Farming practice effects on nitrogen footprints

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Abstract

Organic practices in food production attempt 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. Virtual N factors were used for this comparison. An organic virtual N factor of 4.6 was calculated for vegetables (37% lower than conventional), 0.9 for starchy roots (-64%), 0.7 for grains (-86%) and 0.3 for beans (-53%). The organic food N footprints were 43 – 53% less than the conventionally produced food N footprints. This study found that organic practices reduce N pollution with respect to conventional practices of food production. Tracking the effects organic practices have on N pollution will contribute to raising awareness, popularizing the better management of N in agricultural systems, and reducing the negative environmental and human health consequences associated with N pollution.

Introduction

Over the last century human activities have increased the abundance of reactive nitrogen (N) in the environment, thus contributing to large-scale environmental degradation (Galloway and Cowling 2002). Food production is one of the largest contributors to N pollution (Galloway and Cowling 2002), due in part to the use of synthetic fertilizers by conventional systems. While organic practices to not employ synthetic fertilizers they do use green manure and leguminous cover crops, both of which have the potential to result in increased amount of N lost to the environment.

Because organic methods employ practices that reduce N as well as some that could add reactive N to the systems, the impacts of organic farming on N pollution remain unknown. This study addresses the contribution of conventional versus organic practices to N pollution by comparing virtual N factors for organic crops with established conventional virtual N factors.

Material and methods

To determine the N pollution associated with organic farming practices, the Leach et al. (2012) method for virtual N factor calculations of conventionally produced food was used to calculate organic virtual N factors. Virtual N factors determine the amount of nitrogen released to the environment during the production of a food product per unit of nitrogen endogenous to that food. These calculations sum the reactive nitrogen lost to the environment and recycled at each stage of food production. Using maize as an example (Figure 1A), first, 100 units of new nitrogen enter the system through fertilizer application or fixation of atmospheric nitrogen by biological processes. The calculation then takes into account nitrogen taken up by the crop, nitrogen lost due to processing, nitrogen lost in removing inedible parts of food before consumption, and nitrogen lost during human consumption. Nitrogen from processing waste is sometimes recycled and reused; when it occurs, it is assumed to be recycled as fertilizer for the next crop cycle. Calculations were carried through five crop cycles to account for the nitrogen recycled back into the 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 2) the recycling factor for processing waste (Figure 1B). 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. The nitrogen uptake factors for vegetables were 35% for organic and 20% for conventionally produced crops, 89% for organic starchy roots and 87% for conventionally produced starchy roots, 87% for organic grains and 80% for conventionally produced grains, and 90% for both organic and conventionally produced beans. The nitrogen uptake factor for organic beans was not modified from that of conventionally produced beans because nitrogen-fixing legumes do not require additional nitrogen application for growth, unless soil conditions are poor.

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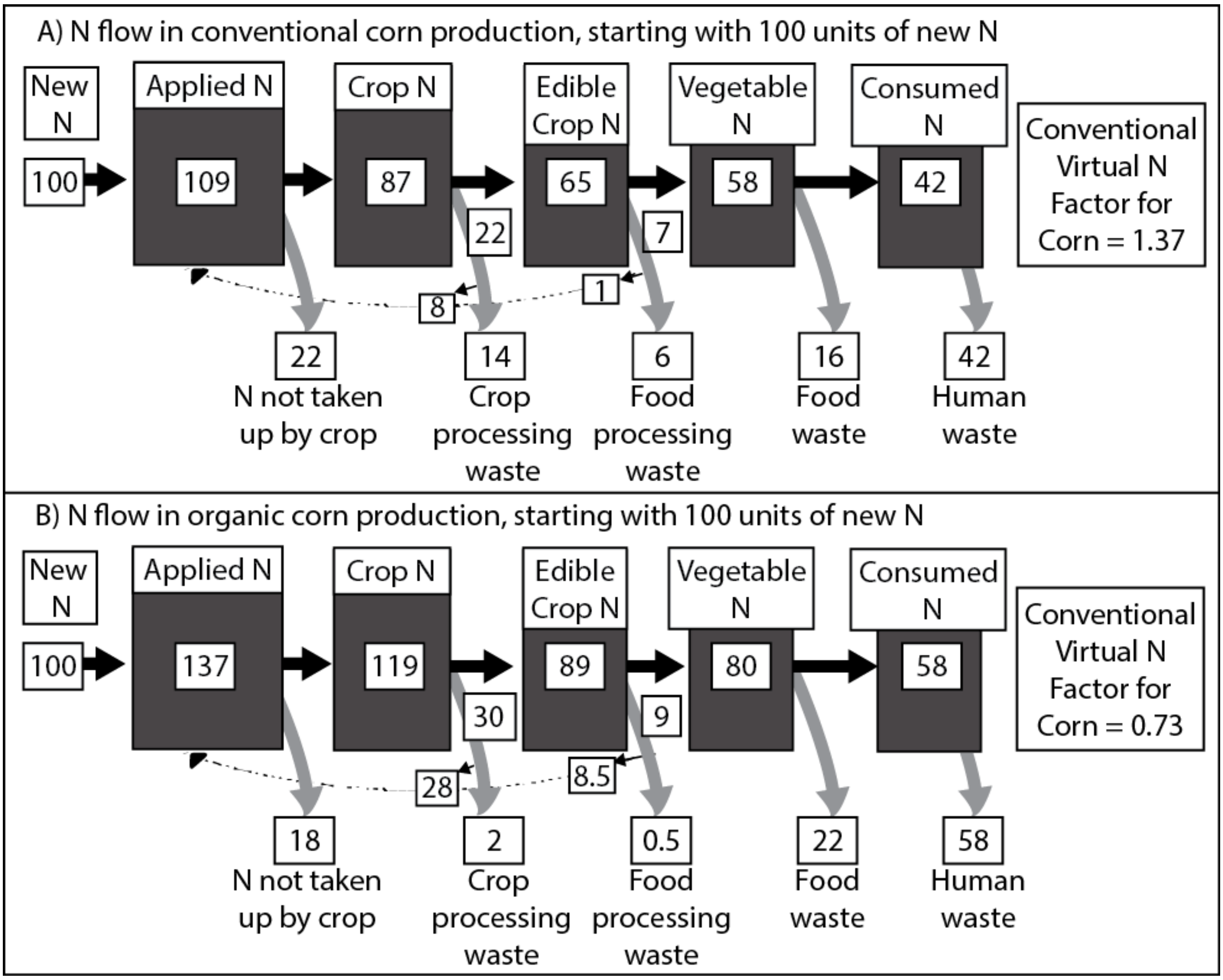

Figure 1: Reactive nitrogen flows in a) conventional and b) organic corn production

Because USDA organic standards prohibit the use of synthetic fertilizer and encourage the recycling of wastes, most organic farms use compost and incorporate residual plant matter into the soil as green manure. To account for this recycling of plant material, a 95% recycling factor for processing waste was incorporated.

Results

When we calculated organic and conventional virtual N factors and their percent differences (Table 1), we found that in all cases, the conventional virtual N factor is larger than the organic virtual N factor (i.e., more N lost to the environment per unit of N in food consumed). Given the differences between the virtual N factors of organic vs. conventionally produced crops, it is not surprising that the N released to the environment in the production of one serving size of vegetables, grains, starchy roots, and beans is considerably lower when foods are produced organically as opposed to conventionally (Table 1).

Table 1: Conventional vs. organic virtual nitrogen factors for vegetables, starchy roots, grains and beans

Food Category	Virtual Nitrogen Factor		% Difference
	Conventional	Organic	
Vegetables	9.6	4.6	-52%
Starchy Roots	1.5	0.9	-43%
Grains	1.4	0.7	-47%
Beans	0.5	0.3	-53%

While all organic virtual N factors were lower than conventional virtual N factors, starchy roots present the smallest difference (43%). Nitrogen uptake factors are similar between agricultural management systems for starchy roots, so the difference in processing waste recycling drives the virtual N factor disparity. Nitrogen uptake factors for starchy roots are high for both conventional (87%) and organic (89%) production, meaning that most N applied to the crop is yielded in the product's protein content, thus indicating good nutrient management. Unlike in conventional production, the majority of this processing waste is recycled in organic production, thus resulting in a low virtual N factor of 0.9 for organic starchy roots.

Grains present a similar situation to starchy roots when comparing organic and conventional production. With N uptake factors of 80% for conventional grains and 87% for organic grains, organic practices contribute to better nutrient management in grain production and therefore less N losses to the environment. In both the organic and conventional cases, more N is lost to the environment due to the processing and consumption of starchy roots than grains. As such, the virtual N factors for both organic and conventionally produced grains are lower than those of starchy roots. Because there is a larger disparity between the organic and conventional N uptake factors, grains show a larger difference (47%) in their virtual N factors.

The difference in organic (35%) and conventional (20%) uptake factors for vegetables also explains the large difference between organic and conventional virtual N factors (52%). The virtual N factors for vegetable production are higher than those of other food types due to the significantly lower N uptake factors. These lower uptake factors indicate that most N applied to the crop does not go to the protein content of the crop but rather stays in the soil, contributing to potential runoff or atmospheric emissions that further pollute the environment. Since vegetables do not yield high amounts protein, most N pollution in vegetable production is released in the first step of crop N uptake, and the residual waste, which leaches into soil, cannot be recycled. Thus, recycling processing waste in vegetable production does not reduce N pollution as much as reducing N application to the plant in the first step of crop growth.

Beans are the most N-efficient crop, as evidenced by their high N uptake factor and present the greatest difference between N released in conventional versus organic production (53%). Similar to starchy roots, beans have high N uptake factors, and as such, most N lost in bean production is due to processing of the crop to its consumable form and its subsequent consumption. Therefore, the increased recycling of processing waste in organic bean production drastically reduces the N losses to the environment. Compared to the other food types, less N is lost in bean production due to the processing and consumption steps, further explaining its low virtual N factor.

These calculations of organic virtual N factors facilitate the determination of specific farming practices that best reduce N pollution. The low virtual N factors of grains and beans demonstrate the effect a high crop N uptake factor has on N pollution due to food production. Increasing N efficiency by enhancing this uptake factor can be accomplished by reducing N application to a crop without leading to decreases in crop yields. Decreasing application of N fertilizer to recommended levels can also result in higher N use efficiency in crops, because many yields plateau as N application rate increases (Fageria and Baligar 2005). Crop systems can become saturated with N, at which point there is limited potential for plants to retain added N through increases in yield and production of organic matter (Vitousek et al. 1997).

Discussion

The movement towards organic farming practices has the potential to reduce N pollution due to food production in the United States. However, while organic farming may result in the reduction of N pollution, such practices also diminish the productivity per unit area of cropland with respect to conventional standards. The determination of virtual N factors specific to organic food production will encourage the tracking of N pollution by agricultural systems and justify the reducing effects organic practices have on N pollution. Future work will assess organic virtual N factors of animal products, which will allow for a more thorough comparison of N pollution of organic farming practices with conventional practices.

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