Global Food Security xx (xxxx) xxxx–xxxx

Contents lists available at ScienceDirect

Global Food Security

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

Global footprints of water and land resources through China's food trade

Tariq Ali[a,b], Jikun Huang[a,b], Jinxia Wang[a], Wei Xie[a,*]

[a] China Center for Agricultural Policy, School of Advanced Agricultural Sciences, Peking University, No 5 Yiheyuan Road, Haidian District, Beijing 100871, China

[b] Center for Chinese Agricultural Policy, Institute of Geographical Sciences and Natural Resources Research, Chinese Academy of Sciences, Jia 11, Datun Road, Beijing 100101, China

ARTICLE INFO

Keywords:
Food trade
Virtual water
Virtual land
Footprint
China
Global

ABSTRACT

China's rapid increase in food imports has repercussions for China's and global resources. This study reviews the recent literature on China's virtual water and land trade through food trade, presents updated results for 2000–2015, and makes projections for 2030. The results show that the increased imports of virtual water and land have significantly eased pressure on these resources in China. Soybean imports have been the main contributor towards China's domestic savings of virtual water and land. China's food trade has increasingly contributed towards global savings of virtual water and land. Our projections suggest that the trend in savings of domestic and global virtual water and land will continue, with significant variations due to changes in resource use efficiency.

1. Introduction

China has largely ensured its food security despite the increase in demand for food due to an increase in population, higher levels of income, and changes in food consumption pattern. The biggest challenges of food supply in the last six decades in China were to meet the increasing food demand, resulting from: (i) increasing population, which increased by around 1% annually over 1978–2014, and (ii) rising per capita GDP, which increased by 9.7% annually over 1978–2014 (NBSC, 2015). The rising income has significantly increased the consumption of high-value products such as meats, dairy, and fruits. At the same time, China has also made tremendous progress in increasing agricultural production and nutritional status of its population (FAOSTAT, 2016). Despite its natural resource constraints, increase in China's food demand has largely been met by domestic agricultural production expansion, except for the demand for soybean (Huang, 2016).

However, in the past, China's agricultural expansion has been at the expense of environment and of sustainable development. Overdraft of groundwater has been one of the most serious problems in China. In 11% of the plain regions, groundwater extraction exceeded its sustainable levels (MWR, 2012). In the Hai River Basin, one of the major grain production regions in China, 91% of the area faces the problems of groundwater overdraft. Groundwater overdraft has resulted in issues such as groundwater table decline, land subsidence, and intrusion of seawater (MWR, 2016; MOEP, 2015). Soil degradation has also become a serious problem in many regions in China. Among other factors, unreasonable human utilization has caused degradation of 540 million ha (Mha) land, accounting for about 56.2% of the total national area (Long, 2013). Additionally, more than 50% of the total cultivated land has experienced land degradation (Li et al., 2011). Deng and Li (2016) estimated that the annual cost of land degradation reached US$ 37 billion in China in 2007 or about 1% of China's GDP. In terms of total resource use in agriculture, China's agricultural water withdrawal and cultivated land have increased 3.2% (from 378 km^3 to 390 km^3) and 5.4% (from 128 Mha to 135 Mha) between 2000 and 2015, which indicates increasing stress on these resources in China (FAOSTAT, 2016).

To meet the challenges of constraints in water and land resources, and of rising food demand, since the 1990s, China has partially but increasingly relied upon the international market to ensure its food supply. The previous studies showed that China, based on its comparative advantage, had expanded its food trade by increasing the import of land-intensive crops (e.g., cereal, soybean, edible oils, and sugar) and the export of labor-intensive products (vegetables, fruits, and processed foods) (Huang et al., 2010). By 2013, China's net food imports accounted for 6.7% of total food consumption (FAOSTAT, 2016). Given that trade in agricultural commodities is also an exchange of resources incorporated into the traded goods, there is a growing volume of recent literature on the impact of increased trade flows on hidden resources like water and land (Kastner et al., 2012; Kissinger, 2012). Regional differences in the quantity of water and land required

* Corresponding author.
E-mail address: xiewei.ccap@pku.edu.cn (W. Xie).

http://dx.doi.org/10.1016/j.gfs.2016.11.003
Received 26 July 2016; Accepted 13 November 2016
Available online xxxx

to produce one ton of crop biomass, termed as virtual water content (VWC) and virtual land content (VLC), can be used to mitigate regional scarcity of water and land. Some studies have suggested that although China's agricultural trade is steered by economic and political reasons, China has unconsciously been importing virtual water (VW) and virtual land (VL). Such VW and VL trade has implications at both national and global levels. A handful of studies have analyzed China's footprint of water and land via food trade (Liu et al., 2007; Liu and Savenije, 2008; Dalin et al., 2012a, 2012b, 2014; Qiang et al., 2013; Shi et al., 2014; Chen and Han, 2015) with different temporal, regional and commodity coverage.

A better understanding of China's historical and future global virtual trade in water and land can help China and the rest of the world evaluate alternate policy options in the future. Therefore, we have designed this study with two major objectives: 1) to draw key conclusions from the literature on China's virtual water trade (VWT) and virtual land trade (VLT) via agricultural commodities trade; 2) to update and provide coherent and consistent results on VWT and VLT over the past decade, and for the future. We contribute to the literature by using better VWC parameters (Hanasaki, 2016) and consistent coverage of commodity types for different years, for both VW and VL trade. We have used country-specific VWC and VLC of the same product for each country. Thus, covering past and future periods in a coherent analysis would help assess the dynamics and effects of various policies, economic and physical factors in China on China's and the world's water and land footprints.

It is worth pointing out that this study is focused on impact of China's food trade on footprints of water and land resources. Water/land saving with trade scenario indicates that more water/land would have to be used if there would be no trade.

The remainder of the paper is organized as follows. Section 2 reviews the literature for key findings. Section 3 describes the most recent (2000–2015) trends in China's trade in VW and VL, embodied in major food commodities. Section 4 contains our projections of China's food trade and corresponding flows of virtual water and virtual land. Section 5 concludes the paper with policy and research recommendations.

2. Key findings from existing literature

2.1. Virtual water trade

At the global level, agricultural commodity trade has helped save water resources. Literature contains different estimates on the amount of water saved via commodity trade, due to varying methods and crop/product coverage. Still, most of the studies have pointed towards water savings (Fader et al., 2011; Dalin et al., 2012a, 2012b). For example, Chapagain et al. (2006) estimated that agricultural trade saved 352 km^3 of global water resources in 2002, which was equivalent to 6% of the global water use in agriculture that year. Dalin et al., (2012a, Dalin et al., 2012b estimated that international food trade led to 8% savings in global fresh water withdrawal in 2005.

For China, VW trade has been growing at a rapid pace since late 1990s. According to Liu et al. (2007), the annual total virtual water imports of all the 32 crops increased steadily from an annual average of 32.0 km^3 (accounting for 7.7% of agricultural water withdrawal) during 1981–1990 to 44.9 km^3 (accounting for 11.5% of agricultural water withdrawal) during 1991–2004. A more recent study by Shi et al. (2014) shows that annual total VW imports (for 27 primary crops covered) increased from 33 km^3 in 1990 to 148 km^3 in 2009, which were 26.3% and 39.8% of China's agricultural water withdrawal in respective years. However, during 1990–2009, the annual total VW exports of all crops remained almost constant, ranging between 12.7 km^3 in 1990 and 16 km^3 in 2009. As a result, total net VW imports due to agricultural trade have been increasing continuously. Net VW import increased from about 78 km^3 in 2004, to a staggering 138 km^3 (accounting for 37.1% of China's agricultural water withdrawal) in 2009 (Shi et al., 2014). In contrast, for both agricultural and industrial trade during 1996–2005, China had 23 km^3 average annual net exports of VW (Hoekstra and Mekonnen, 2012). As pointed out earlier, estimates from these studies have slight differences due to different commodity coverage and parameters used.

A few major crops have been responsible for the rising trend of VW trade for China. Since the 1990s, except for a few years, more than 95% of VW imports consisted of soybean, cereals, and edible oils (Liu et al., 2007; Shi et al., 2014; Zhuo et al., 2016). For soybean, China was a net exporter until before 1996. However, due to increasing imports caused by higher domestic demand and by liberalizing soybean trade since China's joining of WTO in 2001, China's import of Soybean has significantly increased. On the other hand, China also exports many agricultural products such as vegetables, fruits, tobacco, and tea; these exports contributed to the rising trend of total VW export.

In the recent past, geographic distribution and trading partners for China's VW trade have been evolving rapidly. China's total number of virtual water trading partners has increased from 34 in 1986 to 159 in 2009. Generally, Asia, Europe, and Africa are China's net VW export partners. The Americas and Oceania are China's net VW import partners, from whom China imported much larger volumes of VW than that it exported. Further analysis of VW trade network shows that it is heterogeneous and highly polarized, with eight big partners accounting for more than 85% of China's VW trade (Shi et al., 2014).

More importantly, China's agricultural trade has also been saving domestic and global water resources. China's domestic savings of water increased from 16.5 km^3 per year during the period 1961–1980 to 30.6 km^3 per year during 1991–2004 (Liu et al., 2007). More recently, China's domestic savings of water due to agricultural trade increased from 33 km^3 in 2000 to 138 km^3 in 2009 (Shi et al., 2014). These estimates are quite similar to findings of Zhuo et al. (2016), who reported that China saved 108 km^3 of VW in 2008 due to international crop trade. Domestic water savings in 2009 were equivalent to 37% of China's irrigation water use in that year (Shi et al., 2014).

China's role in global water savings through agricultural trade has been significant. During 1998–2001, China contributed around 24% to the total global water savings (263 km^3) related to agricultural trade (Fader et al., 2011). Trade in Soybean has been a major contributor towards global water savings, mostly due to increase in China's imports from the more efficient producers (United States, Argentina, and Brazil). In 2007, China's trade in Soybean was responsible for a significant part (36%) of the total global water savings associated with major food commodities (Dalin et al., 2012a, 2012b).

2.2. Virtual land trade

International trade in agriculture can play an important role in compensating for land scarcity, especially in countries with scarce land endowments. Globally, trade during 1998–2002 saved about 41 Mha land annually, which was about 5% of cultivated land (Fader et al., 2011). The global agricultural system can be more productive if trade is directed from countries with higher yields to countries with lower yields. For example, in comparison to a hypothetical self-sufficient world, agricultural trade pattern in 2001 raised global land productivity by 5% (Fader et al., 2011).

There are very few studies focusing on China's VL trade. In this paper, we summarize the major findings from a recent study by Qiang (2013), which indicates China has been importing significant quantities of VL via its agricultural trade in 6 main crops. Virtual land imports of China grew from 1.2 Mha (equivalent to 0.93% of China's cultivated area or 0.73% of crop sown areas) in 2000 to 33 Mha (27.1% of China's cultivated area or 20.8% of crop sown areas) in 2009. For the past fifteen years, the average cropping intensity index (sown area/ cultivated land) in China has been around 1.25. For simplicity, we will hereafter only compare land savings with cultivated land. Exports of VL