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Article type : Letters to Editor

Title: "*Got rats*?" Global environmental costs of thirst for milk include acute biodiversity impacts linked to dairy feed production

Running head: Alfalfa, rodents, biodiversity and milk trade

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Keywords: Dairy feed (alfalfa) exports to Eastern markets; rodents damaging alfalfa and losses to farmers; rodenticide damages to biodiversity; rodenticide damages resonate beyond dairy feed producing regions through animal migration; overlooked environmental burdens caused by thirst for milk

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Bai et al. (2018) determined that China's increasing milk demand is expected to raise global greenhouse gas (GHG) emissions by 35%, expand dairy land by 32% and lift nitrogen pollution by 48%. Producing the additional milk in China adds to the environmental cost of animal feed transfers (from 1 to 6.2 Tg of alfalfa), while importing the extra milk would disproportionately transfer environmental burdens to exporting nations. Bai et al. (2018) conclude that the more sustainable future for milk-thirsty regions will rely on improving domestic milk and feed production efficiencies up to the level of major milk exporters such as the European Union (EU), the current leading region in milk production (USDA, 2017).

We applaud Bai et al.'s quantitative analysis but point out that the impacts of meeting high milk demand extend beyond those reported. A comprehensive accounting of the environmental implications of the thirst for milk in developing markets should include the large burdens on biodiversity resulting from converting land to dairy feed production. These impacts are well illustrated by the ecological circumstances in northern Spain, where land conversion to alfalfa production is driven by trade with Eastern markets (Figure 1).

Alfalfa is the most favored dairy feed crop worldwide, currently grown on ca. 30 million hectares in temperate regions. Increasing demand for alfalfa by milk markets means that growing this crop is economically attractive to farmers where conditions are favorable (warm climate, water for

irrigation). However, the presence of such a nutritious crop invariably provides ideal conditions for rodent herbivores that become farm pests. Wherever alfalfa is grown, rodent populations periodically attain outbreak densities, when acute crop damages and zoonotic disease transmission cause substantial economic and public health impacts. In the midwestern plains of USA, fossorial rodents (*Geomys* pocket gophers) produce 17-49% reductions in alfalfa yield (Witmer & Engeman, 2007). In Europe, up to 45.8% of the annual production of alfalfa can be consumed by another herbivorous rodent (the common vole, *Microtus arvalis*) during outbreaks, with estimated economic losses of hundreds of million Euros (Jacob & Tkadlec, 2010). Because China lacks suitable land to sustain the growth of dairy feed production, and other consumers such as Saudi Arabia lack the required water (Putnam et al., 2017), alfalfa production has expanded in warm countries like Spain, now the second largest global exporter of alfalfa (AEFA, 2015).

Increased alfalfa cultivation in Spain drove a massive geographical range expansion by common voles during the 1970-90s (Jareño et al., 2015) (Figure 1). Since then, recurrent vole outbreaks occurred, causing much damage to crops and farmer complains. Globally, the main method to control rodent pests remains the application of rodenticides. Both acute poisons and anticoagulants cause mass rodent mortality, although populations often bounce back. Rodenticides frequently also kill non-target fauna, especially rodent predators. In Spain, rodenticide use during vole outbreaks caused the death of non-target wildlife (game species and endangered raptors) as well as heated conflicts between stakeholders (Luque-Larena et al., 2013). Rodents feed migratory raptors worldwide, so the impacts of rodent management on biodiversity resonate beyond the regions that apply control methods, thereby spreading the burden of growing dairy feed. Indeed, the vole-invaded alfalfa-growing areas of Spain are highly attractive for wintering European migratory or nomadic vole-eating raptors (Figure 1), which suffer from secondary poisoning by rodenticides during vole outbreaks. For the endangered red kite (*Milvus milvus*), there is evidence of rapid declines in breeding populations that winter in Spain. Therefore, rodents damaging dairy feed crops cause economic losses to farmers, but management interventions to control rodents are themselves damaging to biodiversity. Large-scale

resonating impacts through animal migration are thus another overlooked part of the transferred environmental burden of the growing thirst for milk in China and elsewhere.

These substantial negative impacts of rodenticides on biodiversity have led to restrictions on their use in open spaces in the EU, but not yet in China or developing countries where the need for dairy feed is increasing. Cultivation of high quality fodder with attendant rodent outbreaks risks contributing to a greater use of rodenticides worldwide. Indeed, the projected global demand for rodenticides has been estimated to rise by 38% between 2015 and 2021 (Zion Market Research, 2016), fueled by Asian Pacific markets. In China alone, outbreaks of rodents affect 25-43 million ha annually, causing harvest losses of 5-10% per year (Yongwang et al., 2013), and rodenticide use already has a concerning impact on biodiversity.

Stricter global regulations on the use of rodenticides are needed to minimize environmental burdens wherever dairy feed is grown to quench the thirst for milk. Rodent outbreaks are closely associated with the cultivation of protein-rich dairy feed but require a more ecologically benign and sustainable management in order to avoid adding another large cost to meeting the projected demand for milk.

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CONFLICT OF INTEREST

There are no conflicts of interest.

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FIGURE CAPTION

FIGURE 1. Spanish alfalfa exports and pan-European damages to biodiversity through animal migration. **(a)** Countries to where most of the alfalfa produced in Spain was exported during 2014 – arrow width indicates relative amounts. In 2014, the government of Spain officially committed to increase exports of dried alfalfa to China; **(b)** Increases in alfalfa and irrigated crops during the 1970-90s triggered the colonization of 5 million ha of farmland by common voles in Castilla-y-León region, NW Spain. Anticoagulant rodenticides have been extensively used to control voles during recent outbreaks; **(c-d)** Castilla-y-Léon is an important wintering area for vole-eating raptors of conservation concern coming from all over Europe. Exposure to anticoagulant rodenticides pose a significant threat to populations of these migratory raptors; **(c)** Countries of origin of marked red kites (red arrows) and hen harriers (blue arrows) wintering in NW Spain; **(d)** Relative densities (lowest in blue; highest in red) of red kites, hen harriers and short-eared owls wintering in Spain (Source: SEO/BirdLife 2012: http://www.mapama.gob.es/es/biodiversidad/publicaciones/atlas_aves_invierno_tcm7-291664.pdf).