Science of the Total Environment 622–623 (2018) 1438–1447

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

Virtual water flows and water-footprint of agricultural crop production, import and export: A case study for Israel

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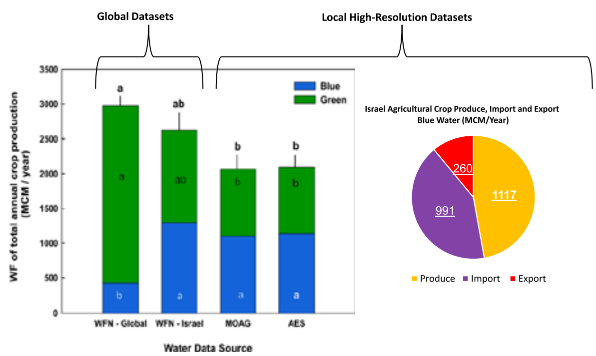
HIGHLIGHTS

- A comparative study using two global and two local high-resolution datasets
- About 25% of the Blue water (irrigation water) used for crop production is exported.
- Global 'Vegetable' Economic Water Productivity is about 2–3 times higher than local.
- Results show importance of local water-use data for agricultural water accounting.
- High-resolution water footprint required for locally suitable agricultural policies.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 23 September 2017
Received in revised form 2 December 2017
Accepted 2 December 2017
Available online xxxx

Editor: D. Barcelo

Keywords:
Agriculture
Water foot print
water use
Israel
import
export

ABSTRACT

Agriculture is the largest global consumer of freshwater. As the volume of international trade continues to rise, so does the understanding that trade of water-intensive crops from areas with high precipitation, to arid regions can help mitigate water scarcity, highlighting the importance of crop water accounting. Virtual-Water, or Water-Footprint [WF] of agricultural crops, is a powerful indicator for assessing the extent of water use by plants, contamination of water bodies by agricultural practices and trade between countries, which underlies any international trade of crops. Most available studies of virtual-water flows by import/export of agricultural commodities were based on global databases, which are considered to be of limited accuracy. The present study analyzes the WF of crop production, import, and export on a country level, using Israel as a case study, comparing data from two high-resolution local databases and two global datasets. Results for local datasets demonstrate a WF of ~1200 Million Cubic Meters [MCM]/year) for total crop production, ~1000 MCM/year for import and ~250 MCM/year for export. Fruits and vegetables comprise ~80% of Export WF (~200 MCM/year), ~50% of crop production and only ~20% of the imports. Economic Water Productivity [EWP] ($/m^3) for fruits and vegetables is 1.5 higher compared to other crops. Moreover, the results based on local and global datasets varied significantly, demonstrating the importance of developing high-resolution local datasets based on local crop coefficients. Performing high resolution WF analysis can help in developing agricultural policies that include support for low WF/high EWP and limit high WF/low EWP crop export, where water availability is limited.

1. Introduction

Freshwater sources around the globe are facing increasing threats (Rockström et al., 2009b). According to recent estimates, >80% of usable

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https://doi.org/10.1016/j.scitotenv.2017.12.012
0048-9697/

water resources are exposed to significant risks including depletion and pollution, with two thirds of the world's population facing severe water shortage at least one month a year (Green et al., 2015; Mekonnen and Hoekstra, 2016). The main consumer of water worldwide, accounting for 70% of the total global water withdrawals, is agricultural crop production (Haddeland et al., 2013). Hence increasing efficiency and reducing water use in the agricultural sector is key to mitigating global water scarcity (Molden, 2007). Over the past decades, it has been argued that international trade of agricultural crop produce from wet-countries to arid and semi-arid countries, is one possible path to alleviating water shortage (Yang et al., 2006).

While global trade of crops may reduce pressures on water resources (by export from wet to dry regions) potentially it can also result in the opposite effect, e.g., export of water intensive crops from semi-arid and arid regions (Sun et al., 2016). In this sense, the export/import of agricultural crops can also be seen as export of *virtual water* (Allan, 2003). In the past decades there has been a substantial and steady rise in global trade of agricultural crops, both in total value and in quantity, as is demonstrated by the increase of cereal crops trade (Fig. 1) (FAO Statistics Division, 2016). A better understanding of the actual and potential role of virtual water trade and water footprint of agricultural crops requires a nuanced and detailed understanding of the economic and environmental aspects related to agricultural production and trade. This information can in turn help decision-making processes when trying to promote appropriate policy measures (Aldaya et al., 2009; Wichelns, 2001; Yang et al., 2006).

Several studies have been published on global trends of agricultural virtual water trade and the benefits, weaknesses, development of agricultural water footprint assessment methodology (Chapagain and Hoekstra, 2003; Fader et al., 2011; Hanasaki et al., 2010; Hoekstra and Hung, 2002; Lovarelli et al., 2016; Mekonnen and Hoekstra, 2011; Siebert and Döll, 2010, Wilchens, 2014). Such studies require detailed quantitative information on import and export biomass, as well as crop water consumption during cultivation at the production sites. Although global databases allow general estimation of trade flows of agricultural crops, they are considered to be limited in accuracy and resolution of the data. The UN's FAO's FAOSTAT data base, for instance, includes a warning that “aggregate (data) may include official, semi-official, estimated or calculated data” (FAO Statistics Division, 2016). The accuracy of the source data for the actual quantity of the import and export of agricultural crops (ton/year) and crop virtual water content (m^3/ton) is an inherent weakness in the calculation of virtual water trade. The reliance on global databases and assumptions regarding the two components of the virtual water trade flows are therefor considered to reduce and limit the result's accuracy (Hoekstra and Hung, 2002; Yang et al., 2006). Furthermore, studies performed based on data collected on the farm level, show significantly different results compared to globally derived data, underlying the importance of relying on high-resolution data (González Perea et al., 2016).

This study aimed to analyze the virtual-water flows from and to Israel by export and import of agricultural crop produce. Focusing on a country scale and using high resolution, local, national databases allowed to increase accuracy and provide results with local relevance and applicability. This is especially true of Israel, a relatively small country with a geographically diverse climate and cultivation conditions, in which the Central Bureau of Statistics [CBS] and Ministry of Agriculture [MOAG] and its subsidiaries, collect and publish yearly, high resolution data regarding the local agricultural sectors.

Israel's agricultural sector consist of only 2.3% of Israel's economy production value, out of which 60% comes from plant crops (Israel Central Bureau of Statistics, 2012a). Nonetheless, Israel relies heavily on intensive agriculture, and the agricultural sector is the largest water consumer and the second largest freshwater consumer after domestic use. In 2010, out of 1200 million cubic meters (MCM) of total natural freshwater used in Israel, 42% (500 MCM) were used for agriculture, with an additional 144 MCM brackish and 400 MCM treated wastewater used in agriculture (Israel Water Authority, 2012). In other words, agricultural production accounts for roughly 40% of Israel's freshwater use. In the past decade, Israel has reduced pressures on water resources by large scale desalination of sea water for urban use and waste water treatment for agricultural use (Becker and Ward, 2015).

Nonetheless, the country's natural water resources are still under large stress. The coastal aquifer is well below its potential capacity and suffers from pollution by nitrates and other pollutants. Water flows and quality in rivers and streams as well as in the Sea of Galilee (the country's largest and only freshwater natural lake and reservoir) are significantly lower than their historical levels (Tal and Katz, 2012). The lack of freshwater allocations for natural resources can be attributed, in part, to the intensive use of water in agriculture. The lack of available freshwater also hurts local farmers who face varied and uncertain water allocations. In the fall of 2017, for example, the Israel Water Authority announced it will cut in half the allocation of freshwater to farmers in the northern part of the country due to low precipitation levels for several years. Reducing the export and increasing the import of water intensive crops might possibly reduce water-use in the agricultural sector, reduce groundwater abstraction and increase natural water flows. In order to accomplish this goal, a high resolution analysis of Israel's agricultural sector WF is required (Shtull-Trauring et al., 2016).

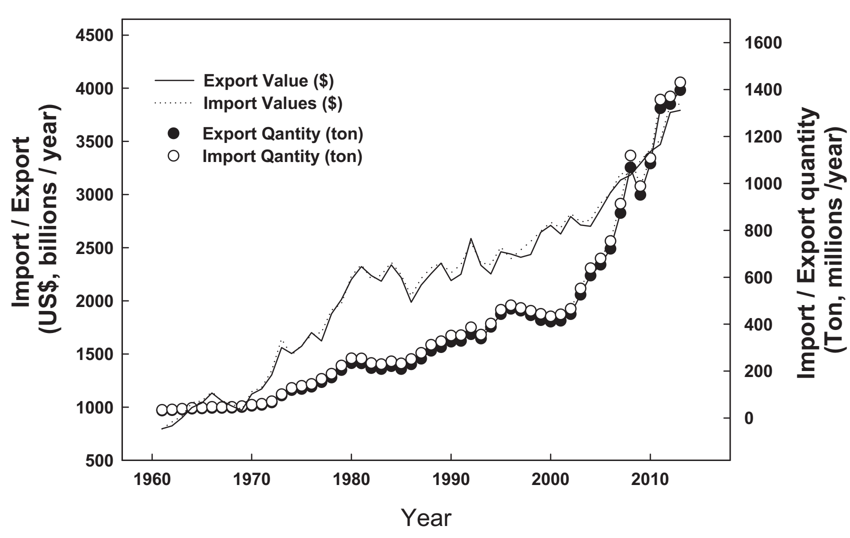

Fig. 1. Temporal global trends of import and export of agricultural cereal crops. Monetary values (in billions of US $/year) and biomass trade (ton/year) during the past decades. (Source: compiled from data from FAO Statistics Division, 2016).