Phosphorus budget and flows in a peri-urban region; a case study of the Lower Fraser Valley, British Columbia, Canada

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Abstract

This study explored the relationship between local food production and the phosphorus (P) balance in a compact region, the lower Fraser Valley (LFV), with a large population and intensive dairy, poultry and horticultural production. Most P enters the region as agricultural feed and fertilizer. Most of the food produced is consumed locally but only 8% of the P used for food production is consumed as food, the remainder is largely left in soils. Other P sources include non-local food, feed for pets and horses, fertilizers for gardens and soaps. The amount of P handled by waste water treatment plants is similar to the P imported as food and soap, while waste from pets and horses is sequestered in landfills. Only 4% of imported P is known to leave the region for agricultural uses; there are no data on exported food processing waste and poultry litter. Technologies and policies are needed to improve the regional P balance through importing less and exporting more P to food producing areas.

Introduction

Studies on national phosphorus (P) budgets have quantified sources and sinks in several countries [1]. Phosphorus used as fertilizer for food production is largely responsible for the vast increase in mobilization of P around the world [2]. Recent studies have examined P in urban and agricultural areas but there have been few studies that have examined the impact of P budgets for food production in large peri-urban regions [3, 4]. Crops used for food and feed are generally grown in less populated areas and transported to urban centres. While there is growing interest in producing food in closer proximity to urban consumers, this trend is countered by loss of agricultural land to development and to restoration of natural habitats such as parks or 'set-aside' lands. There has also been a tendency in Canada and other countries for a concentration of certain livestock operations such as dairy close to markets and labour supply. Evidently, there are positive and negative pressures on farms located in urban pockets, peri-urban regions and adjacent to rural zones. As these lands are in limited supply and costly, they tend to be farmed intensively and require importation of mineral fertilizer and animal feed. There is limited use of human waste as organic fertilizer, especially on edible crops.

The Lower Fraser Valley (LFV) of British Columbia, Canada is a compact region surrounded by steep mountains, ocean and an international boundary. The regions is home to about 2.4 million people and produces C$1.6 billion of food products annually (farm-gate value) on less than 60,000 ha of farmland (averaging 0.025 ha of farmland/person). Agricultural land is intermingled with small to large communities which are spreading rapidly so that few people are more than 50 km from an urban centre and it is difficult to delineate urban and rural zones, hence the entire region may be considered peri-urban. The agricultural land is among the most expensive and productive in Canada due in part to favourable weather. The land is used to support intensive production of livestock, forages and horticultural crops. The livestock sector consists mostly of 'landless' poultry farms and highly productive dairy operations. The land base for dairy farms is about 0.4 ha per lactating cow which is used to produce maize and grass silage and to spread manure. The region also has various other animal operations such as beef cattle, sheep, goats, exotic birds, fur animals and land-based fish such as tilapia. There are significant numbers of horses used for recreation and racing. All grain and feed supplements for animal production are imported from other regions of Canada and the USA where they can be grown more cheaply.

Phosphorus imports to the region also include products used in commercial activity and by consumers. Much of the food produced in the region, especially poultry products and fresh milk, is consumed in the region while a significant portion of the small fruits and green-house grown vegetables are exported.

This study was intended to explore the relationship between local food production and the regional P balance.

Material and Methods

The P budget values (expressed as elemental P) are based largely on 2006 national, regional and industry statistical data, local farm surveys, and collected opinions from industry and government experts. Food consumption values were obtained from Statistics Canada and include waste or shrinkage at the retail and consumer levels because these losses occur within the region. It was assumed that 100% of consumed poultry products and fresh milk (and cream) were produced in the region since the small amounts of exports are balanced by some locally produced cheese and ice cream. We estimated that 80% of vegetables and 10% of fruit was locally produced. Although this is speculative, the effect of these estimates on the P balance is small. All other food was brought into the region. We used standard values or Statistics Canada assumptions for P concentrations in products. Data were cross referenced wherever possible and should be treated as tentative pending further validation.

Results

Of the 8033 kt P imported annually to the LFV, 5664 kt was for agricultural production and 2369 kt was for other societal (commercial and consumer) uses (Table 1). Most of the agricultural P imported to the LFV (4552 kt) was in the form of feedstuffs, mainly grains for poultry and pigs and various grains and concentrate ingredients for dairy and other animals. The poultry (2660 kt P) and pig sectors are completely reliant on imported feed as no grain is produced in the region whereas the dairy sector produces about 60% of its own feed as grass and maize silages. Most of the P fertilizer used by the dairy sector is applied to silage maize because experience and research has shown that, even on fields receiving ample manure, P fertilizer placed near the seed promotes early growth and advances maturity. The dairy industry imports 75% of its P as feed (25% as fertilizer) and the amount of P in feed is similar to that imported for broiler (meat) chicken production within the poultry sector.

Horticultural crop producers import 746 kt of P as various P-containing mineral fertilizers. Berries, potatoes and greenhouse vegetables are the biggest consumers of P in the LFV. The horticultural industry in the LFV is very diverse and P used in production of sod, nursery stock, flowers, hazelnuts, wine grapes, endives, currants, etc. has not been included in the budget. The substantial mushroom industry reuses LFV waste.

The majority of the food produced in the LFV is consumed locally. The exceptions are berries and greenhouse vegetable crops which are largely exported outside the LFV. Based on daily per capita consumption of 1698 mg P in Canada (2004-2008), annual P consumption as food in the region is 1459 kt. Assuming that all the fluid milk and eggs, 20% of the vegetables and 10% of the fruit consumed in the LFV is locally grown, 437 kt of annual food P consumption (about 30%) comes from locally produced food. This P consumption value suggests that about 8% of the P used to produce food in the LFV is consumed locally (total consumption of all food produced including that consumed in other regions would be only marginally higher), which is a very inefficient use of P but not necessarily lower than reported for other regions producing a lot of livestock. The remainder of the P (1022 kt) consumed in food comes from imported food (1459-437 kt).

It should be emphasized that the food values reported above include waste at retail facilities and in kitchens, actual ingestion is about 30% less and the proportion of waste varies with the product. There is a second type of food waste which is produced from processing locally grown agricultural products. Data for the fate of this waste is difficult to obtain from the processing industry but much of it is probably rendered into fertilizer and feed products such as feather meal, blood meal, bone meal, etc.

which may be used locally or exported. Some processing waste is also locally composted. Recycling of waste would not affect the budget presented in Table 1, but any significant export of processing waste would improve the regional balance. Likewise, there is no export of animal waste from the region with the exception of some poultry litter, but the amounts are not tracked by the industry or by government at this time and are not considered to be significant.

Table 1. Phosphorus imported annually (kt yr^{-1}) for agricultural and societal use in the Lower Fraser Valley

Sector	Industry	Fertilizer	Feed/food	Total
Agricultural	Dairy (includes local forages)	366	1092	1458
	Broilers		1541	1541
	Turkeys		336	336
	Breeders		286	286
	Layers		497	497
	Other animals		800	800
	Berries	276		276
	Potatoes	182		182
	Cole	31		31
	Peas/beans	91		91
	Other vegetables	42		42
	Greenhouse vegetables	124		124
	Subtotal	**1112**	**4552**	**5664**
Societal	Human	442*	1086**	1528
	Soap			406
	Horse		277	277
	Pet		158	158
	Subtotal	**442**	**1521**	**2369**
TOTAL				**8033**

* Fertilizers for gardens, lawns and golf courses.
**Calculated by subtracting locally-grown (used material and associated waste) from total food consumed

Other key P imports related to societal uses include 406 kt in dishwasher and commercial soaps (laundry detergent is P-free), 442 kt imported as fertilizer for homes and golf courses, and 158 kt imported in pet food. There is also 277 kt of P imported as feed for race and hobby horses as very little horse feed is grown in the region.

One can assume that the 1021 kt of P ingested (net of waste) is equal to P excreted since there is comparatively little P sequestered when humans are buried. The major waste water treatment plants in the region report processing 1907 kt of P. The P processed through these plants includes the P excreted by humans, some kitchen and retail waste, perhaps some processing waste and from all of the soaps used commercially and by consumers. The independent values for P consumption and P processed as waste are thus fairly consistent.

Of the waste P emitted by treatment plants, 1433 kt is liquid effluent expelled into waterways, and 159 kt of the solid fraction is sequestered in landfills and 315 is exported from the region. One may assume that most P in horse waste and pet waste is sequestered in landfills while most yard-waste in the region is composted and used as soil amendment by municipal users, but with no consideration of its P composition. Overall, of the 8033 kt of P imported into the LFV less than 2000 kt is known to be

exported from the region so most of this is lost into the ocean. Only 315 kt P is known to be exported to farmland outside the LFV but even this contributes little to food production as it is applied mainly as a nitrogen source and soil amendment.

Conclusion and perspectives

The results of the study show that P balances must be considered on a regional scale, because national or farm-gate budgets overlook the important issue of regional accumulation and concentration of nutrients. For P balances to improve, regional imbalances need to be resolved. Since most of the P is imported into the LFV as food/feed and fertilizers from a considerable distance (over 1000 km), there is no clear strategy for addressing the large P surplus. The issue is largely ignored, probably because there is no pressing environmental issue (few inland water bodies in the region) and little public awareness. Concentration of food production in the peri-urban area reduces food transportation costs (economic and energy benefits), provides income and employment, helps preserve the amenity of green space and food awareness, and provides some degree of food security and access to locally-grown seasonal field produce and almost year-round greenhouse produce. Only 8% of the P imported for food production is consumed, most of the surplus is accumulating in farm soils [5]. The overall impact of long-range transportation of feed and fertilizer, intensive production systems, and buildup of nutrients in the soil needs to be assessed. While there are efforts being made to compost yard and food waste in many of the regional communities, this does not greatly improve the nutrient balance as little compost leaves the region and generally does not displace fertilizer. Policies that restrict or ban use of fertilizer P on non-agricultural land will encourage recycling of waste nutrients. A similar policy for agricultural land will encourage more efficient use of wastes for replacing commercial fertilizers and there are clearly technical possibilities which involve better direct use of the P in animal waste [6] and extraction of P from waste which would facilitate return to food production [7] rather than allowing P to accumulate in soils or discharge into rivers, estuaries and oceans. There may also be potential for integrating local energy production with crop production and nutrient recycling. An alternative approach would be to reduce livestock production in the region which would greatly reduce P importation but also economic activity and the amount of food (calorie basis) that will be produced in the region. Currently the provincial government imposes a purchase tax for the disposal/recycling of electronic products, motor oil, tires, etc. and a carbon tax on fossil fuels. Is it time to consider a purchase charge to pay for the relocation of P from population centres back to distant croplands to reduce global reliance on mined P?

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