

Manure Phosphorus Management from a Global Perspective

By April Leytem and James Mutegi

Livestock manures contain significant amounts of the primary nutrients N, P, and K and secondary nutrients (i.e., Ca, Mg, and S) as well as a wide variety of micronutrients which make them an excellent nutrient source for crop growth. In addition, the application of livestock manures can improve soil health via the addition of organic C, which can improve soil structure, water holding capacity, and water infiltration.

Globally, the total amount of P excreted in manure in 2011 was estimated at 23 million tonnes (M t) (Liu et al. and likely exceeds the amount of fertilizer P produced each year (IFA, 2018). Manure-based nutrient application exceeds fertilizer application in parts of South America and Africa, as well as small portions of the eastern U.S., Eastern Europe, Central Asia, Southeast Asia, and Northeastern Australia (MacDonald et al., 2011). Potter et al. (2010) estimated that the global ratio of manure P to fertilizer P in the early 2000's was approximately 1.7, while in some countries such as the U.S. the ratio is close to 1.0 (Yang et al., 2016). The highest rates of P in manures produced are found in the midwestern U.S., southern Brazil, western Europe, northeastern China, northern India, Bangladesh, and New Zealand (where the highest average P production rate, 64 kg/ha, is found) (Potter et al., 2010). MacDonald et al. (2011) provided an analysis of the relative P surplus or deficit resulting from fertilizer P and manure use on cropland around the world (**Figure 1**).

Although the availability of manure P sources is often greater, or similar, to mineral fertilizer P use, manure P is not always effectively used in crop production. Inefficient manure P use can be attributed to several factors including: uneven distribution of manure by grazing animals, incomplete collection and inappropriate storage of manure from housed animals, poor timing of manure application, high cost of transportation, and relatively low prices for mineral P fertilizer. Due to the high moisture content and bulky nature of manures, they are generally applied to crops within a small radius of where they are produced, which leads to buildup of P in soils surrounding livestock farms. This excessive P application has led to P surpluses in croplands, decreased P use efficiency, and increased P losses to surface waters. The poor spatial distribution of manure P use has

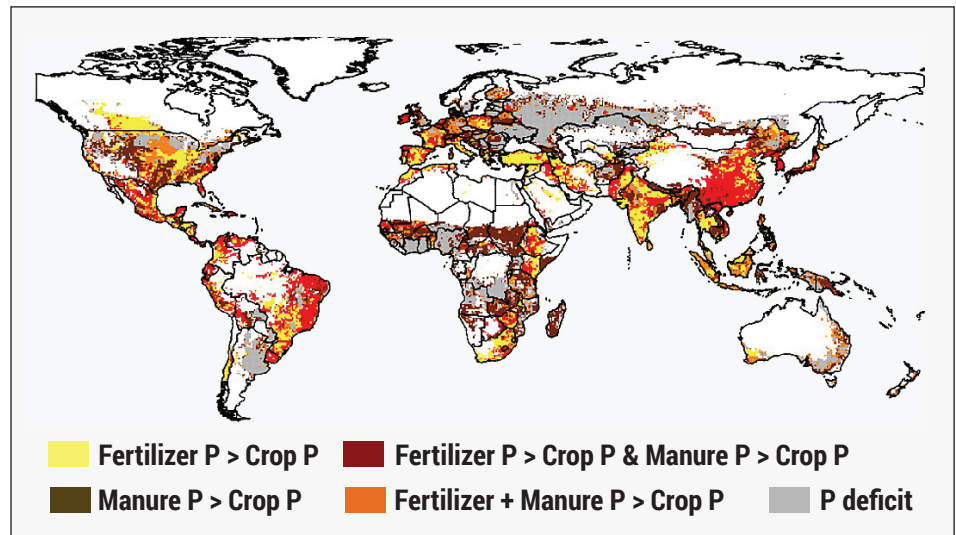


Figure 1. The magnitude of P surplus or deficit (P balance) on cropland around the world can be estimated based on fertilizer use, manure production and crop removal (From MacDonald et al. 2011).

been exacerbated in recent decades in developed countries by structural shifts of livestock operations from small farms to larger-scale confined operations that have resulted in more unevenly distributed patterns of manure P loads to soil.

Elevated P concentrations in receiving waters can lead to eutrophication, which can be costly. For example, in England and Wales it has been estimated that damages due to agricultural losses of P are near US\$24 M (Bateman et al., 2011). In some countries, direct discharge of P in wastewater to surface waters is still common. For example, in Thailand, P-containing wastewaters discharged directly to surface waters from dairy-cow and swine farms were estimated

SUMMARY

While livestock manure is a significant global reserve of P, it is not always used efficiently in agricultural production. Due to the segregation of livestock and cropping systems in many countries, poor redistribution of manure P has led to regions with both surpluses and deficits. As phosphate rock must be considered a finite source, the recycling of P from manures regionally, nationally, and even globally needs to be improved for food security in the future.

KEYWORDS:

soil nutrient balance; manure availability; P recycling; sub-Saharan Africa

ABBREVIATIONS AND NOTES:

N = nitrogen; P = phosphorus; K = potassium; S = sulfur; Ca = calcium; Mg = magnesium; C = carbon; LSU = livestock unit

to be 554 and 261 t P/yr, respectively (Prathumchai et al., 2018). These discharges have a direct negative impact on surface water quality in these regions.

Phosphorus Imbalances – Farm, Local, Regional, National, and Global

Seventy one percent of global cropland area was estimated to have an overall P application surplus in 2000, including most of east Asia, sizeable tracts of western and southern Europe, the coastal U.S., and southern Brazil. This P surplus is desirable during the build-up phase of soil fertility, but then should decrease to avoid excessive P accumulation. In contrast, croplands in all sub-Saharan Africa (SSA) countries are characterized by annual soil P deficits (Macdonald et al., 2011). These P deficits in SSA soils have been attributed to a number of things, key amongst them being low native soil P, high export of P with crop biomass, and P losses (approximately 3 kg P/ha/yr) without proportional replenishment (Lun et al., 2018). The low native soil P that characterizes soils in SSA and other tropical regions like South America reflects a high degree of weathering and/or a low concentration of P in the parent material (van der Waals and Laker, 2008). In particular, while Ultisols and Oxisols represent about 70% of P-deficient soils globally, about 20% of these soil orders are found in SSA (Fairhurst et al., 1999).

Approximately 9.6 M t P/yr, or 40% of total manure P excreted by livestock in 2000, was used for cropland application based on estimates of recoverable manure for 12 regions and for U.S. states (MacDonald et al., 2011). **Figure 2** indicates that P surpluses increase with greater livestock density at the national scale, especially at livestock densities above 2 LSU/ha (Liu et al., 2017; Nesme et al, 2015). One

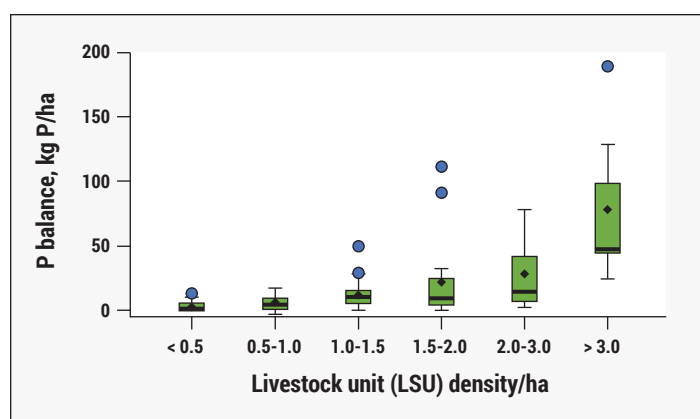


Figure 2. High livestock density generally results in a country-wide P surplus. The mean P balance for the whole food production–consumption system is shown at the country level for 150 countries. The LSU reference unit aggregates livestock from various species and age based on the nutritional or feed requirement of each type of animal. Boxes show the 25th to 75th percentiles, horizontal lines indicate median values, filled symbols show the mean, whiskers indicate the 5th and 95th percentiles and open symbols indicate outliers. Reproduced from Liu et al. (2017) with permission from CSIRO Publishing.



Examples of in-row and surface application of cattle manures in sub-Saharan Africa.

of the main causes of these surpluses is the large amount of P imported in feed coupled with low P use efficiency of most livestock. Therefore, there is often a clear relationship between livestock density and P balance at the farm level.

At the local scale, the transfer and recycling of manure P, and reduced fertilizer P use, remain compatible. At the regional scale, such transfers are virtually absent due to manure transport costs; manure P recycling on croplands is hampered and mineral fertilizer P use is instead favored to meet crop demand (Nesme et al., 2015). However, as farms grow in size, even local and within farm imbalances can occur due to the high transportation costs of manure.

In several countries such as the U.S., Netherlands, Norway, Denmark, and Finland, manure P can meet or even exceed the amount needed to achieve sustainable crop productivity (Smit et al., 2015; Hanserud et al., 2016; Yang et al., 2016; Parchomenko and Borsky, 2018; Svanbäck et al., 2019). Despite this large potential for within-country P recycling, areas with the largest amounts of manure P are not co-located with areas having the highest P deficits, which

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can create hotspots of excess manure P. Compounding the issue in these regions, fertilizer P is still often applied with the excess manure, resulting in high soil test P concentrations. Globally there are regions, including portions of SSA, Eastern Europe, and South America that are experiencing the opposite extreme of high P deficits, where P from manure is sought after in order to enhance both soil fertility and quality. Most of these imbalances are related to higher P removal/losses relative to P application via manure and other sources.

Sub-Saharan Africa is a case of extreme P deficit where manure application to croplands does not provide an adequate solution for meeting the crop P demand. Depletion of P and other macronutrients from the soil is widely reported in the region. The low capacity of manure to reverse the trend is associated with low quantities of manure production, due to limited livestock populations (Titonell and Giller, 2013), and the low quality of livestock feeds. Low-quality livestock diets, affordable to the majority of smallholder farmers', results in a low nutrient concentration of manures, including relatively low P. A good example is the case of a Zimbabwe trial where 17 t/ha of cattle manure resulted in an annual application of 31 kg P/ha (Zingore et al., 2008). Surprisingly, after three seasons of manure application, the soils showed a decline of about 0.6 mg P/kg relative to an unfertilized control. This observation was hypothesized to result from the drop in pH from 5.1 to 4.9 resulting in increased P fixation as well as greater P export via the increased harvested yield.

Phosphorus Fertilizer-Manure Substitution

Livestock manures are a valuable global reservoir of reusable P and hold the most conspicuous potential for mineral fertilizer substitution. Although this makes theoretical sense, the practicality of distribution of manure P hinders its efficient recycling. If manure P is to be reused in the agricultural P cycle, cost-effective methods for redistribution of manure P from areas of surplus to areas of deficit will need to be developed. In many countries, there is currently a lack of regulatory and economic incentives for farmers in livestock-dense areas to transport surplus manure P over greater distances. Therefore, regulations, economic incentives and technical solutions for enhanced relocation of livestock manure P from areas with surplus to areas with deficit will be crucial.

Achieving more effective manure P recycling at the global scale will require broader management or structural changes in livestock farming. Adequate manure collection, storage, and application techniques are critical prerequisites for efficient use of manure P. Education about manure P and its bioavailability is needed, as the fertilizer value of manure P may be unknown to producers or disregarded. It



TAKE IT TO THE FIELD

Despite the potential for P recycling, areas with the largest amounts of manure P are often not co-located with the highest P deficits. P "hotspots" result where manure P exceeds the amount needed to achieve sustainable crop productivity.

is commonly reported that, in most cases, the P content of manures is often not accounted for when calculating fertilizer recommendations. Development of tools, such as the Nutrient Expert® decision support tool (Pampolino et al., 2012), that consider the nutrient supply of manure into fertilizer recommendations, can help reduce the risk of P overapplication. Support for processing and trading of manure-based nutrients can help reduce P imbalances between crop and livestock farms. Changes in livestock diets to enhance P use efficiency may also be needed to decrease P surpluses in areas with intensive livestock production. Technologies for capturing P from manure streams and concentrating it into a more easily transportable form will be essential for long range redistribution.

Closing Thoughts

While livestock manure is a significant global reserve of P, it is often used inefficiently in agricultural production. Due to the segregation of livestock and cropping systems in many countries, poor redistribution of manure P has led to regions with both surpluses and deficits. As phosphate rock is a finite source, the recycling of manure P regionally, nationally and even globally may be necessary for food security in the future. Therefore, technologies, regulations and economic incentives to enhance the reuse of manure P in agricultural systems are essential. **BC**

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