Nitrogen footprint updates in Japan: Significance of global trades and food culture

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Abstract
Nitrogen (N) footprint is a powerful parameter to understand loss of reactive N (i.e. all forms of nitrogen except N_2) to the environment by use of food, and energy in human's daily life. The amount and composition of the N footprint differs among communities, countries and regions depending on various factors such as environment, economy, technological development and their culture. Japan is the top net importer of embodied reactive N emissions in food, feed, energy, and goods among countries, resulting in large loss of reactive N to the environment both inside and outside of Japan. Here we present updated information of N footprint in Japan by synthesizing the recent research findings. Virtual N factors (VNFs) of meat processed food in Japan are mostly higher than those in other countries while fish and seafood (especially wild-caught fish) is also important source of animal protein with generally lower VNFs than that of animal meat. It was suggested that shifting consumer preferences from meat- and dairy-intensive diets to diets with more fish and vegetables would have potential to reduce the N footprint in Japan. Increase of N use efficiency during production, processing, and consumption of food through technological improvements in agriculture and food industries with changes in personal dietary choices are needed to decrease loss of reactive N to the environment both in Japan and countries that provide food and feed to meet demand of Japan.

Keywords
Reactive nitrogen, Food, Energy, Virtual nitrogen factor, Life cycle assessment

Introduction

Nitrogen is an essential nutrient for all biota, but reactive N (all forms of N except N_2) becomes a source of pollutant for water, air, and soil when the amount and/or concentration of N exceed the demand of ecosystems and the thresholds of certain environment capacity (Galloway et al. 2014; Shibata et al. 2015). Human use of food, energy, transportation, goods and services produces much amount of reactive N which can be lost to the environments. Air pollution, water eutrophication and pollution, soil acidification, nitrogen saturation in ecosystems and greenhouse gas emissions (i.e., N_2O), are all those environmental problems that relate to the excess loss of reactive N to the environment (Shibata et al. 2015).

Nitrogen footprint analysis has been developed to estimate direct and indirect loss of reactive N to the environment through the use of food, energy, goods and services, and transportation (Leach et al. 2012; Shibata et al. 2016). Those include reactive N loss through food production, processing and consumption for each food category. Previous studies have indicated that per capita N footprints vary widely among countries influenced by various factors such as food intake characteristics, waste water treatment, economic status, food self-efficiencies and others (Galloway et al. 2014; Shibata et al. 2015; Oita et al. 2016a).

Japan, which was previously an agricultural and fishery country, currently relies on much imported food and feed from foreign countries and is being further impacted under the global trades with the third largest gross domestic product (GDP) following the U.S.A and China. Those characteristics would affect the national and per capita N footprint in Japan. Recent studies provided several important insights in the N footprint in Japan (Shibata et al. 2015; Oita et al. 2016a, 2016b, 2016c). Here we synthesize them to update the current situation and discuss the future research need.

The per capita and national N footprint in Japan

Shibata et al. (2014) developed the N-Calculator for Japan using the protocol developed by Leach et al. (2012) and various statistics and available data in Japan. They indicated that the current per capita N footprint is 28.1 kg N/capita/year dominated (ca. 78%) by food productions (Figure 1). Using a top-down approach, extended multi-region input–output analysis, Oita et al. (2016a) recently calculated N footprint of nations, including the average per capita N footprint in Japan of 39.8 kg N/capita/year. The difference of two estimated N footprint values is due to the different calculation methods. The total N footprint in Japan was 5,040 Gg /year and about a half (ca. 48%) of the embodied reactive N loss was potentially exported as reactive N in water bodies (mainly as nitrate), while the rest was release as N_2O, NH_3 and NOx (Figure 2) (Oita et al. 2016a).

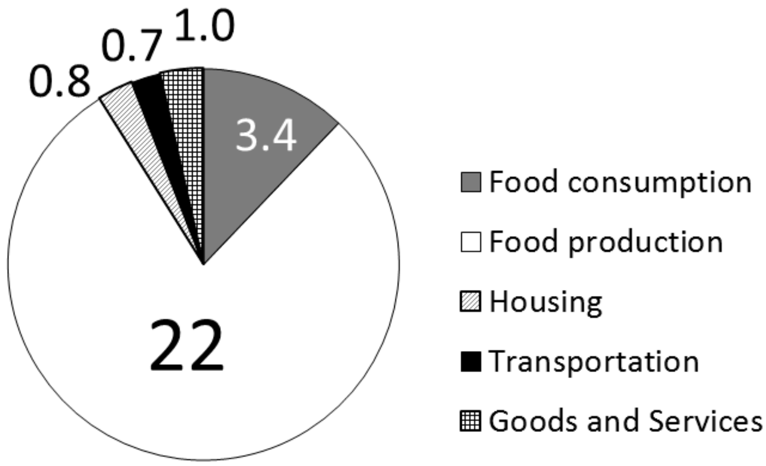

Figure 1. The per capita N footprint (kgN capita^{-1} year^{-1}) in Japan, predicted using N-Calculator (created from Shibata et al. 2014.)

Impact of global trades

The self-efficiency of food and feed in Japan was low, relying on imported food and feed (ca. 61% for food, ca. 75% for feed). The per capita of N footprint in Japan was strongly affected by those trades (Shibata et al. 2014; Oita et al. 2016a). The Virtual N factors (VNFs; Ratio of reactive N released to the environment during food production per unit of reactive N consumed) of major meat production (i.e., pigmeat, poultry meat and bovine meat) in Japanese domestic production/processing process were much higher than imported food (Shibata et al. 2014). Therefore, the consideration of trade decreased the per capita N footprint in Japan compared to the value predicted without trades. Oita et al. (2016a) indicated that Japan is a top net importer of N footprint and net N footprint (import minus export) exceeded over 3,300 Gt/year. The major trading countries for Japan are China (mainly textiles), the U.S.A. (mainly bovine meat and swine meat), Australia (mainly bovine meat. lamb meat, and edible offal of animals), India, and Thailand (Oita et al. 2016a, supplemental information). All those findings indicate that the global trade is a significant driver for the per capita and country total N footprints in Japan, also suggesting a significant contribution to the global N footprint dynamics.

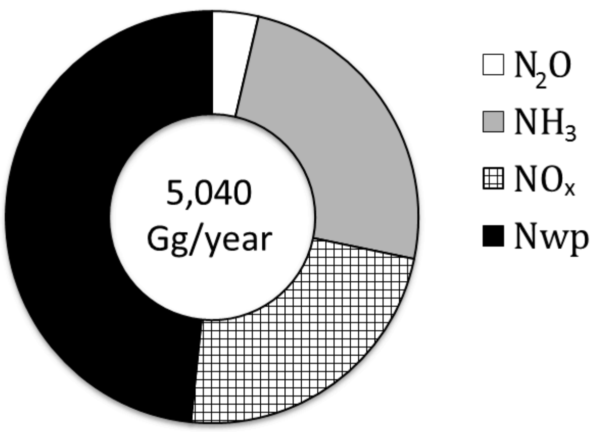

Figure 2. Total N footprint in Japan (5,040 Gg/year) as each form of reactive N loss to the environment. Nwp: nitrogen potentially exportable to water bodies, mostly nitrate (created from Oita et al. 2016a).

Food culture and N footprint

The VNFs of meat production are found to be much higher than those of crop production (Figure 3, Shibata et al. 2014). In addition, fish and seafood generally has smaller VNFs compared to the bovine and pig meat production, especially for wild-caught fish and non-fed farmed fish due to the absence of feeding. Oita et al. (2016b) provided updated VNFs of seafood in Japan by analysing the detail processes of N flows for different types of seafood as 0.2 (non-fed aquacultured and captured), 4.3 (fed freshwater and diadromous fish), 3.4 (fed marine fish), and 7.6 (fed crustaceans) (Figure 3) (Oita et al. 2016b). All those VNFs are much lower than those of the other meat products determined by Shibata et al. (2014). It was suggested that food choices in daily life can alter the per capita N footprint and shifting from meat -intensive diets to diets with more seafood would contribute to reduce the loss of Nr to the environment significantly.

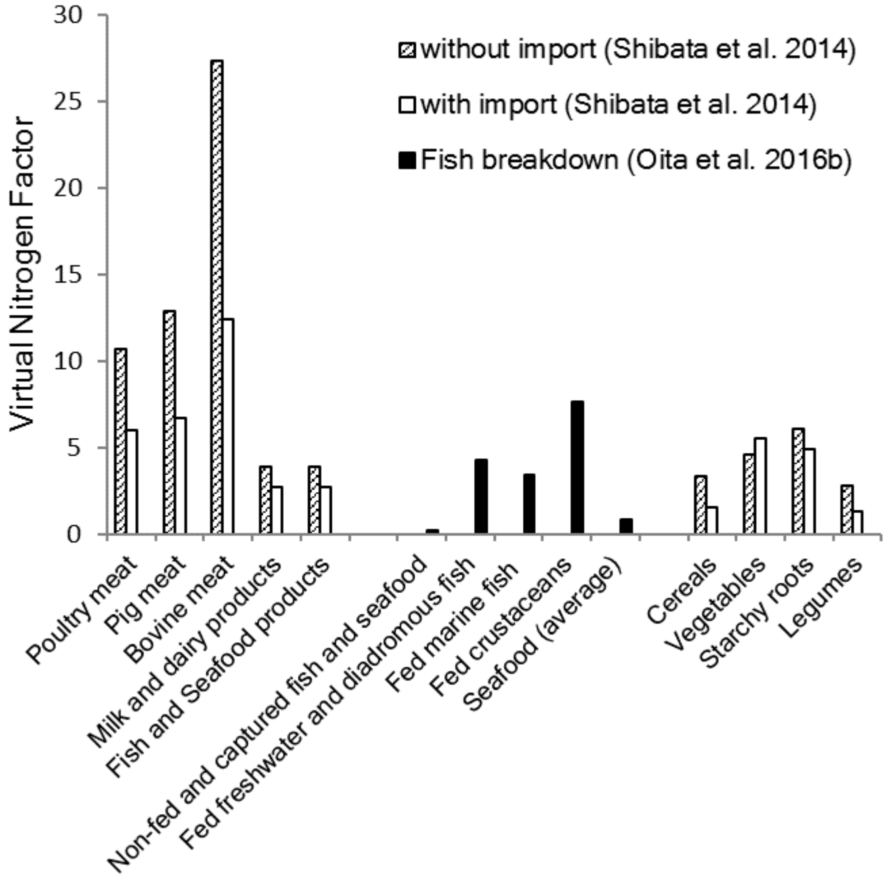

Figure 3. Virtual N factor (Ratio of reactive N released to the environment during food production per unit of reactive N consumed) for major food category in Japan (created from Shibata et al. 2014 and Oita et al. 2016b)

Conclusion

Demand by Japanese consumers is associated with much reactive N loss both within Japan and in imported countries as the top net N footprint importer. Further understanding for future trends of N footprint with aging and shrinking population in Japan is needed to develop a sustainable society under limited recourses. Spatial gaps of consumers and producers of reactive N derived from N footprint and their environmental consequence should also be addressed locally, regionally and globally. More public awareness for adequate dietary choices from the aspects of human health, economy and environment is critical to reduce the loss of reactive N to the environment as well as technical innovation to increase the N use efficiency in various food and energy sectors, especially in agricultural practices.

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