Nitrogen Footprints Affected by Consumption of Organic Products

James Galloway[1], Laura Cattell Noll[1], Allison Leach[2], Verena Seufert[3] and Jessica Shade[4]*

Abstract

Plant available nitrogen is necessary for crop and animal production, but when it is lost to the environment, it creates a cascade of detrimental environmental impacts, including smog, acid rain, eutrophication, climate change and stratospheric ozone depletion. Nitrogen management creates a dilemma to maximize its food production benefits, while minimizing its losses to the environment. Organic practices in food production intend to reduce the detrimental impacts of agricultural systems on the environment and human health. This study explores the effects such practices have on nitrogen (N) pollution, in comparison to conventional food production practices.

To examine the effects of farming system on nitrogen lost during food production we used virtual nitrogen factors (VNFs) that quantify the amount of nitrogen lost to the environment per unit nitrogen consumed. Virtual nitrogen is defined as 'nitrogen used in the food production process and is not in the food product that is consumed' (Leach et al 2012). This virtual N includes nitrogen lost throughout the food production process, including, N in the applied fertilizer that is not taken up by the whole plant, crop residue N that is not recycled, N lost during food processing, N lost as food waste and other losses.

Data on organic crop products was collected using a literature review. Primary data inputs were N applied (kg N ha^{-1}) and N in the yield (kg N ha^{-1}), however data was also collected on crop type, crop species, site location, field management, years of data collection and other research details. Data from studies where not all N inputs were accounted for were excluded. N inputs (kg N ha^{-1}) for each crop included green manures, BNF, compost, animal manures etc. N inputs (kg N $crop^{-1}$ ha^{-1}) were averaged over the entire crop rotation using equation (1).

1) $$N_{Inputs} = \frac{\sum_{i=1}^{n} N\ Inputs_{\ Crop\ 1} + N\ Inputs_{Crop\ 2} \ldots\ldots N\ Inputs_{Crop\ n}}{n}$$

N in the yield (kg N ha^{-1}) was calculated using yield data (kg crop yield ha^{-1}) and N content (%) data from IPNI. Harvest index factors (kg yield/kg crop residue) and N content data (%) were used to convert N in the yield to N in the whole plant by equations (2) and (3).

2) $$N_{Crop\ Residue} = N_{Yield} \times \frac{1}{Harvest\ Index}$$

3) $$Whole\ Plant\ Uptake = \frac{N_{Yield} + N_{Crop\ Residue}}{N_{Inputs}}$$

[1]University of Virginia, Charlottesville.

[2]University of New Hampshire, Durham.

[3]University of British Columbia, Vancouver.

[4]The Organic Center, Washington, DC.

[*]Corresponding author: jshade@organic-center.org.

The edible crop uptake was then back calculated by equation (4).

4) $$Edible\ Crop\ Uptake = \frac{N_{Yield}}{N_{Yield} + N_{Crop\ Residue}}$$

This value is often referred to as a Nitrogen Harvest Index Factor. All units are in kg N ha^{-1}. These calculations assume that 1) the N content (%) of the yield and the crop residue is the same, 2) the moisture content of the yield and the crop residue is the same and 3) harvest index factors are the same for organic and conventional products. These assumptions were made because more detailed data was not available.

The calculation for soybeans was adjusted by equations (5) – (7) to account for biological N fixation.

5) $$N_{Fixed\ By\ Soybean} = (N_{Yield} + N_{Crop\ Residue}) \times 0.6$$

6) $$N_{From\ Soil\ Pool} = (N_{Yield} + N_{Crop\ Residue}) \times 0.4$$

7) $$Soybean\ Whole\ Plant\ Uptake = \frac{N_{Yield} + N_{Crop\ Residue}}{N_{Inputs} + N_{Fixed\ by\ Soybean} + N_{From\ Soil\ Pool}}$$

While this calculation deviates from the calculations for the other crops, it represents the closest approximation of N cycling in a soybean system.

The calculations for organic virtual nitrogen factors modified the calculations of the conventional virtual nitrogen factors in two areas – 1) the crop's nitrogen uptake factor, or the amount of nitrogen taken up by the crop per unit of nitrogen applied, and the recycling factor for processing waste. The nitrogen uptake factor was calculated by dividing the nitrogen content of crop yield by the amount of nitrogen applied in organic production practices. Average yield and nitrogen input information were obtained by a literature review.

Our preliminary results suggest that there is no statistical difference between organic crop VNFs and conventional crop VNFs. However, because conventional production relies heavily on the production of plant available nitrogen, such as by the Haber-Bosch process as well as biological nitrogen fixation, and organic production primarily recycles plant-available nitrogen, mainly in the form of manure and crop residue, our data suggest that organic production contributes less soluble and volatile nitrogen to the environment than conventional production. Therefore, on a local scale, nitrogen pollution from organic crop production is comparable to conventional, but organic crop production introduces less new soluble and volatile nitrogen to the global pool. Since there are larger differences between organic and conventional livestock production, the animal protein VNFs reflect a more complicated picture for which the VNF calculation must be adjusted.

In order to minimize the negative impacts of plant available nitrogen, consumers must make lifestyle choices that minimize their nitrogen footprint. With a deeper knowledge of the N losses from organic production relative to conventional, consumers will be more equipped to determine the potential sustainability of purchasing organic products.