Alpheus Water Blog

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Virtual Water—Real Price Upside for Benefitted Land

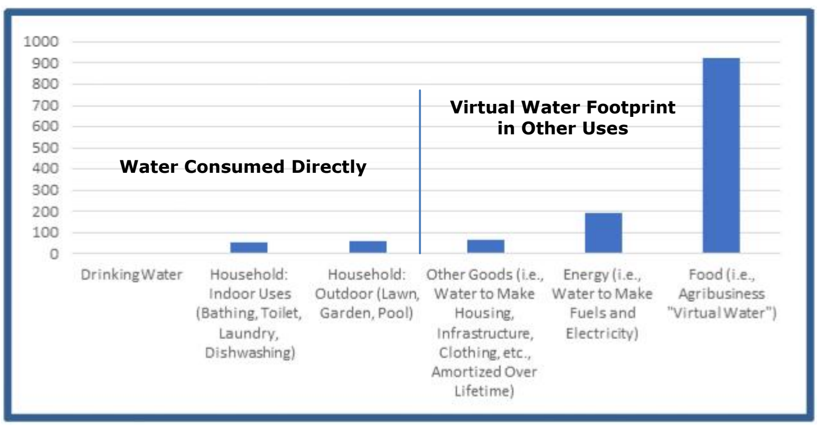
Summary

With a given amount of land and sun, agribusiness sustainability will be increasingly driven by access to water. Most of the world's largest agricultural zones rely on rapidly depleting supplies of artificially cheap water. The water is underpriced because it only reflects the cost of pumping from the depleting aquifers and/or the transportation cost of aqueducts and pipes.

"Wholesale" water is difficult to price because it is not easily tradable, is heavily subsidized, and is usually subject to archaic water-rights laws that lead to a "tragedy of the commons." Without specific, quantifiable rights, aquifer resources are depleted in a "rush to drill" that has been called "akin to an arms race" in some parts of the world. However, water scarcity will ultimately lead to higher water costs and dramatically alter the world's production of "virtual water": i.e., the more easily traded "downstream" crops and other water-intensive products. As indicated in Figure 1,[1] the virtual water of the food we eat and the products we use is far more important than the water we consume directly.

0251797504Ultimately, water scarcity will also close the cost-of-farmland gap for millions of acres of water-stressed vs. water-benefitted land. As water scarcity increases, the cost of water will increase, but the land that has sustainably inexpensive water[2]—including Brazil's "Cerrado" and parts of Africa—will likely appreciate. Conversely, most of the world's most productive agricultural basins—including California and the high-plains U.S. Midwest, as well as China, India, and Australia—are increasingly fed from depleting aquifers. These farms will need to become much more water efficient, shift to less water-intensive agricultural goods, completely repurpose the land, or abandon the land entirely.[3]

Figure 1: Average per Capita U.S. Water Use (Gallons per Day)



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[1] Alpheus Water Research estimates, based on: "Water Questions and Answers: How Much Water does the Average Person Use at Home per Day," USGS Water Science School, water.usgs.gov/edu/qa-home-percapital.html; "Water for Food" one-page summary, UNWater.org.

[2] In other words, particularly the land that is fed with rainfall and nearby rivers rather than depleting aquifers.

[3] Please also refer to prior Alpheus Water Blog report, "Depleting Aquifers: The End Game for Cheap Water."

Water Pricing Distortions Everywhere

Water is chronically underpriced globally and mispriced from region to region due to:

1. **Subsidies:** Since water is considered a "human right" that is usually unsubstitutable at any price, water pricing benefits from a plethora of direct and indirect subsidies, including inexpensive government-backed financing and dilapidated legacy assets (i.e., that have no book value but that are deferring huge replacement and upgrade expenditures).
2. **Artificially Low Costs:** Costs are low due to the "borrowed" water of tapping aquifers, lakes, and rivers beyond their natural replenishment.
3. **Poor Fungibility:** Water is difficult to transport or trade because it is very heavy, yet very inexpensive; while oil is $45/bbl, water is only $0.35/bbl. Hence, any significant manmade transportation infrastructure will usually dwarf the cost of "local" water.
4. **Antiquated Water Rights Laws:** "First come, first served" legacy water right laws and a growing population have led to over-tapping rivers and a "rush to drill" aquifers. Using the United States as an example, these water laws are divided into two categories:
   a. **Prior appropriation laws**, which govern the water rights in the western United States and are based on the view that the first person/entity to use a certain area's water resources has senior rights to that water in perpetuity as long as the use is continual.
   b. **Riparian rights**, which are dominant in the eastern United States and are based on the premise that every landowner on a riverbank has the right to use that water as it flows by.

Under both frameworks, the amount of water that can be drawn is ill-defined, leading to a "tragedy of the commons" of overdrawn aquifers and river depletion. The laws are also difficult to change given their "perpetuity" language and the many constituencies involved.

In most of the world, "wholesale" water costs are increasing modestly (from a practically zero base) due to deeper and more expensive pumping. Several countries and U.S. states have been able to implement some withdrawal rights that allow the water to be monetized. However, even without a full price signal (i.e., the cost of "new" water to offset depletion), the lack of available water at *any price,* especially during droughts, is forcing agribusiness and many water-intensive companies to re-think their water strategy.

Scarcity Begets Higher Prices for Water

Aquifers currently supply 30% of fresh water (and rising), and agribusiness uses 70% of global freshwater.[4] However, of the world's 37 largest aquifers, 21 are being depleted at unsustainable rates as the water extracted exceeds the natural rain/snowmelt replenishment.[5] Most of the depleting aquifers are in areas of the greatest population, agribusiness, and economic centers. As a result, 40% of the world's population is classified as "under water-stressed conditions," and this is expected to increase to 66% by 2025.[6] Many aquifers[7] (such as in California and the Ogallala in the Midwest United States) were formed prior to or during the last ice age and are not expected to replenish in any rainfall scenario.

The successive impacts of depleting aquifers include:

- In the short term, an increasing amount of energy is needed to pump water from deeper in the earth, leading to a rising cost for this water, especially versus purely rain-fed crop acreage.
- In the medium term, the cost of water rises even more as utilities scramble to build new infrastructure and technology that costs many multiples of water from rain, nearby rivers/lakes, and aquifers. A less

[4] "Aquifers: Underground Stores of Freshwater," Live Science, January 2014, and Browning World Climate Bulletin, July 2015.

[5] "Study: A Third of the Biggest Groundwater Sources in Distress," NASA's Jet Propulsion Laboratory, 2015.

[6] UN-Water: Statistics, Food and Agricultural Organization thematic fact sheet, October 7, 2014.

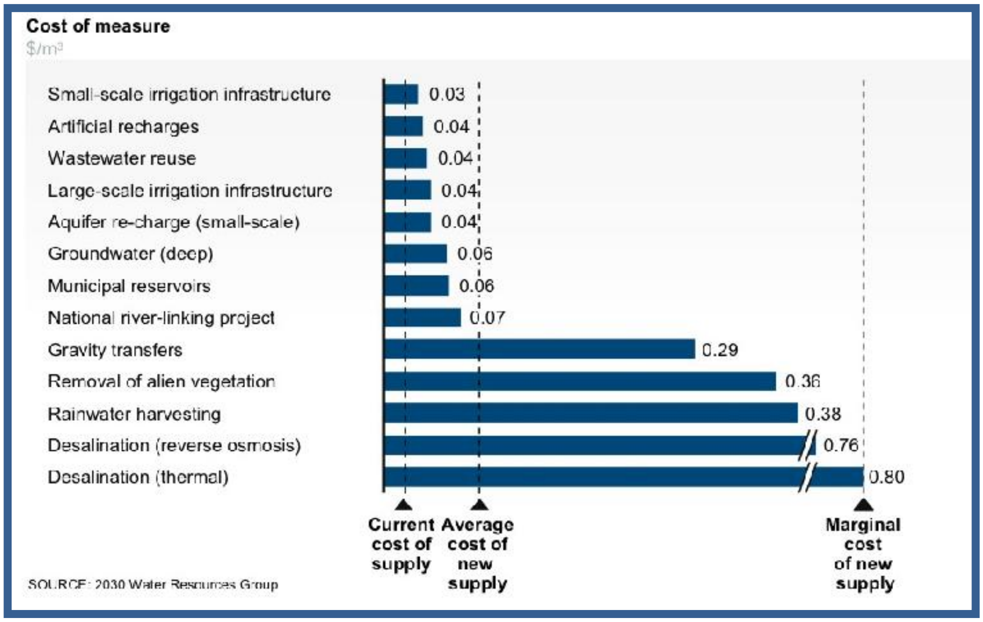
[7] Including in the United States, California's Central Valley aquifer and the Ogallala aquifer in the Midwest that support the country's two main agricultural zones.

visible consequence of depletion is sinking land: a recent study[8] identifies 26 (as a "non-comprehensive" list) of the world's largest cities and regions as sinking.[9]

- The long-term and most dramatic consequences can be shifts back to natural habitats (in many cases, deserts) and plants that can survive only from natural precipitation.

Throughout most of the world, the cost of water does not reflect the "marginal cost" of new water sources (such as longer aqueducts, desalination, water reuse, and other new technologies) that will be needed to replace depleting existing sources. Figure 2[10] below relates to India, with one of the worst water-deficits in the world but with a cost curve that is fairly representative globally. The cost of rainfall irrigation is close to zero, and aquifer pumping and legacy river aqueducts is generally less than two cents per cubic meter. Thus, all of these supply-side alternatives are at least 2–10x the cost of existing sources. More importantly, the two most scalable water sources have significant drawbacks: i) water reuse is politically difficult in the developed countries; and ii) desalination is very expensive, energy intensive, and can only be used near coastal areas due to the up-gravity pumping costs from sea-level.

Figure 2: Future Water Supply Faces a Steep Marginal Cost Curve (India)



Higher Water Costs Rationalize Land Use, Values

Despite a steadily increasing population and calorie consumption per capita, the earth's total developed farmland is expected to decline (Figure 3[11]) as a result of two offsetting factors:

1. **Unsustainable "Borrowed" Water:** As global aquifers are depleted, many farms will become uneconomical and repurposed.
2. **New Land:** Development of new farm acreage will be limited to the very few areas of the world with the undeveloped trifecta of soil/sun/water (mainly Brazil and Africa).

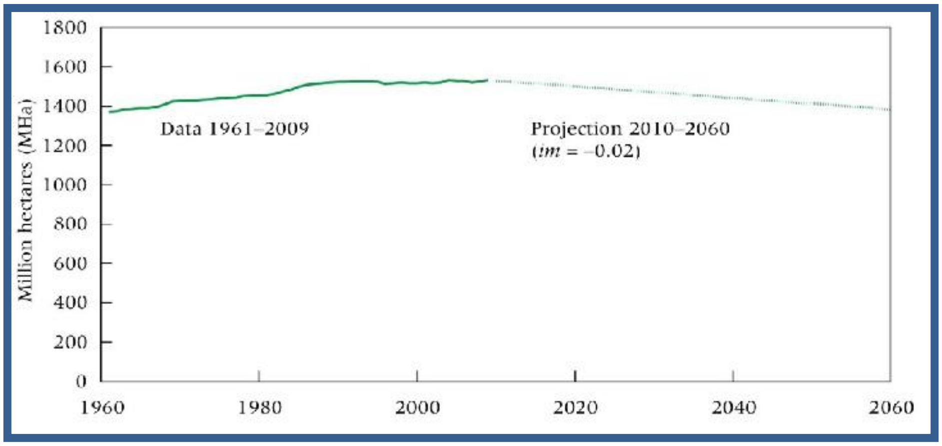
[8] "Rising Tides, Sinking Cities," *TNT World*, August 10, 2016, and "Sinking Cities," *Deltares*, 2013.

[9] Including: 10 in the United States (California, Arizona, Nevada, Idaho, Colorado, Texas, Louisiana, Delaware, Georgia, New Jersey); Mexico City; Bogota, Colombia; Amsterdam; Thessaly, Greece; Tehran, Iran; Quetta Valley, Pakistan; Bangkok, Thailand; Calcutta, India; Beijing, China; Tokyo, Japan; Ho Chi Minh, Vietnam; and Manila, Philippines.

[10] "Charting Our Water Future," The 2030 Global Water Resource Group (2009).

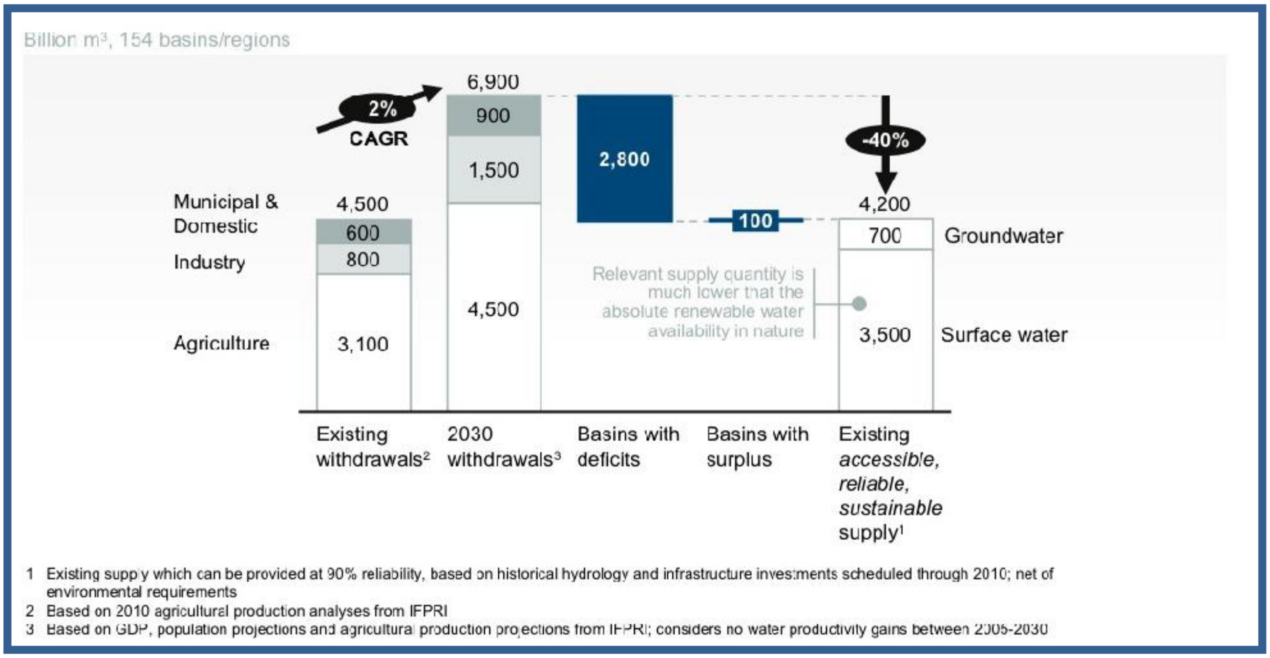
[11] Roser, Max, "Land Use in Agriculture," published online at OurWorldData.org (2016). 1961–2009 is from FAO, 2009.

Figure 3: Total Global Farmland Over Time



Thankfully, the gap from rising demand vs. slightly declining acreage will be offset by steady increases in water efficiency and agricultural yield due to new technologies for seeds, fertilizers, and irrigation. However, these gains will need to be enormous; the Global Water Resource Group[12] projects aquifer depletion of 2.8 trillion m^3 (or 40% of total demand) (Figure 4[13]), which will need to be offset by a matching 40% increase in sources and efficiency gains.

Figure 4: Aggregated Global Gap between Existing Accessible, Reliable Supply and 2030 Water Withdrawals, Assuming No Efficiency Gains



The U.S. Example: "Less Worse"

[12] A think-tank led by McKinsey & Co., Inc. that did a two-year study, "Charting Our Water Future" (2009).

[13] Water 2030 Global Water Supply and Demand model; agricultural production based on IFPRI IMPACT-WATER base case.

The United States is the third largest agricultural producer in the world, and its water challenges are less than that of China (#1) and India (#2) given a much smaller population per acre, less pollution, and more rational management.

However, even the U.S. agribusiness sector faces increasing water stress, the likelihood of rapidly increasing costs, and huge shifts in how the country manages its main two agricultural zones. Both of the United States' main agricultural regions are increasingly fed by depleting aquifers[14]: 1) the Ogallala, the largest known aquifer in the world covering most of the Midwest "grain belt" from South Dakota to Texas; and 2) California, which is increasingly dependent on its Central Valley aquifer to irrigate most of the fruits, vegetables, and nuts produced in the United States. Despite increasing water-stress, these two regions include some of highest cost farmland in the world (LHS) (Figure 5[15]), and U.S. farm prices have increased significantly in the past decade (RHS) (Figure 6[16]) even though crop prices have been benign.

Figure 5: Cost of Farmland per Acre

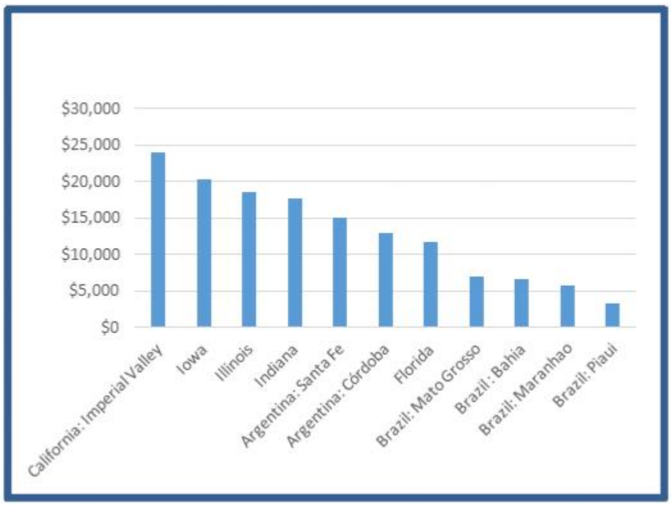
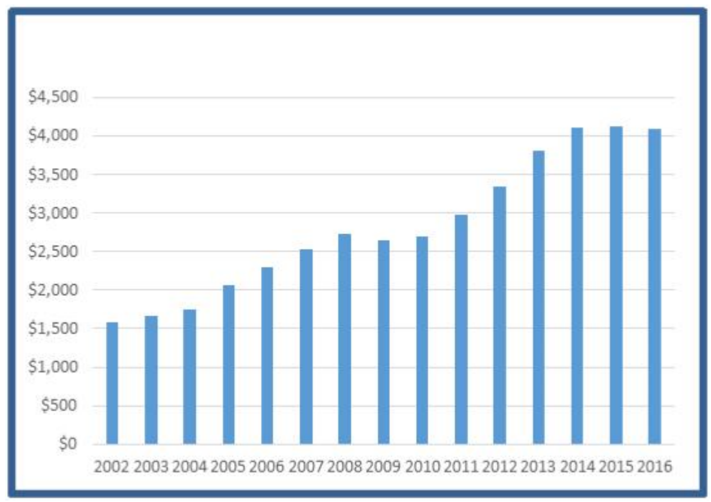


Figure 6: U.S. Cropland Historical Prices (US$/Acre)



Shifting to Higher "Crops per Drop"

Increasing water scarcity should also lead to a better allocation of the thirstiest crops to the most water-abundant areas. Figure 7[17] compares farm land that is relatively inexpensive vs. its water competitive advantage (upper left) to land that is relatively expensive vs. its low rainfall (lower right), the latter usually being supported by depleting aquifers. For example, both California and Florida have enormous agricultural sectors, together representing 99% of the country's water-thirsty orange production.[18] However, while both states have artificially cheap water from depleting underground aquifers, Florida's average rainfall is approximately 10x that of California's Imperial Valley.[19] Thus, although both states have similarly cheap water based on depleting aquifers, California's water should be priced at a level that is more in line with the cost of "new" water (i.e., from desalination or other technologies that are 2–5x the current cost), and the premium for California vs. Florida land will likely decline over time.

[14] Please also refer to the prior Alpheus Water Blog report, "Depleting Aquifers: the End of Cheap Water."

[15] SLC Agricola; Deloitte Touche; Information Economics, 2016; USDA; LandandFarm.com (California).

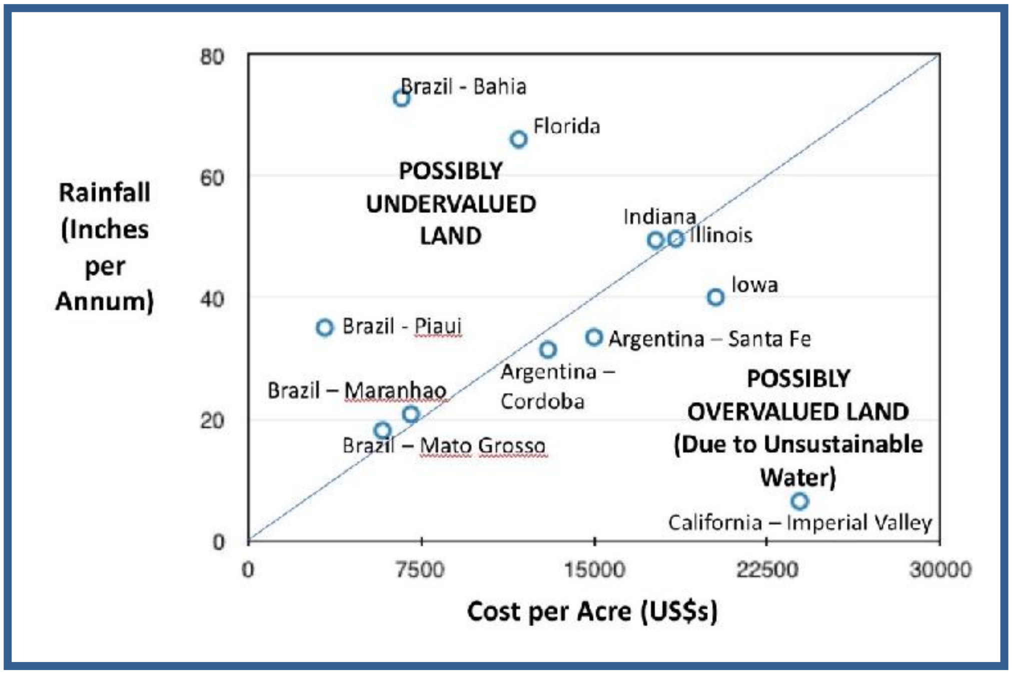
[16] USDA NASS

[17] SLC Agricola; weather.com.

[18] USDA National Agricultural Statistics Service.

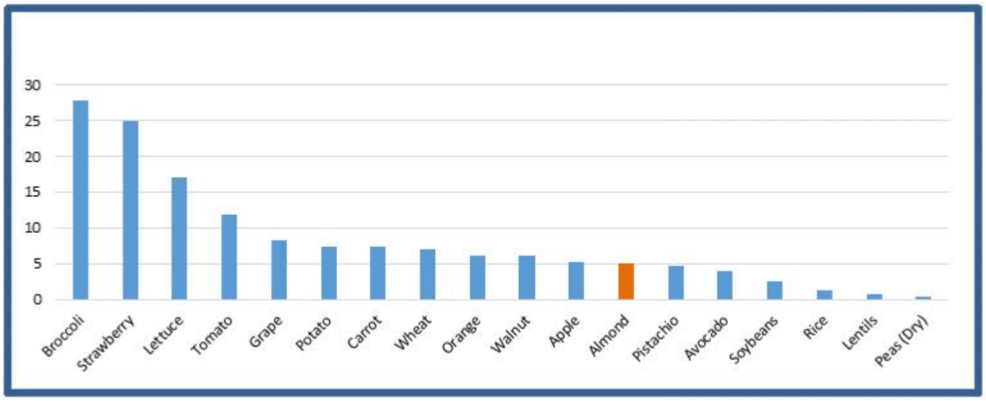
[19] Maxwell, Steve, *The Future of Water*, p. 76, 2011.

Figure 7: The Correlation of Global Farmland Price vs. Rainfall



Water scarcity will also shift from low value-added/gallon-of-water crops to higher value-added/gallon uses. Nevertheless, the value-add for agriculture is inherently subjective. For example, California almonds are oft-criticized for consuming about 10% of all the state's water (almost double that of Los Angeles), and opponents cite that it takes 1.1 gallons of water to produce a single almond (Figure 8[20]). However, one could also argue that if various crops are adjusted for their caloric value—as a measure of "nutritional value-add"—then almonds would be at least comparable in value-add per unit of water (Figure 9[21]).

Figure 8: Calories per Gallon of Water to Produce Fruits, Nuts, and Vegetables



[20] www.h2conserve.org, Water Footprint Handout; Olson-Sawyer, "Beef: The 'King' of the Big Water Footprints," dated August 1, 2011. GRACE Communications Foundation, 2016; www.growbiointensive.org and www.bountifulgardens.org; HLPE, 2015, Water for Food Security and Nutrition, a report by the High Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security, Rome 2015; Calories and protein information from Vegetable Nutrition Facts, US FDA, and from caloriecounter.io.

[21] Ibid.

An even more sophisticated view of value-add/gallon for agribusiness is to compare the overall nutritional value—including protein value[22]—with protein-rich meats (Figure 9[23]). Intuitively, "downstream" meats consume much more water than the "upstream" grasses and grains that the livestock feed on. As a result, their relatively high nutritional value is more than offset by their very high water consumption on a nutritional value/gallon basis, even after including the protein benefit.

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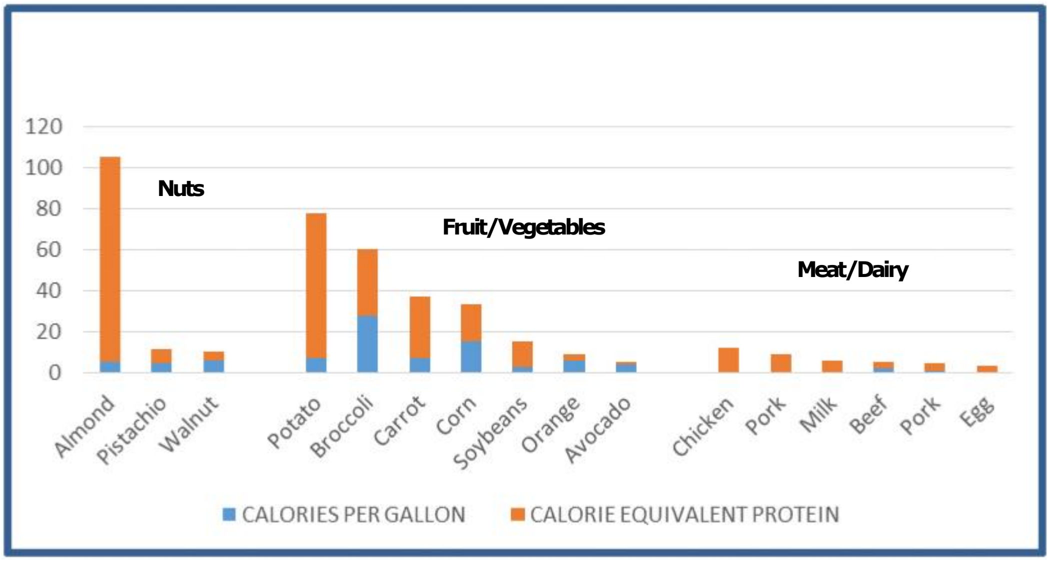
Figure 9: Nutritional Value per Gallon of Water—Nuts, Fruits/Vegetables, Meat Products



Crops for Megawatts

Underpinning the water-food-energy nexus, many agribusiness farms will likely be repurposed to wind or solar farms. In contrast to other forms of electricity generation (coal, gas, and nuclear power), neither solar[24] or wind power use significant water, as do the (Figure 10[25]). In some cases, the "water saved" credit can be sold, and wind turbines can often operate alongside agribusiness. As a win-win to both its water deficit and a state mandate to increase renewable energy to 50% by 2030, California's agricultural acres are already giving way to solar and wind farms.

Alternative energy is a more direct and efficient means of getting energy since solar farms derive energy directly from the sun. By contrast, converting crops to energy (either via biofuels for hydrocarbon energy or food for carbohydrate energy/human consumption) amounts to converting "stored" solar energy and requires a lot of water. Thus, solar and wind are much more water-efficient means of creating electricity (LHS) or liquid energy (RHS), noting that biofuels are off-the-charts in their water intensity (Figure 11[26]).

[22] Note: To make this adjustment, the protein in each good was adjusted upward to the caloric equivalent of protein as per FDA Recommended Daily Allowances.

[23] Various sources, see footnotes 20 and 21.

[24] Photovoltaic only.

[25] P.W. Gerbens-Leenes, A.Y. Hoekstra, Th.H. van der Meer, "Water Footprint of Bio-Energy and Other Primary Energy Carriers," *Research Report Series* No. 29, UNESCORTED-IHE (2008); Ridoutt, Brad, *Global Environmental Change Journal*, February 2010.

[26] Ibid.

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Figure 10: Electricity: Gallons of Water per MWh

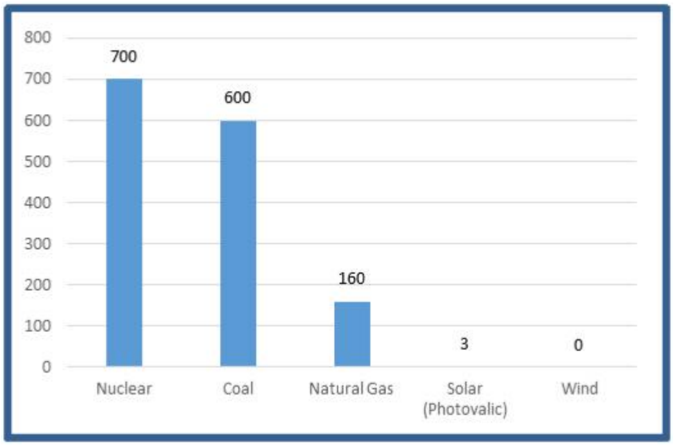
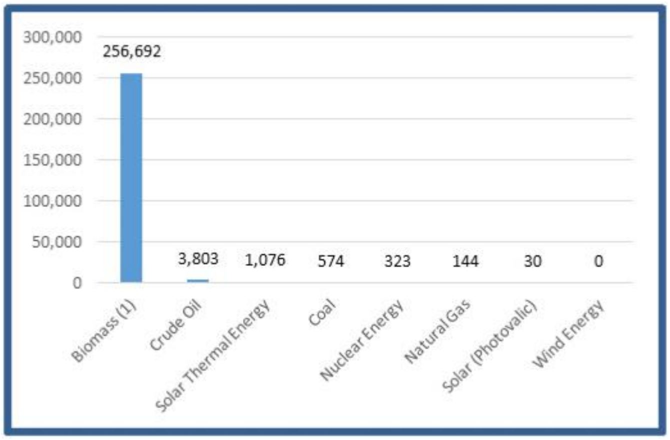


Figure 11: Energy: Gallons of Water per BTU



Crops for Big Data

As water scarcity and prices increase, water will also be allocated to other highly water-intensive uses such as high-tech manufacture. Smartphones and the like have many small and "nano" circuits and chips that go through many washings; some need to be washed over 400x with ultra-pure water in their manufacturing processes. As a measure of this value-add, the amount of water it takes to produce $100 of alfalfa in the United States could be used to produce $5 million of computer chips.[27]

In addition, the data centers that run the internet need vast amounts of water to cool the electronic heat. Predictably, Facebook, Google, Intel, and Microsoft all have located their manufacturing and data server farms in the Pacific Northwest as the rainiest states in the United States.

Virtual Water Globally

On a more global scale, the "virtual water" of international trade in crops and proteins should also continue to increase. Figure 12[28] compares "water stressed" vs. "water blessed" countries using three highly water-intensive products: cotton, cattle/beef, and alfalfa. In some cases, the trade balance of these products is counterintuitive (designated in red and yellow) vs. the country's water resource.

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[27] Maxwell, Steve. The Future of Water, p.85–86, 2011.

[28] Luo, T., R. Young, P. Reig, "Aqueduct Projected Water Stress Country Rankings," Technical Note, Washington, D.C., World Resources Institute; United Nations FAO STAT Agriculture Database, 2015 (most recent trade data is 2013–2015).

Figure 12: "Water Stressed" vs. "Water Blessed" Countries (Larger Economies Only)

Note: Includes only larger economies that are on extremes of "water stressed" or "water blessed."

Key:		
	Red =	Doesn't "make sense" from water resource standpoint
	Yellow =	Mildly doesn't "make sense" from water resource standpoint

	Forecast Global Water Stress Ranking: 2040 Business As Usual Scenario	Trade Balance of Water Intensive Products (000's)		
Water Stressed Regions (Lower Numbers = More Stressed)		**Cotton**	**Cattle/Beef**	**Alfalfa**
Middle East Countries(3)	**1–16**	($757)	($757)	($31,864)
Mexico	**34**	($183)	$168,854	$1,440
India	**40**	$1,022	$266	($18)
United States	**47**	$1,986	$546,337	$46,571
China	**48**	($931)	($181,358)	($204)
Net Trade from Water STRESSED		**$1,137**	**$533,342**	**$15,925**
Water Blessed Regions(1) (Higher Numbers = More Blessed)				
Brazil	**116**	$919	$12,278	$0
Scandinavia(2)	**108**	$0	$0	($213)
Vietnam	**107**	($969)	$904	($1,978)
Taiwan	**99**	($152)	($7,737)	$0
Canada	**94**	($367)	$7,964	$10,689
Net Trade from Water BLESSED		**($569)**	**$13,409**	**$8,498**

(1) = Note analysis begins at relatively high rank as most of the "water benefitted" economies are very small.

(2) = Includes average of Norway, Denmark, Finland.

(3) = Includes average of the top 16 Middle East countries that report trade data for each category.

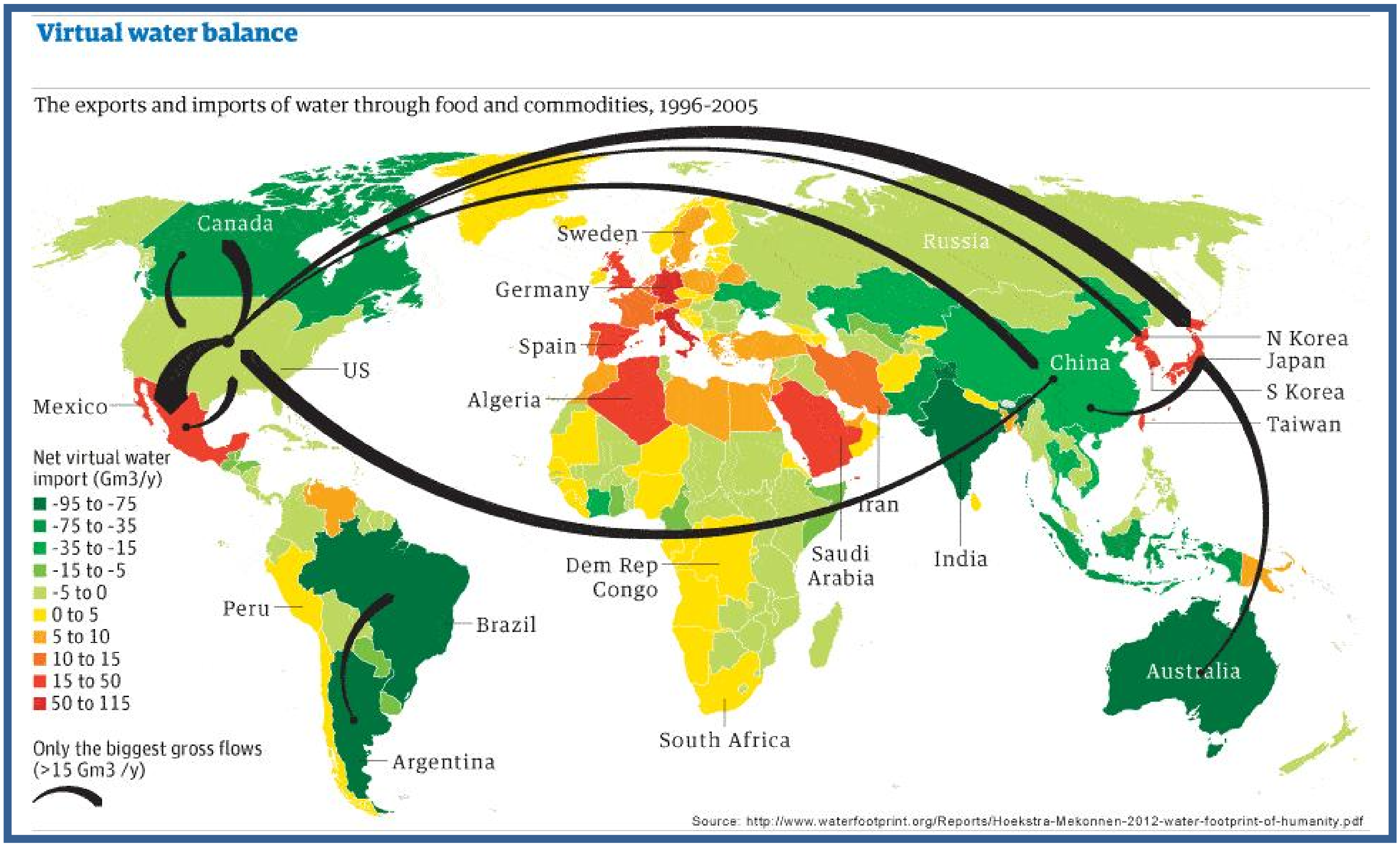
However, there are other factors at play, particularly in agribusiness subsidies and trade-offs from the other natural advantages (such as soil and sun) that a country may have (see next page Figure 13[29]). For example, the United States' huge net exports of water-intensive cattle and alfalfa are mainly explained by a huge trade deficit that the country has with China. As a result, the cargo ships that bring consumer goods to U.S. ports generally go back empty. Arguably, this reflects an undervalued Chinese currency. Regardless, the end result is that the United States is able to ship alfalfa and beef back to China practically for free. On the other hand, although Taiwan is water blessed, its imports of U.S./Mexico beef make sense as the relatively small country uses its water capacity for an even more water-intensive and value-added use in its huge semiconductor and electronics industry.

A very few areas of the world (notably, Brazil and certain parts of Africa) have the ideal trifecta of water, sun, and soil. For now, both of these countries' agribusiness potential is hindered by terrible infrastructure. However, as water scarcity becomes more severe in the rest of the world, the natural advantage of

[29] www.waterfootprint.org/reports/hoekstra-medonnen-2012-water-footprint-of-humanity.pdf.

sustainable water will allow these countries to export increasing water-intensive and higher value-add goods. Hence, all else being equal, the huge price gap of Iowa vs. western Brazil and some areas of Africa is likely to close over time.

Figure 13: Global Agribusiness Trade



Conclusion

As the quintessential naturally replenishing resource, we will never run out of water, and many doomsday forecasts of a global water crisis are exaggerated. Rather, scarcity and inevitably higher costs will eventually overcome many subsidies, regulations, and legacy water-management practices, leading to a higher water price globally and less mispricing locally.

This transformation will be highly disruptive, leading to enormous shifts in how and where water is used. A major part of this transformation will be increased trade of "virtual water," removing huge distortions in the use and value of land that is either water-deficient (downside to current pricing) or water benefitted (upside).

As with all disruption, these changes will create many investment opportunities. For investors that are focused on long-term sustainability, access to inexpensive water will be a critical to the long-term value of land.

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