LETTER

Phosphorus is a key component of the resource demands for meat, eggs, and dairy production in the United States

Eshel et al. (1) quantify the land, irrigation water, and reactive nitrogen demands of feed production, and calculate a full life cycle of greenhouse gas emission estimates for each of the five major animal-based categories in the United States diet: dairy, beef, poultry, pork, and eggs. The authors find that beef contributed most to these impacts, making decreases in beef consumption an important lever in changing the impact of United States human diet on the environment.

However, Eshel et al.'s (1) important new analysis fails to consider resource demands for phosphorus (P), a critically important nutrient for the short- and long-term sustainability of both United States and global food production (2). The world's primary source of P for food production—phosphate rock—is nonrenewable, concentrated in only a few countries, and becoming increasingly scarce and expensive (2). P runoff from agriculture is also an important water pollutant (3). For example, in July 2014 a toxic algal bloom in Lake Erie (United States/Canada) caused by excess P deprived 400,000 local residents of potable water for several days.

As domestic phosphate rock reserves decline, the United States will become increasingly dependent on imported mineral P, meaning United States food security will become much more vulnerable to geopolitical risks in phosphate-producing countries and economic uncertainties from higher and more volatile commodity prices (2). P use in the United States agricultural system is highly inefficient: only 8% of P fertilizer and livestock supplements entering the United States agricultural system find their way into the diet (4). The remainder is lost to surface water, dissipated in other parts of the food chain, or exported. Metson et al. (5) demonstrated that animal product consumption accounts for 72% of the global average P footprint. In 2007, the average United States diet required 6.9 kg of P, the second highest dietary P footprint in the world, and 82% of this requirement was because of animal product consumption (5). Beef alone contributes 44% of the footprint associated with per capita animal product consumption in the United States (5) (Fig. 1), and P requirements for animal product production follow the same hierarchy of resource requirements found by Eshel et al. (figure 1 in ref. 1). Metson et al. (5) concluded that dietary shifts are an important component of the human amplification of the global P cycle, and an important challenge for sustainable P management. If animal waste and byproducts were effectively recycled, the sensitivity of the P requirement to meat consumption could be decreased [although the other impacts considered by Eshel et al. (1) might not be].

Nevertheless, we strongly agree with Eshel et al. (1): Decreasing beef consumption would reduce our impact on the environment and improve management of the livestock production-related resources that they analyzed, allowing for management synergies in the future. Given the critical role of P in both food security and aquatic pollution, and the clear impact of diet choices on P throughout the human food system, this nutrient should not be overlooked in an assessment of the effects of dietary choices on anthropogenic resource demands in a globally changing world.

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1 Eshel G, Shepon A, Makov T, Milo R (2014) Land, irrigation water, greenhouse gas, and reactive nitrogen burdens of meat, eggs, and dairy production in the United States. *Proc Natl Acad Sci USA* 111(33):11996–12001.

2 Cordell D, White S (2014) Life's bottleneck: Sustaining the world's phosphorus for a food secure future. *Annu Rev Env Resour* 39(1): 161–188.

3 Smith VH, Schindler DW (2009) Eutrophication science: Where do we go from here? *Trends Ecol Evol* 24(4):201–207.

4 MacDonald GK, Bennett EM, Carpenter SR (2012) Embodied phosphorus and the global connections of United States agriculture. *Environ Res Lett* 7(4):044024.

5 Metson GS, Bennett EM, Elser JJ (2012) The role of diet in phosphorus demand. *Environ Res Lett* 7(4):044043.

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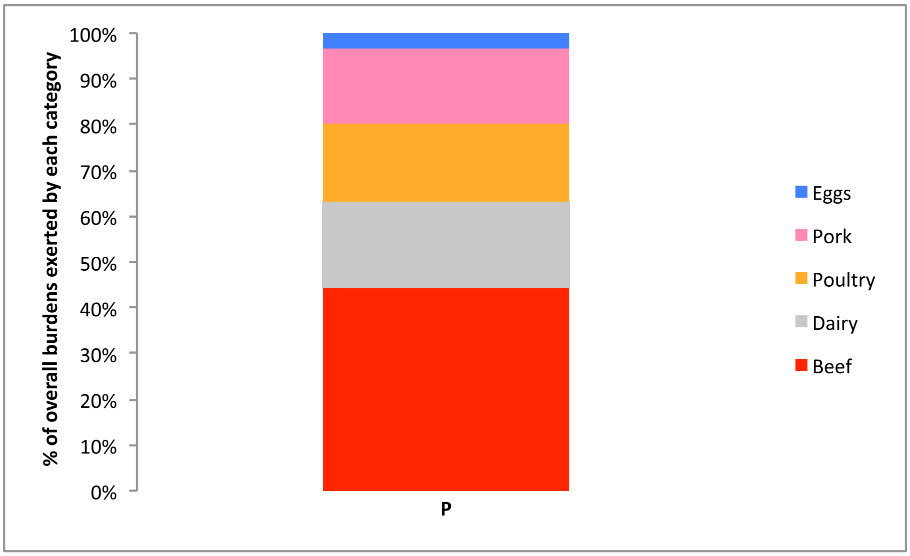

Fig. 1. Relative contribution of each animal product in the United States per capita P footprint [as an addition to figure 3 in Eshel et al. (1)].