0	0	
Aug	0	0	0	0	0	0	0	0	0	0	
Sep	0	0	0	0	0	0	0	0	0	0	
Oct	0.15		0.23		0.22		0.21		0.13		
Nov	0.26		0.32		0.29		0.26		0.25		
Dec	0.228	0.228	0.188	0.188	0.192	0.192	0.172	0.172	0.144	0.144	
Annual (in)	0.958	0.548	1.2	0.65	1.186	0.676	1.008	0.538	0.978	0.598	
Annual (mm)		13.92		16.51		17.17		13.67		15.19	15.29
Liters / hectare		139,192		165,100		171,704		136,652		151,892	152,908
Avg. yield (kg/ha)		7,175		7,175		7,175		7,175		7,175	7,1750
Green water footprint m^3 / MT		19		23		24		19		21	21

* Base values from Table 3 adjusted by effective monthly precipitation coefficients (Jensen, 1993, 1998): 0.4 from October to February, 0.2 for March, and 0.0 for April to September

Table 5. Precipitation estimates from LCRAS and upper bound green water footprint (excluding water lost to runoff, evaporation, or deep percolation)

	Wellton Mohawk		Yuma Area	
	Precipitation (in)		Precipitation (in)	
	12-month	Crop season	12-month	Crop season
Jan	0.19	0.19	0.85	0.85
Feb	0.23	0.23	0.02	0.02
Mar	0.06	0.06	0.08	0.08
Apr	0	0	0	0
May	0	0	0	0
Jun	0	0	0	0
Jul	1.11	1.11	0.94	0.94
Aug	0.19		1.12	
Sep	0.63		1.06	
Oct	0.02		0	
Nov	1.41		1.39	
Dec	0.75	0.75	0.09	0.09
Total (in)	4.59	2.34	5.55	1.98
Total (mm)		59.44		50.29
liters /ha		594,360		502,920
kg/ha		7,175		7,175
liters /kg		82.8		70.1
Share of county wheat acres		34%		66%
Contribution to footprint		28		46
Green water footprint				74

Table 6. Effective precipitation* estimates from LCRAS and upper bound green water footprint

	Wellton Mohawk		Yuma Area	
	Precipitation (in)		Precipitation (in)	
	12-month	Crop season	12-month	Crop season
Jan	0.076	0.076	0.34	0.34
Feb	0.092	0.092	0.008	0.008
Mar	0.012	0.012	0.016	0.016
Apr	0	0	0	0
May	0	0	0	0
Jun	0	0	0	0
Jul	0	0	0	0
Aug	0	0	0	0
Sep	0	0	0	0
Oct	0.008	0	0	0
Nov	0.564	0	0.556	0
Dec	0.3	0.3	0.036	0.036
Total (in)	1.052	0.48	0.956	0.4
Total (mm)		12.192		10.16
liters /ha		121,920		101,600
kg/ha		7,174.90		7,174.90
liters /kg		17.0		14.2
Share of wheat acres		34.0%		66.0%
Contribution to footprint m^3 / MT		6		9
Green water footprint m^3 / MT				15

* Base values from Table 5 adjusted by effective monthly precipitation coefficients (Jensen, 1993, 1998): 0.4 from October to February, 0.2 for March, and 0.0 for April to September

Table 7. Blue water footprint for Yuma durum wheat production

Total crop ET (acre feet)	76,915
Durum acres	43,752
ET / Acre (acre feet)	1.76
ET / acre (inches)	21.10
m^3 of blue water	94,873,497
Durum hectares	17,706
Blue water m^3 / hectare	5,358
Durum bushels	4,667,872
Durum kg	127,059,482
Blue water footprint (m^3 / MT)	747