Importing food damages domestic environment: Evidence from global soybean trade

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Contributed by Harold Mooney, March 1, 2018 (sent for review October 18, 2017; reviewed by Jonathan Foley and James N. Galloway)

Protecting the environment and enhancing food security are among the world's Sustainable Development Goals and greatest challenges. International food trade is an important mechanism to enhance food security worldwide. Nonetheless, it is widely concluded that in international food trade importing countries gain environmental benefits, while exporting countries suffer environmental problems by using land and other resources to produce food for exports. Our study shows that international food trade can also lead to environmental pollution in importing countries. At the global level, our metaanalysis indicates that there was increased nitrogen (N) pollution after much farmland for domestically cultivated N-fixing soybeans in importing countries was converted to grow high N-demanding crops (wheat, corn, rice, and vegetables). The findings were further verified by an intensive study at the regional level in China, the largest soybean-importing country, where the conversion of soybean lands to corn fields and rice paddies has also led to N pollution. Our study provides a sharp contrast to the conventional wisdom that only exports contribute substantially to environmental woes. Our results suggest the need to evaluate environmental consequences of international trade of all other major goods and products in all importing countries, which have significant implications for fundamental rethinking in global policy-making and debates on environmental responsibilities among consumers, producers, and traders across the world.

agriculture | environment | nitrogen | Sustainable Development Goals | telecoupling

International food trade plays a critical role in global food security and economic development, but has also caused many environmental problems, such as water pollution and biodiversity loss in exporting countries (1–3). For example, due to increasing oversea demands, unprecedented deforestation in the Brazilian Amazon and *cerrado* caused by soybean and grazing land expansion has drawn global concern (4–6).

Much research has concluded that international trade inherently displaces environmental burdens from importing countries to exporting countries, and thus importing countries benefit from the displacement environmentally (7–10). Based on the new integrated framework of telecoupling (socioeconomic and environmental interactions over distances) (11, 12), we hypothesize that importing countries could also suffer from environmental problems.

To test this hypothesis, we analyzed environmental effects of soybean trade at the global level by performing a metaanalysis of 168 studies across six continents on per-hectare nitrogen (N) balance (N applied to the growing field minus the N appearing in the crop) (Fig. S1), where the crops include soybeans and four major crops (wheat, corn, rice, and vegetables) converted from soybeans (Fig. 1*A*). We estimated the N balance change associated with the crop conversion (soybeans to four major crops) affected by soybean imports in the top 10 destinations of exported soybeans from the world's top two soybean producers and exporters (Brazil and the United States) (Fig. 1*A* and Table S1) (13).

To verify the findings at the global level, we conducted an intensive study in the most important soybean production region of the world's largest soybean importer (China) that has gone through extensive crop conversion due to the soybean import. China imported 61% of global exported soybeans (71.4 million tons) in 2013, for example, with Brazil and the United States being the top two suppliers that provide cheaper soybeans to China (14, 15). Soybean lands in China are experiencing a clear decreasing trend because more than 80% of soybeans used by its domestic food industry are now imported (11).

Results

Globally, crop conversion from soybeans to wheat, corn, rice, and vegetables in importing countries caused N pollution (excess over growth requirement that ended up as runoff, leaching, and losses to the atmosphere). Results calculated from the meta-analysis indicate that the global average of per hectare N balance varied substantially among different crops: per hectare N balance of soybeans was negative, while the per hectare N balance of wheat, corn, rice, and vegetables was positive (Fig. 1 *B*) and increased after

Significance

Achieving global environmental sustainability and food security is among the world's biggest challenges. International food trade plays an important role in global food security. It is widely believed that importing countries benefit environmentally from international food trade at the environmental cost of exporting countries. Contrary to the conventional wisdom, our study reveals a major environmental problem in importing countries. The unexpected findings suggest the need to reevaluate environmental consequences of international trade in all importing countries through discussions regarding environmental responsibilities among consumers and producers. There is an urgent need for innovative solutions for reducing environmental pollution and enhancing food security to offset the negative impacts of international trade globally.

Author contributions: J.S., H.M., and J.L. designed research; J.S., Y.T., and J.L. designed the survey; J.S., W.W., H.T., Y.T., Z.X., B.H., Y.C., X.Y., D.W., and F.Z. coordinated and conducted the survey; J.S. analyzed the data; J.S., H.M., and J.L. wrote the paper; and all authors reviewed and revised the manuscript.

Reviewers: J.F., California Academy of Sciences; and J.N.G., University of Virginia.

The authors declare no conflict of interest.

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This article contains supporting information online at www.pnas.org/lookup/suppl/doi:10.1073/pnas.1718153115/-/DCSupplemental.