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Earth's Future

COMMENTARY

10.1029/2020EF001482

Key Points:

- China imports a large and still increasing amount of agricultural products, particularly soybean
- The U.S.-Sino trade conflict has significant and profound impacts on China's agricultural trade
- China needs to diversify sources of soybean imports and pay attention to avoid unintended environmental impact on food source countries

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China's Food Supply Sources Under Trade Conflict With the United States and Limited Domestic Land and Water Resources

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Abstract The U.S.-China trade conflict has already considerably reshaped China's food imports, and should the conflict continue, it might have substantial impacts on global food supply dynamics as well as China's food supply sources. We address these implications by analyzing recent trends in China's food imports and associated use of land and water resources. We show that China's limited land and water availability will make it challenging to replace soybean imports from the United States with its own production, but switching to new trading partners by investment and cooperation could secure China's food supply while avoiding much negative environmental impacts on exporting countries.

Plain Language Summary The U.S.-China trade conflict has substantial impacts on international food market and China's food supply. We answer the question how China can safeguard its food supply in the context of trade conflict by tracking China's recent food imports and embodied virtual water and land imports. We find that China may have to diversify its trade partners for compensating reduction in imports from the United States and pay attention to avoid unintended environmental impacts on food source countries.

1. Introduction

China's rapid economic development, improvement of living standards, and growing population, of 1.4 billion in 2018 (NBSC, 2019), have boosted its food demand (Lu et al., 2015). A substantial portion of this increased demand has been met by imports from the global market, particularly for animal products and feed, such as soybean (Dalin et al., 2014). As one of the world's largest food and feed exporters, the United States has been the most important source for China's food imports. The rapid increase in food imports since the year 2000 relates to China's accession to the WTO in 2001 as well as the tight Sino-U.S. economic linkage. In 2016, about 22% of the United States food exports were directed to China, amounting to 49 Mton (million metric tons) of products at a value of US\$21 billion (FAO, 2019).

Associated with food imports, China imported a large amount of virtual water and virtual land from the United States (Hou et al., 2018). Meanwhile, the food imports would have also been beneficial to China's environment, as otherwise more pollutants would be emitted from the additional fertilizer applications and animal production (Bai et al., 2014; Liu et al., 2019).

The recent trade conflict between the two countries has led to a dramatic reduction of China's food and feed imports from the United States. China's soybean imports from the United States dropped abruptly by 98% after the United States introduced 25% higher tariffs on US\$34 billion of goods from China on 6th July 2018 (Figure 1). The soybean imports from the United States went to zero in November 2018, whereas it amounted to 4.7 Mton in the same month of 2017. In total, China's soybean imports from the United States in the year 2018 were only half of that in 2017 (Fuchs et al., 2019).

The most recent trade data show a slow increase in China's soybean imports from the United States since March 2019 (Figure 1). A switch to alternative supplies of soybean is also seen in Figure 1, with a massive increase of imports from Argentina and Canada in 2019. Early 2019, the Chinese government issued the

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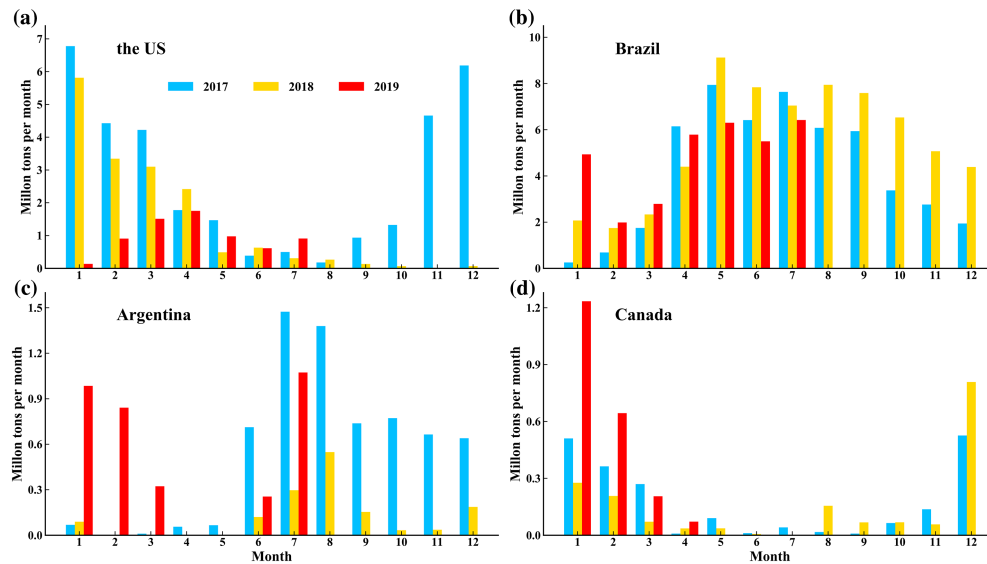


Figure 1. China's monthly soybean imports from four major exporting countries since 2017. (a) The United States; (b) Brazil; (c) Argentina; (d) Canada. (Data available from the General Administration of Customs, P.R. China: www.customs.gov.cn).

“Soybean Revitalization Plan”, aiming at the expansion of sowing areas and production of soybean. It remains unclear whether China can compensate for all food imports from the United States through increased domestic production or whether it will have to switch to increased imports from other countries.

2. Methods

We analyze changes in China's food demand and supply (including domestic production and imports) between 2000 and 2017 and quantify the land and water resources virtually embodied in China's food and feed imports. This study focuses on five important commodities for China's food security: soybean, maize, rice, wheat, and pork. We obtain the data on yields, production and sown areas of the four crops, pork production, total sown areas, and agricultural water supply from the Chinese National Statistics for the period 2000–2017 (NBSC, 2019). International food trade data from 2000 to 2016 are derived from the FAO (the Food and Agriculture Organization of the United Nations) (FAO, 2019). China's food imports and exports in 2017 are obtained from the Chinese Statistical Data. We checked the FAO data against the Chinese Statistical Data and found that they are generally consistent. As the U.S.-China trade conflict mainly affects soybean imports, we derive China's monthly soybean imports for the period from January 2017 to July 2019 from the General Administration of Customs of the People's Republic of China (www.customs.gov.cn) to present the most recent trade shifts.

Blue water footprint (evaporated irrigation water per unit of production) is defined as the volume of evaporated irrigation water resources per unit of production ($m^3 \text{ ton}^{-1}$). The blue water footprints of crop commodities used in China are derived from the Water Footprint Network (Mekonnen & Hoekstra, 2011, 2012). An average irrigation efficiency of 0.45 is used for China (Peng, 2011) to translate blue water footprints into estimates of blue water supply. Land footprint ($ha \text{ ton}^{-1}$) of crops is defined as the inverse of crop yields. Net land and water embedded in imports are estimated by multiplying net food imports by their respective land and water supply footprints. In order to calculate the land footprint of pork products, a feed conversion coefficient (defined as dry matter feed requirements per ton of meat production) of 6.4 is used on the basis of Mekonnen and Hoekstra (2012) for China. Then, 16%, 48%, 17%, and 13% of the dry matter feed is allocated to soybean, maize, rice, and wheat in China (Dalin et al., 2014).

3. Results and Discussion

China's domestic production of maize, rice, wheat, and pork increased during the period 2000–2017 (Figure 2a). The largest increase was achieved for maize with production more than doubled, from 106 to

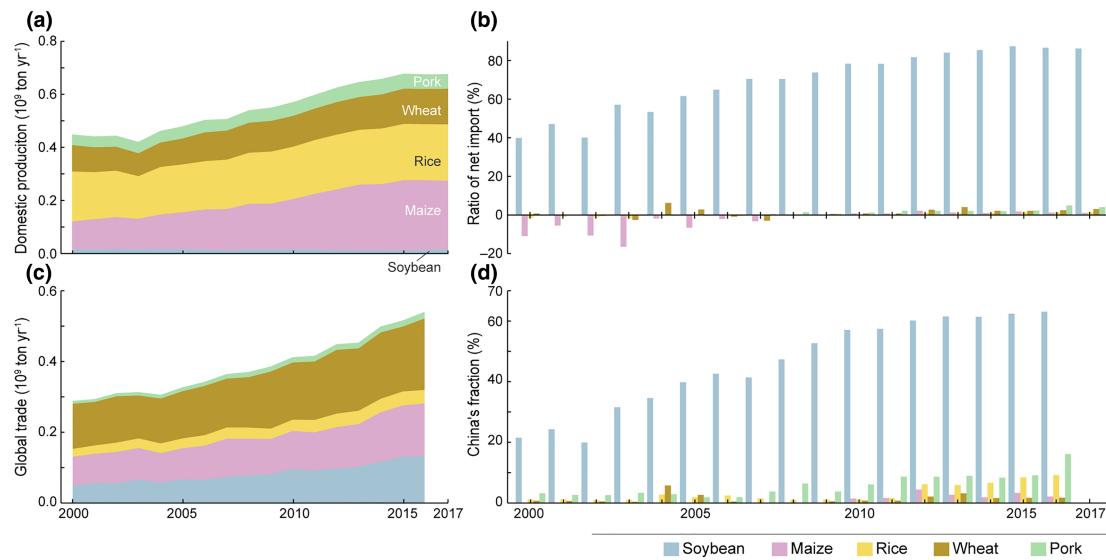


Figure 2. China's domestic food production and import and China's share in global food trade. (a) Domestic food production; (b) ratio of net import to China's total food consumption; (c) global food trade; (d) fraction of China's import in global trade. Negative numbers in subplot (b) indicate net food export.

259 Mton year⁻¹ (million tons per year), but the production growth of other cereals has recently stagnated. For maize and rice as well as wheat, domestic production ensured about 97% of the total supply in 2017, in line with China's food security policy (Ghose, 2014). It is notable, however, that over the past two decades, China turned from a net exporter into a net importer for maize, rice, and wheat, even though the ratios of imports/exports to domestic production remained small (Figure 2b).

By contrast, the production of soybean in China has remained small and even experienced a decrease while imports grew substantially. The share of imported soybean, primarily from the United States and Brazil, in the national consumption increased from 40% in 2000 to 86% in 2017 (Figure 2b). As most of imported soybean (about 70%) is used for livestock feed (Fuchs et al., 2019; Taherzadeh & Caro, 2019), the production of pork critically depends on soybean imports.

The global food market has been expanding rapidly during the past two decades (Figure 2c), with China as one of the major players (Figure 2d). China's imports of rice, pork, and soybean accounted for 9%, 16%, and 63% of the total global trade volumes in 2016, respectively. In contrast to a large number of importing countries, there are currently only a few major food exporting countries in the world, namely, the United States, Brazil, Canada, Argentina, and Australia. For soybean, about 95% of China's imports have been from the United States, Brazil, and Argentina. Therefore, the recent trade volume reduction between China and the United States and resulting changes in the global food market have considerable implications for China's domestic food supply sources.

China's domestic crop production uses 160 Mha (million hectares) or 0.12 ha per capita (for both food crops and nonfood crops) (Figure 3a). The four major crops take up the majority of these hectares, together accounting for about 65% of total sown areas. From 2000 to 2017, there were slight increases in sown areas for maize, rice, and wheat, but these increases stalled recently (Figure 3a). Soybean's sown area actually decreased since 2000. China's total agricultural water supply changed little over the past two decades, being around 380 Gm³ year⁻¹ (billion cubic meters per year) (Figure 3b).

The food imports can be viewed as an additional source of land and water for China, so-called "virtual land" and "virtual water", defined as the land and water required for the production of the imported products (Hoekstra & Mekonnen, 2012). The external land footprint related to the products considered here increased from 3.6 to 56.2 Mha year⁻¹ within the study period (Figure 3a). The virtual land imports in 2017 were almost equal to the sown areas devoted to "other crops" (about 60 Mha). Besides, China also externalized a substantial part of its water supply, with the virtual water imports increasing from 2.5 to 61 Gm³ year⁻¹ during the study period (Figure 3b). Imported soybean accounted for 87% of this virtual water supply. The

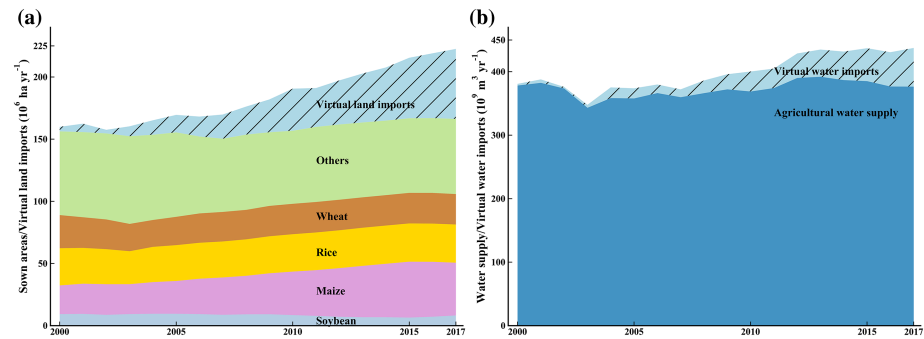


Figure 3. Sown areas, agricultural water supply, and virtual land and water imports in China. (a) China's sown areas and net virtual land imports; (b) China's total agricultural water supply and net virtual water imports (see section 2). "Others" in subplot (a) means China's sown areas for other crops.

virtual land and water supply from the United States alone reached 20.1 Mha and 20 Gm³, or one third of total imports, in 2016.

Despite the aim of the Chinese government to keep a high level of food self-sufficiency, food supply is increasingly relying on international imports (Figure 2b). Virtual land imports accounted for one third of the total sown cropland areas in China, while virtual water imports accounted for 16% of China's total agricultural water supply in 2017 (Figure 3). The higher fraction of virtual land imports in total sown areas than the fraction of virtual water imports in total agricultural water supply is noticeable. This is mainly because soybean yield is much lower than the yields of the three other crops (NBSC, 2019), but its blue water footprint is relatively comparable to the three other crops (Mekonnen & Hoekstra, 2011). China has a total arable land of around 135 Mha (NBSC, 2019). The Chinese government has set 103 Mha as the basic agricultural land areas, which must be protected from being used for other purposes (MLR, 2016). Currently, Chinese crop sown areas are already 1.6 times larger than this area (Figure 3a), primarily because of multiple cropping in some regions. There is thus very limited space to expand cropland. This is particularly so with China's increasing attention to ecological restoration and environmental protection. China's water policy sets a "red-line" for total water supply at 670 Gm³ by 2020 (Liu et al., 2013), leaving little room to increase agricultural water supply because total water supply already reached 611 Gm³ in 2018 (NBSC, 2019). The current water scarcity and depletion of groundwater in many places in China, notably in the main breadbasket of the North China Plain (Rodell et al., 2018), makes the domestic increase of food production even more challenging. Given the limited land and water availability, it will be hard and also economically irrational for China to replace the imported food from the United States with domestic production. With China's determination to maintain a high level of self-sufficiency for wheat, rice, and maize, soybean would be at the center of China's food production, food trade, and food security strategies.

In May 2019, the Chinese government planned to extend the soybean area from 8.3 Mha in 2017 to 9.3 Mha in 2020, and to improve soybean yields from 1.8 to 2.0 ton ha⁻¹ over the same period (MARA, 2019). With these targets achieved, China could increase national soybean production by 3.7 Mton year⁻¹, which would replace about 10% of the imports from the United States in 2017. In the long term, improving soybean yields to an estimated attainable level of 2.8 ton ha⁻¹ based on Mueller et al. (2012), about 33% of the imports from the United States in 2017 could be compensated with domestic production under soybean area of 9.3 Mha. The remaining gap would still need to be filled by imports. Therefore, China needs to find more soybean sources and diversify its trading partners to secure the long-term food, particularly soybean supply.

Kummu et al. (2017) estimated that if China could reduce its animal protein intake to 25% of total protein supply, as recommended by the World Health Organization (WHO), it could increase national plant-based protein supply by 20% owing to the reduced conversion need from plant protein to animal protein. However, it is currently challenging for China to take the WHO recommended level given its rapid economic growth and expansion of middle-class people. The increase in meat consumption in the total diet is expected to continue to increase in the coming years—getting closer to consumption in Europe and the United States (Du et al., 2018). Further, population growth in China is projected to level off only in 2030

Table 1

Soybean Production in 2016, Possible Land for Soybean Extension and Possible Additional Soybean Production, as well as Total Water Resources and Water Supply in Six Major Soybean Producing Countries

	Yield	Production	Agricultural land	Cropland	Land for soybean extension	Additional production	Water resources	Water supply
	(ton ha ⁻¹ year ⁻¹)	(Mton year ⁻¹)	(Mha)	(Mha)	(Mha)	(Mton year ⁻¹)	(Gm ³ year ⁻¹)	(Gm ³ year ⁻¹)
	C1	C2	C3	C4	C5 = C3 – C4	C6 = C1 * C5	C7	C8
Argentina	3.0	58.8	148.7	40.2	108.5	327.1	876.2	37.8
Bolivia	2.4	3.2	37.7	4.7	33.0	79.1	574	2.1
Canada	3.0	6.6	58.1	38.7	19.3	58.2	2,902	37.3
Paraguay	2.7	9.2	22.0	5.0	17.0	46.2	387.8	2.4
Russia	1.5	3.1	216.2	123.2	93.0	137.5	4,525	69.5
Ukraine	2.3	4.3	41.5	33.7	7.8	18.0	175.3	12.4

Note. Data on soybean yield and production, agricultural land, and cropland are derived from FAO. Water resources and supply are downloaded from the AQUASTAT data set (<http://www.fao.org/aquastat/en/>) for the period 2008–2017.

(FAO, 2018). Therefore, the demand of food supply, particularly soybean, is predicted to be even higher in the future.

The sharp drop in soybean imports from the United States in 2018 was substituted solely by imports from Brazil—making Brazil the dominant soybean exporter to China (75% of China's total imports), while there was a slight decrease of imports from Brazil in 2019 (Figure 2). Expanding imports from Brazil could incentivize deforestation in the Amazon rainforest (DeFries et al., 2010; Fuchs et al., 2019). Besides, strongly relying on imports from a single country introduces another risk for China's food security. An increasingly wealthy China with a growing population means additional food demands at least in the next two to three decades (FAO, 2018). Global climate change, on the other hand, poses further possible negative effects on food production and supply stability (Wheeler & von Braun, 2013). Taking together all these factors, the best risk mitigating strategy for China would be to diversify its food trade partners.

Currently, in addition to the United States and Brazil, other large soybean producers are Argentina, Paraguay, Canada, Ukraine, Bolivia, and Russia, with 85 Mton year⁻¹ production together in 2016—accounting for 25.4% of global soybean production (FAO, 2019). It is likely that China will enlarge imports from these countries, if imports from the United States do not resume in the coming years. In fact, we have already seen large increases in China's soybean imports from Argentina and Canada from January to July 2019, with respective 5.9 and 2.4 times increases relative to the same period in 2018 (Figure 1). Although these six countries above are currently not major soybean exporters (together about 15% of total world exports in 2016) (FAO, 2019), they generally have abundant land and water resources (Table 1). The average ratio of cropland to total agricultural land in these six countries is about 0.44, while the average ratio of water supply to water resources is only 0.03. There is thus a large potential for them, especially Russia, Argentina, and Canada, to increase soybean production and exports even with the current level of yields. Utilizing a fraction of this potential would already be sufficient to compensate China's loss of imports from the United States.

We would like to mention that the trade relationships between countries are very complex. The signing of the Sino-U.S. first phase trade agreement in January 2020 has not reduced the uncertainties/conflicts, evident by the situation since 2020. A deeper analysis on China's actual strategies to deal with the Sino-U.S. trade relations and to diversify its trade partners is out of the scope of the study. However, the relatively favorable water and land endowments of the above-specified countries and the trends of their food trade with China in recent years suggest that there is a large potential for China to diversify its food imports among these countries.

Soybean cultivations in above six potential substitute countries are mostly under rainfed condition (Mekonnen & Hoekstra, 2011), hence have little effects on blue water resources. Argentina, Canada, and Paraguay have similar or even higher soybean yields than Brazil (2.9 ton ha⁻¹ year⁻¹) in 2016 (Table 1), so require comparable land (relative to Brazil) to expand soybean production. Although the other three countries may need more land than Brazil to have the same level increases in soybean production due to

lower yields, their influences on clearing forests for enhancing production are much minor than Brazil (Henders et al., 2015) because of abundant agricultural land (Table 1). Therefore, swifiting China's soybean imports to these countries would not have much local negative environmental impacts while benefit for the Amazon's forest.

Besides, China could also help release the food production potential in other countries with favorable water and land endowments by direct investments into these countries. China is currently ranked the third in countries with large investment for acquiring land (or "land grabbing") in other countries, following the United Kingdom and the United States (Rulli et al., 2013). These land acquisitions could increase China's food supply, but could also have negative effects on the countries and local communities where the land acquisition occurs (Dell'Angelo et al., 2017). Therefore, it is important and obligatory for China to reduce the negative impacts on these countries.

4. Conclusions

Coming to this end, we would say that the challenge facing China's food supply is not whether it can find the alternative food sources to replace the imports from the United States, but how to unleash the potential of exporting countries to increase food supply without imposing negative impacts on their environment. With the increasing demand for animal products, soybean will continue to play a pivot role in China's food trade. China's huge investment capacity would enable it to help the existing exporting countries to boost their soybean supply in a relatively short time. In the long run, China's investment in agriculture could also unleash the potential of some African countries and turn them into new sources of food exports (FAO, 2018). Such investment and food security strategy can be well embedded in China's "Belt and Road Initiative" currently pushed by the government. By diversifying the trade partners, China could also contribute to the reduction of deforestation in Brazil, caused by encroachment of soybean area into the Amazon rainforest, with mostly no effects on blue water resources as well.

Finally, there are many uncertainties in the current and longer-term Sino-U.S. trade relations. The signing of the first phase trade agreement does not guarantee the stability of the trade, as there are still many uncertainties in the relations between these two countries. These uncertainties would even increase the need for China to diversify its trading partners to secure the long-term food, particularly soybean supply.

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