# Mapping Israel's Virtual Water Trade

Raphael Astrow

Advisor: Dr. Randy Weinberg

Carnegie Mellon University

***Introduction to virtual water trade***

Virtual water trade is the hidden flow of water when food or other commodities are traded from one place to another. For instance, it takes 40 liters of water on average to produce and ship one slice of toast. When a country like Israel imports a slice of toast, it indirectly imports 40 liters of water on average. The precise volume of virtual water in any commodity is affected by climatic conditions and agricultural practice (Allan 2).

Aggregate virtual water trade is a good indicator of how strong a country's agricultural sector is and how much agricultural products are consumed in the origin country and how much are exported abroad. Aggregate virtual water trade is also a strong indicator of how economically and environmentally sound a country is. When countries import large amounts of virtual water, it may indicate that the country's economy is strong and the country can engage in international trade (Allan 19). Countries that import more virtual water than they export may be in a water deficit – its freshwater sources cannot sustain its inhabitants' water needs. Still, relatively few people understand the concept or realize its significance to the world's economy and the natural environment.

***Outline of Essay***

This essay will begin with a discussion of virtual water trade in Israel and an introduction to the app developed to support research about Israel's virtual water trade. Then, virtual water will be described in more detail and green, blue, and grey water will be defined. What follows is a literature review that covers literature about virtual water, Israeli and Palestinian agriculture, and the role virtual water trade plays in Israel. Then, the app is showcased in case studies of Israel's virtual water trade in three different commodities. Afterwards, a discussion is provided about the data challenges encountered while developing the app. Finally, a set of instructions for using the app and a glossary of key terms is found at the end of the paper.

***Virtual water trade in Israel***

Israel's has one of strongest economies in the world, especially for a country of its size, and also is experiencing a longstanding water deficit. This mostly-arid country has a high population density and its water systems are under demand by Israelis and Palestinians. According to Wikipedia's December 2010 figures, Israel has the 32nd highest population density in the world and the Palestinian territories have the 20th highest population density ("List of Countries by Population").

In Israel, 81.5% of the water footprint is imported from outside the country. Israel's average virtual water footprint is 2303 $m^3$/year/capita, well above the global average virtual water footprint: 1385 $m^3$/year/capita (Mekonnen and Hoekstra). Since Israel is located in an arid climate with long, dry summers and inconsistent rainy seasons, its water economy is reliant on virtual water imports.

***Introduction to the app***

Given Israel's reliance on virtual water trade and that Israel has a significant agricultural sector, there is much to learn from virtual water trade in Israel. An app that illustrates Israel's virtual water trade data could support further research into Israel's virtual water trade.

*Where in the World is Israel's Virtual Water?* is a mobile/web application that presents data about Israel's virtual water trade in an accessible format. It teaches users about Israel’s import and export of 40 commodities and its implications for Israel’s water economy.

Figure 1: Application logo (UO Teacher Knowledge Journal)

It calculates Israel’s total imports and exports of those 40 commodities by combining two data sources – the United Nations total trade data between 2001-2012 and the Water Footprint Network’s conversion factors between trade data and virtual water sums ("Bilateral Trade" and Mekonnen and Hoekstra 23-49). The data is broken down by water type – blue (rainwater), green (groundwater), and grey (wastewater offsetting). The app demonstrates Israel’s virtual water trade imbalance – it imports more virtual water than it exports.[1]

[1] The app was deployed to the Internet for public use during summer, 2014 and there are plans to redeploy it, particularly during spring, 2015. The app was developed with nodeJS supported by a mongoDB database and presented with jQuery Mobile. The app was deployed to Nodejitsu and the database was deployed to MongoHQ. When deployed, the app can be accessed on all devices at http://israelvirtualwater.jit.su.

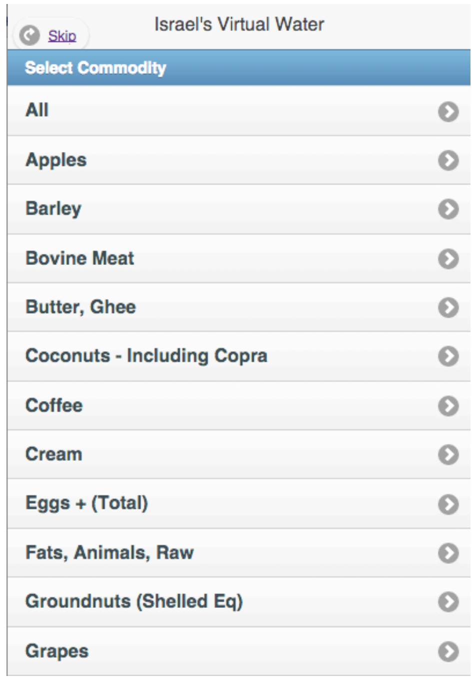



Figure 2: commodity selection options

The 40 commodities demonstrated in the app are diverse – most are produce or meat, though there are non-food commodities as well, such as rubber[2]. There is also an option to view data for all 40 commodities combined into one set of charts.

***Introduction to blue/green/grey water***

The majority of water on earth is green water – water that the ground absorbed and is not readily accessible for human consumption. In other words, planet earth absorbs green water, which allows vegetation to grow naturally without human inputs or attention. Green water eventually evaporates or transpires through plants.

[2] The commodities are: apples, barley, bovine meat, butter, ghee, coconuts - including copra, coffee, cream, eggs, raw animal fats, groundnuts (shelled equivalent), grapes, maize, millet, mutton & goat meat, nuts, oats, offals, olive oil, olives, onions, palm oil, palmkernel oil, pepper, potatoes, rape and mustard oil, rape and mustardseed, rice (milled equivalent), rubber, rye, sorghum, soyabean oil, soyabeans, sugar beet, sugar cane, sunflowerseed oil, sunflowerseed, sweeteners, tea, tobacco, and wheat.

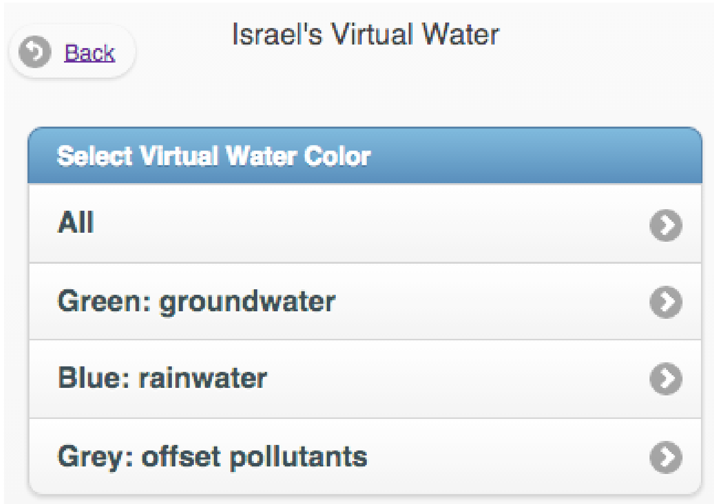



Figure 3: virtual water type selection options

Blue water is rainwater that is readily accessible for human consumption – in places such as reservoirs, streams, and aquifers. The water consumed in domestic and industrial settings is blue water (Allan 40-44). For example, tap water is blue water.

Grey water is trickier to define in a virtual water essay because grey water is different from a virtual grey water footprint. Grey water in a non-virtual context is wastewater. For example in domestic settings, grey water is the wastewater flushed down toilets and consumed in a dishwasher cycle. In a virtual context, grey water footprint is the amount of fresh water needed to offset the pollutants in water to preserve water quality. For example, when fertilizing corn, a large amount of water is needed to offset the pollutants in the fertilizers so that the water quality sustaining the corn remains acceptable. In other words, it may cost 1,000 cubic meters of freshwater to treat 100 cubic meters of water contaminated with chemical fertilizers before those 100 cubic meters of water are of acceptable quality. In this example, the grey water footprint is 1,000 cubic meters of freshwater. Throughout the paper, the virtual grey water footprint definition will be used. The definition for grey water footprint provided in the glossary may serve as further clarification for this concept (Mekonnen and Hoekstra).

***Literature Review***

Book Review 1

In Tony Allan's Virtual Water: Tackling the Threat to Our Planet's Most Precious Resource, the author argues that virtual water has served as the hidden solution for much of the world's food and water insecurity. He claims that large industrialized nations such as the United States have the most access to virtual water resources and may export it to more water-starved countries such as Israel through food commodities such as wheat as necessary (86-87). Given the potential conflicts over native water resources, Allan believes that virtual water has prevented wars, particularly in the Middle East – and he uses the 1970 peace treaty between Egypt and Israel as an example (48-49). Egypt realized that it could receive large quantities of cheap staples foods from the United States and thus aligned its foreign policy with the US's. By declaring peace with Israel, Egypt further aligned its diplomatic relations with the US. In 2010, 40% of Egypt's water was virtually imported (262).

Allan views virtual water trade as the best long-term solution for many water scarce countries, such as Israel. He encourages water-deficient countries to diversify their economies so that they can export resources that demand little water in exchange for water intensive commodities grown in countries such as the US and Australia (75). However, Allan cautions that some of the world's current virtual water trade patterns are unsustainable. For example, he insists that people need to become more responsible eaters – in other words, people must consume less meat (4-5). Additionally, he laments that arid southern California exports 10 cubic kilometers of virtual water to other countries each year – arid regions should not export much virtual water, he claims (109).

While over 70% of the world's water is consumed in producing food, Allan still regrets that most countries use drinkable water for tasks that could be accomplished with undrinkable water, such as watering a garden – and even worse for crop irrigation (23).

Overall, this book provides an excellent description of virtual water and is an excellent starting point for readers interested in understanding virtual water. The author is a pioneer in the field and has helped define virtual water for many beginners and experts. Readers who have little prior knowledge about virtual water will find this book engaging and interesting. While Allan does not discuss Palestinian water issues, he would likely assert that their water concerns could be met through virtual water imports and international aid.

## Book Review 2

In Thomas Kostigen's The Green Blue Book: the Simple Water Savings Guide to Everything in Your Life, the author strongly encourages his readers to conserve water – he begins the book claiming that the most important activity people can do to save the planet is to save water. The author reasons that the world is quickly running out of readily available freshwater and that recent natural disasters in the world and particularly the United States are a direct result of our unsustainable water economy. The author cautions that two thirds of the global population will face severe water shortages by 2025 (ix). The book is one of the first to instruct readers how to consume less water in an accessible way.

Kostigen begins by listing ways the average American can save water in his/her home – reducing consumption from 400 gallons of water per day to 100 gallons of water daily on average (3). For example, he suggests that people should install low flush or dual flush toilets, like those mandatory in Israel (5). He also recommends washing dishes with dishwasher machines, rather than washing by hand (8). He notes that in some parts of the United States, 70 percent of domestic water is used for lawn irrigation and that 50 percent of all water used for landscape irrigation is wasted by evaporation, runoff, or overwatering (13). All of these are examples of conserving the water that people see.

Next, Kostigen discusses how people can conserve virtual water – the water that people do not see. He explains that 70 percent of freshwater in the world is consumed in agriculture (44). Then, he lists calculations of how much virtual water a unit of produce, meat, sweets, and other foods costs. One apple costs 18.5 gallons of virtual water (45). One pound of potatoes costs 12.7 gallons of virtual water (53). One pound of beef costs 1,581 gallons of virtual water (54). Then, he lists virtual water costs of clothing, furniture, and machines. One pair of jeans costs 2,866 gallons of virtual water and one cotton T-shirt costs 569 gallons of virtual water (69, 71). One leather couch costs over 35,600 gallons of virtual water (76). One bar of soap costs 180.4 gallons of virtual water (82). One computer costs between 10,566 and 42,267 gallons of virtual water and one car costs 39,000 gallons of virtual water (87, 92). The book concludes with a number of water footprint calculator tables where readers can calculate their daily water consumption (113-124).

This book serves as a guidebook for those concerned about conserving water and learning about the consequences of overusing water, particularly in the United States. The book paints a dire picture of the United States' current water economy and the author is a water conservation activist. Readers who doubt the severity of America's water overuse would likely prefer another book that also offers an optimistic point of view about water consumption patterns. Overall, this book serves as an excellent reference guide for virtual water conversion factors and actions that can reduce personal water consumption.

At the end, the book includes a table equating different items to their virtual water content (189-196). Here is a sample of non-food items' cost in virtual water content. Note that virtual water content is not broken down into green, blue, and grey virtual water as most of the other data in this essay is broken down.

| **Item** | **Virtual Water Content** |
|---|---|
| Antiperspirant (2.4 ounce, stick) | 220 gallons each |
| Bed (queen size) | 2,878.3 gallons for a spring mattress |
| Blanket | 3,824 gallons for wool |
| Books | 42.8 gallons each |
| Clothes dryer | 16,909 gallons each |
| Computer | 10,556 to 42,267 gallons each, depending on type |
| Diamond ring | 630.7 gallons per carat diamond |
| Hardwood flooring | 7,200 gallons per 1,000 square feet |
| Jeans or pants | 2,866 gallons each |
| Jets | 1 billion to 2 billion gallons, depending on size and style |
| Oven | 13,738 gallons each |
| Pet food | 1,580 gallons per pound of meaty canned food |

| | |
|---|---|
| Piping (copper) | 6,930 gallons per 280 feet |
| Refrigerator (standard side-by-side) | 25,363.2 gallons each |
| Running sneakers | 1,247 gallons per pair |
| Shampoo (22 ounces) | 17 ounces |
| T-shirt (cotton) | 569 gallons each |
| Television | 3,900 to 65,600 gallons each, depending on size and type |

Figure 4: chart of some non-food items' virtual water content (Kostigen 189-196)

Book Review 3 – Part 1

In Alon Tal's and Alfred Abed Rabbo's Water Wisdom: Preparing the Groundwork for Cooperative and Sustainable Water Management in the Middle East, the authors compare essays by Israeli and Palestinian experts in water management to determine areas of agreement and conflict. The book briefly touches on virtual water, although its main focus is on the sharing of cross-border aquifers and expanding wastewater treatment, particularly in Gaza and the West Bank.

The authors' view on the role of virtual water in Israel is summarized in the following paragraph.

> The relative contribution of agriculture to both economies has generally declined over the years and, in the long run, will continue to do so. In both communities there are those who believe that the overall water scarcity mandates a steady down-sizing in agricultural production. The growing demand of the predominant urban sector is argued to be more important than maintaining production in a water-intensive agricultural sector, notwithstanding the cultural significance and heritage of farming. Expansion of "virtual water" through the increased importation of produce is considered to be inevitable. (224)

In other words, Israel will need to import additional virtual water in the future as agriculture continues to decline in Israel and Palestine due to its rising costs and water scarcity. The editors predict that much of what water that Israel and Palestine has will be reserved for urban life and the general population, not so much for agriculture. As a result, Israel and Palestine will import more virtual water to offset agriculture's decline and the populations' projected growth. Some of Palestine's virtual water imports will come in the form of international aid, sometimes facilitated by the United Nations Relief and Works Agency (UNRWA). However, the authors stress that both Israelis and Palestinians will not accept a complete abandonment of agriculture because farming is ingrained in their cultures.

The authors conclude that the Israeli-Palestinian water conflict can be a subject for negotiation because Israel is capable of being flexible about water, particularly since virtual water already reduces Israel's reliance on agriculture and use of freshwater. They also claim that future joint management of water resources between Israel and Palestinians is inevitable (224-226). While virtual water is not a focus of the book, the authors realize its importance in future water negotiations between Israelis and Palestinians.

Book Review 3 – Part 2

In the same book, Water Wisdom: Preparing the Groundwork for Cooperative and Sustainable Water Management in the Middle East, the essay *Sustainable Water Supply for Agriculture in Israel* by Alon Ben-Gal provides historical and legislative context to Israel's water management strategies. The author begins by describing the *kibbutz* and *moshav*, different types of agricultural communities that many of Israel's first pioneers joined. Still today, these communities provide most of the Israel's fresh produce as well as processed food products and almost all meat, poultry, and fish. Many of these communities were established in Israel's arid south and a popular slogan in Israel has long been "make the desert bloom" (211).

Ben-Gal writes that as of 2010, The Ministry of Agriculture in Israel still invests about $70 million a year in agricultural research. Today, the agricultural sector accounts for about 2.5% of Israel's gross national product and approximately 3% of Israel's exports. Although water prices have gradually increased and subsidies for agricultural water have decreased, the agricultural lobby remains very powerful (212).

Ben-Gal provides more data to describe the Israeli agricultural sector's resilience. He cites that Israel produces some 70% of its own food requirements and 70% of Israel agricultural inputs are exported (214). He discusses how Israel has increased agricultural water efficiency by utilizing brackish and recycled water for crop irrigation (215). Additionally, he mentions that Israeli greenhouses offer controlled conditions for lengthening seasons, increasing yields, and saving water (213). Ben-Gal also provides data about which crops are most frequently grown in Israel.

> Fruits account for some $280 million in annual exports, two-thirds of which are citrus. Much of the fruit is harvested out of season for European markets… Approximately 1.7 million tons of fresh vegetables are produced annually, representing 17% of Israel's total agricultural production. Some 110,000 tons of these vegetables, valued at $100 million, are exported each year… Dairy and beef products comprise some 17% of county's total agricultural production. Israel holds the world record for milk production with more than 10,000 kg of 3.3% butterfat milk per cow per year… Grains, oilseeds, meat, fish, sugar, coffee, and cocoa are imported. (213-214)

This data shows that Israel produces a wide range of produce, processed goods, and meats – some of which feed the country and some help feed other countries – particularly European countries (213). Considering that agriculture remains heavily subsidized by taxpayer money, it is likely that some Israelis would prefer that fewer agricultural goods were exported to other countries.

Ben-Gal's essay offers an Israeli perspective on water use in agriculture. It is included in the chapter "Agriculture and Water," where there is another essay that offers a Palestinian perspective on water use and Palestinian agricultural needs. Ben-Gal's essay was included in this thesis for review because it provides interesting data that helps describe Israel's current virtual water trading patterns. A reader interested in Palestinian water needs and how Israel has fallen short of meeting them might also choose to read the corresponding Palestinian-perspective essay in the chapter by Said A. Assaf, *Sustainable Water Supply for Agriculture in Palestine* (195).

## Book Review 4

In *Chapter Six: The Agricultural Roots of Israel's Water Crisis* by Hillel Shuval in the book Between Ruin and Restoration: An Environmental History of Israel by Daniel Orenstein, Alon Tal, and Char Miller, Shuval claims that Israel's excessively strong agricultural sector has overused scarce water resources over the past fifty years (139). He discusses virtual water imports as a key solution to Israel's water crisis and argues that imports should continue to take the place of local agriculture that consumes large quantities of freshwater (142-143). He also discusses that in part since Israeli farmers re-use 75% of wastewater, limited agriculture can continue to thrive (132).

He cites Israel's severe droughts between 2006 and 2009 as a cause for agricultural cutbacks of up to 40-50% of the annual allocations of freshwater resources in recent years. In those droughts, rainfall was 15-20% less than average (129). Usually, 90 percent of rainfall falls during the period of September to April, the non-irrigation season (131). The damage to water resources was perhaps exacerbated by overutilization of water resources in Israel. Shuval estimates that local freshwater resources can sustain 50% of the agriculture that it did when Israel was first established (138). He also cites FAO data that has found that globally, each person requires 1,000 to 2,000 cubic meters of his/her country's freshwater every year (142). In Israel in 2010, there was less than 200 cubic meters of available freshwater per person– so Israelis can at best meet 10-20% of their food needs locally (143).

Shuval also discusses the virtual water concept. He writes that almost 100% of Israel's wheat, grain, rice, animal feed, edible oils, soybeans, fish, and sugar are imported from other countries. As a result, 80% of Israel's caloric intake is imported (142). He also dissuades Israel's export of virtual water. For example, he laments how cotton was grown intensively in the 1980s and 1990s so that it could be exported to other countries - thereby exporting large amounts of Israel's freshwater and contributing to permanent damage to wastewater resources (139). He also suggests a model for Israel's economy: more hi-tech, less agriculture.

> Painful as it may be, it can be argued that Israel can survive only as a high-tech urban-industrial society and will have to reallocate most of its high-quality drinking water from agriculture to the domestic, urban, tourist, and industrial sectors. (141)

Indeed, Israel has emerged as one of the strongest countries in hi-tech with many start-ups developing in Tel Aviv and Haifa, where the renowned Technion Institute of Technology is located. Israel has many other strong sectors that contribute to its robust economy.

However, Shuval emphasizes that agriculture is strongly ingrained in Israeli culture and Jewish tradition and this has influenced water policy (134). He quotes two verses in Deuteronomy, one that extols the availability of water and Israel's fertile land and the other that cautions that Israel has relatively few water resources.

> For the land which you are going in to take possession of is not like the land of Egypt where you came from, where you sowed your seed and watered your garden easily with your foot like a vegetable garden. But the land which you are going over to, is a land of hills and valleys which drink up the water by the rain of heaven (Deuteronomy 11:8-11). (135)

In this verse, G-d is warning the Jewish people settling in Israel that their new land has less water than Egypt, where they had previously lived and farmed. G-d thus implies that Israel should be careful about water resources and pray for strong rainy seasons. Shuval also describes the Jewish holidays of Sukkot and Rosh Hashanah, where strong harvests and rainfall is included in a number of prayers. (135)

Shuval's chapter is included in a book of essays by different authors discussing Israel's historical water management. It was selected for review because it includes a discussion of virtual water that most essays in the book do not. It provides a strong historical context for Israel's water consumption in agriculture, however the author rarely discusses advantages of having stronger agriculture. Readers who are unconvinced that Israeli agriculture must be limited would likely disagree with many of Shuval's claims.

***Case Studies Using App***

Next, Israel's virtual water trade of a small selection of commodities – apples, beef, and potatoes – will be examined using data from the app. First, a screenshot of the app is presented for each virtual water type (green, blue, and grey) and a discussion follows each screenshot.

***Case Study: Apples***

Start Over

Israel's Virtual Water

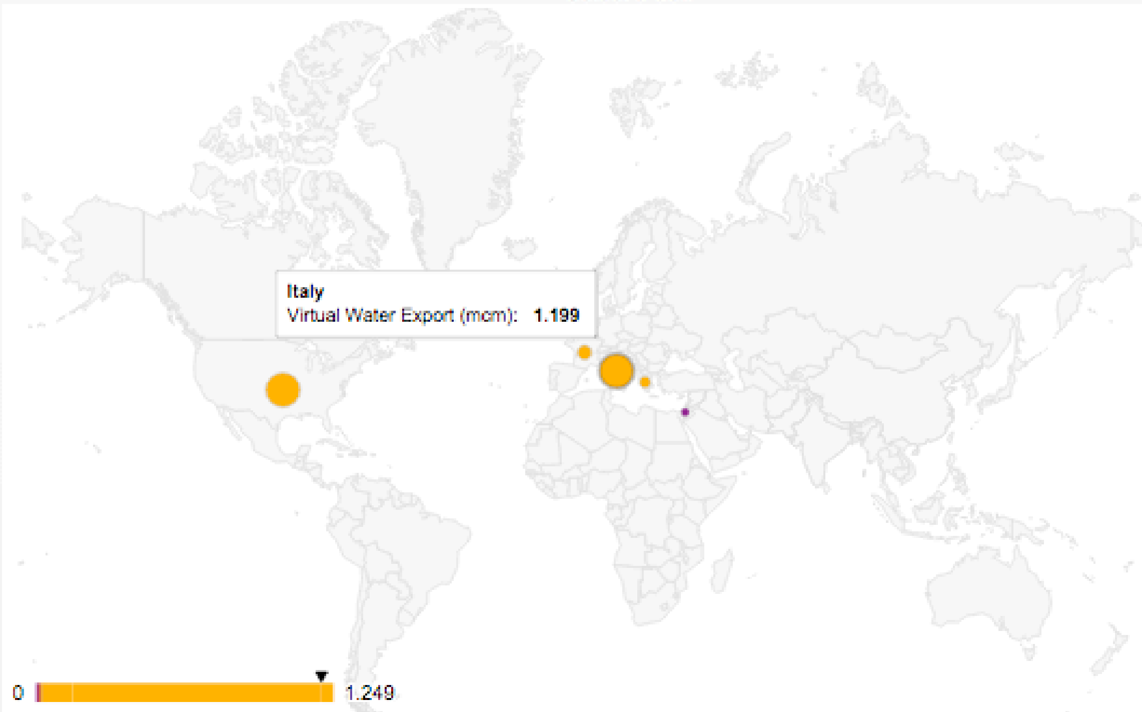
Green

## Apples

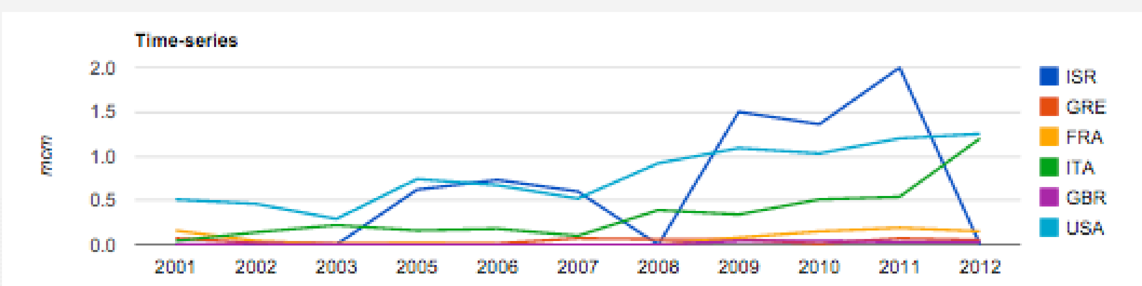
2012

Purple dot = Israel's export to all other countries.
Orange dots = Israel's import from one other country.

Select a dot.




| Country | Quantity (tons) | * | Average Virtual Water Cost (mcm/ton) | = | Total Virtual Water (mcm) |
|---|---|---|---|---|---|
| United States | 6,505 | | 0.000192 | | **1.249** |
| Italy | 7,177 | | 0.000167 | | **1.199** |
| France | 937 | | 0.000164 | | **0.154** |
| Greece | 236 | | 0.000209 | | **0.049** |
| United Kingdom | 135 | | 0.000217 | | **0.029** |
| *Israel* | 0 | | 0.000167 | | **0** |




There are 70 liters of virtual water per apple.

Explanation

Sources

Figure 5: apples, green, 2012

Figure 5 shows Israel's total green virtual water trade in 2012 in apples. The map in figure 5 shows that Israel imports most of its green virtual water in apples from the United States (1) and Italy (2). This is indicated by the large orange dots hovering over those two countries. There are smaller orange dots hovering over France, Germany, and the United Kingdom because Israel imports less virtual water in apples from those countries. In comparison, there is a miniscule purple dot hovering over Israel. This signifies that Israel exported no green virtual water in apples to other countries in 2012. Recall that green virtual water is water naturally absorbed by the ground and not readily available for human consumption. This map is demonstrating that Israel imports a lot more water absorbed by nature in other countries than it exports to other countries.

The calculations behind this data are demonstrated in a table below the map. In that table, Italy is highlighted. In 2012, Israel imported 7,177 tons of apples from Italy – the highest quantity of apple imports for any country Israel imported from. That 7,177 tons figure was taken from *United Nations Educational, Scientific and Cultural Organization* (UNESCO) data within an application made by the *International Trade Center* and is listed in the leftmost column of the table.

Next, the Water Footprint Network provides conversion factors between tons of foodstuffs to cubic meters of virtual water based on water type and country. So, the second column of the table shows the unique conversion factor for apples grown in Italy from tons of apples to millions of cubic meters of green virtual water. The figure is 0.000167 mcm/ton – mcm means millions of cubic meters – the standard measurement of large quantities of virtual water. In other words, for every ton of apples, the total green virtual water costs increase by 0.000167 mcm or 167 cubic meters. Multiplying the first column (tons – total quantity of apples) by the second column (mcm/ton conversion factor - millions of cubic meters of green virtual water per ton of apples) equals column 3 – total green virtual water for apple trade in 2012.

The figure in column 3 is thus 1.199 mcm of virtual water because 7,177 * 0.000167 = 1.199. The values in this third column are the values reflected by the dots on the map above the table. This can be seen because the tooltip hovering over the dot over Italy shows 1.199 as the figure it is reflecting, the same figure found in the third column of the table for Italy. It is interesting to note that although Israel's biggest trading partner in apples was Italy, the virtual water footprint of Israel's trade with Italy is second to the United States. In other words, the United States sent more virtual water in apples to Israel than Italy did even though Italy sent a higher quantity of apples to Israel. This is because the conversion factor from tons of apples to millions of cubic meters of virtual water is different between the United States (0.000192 mcm/ton) and Italy (0.000167 mcm/ton) – Italy produces apples more water efficiently than the United States does.

Virtual water costs differ from country to country because of climatic conditions and agricultural practices. It is not always easy to understand why, for example, Italy grows more apples with less water than the United States does – perhaps less water is naturally evaporated in Italy or perhaps Italy performs more efficient irrigation than the United States does. The Water Footprint Network's dataset is remarkable for capturing the differences between countries and virtual water types. Many virtual water experts have praised the Water Footprint Network and its leaders Mekonnen and Hoekstra for being the first to provide extensive quantitative data for international virtual water trade.

The above map shows a small dot over Israel and larger dots over every country because Israel exported no apples while importing thousands of tons of apples from other countries. However, this was only the case in 2012. In fact, just one year before – 2011, Israel exported much more green virtual water in apples than it imported – in fact its export of apples peaked. This is demonstrated in the time-series chart. This chart shows the progression of virtual water between 2001 and 2012. Israel's line is colored blue and it generally can be seen rising over time. Israel exported the most apples between 2009 and 2011, exported roughly as many apples as it imported between 2005-2007 and exported very few apples from 2001-2003. Data for 2004 is omitted because the United Nations' data was incomplete in 2004. The dramatic dip in 2008 is more significant and there are many possible factors that contribute to apple trading patterns – one might speculate that the global recession of 2008 was partially responsible.

Indeed, Israel's apple export market is very unique and has a back-story: all of Israel's apple exports in 2011 went to Syria, the year before it began a long civil war. Israeli Druze Arabs living in the Golan Heights border region with Syria have been given free permission to cross the border to Syria to sell the apples they grow at Syrian Druze markets. This is because these particular Israeli Druze communities used to live within Syrian borders before the 1974 Yom-Kippur war, which resulted in Israel's annexation of a large portion of the Golan Heights. At that point, the Druze living in the annexed region were given the option to acquire an Israeli citizenship. However, most of the Druze people declined – feeling more attached to Syria than Israel. Ever since, the Israeli Druze along the border have continued to be connected to the Druze living on the Syrian side of the border. Therefore, they chose to sell their apples in Syria and Israel made a special exception to allow them to freely cross the Syrian border. However, this pattern stopped in 2012 when Syria engaged in a violent civil war. In 2012, Israeli Druze stopped bringing their apples across the border for sale in Syria. As a result, Israel's export of apples was zero in 2012. However, the Israeli Druze restarted selling apples in Syria in 2013. (Atkins).

It is also interesting to note that while the United States' apple trade with Israel has steadily increased since 2001, Italy's took a significant jump between 2011 and 2012 – in the past, Italy exported less apples to Israel than it did in 2012. However, it is important to note that apples are not a particularly significant component of Israel's virtual water trade economy. Commodities such as beef are far more significant, as will be demonstrated.

The last aspect of figure 5 to point out is that there are 70 liters of virtual water embedded in one apple on average. This figure incorporates all blue, green, and grey water needed to produce one conventionally grown apple. This is a relatively small figure – one hamburger costs 2,400 liters of virtual water on average. This is because in general, meat costs much more virtual water than produce does. The average non-vegetarian diet in developed countries such as Israel consumes about 5 cubic meters of water each day. 5 cubic meters of water is equivalent to 15 bathtubs of water consumed every day. In comparison, vegetarians consume eight bathtubs of virtual water per day (Allan 3-4). Indeed, virtual water costs are a big reason for people to eat more sensibly and for better vegetarian options to be served at popular restaurants that mostly serve cheap meat whose cost does not assume the virtual water costs of its production (Allan 3-4).

Figure 6 (below) shows what the app looks like when apples are the commodity, the virtual water type is blue, and the year is 2011.

Israel's Virtual Water

Start Over

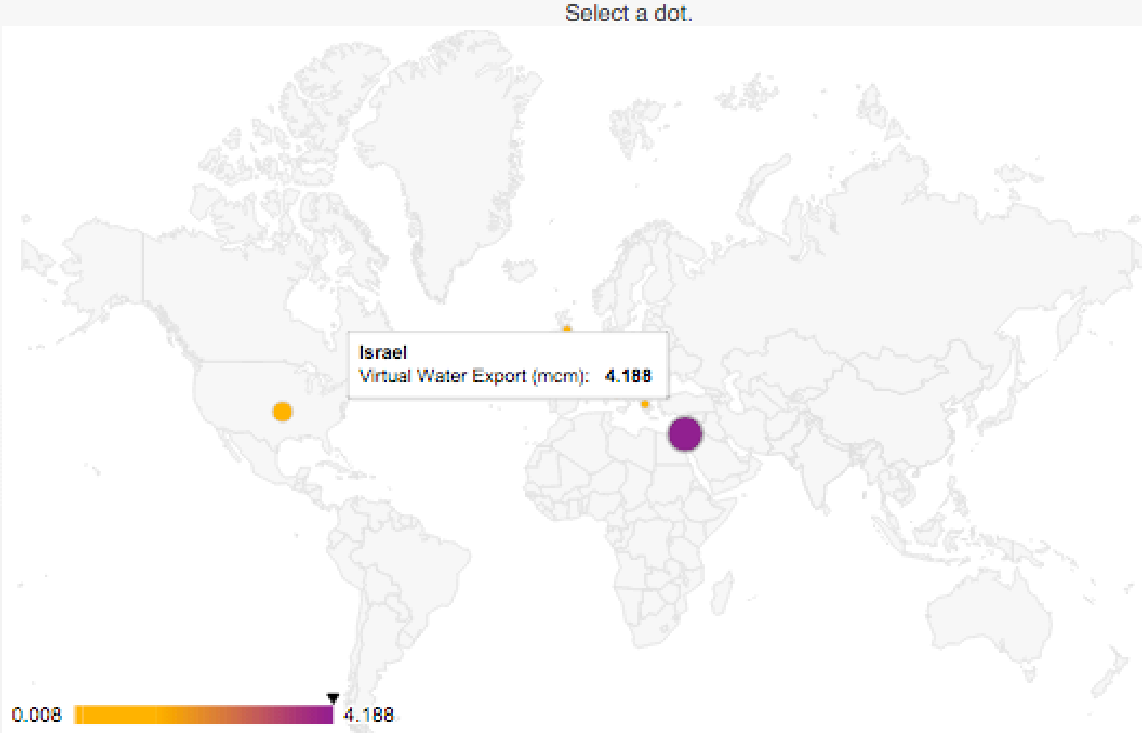
Blue

## Apples

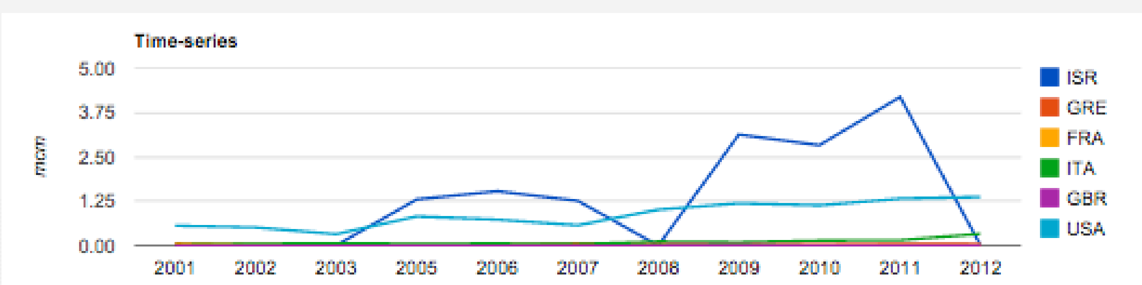
2011

Purple dot = Israel's export to all other countries.
Orange dots = Israel's import from one other country.

Select a dot.




| Country | Quantity (tons) | * | Average Virtual Water Cost (mcm/ton) | = | Total Virtual Water (mcm) |
|---|---|---|---|---|---|
| Israel | 11,999 | | 0.000349 | | **4.188** |
| United States | 6,237 | | 0.000211 | | **1.316** |
| Italy | 3,261 | | 0.000046 | | **0.15** |
| Greece | 332 | | 0.000134 | | **0.044** |
| France | 1,132 | | 0.000029 | | **0.033** |
| United Kingdom | 148 | | 0.000051 | | **0.008** |




There are 70 liters of virtual water per apple.

Explanation

Sources

Figure 6: apples, blue, 2011

Interestingly, this map looks much different than the previous map, which showed 2012 data for green virtual water. Recall, this map is portraying blue water trade – blue water is rainfall that is assimilated into drinkable, human accessible water sources such as aquifers and reservoirs. It is remarkable that for apples, Israel exports far more drinkable water than it imports – however, Israel's apple export is isolated to the Golan Heights. Most of the country likely consumed apples grown in other countries such as the United States and Italy that year.

It is also interesting to compare the conversion factors in column 2 of the table between figure 5 (green water conversions) and figure 6 (blue water conversions). For the United States the conversion factors are 0.000192 green mcm/ton apples (192 cubic meters/ton) and 0.000211 blue mcm/ton apples (211 cubic meters/ton) – relatively small differences between the factors. However, for Italy the conversion factors are 0.000167 green mcm/ton (167 cubic meters/ton) apples and 0.000046 blue mcm/ton (46 cubic meters/ton) apples – much more significant differences between the blue and green conversion factors.

This means that most of Italy's apples are naturally supplied more water than artificially provided water with human irrigation. The United States irrigates its apples far more than Italy does. Of course, a water economist would therefore suggest that countries purchase more apples from Italy than the United States whenever possible. Countries might prefer American apples if they are cheaper than Italian apples and there is a greater supply of American apples.

For completeness sake, figure 7 (below) is a screenshot of grey virtual water imports of apples in Israel in 2003. It depicts a time when Israel traded far fewer apples than it did in 2012. It is important to note that the conversion factors are constant across the eleven depicted years. The conversion factors were aggregated for 2000. As such, the app is primarily intended for educational purposes about virtual water; however, some users may find the data and methodology sufficient for non-academic purposes.

Israel's Virtual Water

Start Over

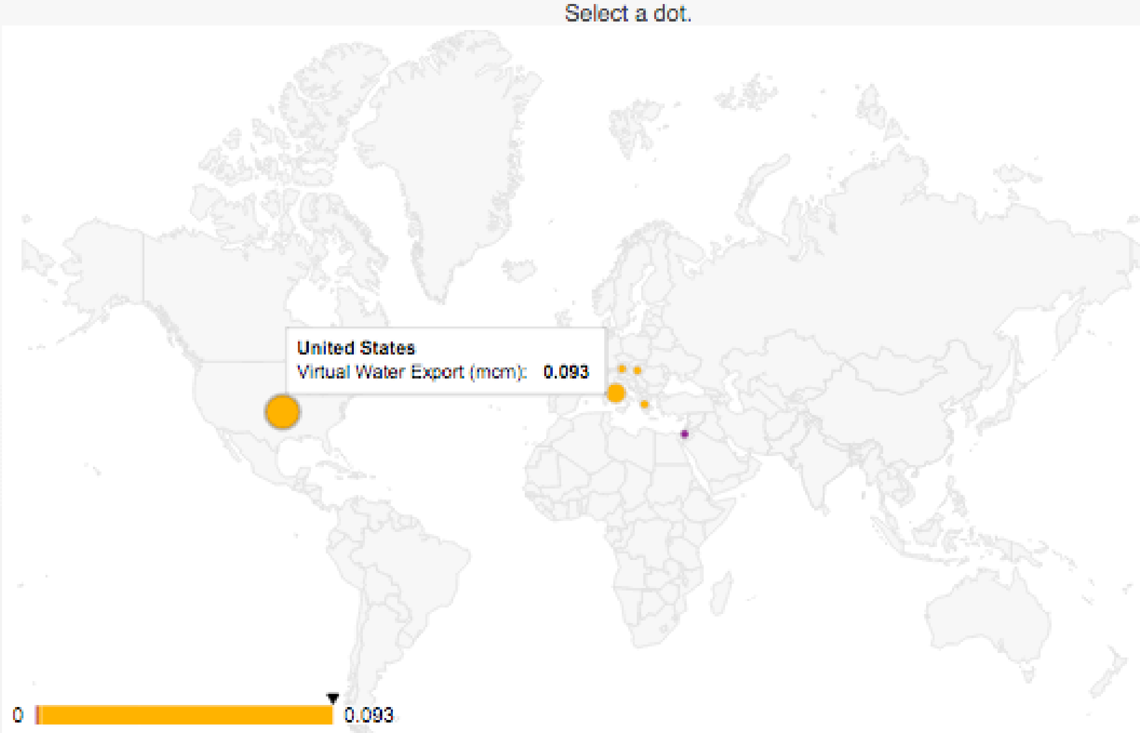
Grey

## Apples

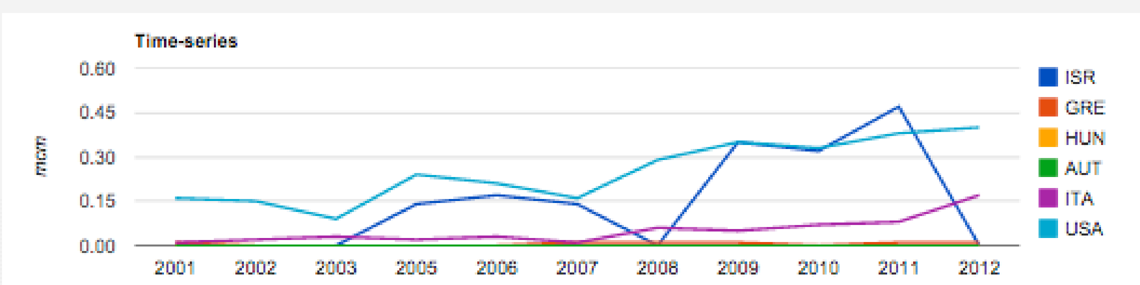
2003

Purple dot = Israel's export to all other countries.
Orange dots = Israel's import from one other country.

Select a dot.




| Country | Quantity (tons) | * | Average Virtual Water Cost (mcm/ton) | = | Total Virtual Water (mcm) |
|---|---|---|---|---|---|
| United States | 1,524 | | 0.000061 | | **0.093** |
| Italy | 1,336 | | 0.000024 | | **0.032** |
| Greece | 59 | | 0.000041 | | **0.002** |
| Hungary | 34 | | 0.00005 | | **0.002** |
| Austria | 101 | | 0.000013 | | **0.001** |
| *Israel* | 0 | | 0.000039 | | **0** |




There are 70 liters of virtual water per apple.

Explanation

Sources

Figure 7: apples, grey, 2003

In figure 7 there is much smaller virtual water totals because in general, much less grey water is expended when producing food commodities. Recall, grey water is the amount of freshwater needed to offset the pollutants used in producing foodstuffs. In the case of apples, grey water is the freshwater likely used to offset chemical fertilizers and its potentially damaging impact on local ecosystems, arable land, and fresh water sources. The differences in conversion factors between countries such as the United States (0.00061 grey mcm/ton apples) versus Israel (0.00039 grey mcm/ton apples) may be due to differences in agricultural practices. For example, American farmers may use higher concentrations of chemical fertilizers in their production of apples than Israeli farmers do.

Indeed, sustainable agriculture has been discussed in many settings in the United States: politics, movies, university courses, and much more. Some believe that American agricultural practices could be much more environmentally sustainable. Large agribusinesses such as Monsanto Company have come under fire for harming eco-diversity with strong chemical fertilizers that significantly increase production of one crop – such as corn - but may hamper the growth of neighboring crops. Organic farming has been suggested as one improvement towards achieving sustainable agriculture. Alternative, small-scale farming has also been viewed by some as part of the solution to sustainable farming needs in the United States. The data presented by the app does seem to indicate that American farming is less ecologically efficient that farming is in many other countries, including Israel. As one virtual water expert, Tony Allan, wrote – Southern California farming is in particular need of reform because it is very water inefficient as it is an arid region in a country and state with greater natural sources of water elsewhere (Allan 109). Figure 8 (below) is a screenshot of Israel's bovine meat (beef) imports in 2012.

***Case Study: Bovine Meat***

Start Over

Israel's Virtual Water

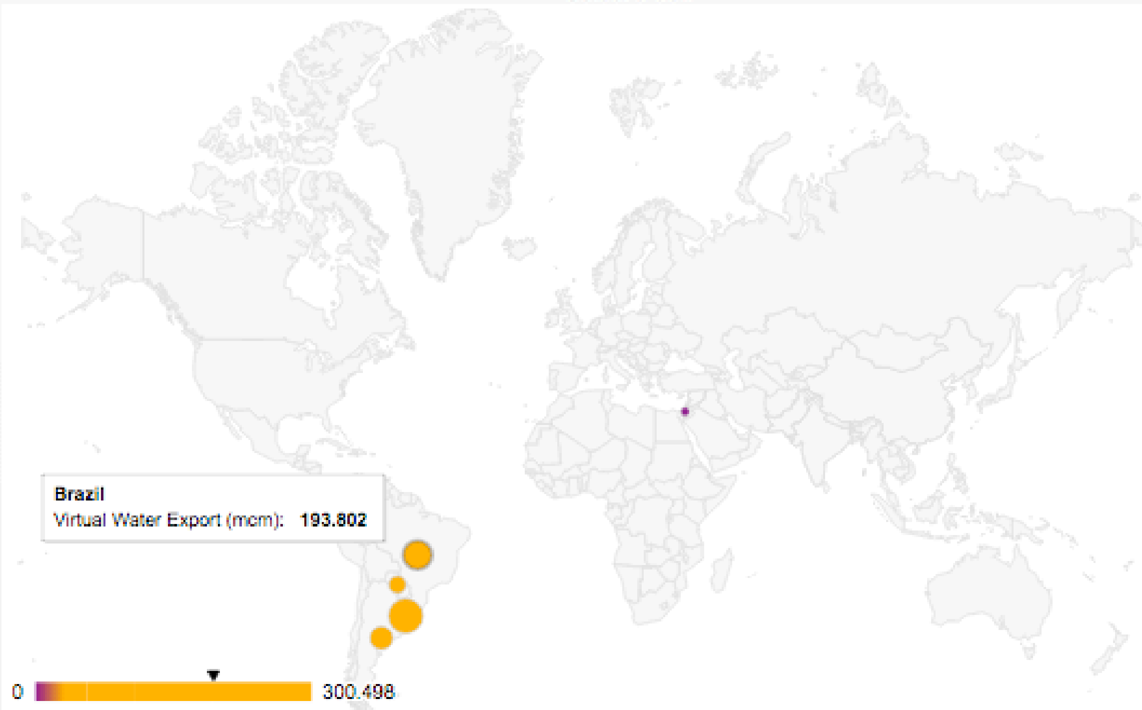
Green

## Bovine Meat

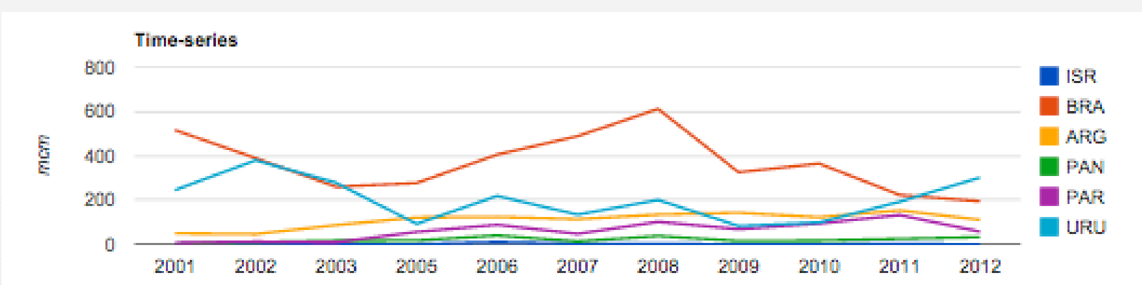
2012

Purple dot = Israel's export to all other countries.
Orange dots = Israel's import from one other country.

Select a dot.




| Country | Quantity (tons) | * | Average Virtual Water Cost (mcm/ton) | = | Total Virtual Water (mcm) |
|---|---|---|---|---|---|
| Uruguay | 22,000 | | 0.013659 | | **300.498** |
| Brazil | 10,107 | | 0.019175 | | **193.802** |
| Argentina | 19,445 | | 0.005602 | | **108.931** |
| Paraguay | 3,181 | | 0.017511 | | **55.702** |
| Panama | 4,161 | | 0.007545 | | **31.395** |
| *Israel* | 0 | | 0.023472 | | **0** |




There are 15,500 liters of virtual water per kilogram of beef.

Explanation

Sources

Figure 8: bovine meat (beef), green, 2012

In figure 8, there are large dots over Southern American countries Paraguay (largest dot) and Brazil (2nd largest dot) and a tiny dot over Israel. The chart lists virtual water totals that are much greater than those apples – because beef has much higher virtual water costs than apples. In other words, the conversion factors between tons of beef and total virtual water are much greater for beef than for produce. This is because animals raised for meat must be fed very well and their slaughter and processing is very water intensive.

It is interesting that most of Israel's beef imports are from water-rich South American countries. For example, the Brazilian Amazon River, the biggest freshwater source in the world contributes to Brazil's excesses of water. In fact, green water (ground water) is in particular excess in Brazil as the soil contains high water concentrations (Allan 204-206). Perhaps in part due to Brazil's excesses of blue and green water, it was Israel's biggest trade partner in beef between 2005-2011, as the above time-series shows. The green line that peaks at 600 mcm in 2008 belongs to Brazil. Brazil's trade of beef with Israel has steadily declined since then. Again, 2004 data is omitted because incomplete data was collected for that year. It is also interesting to observe that even though Argentina exported nearly double the amount of beef that Brazil did in 2012, its total virtual water export for beef that year is nearly half of Brazil's. Of course, this is because Brazil's conversion factor from beef to virtual water is nearly quadruple the conversion factor for Argentina. Recall that the conversion factors are constant across all the years. Therefore, Brazil's conversion factor is the highest of all the countries listed between 2001-2012 and as a result, it is shown to have much higher virtual water trade during the course of the time-series chart.

It is also interesting to note that although Israel did not produce any meat for export, if Israel did export meat – it would be at a much greater cost than any of the South American countries it imports meat from. Israel's conversion factor between beef and virtual water is 0.023472 mcm/ton, which is greater than each of the South American countries' conversion factors listed.

As mentioned above, Brazil's virtual water trade with Israel peaked in 2008. Figure 9 (below) is a screenshot of blue virtual water trade in 2008. The Amazon River is one of the largest blue water sources in the world, and surprisingly it remains substantially untapped. In the future, it may become a more important source of water that helps sustain water economies around the world.

Start Over

Israel's Virtual Water

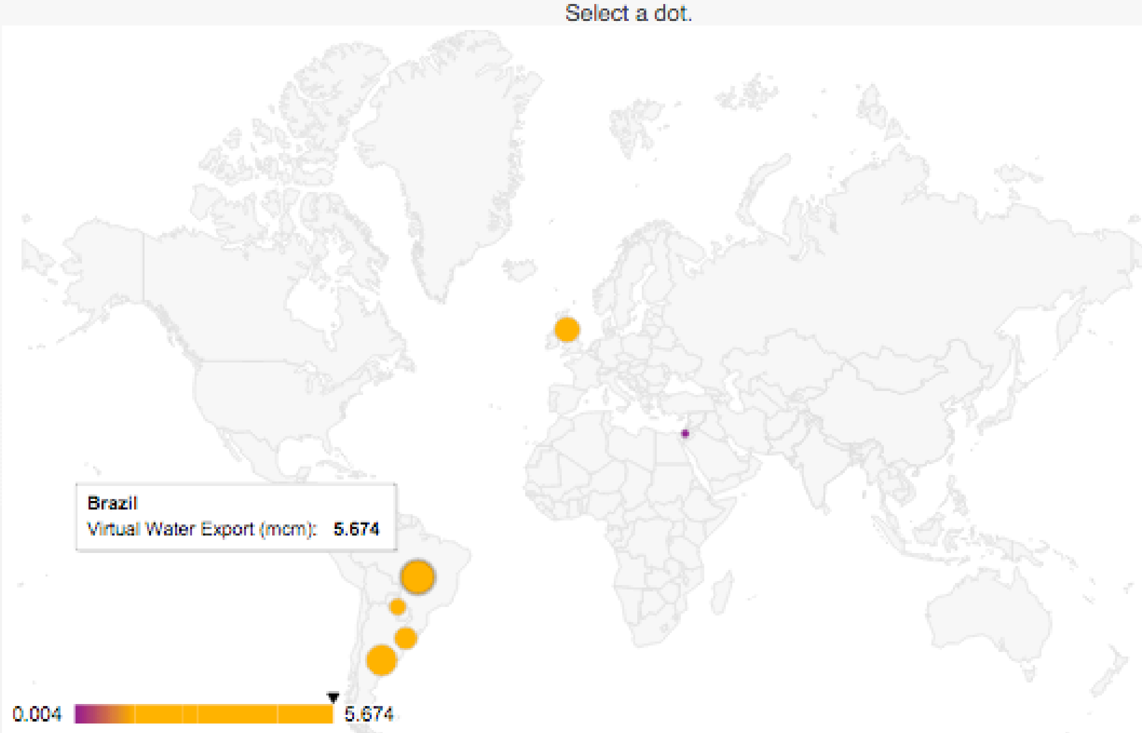
Blue

## Bovine Meat

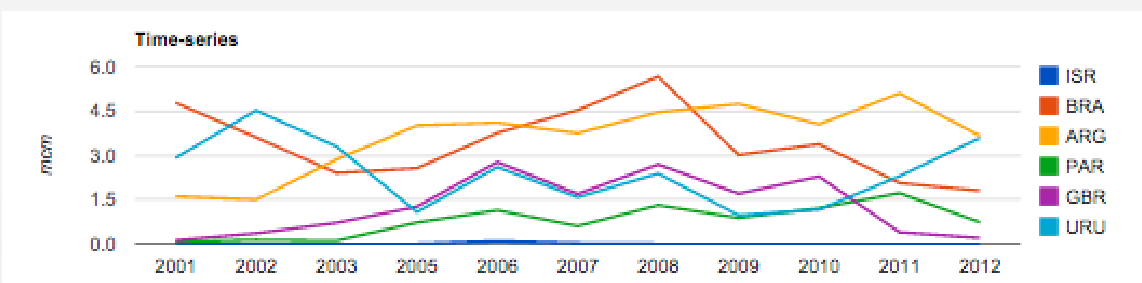
2008

Purple dot = Israel's export to all other countries.
Orange dots = Israel's import from one other country.

Select a dot.




| Country | Quantity (tons) | * | Average Virtual Water Cost (mcm/ton) | = | Total Virtual Water (mcm) |
|---|---|---|---|---|---|
| Brazil | 31,879 | | 0.000178 | | **5.674** |
| Argentina | 23,704 | | 0.000188 | | **4.456** |
| United Kingdom | 10,702 | | 0.000251 | | **2.686** |
| Uruguay | 14,610 | | 0.000163 | | **2.381** |
| Paraguay | 5,711 | | 0.00023 | | **1.314** |
| *Israel* | 15 | | 0.000241 | | **0.004** |




There are 15,500 liters of virtual water per kilogram of beef.

Explanation

Sources

Figure 9: bovine meat (beef), blue, 2008

In figure 9, the conversion factors for blue water are once again much lower than the conversion factors for green water. As shown before in this essay, grey water conversion factors are lower than blue and green water conversion factors. So, the conversion factors can be seen in relation to each other as green > blue > grey.

Skipping to the time-series graph, notice that it looks much different that the time-series graph for green virtual water trade of beef. One reason for this is that the conversion factors are reduced and as a result, the spread of data is more limited. Additionally, Brazil's conversion factors between beef and blue virtual water is no longer the greatest of the countries sampled – it is second lowest in front of Uruguay.

Finally, notice that there are 15,500 liters of virtual water per kilogram of beef. This is much more than the 70 liters of virtual water per one apple. Producing one pound of beef also includes all of the animal feed that cattle consumed to become meatier and the water costs of producing the animal feed. Animal feed usually consists of corn and soybeans, and can also consist of wheat, oats, barley, and rice. The virtual water costs of beef also include preparing land for pasture for cattle to graze on. Pasture mostly consists of grasses and can also include legumes and grains such as sorghum. Virtual water costs may also consist of barn construction to house the cattle and any other resources required to own cattle. These virtual water costs add up to make meat the biggest source of virtual water consumption in the world. As a result, vegetarianism is recommended to limit daily virtual water needs. For completeness sake, figure 10 is a view of grey virtual water trade of beef in 2006, when the United Kingdom achieved a dramatic increase in beef exports to Israel.

Start Over

Israel's Virtual Water

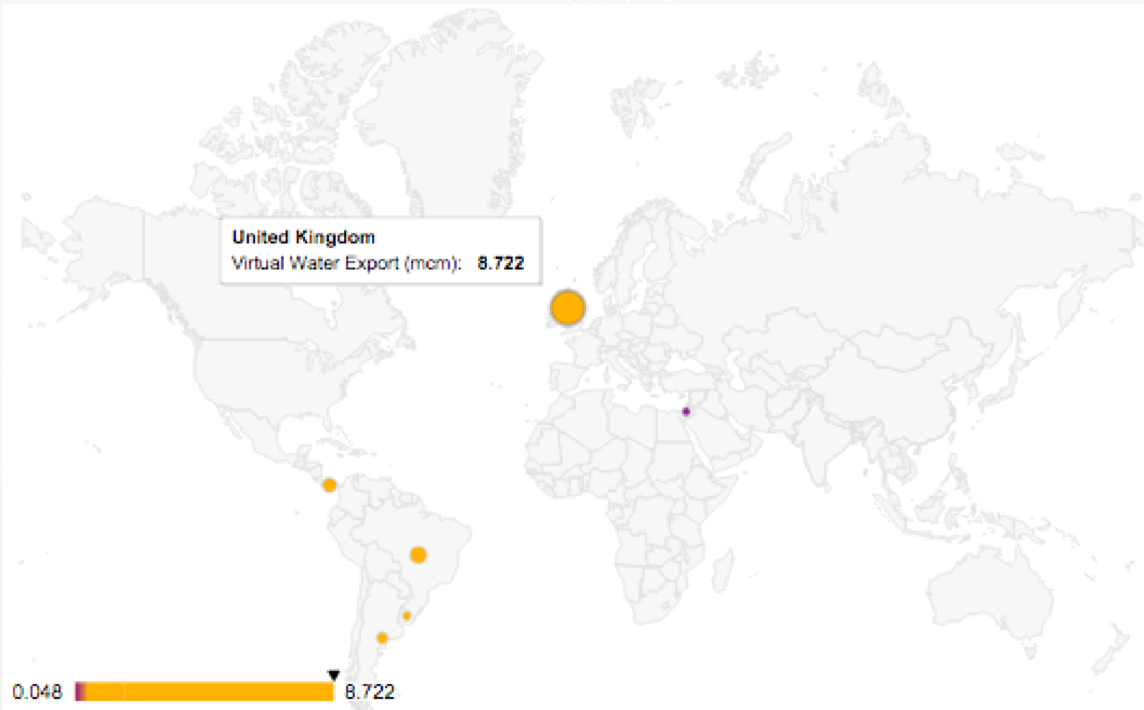
Grey

## Bovine Meat

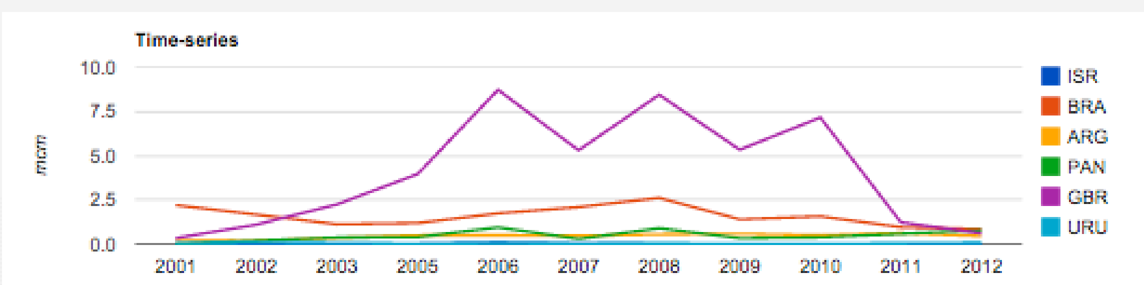
2006

Purple dot = Israel's export to all other countries.
Orange dots = Israel's import from one other country.

Select a dot.




| Country | Quantity (tons) | * | Average Virtual Water Cost (mcm/ton) | = | Total Virtual Water (mcm) |
|---|---|---|---|---|---|
| United Kingdom | 11,055 | | 0.000789 | | **8.722** |
| Brazil | 21,098 | | 0.000082 | | **1.73** |
| Panama | 5,093 | | 0.000185 | | **0.942** |
| Argentina | 21,823 | | 0.000023 | | **0.502** |
| *Israel* | 355 | | 0.000198 | | **0.07** |
| Uruguay | 15,952 | | 0.000003 | | **0.048** |




There are 15,500 liters of virtual water per kilogram of beef.

Explanation

Sources

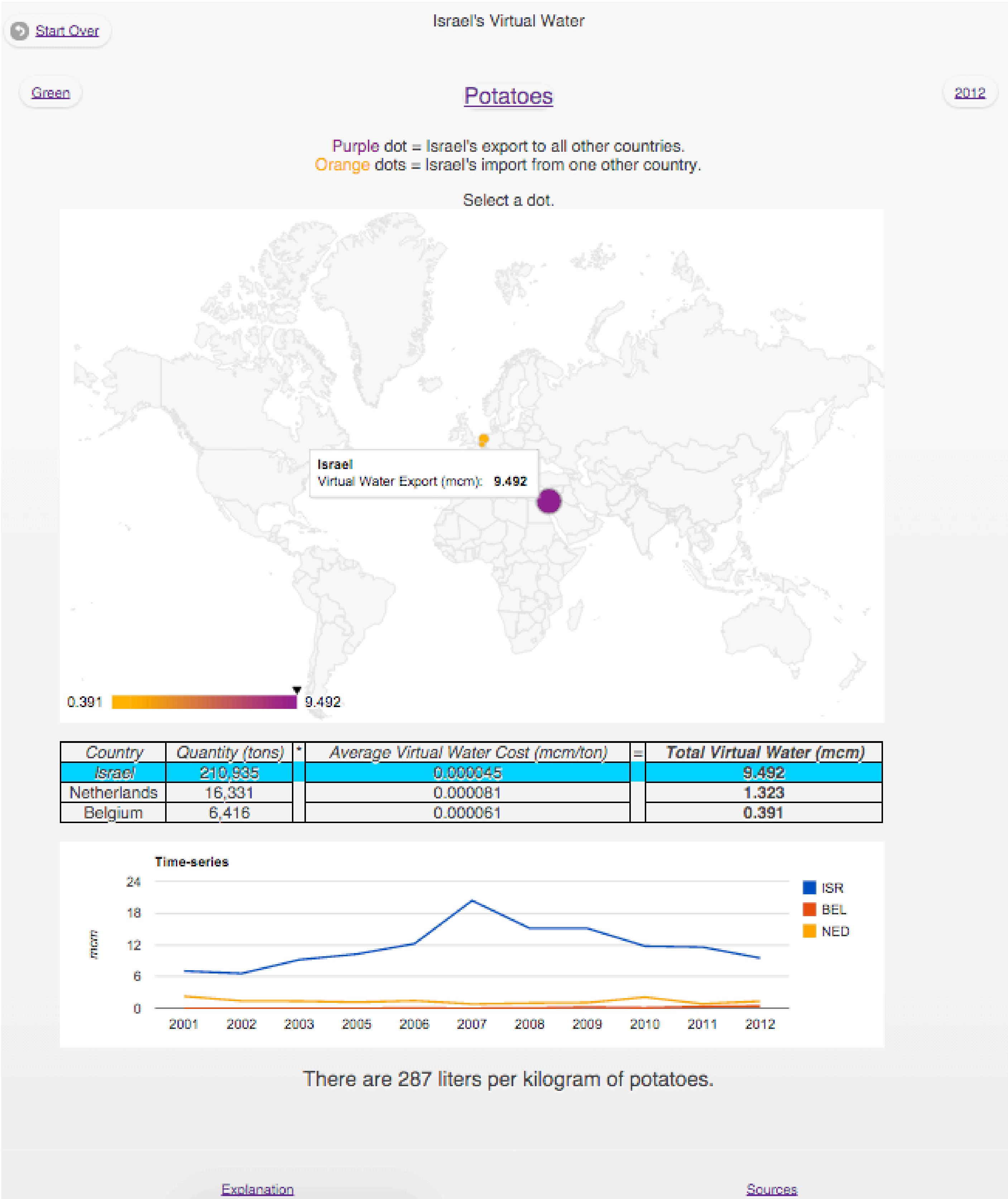
Figure 10: Bovine meat (beef), grey, 2006

In figure 10, a large orange dot appears over the United Kingdom signifying a great quantity of grey virtual water exports in beef to Israel in 2006. This dot may be confusing because the UK is not particularly well known for beef exports. In fact, the United Kingdom did not export the most beef in 2006, they exported just 11,055 tons of it, half of what Brazil and Argentina exported. However, their conversion factor (0.000789 mcm/ton) between tons of beef and grey virtual water is the highest of those countries sampled by nearly four-fold. This means that the UK's water treatment and reuse system is water expensive compared to other countries. In other words, a lot of treated water needs to be consumed in order to support beef production in the United Kingdom. This could be a good sign that the UK uses a lot of recycled grey water in its agricultural systems, thereby preserving freshwater consumption.

On the other hand, it is interesting to notice that Uruguay's conversion factor between tons of beef and grey virtual water is miniscule (0.000003 mcm/ton) compared to the other countries sampled. Even though Uruguay traded more beef to Israel is 2006 than the United Kingdom did, its total grey virtual water costs are the lowest of the countries sampled. This means that very little treated wastewater is consumed when producing a ton of beef in Uruguay. This potentially means that Uruguay does not use much treated wastewater in its agriculture and livestock development. Instead, it uses more blue and green water to sustain its beef production.

Next is an analysis of Israel's virtual water trade of potatoes.

***Case Study: Potatoes***



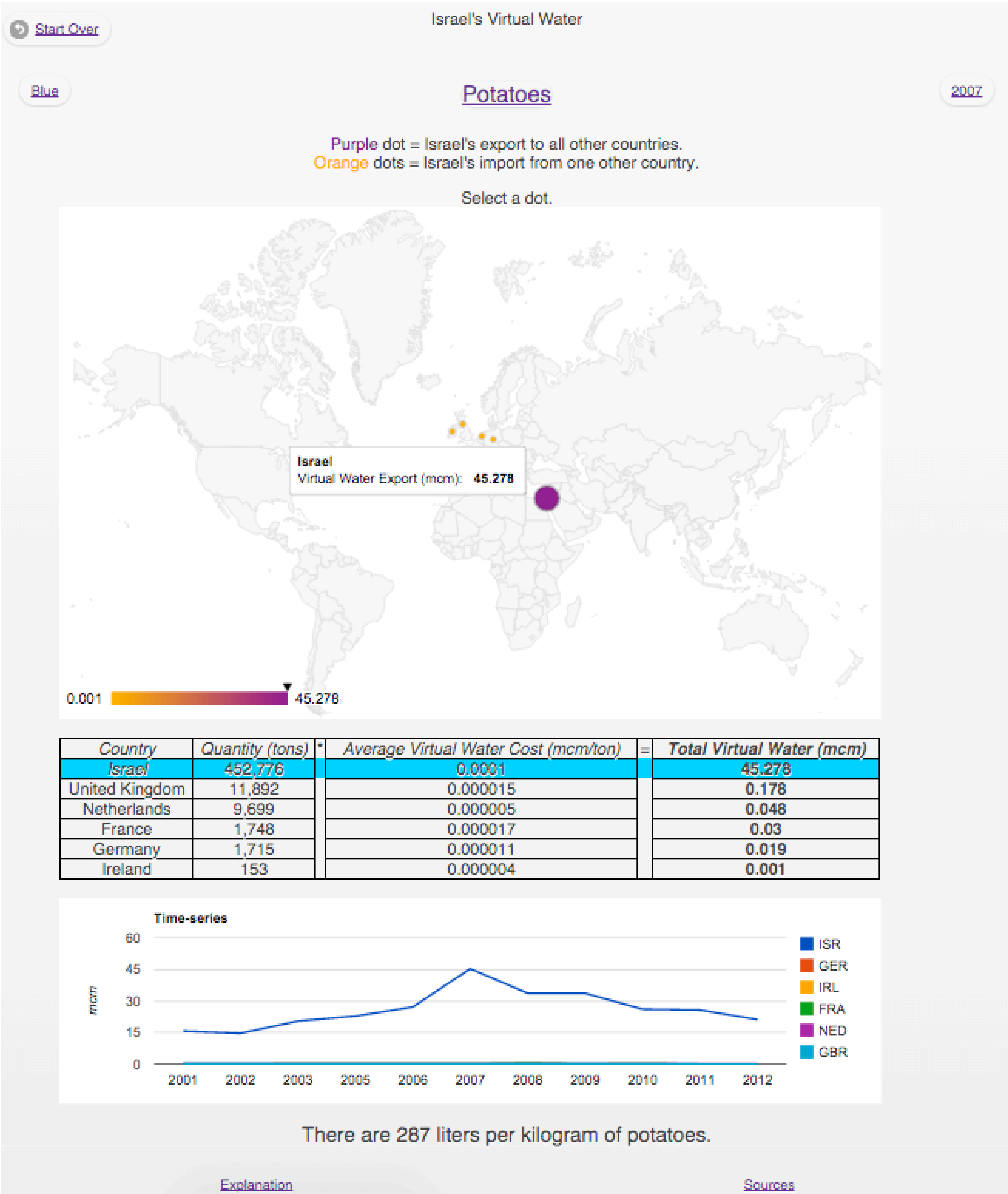

| Country | Quantity (tons) | * | Average Virtual Water Cost (mcm/ton) | = | Total Virtual Water (mcm) |
|---|---|---|---|---|---|
| Israel | 210,935 | | 0.000045 | | 9.492 |
| Netherlands | 16,331 | | 0.000081 | | 1.323 |
| Belgium | 6,416 | | 0.000061 | | 0.391 |

Figure 11: potatoes, green, 2012

In figure 11, notice that for the second time in this essay, the largest dot is the purple dot over Israel. This indicates that Israel exports far more virtual water in potatoes than it imports. Additionally, notice that there are only two substantial trading partners from which Israel imports potatoes – two European countries, the Netherlands and Belgium. For most other commodities, Israel imports from all over the world and the app's algorithm selects the top 5 trading partners. The only commodities sampled that Israel exported a substantial quantity of were grapes, apples, groundnuts, and potatoes. Of those four commodities, Israel by far exported the most virtual water in potatoes – peaking at 20.37 mcm of green virtual water in 2007. Israel exported more virtual water in grapes than in groundnuts.

Figure 11 shows that the conversion factor between potatoes and green virtual water is small (0.000045 mcm/ton) or 45 cubic meters/ton. Additionally, this conversion factor is the lowest of the countries sampled – so growing potatoes is more green water efficient in Israel than it is in other countries. As a result, Israel is able to produce about 13 times as many potatoes as the Netherlands at a virtual water cost that is only 7 times greater than the Netherlands' virtual water cost.

Finally, the time-series chart shows that Israel's potato export consistently increased through 2007. Starting in 2008, Israel's potato export has steadily decreased – perhaps in part because of the lengthy drought Israel experienced from 2006 – 2009. Also notice that one kilogram of potatoes costs 287 liters of virtual water – a relatively small amount. Perhaps this low amount is part of the reason why Israeli farmers chose to export more potatoes than any of the other commodities sampled.




| Country | Quantity (tons) | * | Average Virtual Water Cost (mcm/ton) | = | Total Virtual Water (mcm) |
|---|---|---|---|---|---|
| Israel | 452,776 | | 0.0001 | | 45.278 |
| United Kingdom | 11,892 | | 0.000015 | | 0.178 |
| Netherlands | 9,699 | | 0.000005 | | 0.048 |
| France | 1,748 | | 0.000017 | | 0.03 |
| Germany | 1,715 | | 0.000011 | | 0.019 |
| Ireland | 153 | | 0.000004 | | 0.001 |

Figure 12: potatoes, blue, 2007

In figure 12, the peak of Israel's trade of potatoes is shown as Israel exported the most potatoes in 2007 (452,776 tons). Additionally, since Israel's blue water conversion factor for potatoes is very high (1000 cubic meters per ton), Israel's total export of blue virtual water is 45.278 mcm – much higher than any of the countries Israel imported potatoes from that year. As a result, the dot over Israel is very large while the dots over all the other countries are very small – a sight seldom seen in the app. Additionally, in the time series graph where total virtual water data for all six of the countries sampled is shown, in every year Israel's line is visible while all the other countries' line are hovering so close to 0 that they are barely visible. This is mostly because Israel consumes much more blue virtual water when producing potatoes than most other countries. This is a cause for concern because Israel can little afford to consume freshwater to produce potatoes for export. Instead, Israel should be importing virtual water from other countries in exchange for goods that require little water for production, such as hi-tech. As mentioned earlier, Israel's farmers may have had to cut back on potato farming as water prices rose during Israel's recent three-year drought.

Start Over

Israel's Virtual Water

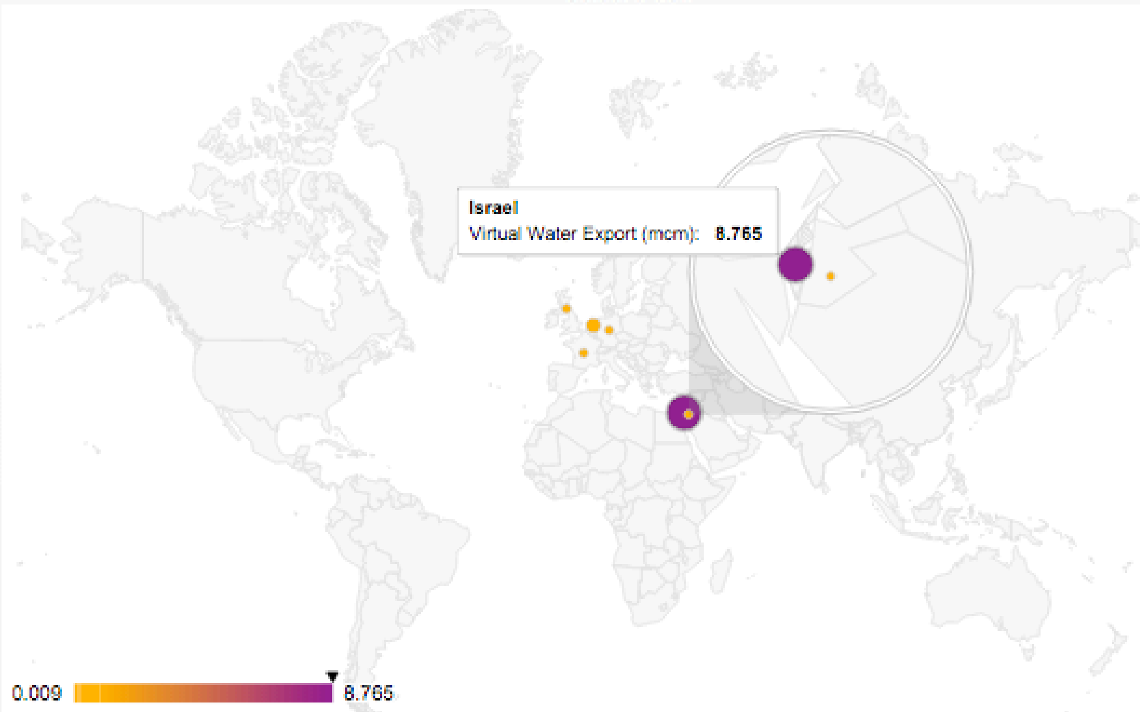
Grey

## Potatoes

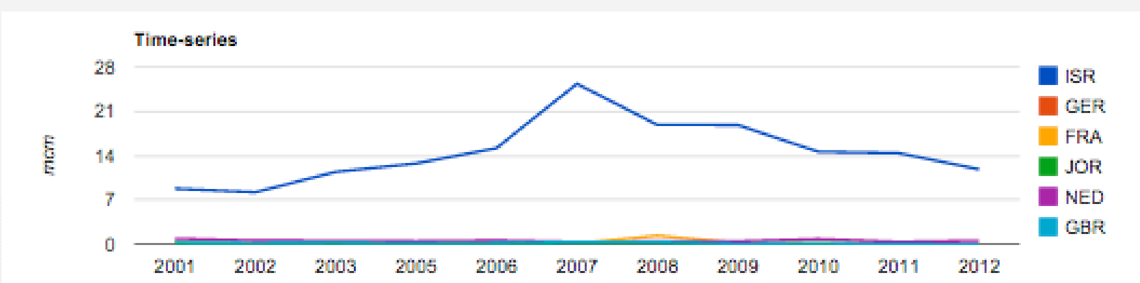
2001

Purple dot = Israel's export to all other countries.
Orange dots = Israel's import from one other country.

Select a dot.




| Country | Quantity (tons) | * | Average Virtual Water Cost (mcm/ton) | = | Total Virtual Water (mcm) |
|---|---|---|---|---|---|
| Israel | 156,513 | | 0.000056 | | 8.765 |
| Netherlands | 27,651 | | 0.000031 | | 0.857 |
| United Kingdom | 7,604 | | 0.000027 | | 0.205 |
| France | 3,449 | | 0.000046 | | 0.159 |
| Germany | 421 | | 0.000029 | | 0.012 |
| Jordan | 477 | | 0.000019 | | 0.009 |




There are 287 liters per kilogram of potatoes.

Explanation

Sources

Figure 13: Potatoes, grey, 2001

Figure 13 shows Israel's export of grey virtual water through potatoes in 2001. In this figure, the dot over Israel is not quite as large because Israel's conversion factor for grey virtual water of potatoes is much smaller than the conversion factor for blue virtual water of potatoes. While Israel still has the largest conversion factor among the countries sampled for grey virtual water, the factor is much closer to other countries' than the blue water factor is. Still, Israel exported far more grey virtual water than it imported between 2001 and 2012, as the time-series chart shows.

Figure 13 also demonstrates the magnifying glass feature of the map: a magnifying glass appears in Asia and points to the dots over Israel and Jordan because those two dots overlap. To select either of the dots, users select the dots within the magnifying glass. The dot over Jordan is rarely seen in the app because even though Israel and Jordan are trading partners, they are seldom within the top 5 of Israel's trading partners. One example where Jordan is a leading trade partner with Israel is olives in 2012 – Israel imported olives only from Jordan that year.

Overall based on the app, it is difficult to understand why Israel chose to export more potatoes than most other commodities sampled. According to the conversion factors, particularly for blue virtual water, Israel expends much more water producing potatoes than other countries. Additionally, Israel's conversion factors for potatoes – particularly the blue virtual water factor - are higher than the factors for other commodities that Israel could export more of. Perhaps Israeli farmers will reconsider their potato production if water prices become too high.

***Data challenges***

A number of other commodities were excluded from the app because the Water

Footprint Network's (WFN) data used different categories for groups of products than the International Trade Center (ITC) did. In particular, the ITC data did not include the ideal categories for different meats and as a result, many types of meat were excluded from the app. Other commodities where the category in the ITC data did not exactly match the WFN data were included in the app – although there are potential issues with the calculations. These commodities include wheat, millet, sugar beet, sweeteners/other, rape and mustardseed, Rape and Mustard Oil, Palmkernel Oil, Grapes (mostly dried), Coffee (Values and Quantities differ), Pepper (Not specific), Beer (Cubic Meters in 2012), Bovine Meat (Frozen), Fats, Animals, Raw (Used Bovine, sheep, and goat fats), Cream (Used Milk and cream, concentrated or sweetened), and Offals + Total (Used edible offal of red meat). Other commodities that had more minor issues between the data sources were Rice (Milled Equivalent) - should be Rice, Butter/Ghee - should be Butter, Groundnuts (Shelled Eq) - should be Groundnuts. Additionally, the ITC had not published 2012 data for a number of commodities: tobacco, rubber, eggs, tea, and sugar cane.

An additional two commodities – beer and wine – were demonstrated in a previous version of the app. They were removed because the ITC data used different metrics every few years and different metrics for certain countries – potentially adding layers of complexity to the app's calculations. Additionally, the app does not include transportation costs of commodities to and from Israel – these costs should generally be included in virtual water trade calculations.

46 other commodities with major issues between the data sources were excluded. Among these 46 excluded commodities were yams, beans, cottonseed, tomatoes, and

oranges. It is unfortunate that oranges and tomatoes had to be excluded. According to Wikipedia, at one point Israeli farmers reduced their oranges export because oranges have high virtual water content and their export meant that too much Israeli water was being consumed elsewhere.

Another major challenge with the app is of third party intermediaries. This is a challenge that perhaps has no good solution – and the app does not offer a solution. An example of this issue is shown in figure 14 below.

Start Over

Israel's Virtual Water

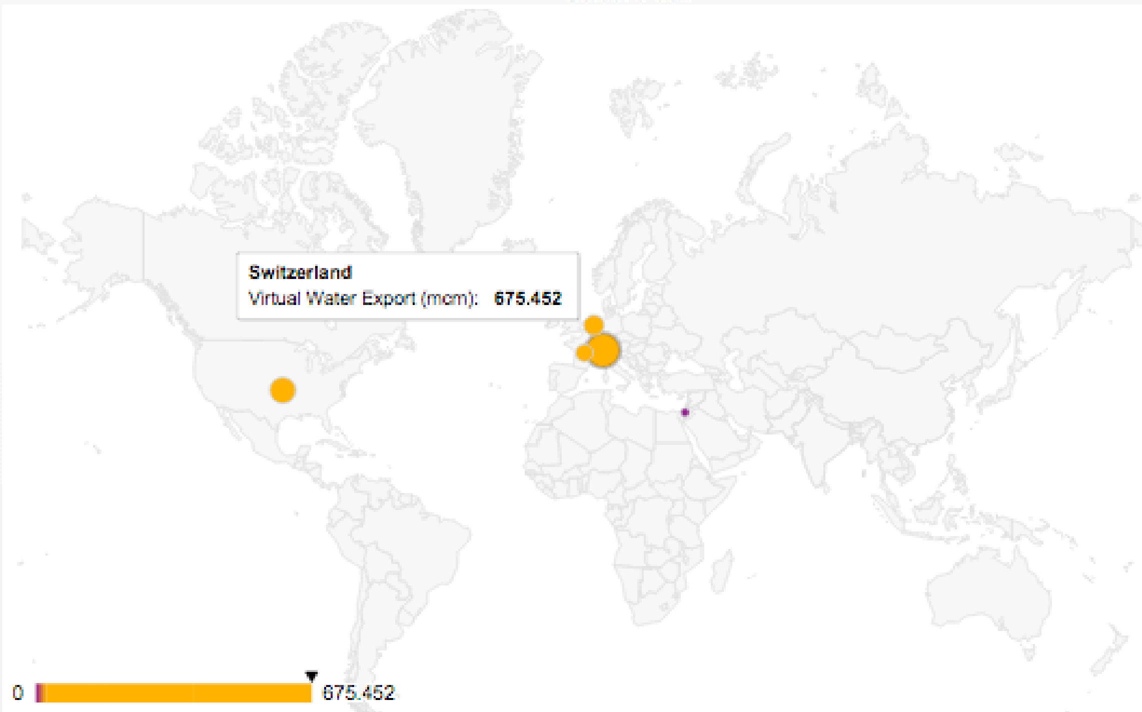
Green

## Wheat

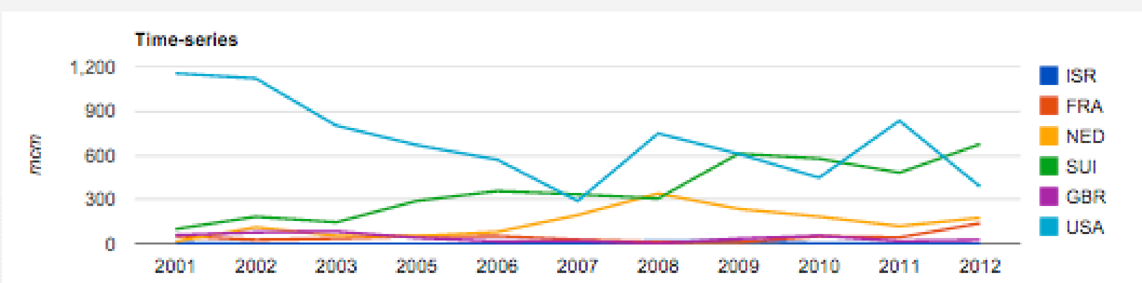
2012

Purple dot = Israel's export to all other countries.
Orange dots = Israel's import from one other country.

Select a dot.




| Country | Quantity (tons) | * | Average Virtual Water Cost (mcm/ton) | = | Total Virtual Water (mcm) |
|---|---|---|---|---|---|
| Switzerland | 800,299 | | 0.000844 | | 675.452 |
| United States | 210,493 | | 0.001842 | | 387.728 |
| Netherlands | 296,241 | | 0.000595 | | 176.263 |
| France | 235,527 | | 0.000591 | | 139.196 |
| United Kingdom | 52,971 | | 0.000455 | | 24.102 |
| *Israel* | 0 | | 0.001684 | | 0 |




There are 1,300 liters of virtual water per kilogram of wheat.

Explanation

Sources

Figure 14: wheat, green, 2012

Figure 14 demonstrates this odd phenomenon where Switzerland is credited as being Israel's greatest trading partner in wheat in 2012. In truth, Switzerland is not a large enough country to produce that much wheat for export – it is likely that there is a third party intermediary based in Switzerland to facilitate Israel's import of wheat. Indeed, Shintraco Ltd., an Israeli company, partnered with one company based in Geneva, Switzerland – Proalim SA – and claimed $1 billion revenue in 2012 through importing commodities to Israel. According to an Israeli business analysis website, "The company imports to Israel various grains and seeds including wheat, beans, corn and animal feed as well as sugar and pulses" (Globes and Dun & Bradstreet Israel Group). It is possible that all of Shintraco's imports to Israel are being credited to Switzerland in the United Nations data used by the app. In reality, these imports are likely being traded from all over the world. The chart at the bottom of the figure shows the United States' export of wheat decreasing at roughly the same rate as Switzerland's increase in wheat export. This might signify that much of the wheat trade credited to Switzerland is truly wheat produced in the United States.

Finally, as aforementioned, the app mixes data from different years – all the conversion factors are applicable to 2000 while the trading totals are from 2001-2012. Given this challenge, the app should primarily be used for educational purposes.

***Instructions for using the app***

1. During the period of time that the author has deployed the app, navigate to http://israelvirtualwater.jit.su to begin.
2. Click on the button to begin.
3. Select a commodity from the 40 options. To use the default commodity,

select ‘skip’ at the top right corner of the screen.

4. On the main screen, there are a number of customization options.
    a. The current virtual water color that data is being displayed for can be seen in a small oval button at the top left corner of the screen. The button will either contain the text ‘Green’, ‘Blue’, ‘Grey’, or ‘All’. ‘All’ means that data being displayed is aggregated for all three virtual water colors green, blue, and grey.
        i. To change the virtual water color, select this small oval button at the top left corner of the screen.
    b. The current year that data is being displayed for can be seen in a small oval button at the top right corner of the screen. This button will contain text reading any year between 2001-2012. Complete data for years after 2012 are not yet available.
        i. To change the year, select this small oval button at the top right corner of the screen.
    c. The current commodity that data is being displayed for is found in a large oval button at the top center of the screen. This button will contain text indicating which of the 40 commodities data is currently being displayed for.
        i. To change the commodity, select this larger oval button at the top center of the screen.
5. To begin analyzing data, select or hover over any of the dots in the large map in the center of the screen. On mobile devices, users must select a dot to view

a tooltip containing the data. Once a dot is selected, its corresponding country's data will become highlighted in a table below towards the bottom of the screen. This table is explained in the 'case study: apples' section above.

***Glossary***

The Water Footprint Network, a leader in virtual water data and education, defines the following key terms (Hoekstra et al.).

**Virtual-water content** – The virtual-water content of a product is the freshwater 'embodied' in the product, not in real sense, but in virtual sense. It refers to the volume of water consumed or polluted for producing the product, measured over its full production chain. If a nation exports/imports such a product, it exports/imports water in virtual form. The 'virtual-water content of a product' is the same as 'the water footprint of a product', but the former refers to the water volume embodied in the product alone, while the latter term refers to that volume, but also to which sort of water is being used and to when and where that water is being used. The water footprint of a product is thus a multidimensional indicator, whereas virtual-water content refers to a volume alone.

**Virtual-water export** – The virtual-water export from a geographically delineated area (for example, a nation or catchment area) is the volume of virtual water associated with the export of goods or services from the area. It is the total volume of freshwater consumed or polluted to produce the products for export.

**Virtual-water import** – The virtual-water import into a geographically delineated area (for example, a nation or catchment area) is the volume of virtual water associated with the import of goods or services into the area. It is the total volume of freshwater used (in the export areas) to produce the products. Viewed from the perspective of the importing area, this water can be seen as an additional source of water that comes on top of the available water resources within the area itself.

**Green water footprint** – Volume of rainwater consumed during the production process. This is particularly relevant for agricultural and forestry products (products based on crops or wood), where it refers to the total rainwater evapotranspiration (from fields and plantations) plus the water incorporated into the harvested crop or wood.

**Blue water footprint** – Volume of surface and groundwater consumed as a result of the production of a good or service. Consumption refers to the volume of freshwater used and then evaporated or incorporated into a product. It also includes water abstracted from surface or groundwater in a catchment and returned to another catchment or the sea. It is the amount of water abstracted from groundwater or surface water that does not return to the catchment from which it was withdrawn.

**Grey water footprint –** The grey water footprint of a product is an indicator of freshwater pollution that can be associated with the production of a product over its full supply chain. It is defined as the volume of freshwater that is required to assimilate the load of pollutants based on natural background concentrations and existing ambient water quality standards. It is calculated as the volume of water that is required to dilute pollutants to such an extent that the quality of the water remains above agreed water quality standards.

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