CIAS RESEARCH BRIEF 102

Composting manure and bedding reduces potential soil and phosphorus loss

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CENTER FOR INTEGRATED AGRICULTURAL SYSTEMS • UW-MADISON COLLEGE OF AGRICULTURAL AND LIFE SCIENCES

Fertilizing fields with manure from dairy farms can contribute to elevated levels of phosphorus in waterways. Researchers at UW-Madison hypothesized that composting manure before spreading it on fields would reduce this problem. Their study found that composting is a viable way to reduce phosphorus runoff losses from livestock operations with bedded pack manure. In part, these runoff losses derived from the reduced water solubility of phosphorus in composted manure, as well as reduced erosion due to the addition of stable organic matter in compost and the elimination of the need to spread manure in the winter, when the ground is frozen.

Background

The 536-square-mile Yahara River Watershed extends from Columbia County through Dane and Rock Counties in southern Wisconsin. Lakes in this watershed have an excess of phosphorus (P) and suffer from blue-green algae blooms and fish deaths. Efforts are underway to reduce P entering the Yahara lakes from urban and agricultural sources. Reducing P losses from runoff after manure applications to cropland is especially important. When manure is applied to meet crop nitrogen needs, it commonly has excess P that can concentrate in soil and potentially pollute surface water through runoff.

Field applications of composted manure can lead to lower levels of P runoff than uncomposted manure as shown in this Dane County, Wisconsin study.

Researchers at UW-Madison worked with three farmers in the Yahara watershed to evaluate the potential water quality benefits of applying manure that has been composted using windrow methods. Due to data limitations on one of the farms that made comparisons difficult, this brief reports on findings from two of the farms. The researchers found that applying composted manure rather than unprocessed manure to cropland reduced the estimated P runoff from the fields. In addition, the benefits of composting include reducing pathogens and moisture levels, which can make manure nutrients easier to handle and transport.

With funding from the Lake Michigan Federation and the Clean Lakes Alliance, UW-Madison researchers Laura Ward Good of the Soil Science Department and Pam Porter from the Center for Integrated Agricultural Systems compared modeled runoff P losses from heifer bedded pack manure with and without composting on dairy farms located in the Yahara Watershed. ("Heifer bedded pack" is a dairy housing system where the manure is contained within the structure and additional materials are added for bedding.) The researchers' objective was to see how potential P losses from runoff changed when the bedded pack manure was composted before land application compared to the normal practice of applying it directly to cropland.

In 2012, 84 percent of the farms in the Yahara watershed were dairy farms, with a combined total of 79,000 animal units (each animal unit is equivalent

Farm A composted bedded pack manure from 400 mixed-age heifers under a roof.

to a 1,000-pound animal). Many of these dairy farms—particularly smaller farms—do not have the capacity to store all of the manure generated on the farm, so it must be spread on fields throughout the year, including winter application on frozen and snow-covered fields. Spreading manure on frozen fields has a higher risk of runoff P loss than applications at any other time of the year because manure and water cannot seep into a frozen soil as well as an unfrozen soil. Manure is typically applied to cropland as fertilizer before crops are planted, or after harvest. When it is removed from a livestock housing facility while a crop is standing, it is stockpiled and applied after the crop is harvested. More P from manure is generated in some parts of the Upper Yahara watershed than is removed by crops leading to a build-up of P in the area, which can increase losses over time. Removing the excess outside the watershed or redistributing it to P-deficient locations within the watershed are potential solutions in addressing this issue. Manure contains a lot of water and is therefore heavy and bulky. Large-scale redistribution requires a way to concentrate the manure nutrients, to reduce volume and trucking costs. Composting is one way to accomplish this.

"Windrow" composting of manure and organic material that is piled in rows and turned regularly for aeration is an alternative to stacking or storing manure. Windrow composting is an ancient and relatively cost-effective method of processing animal manures. Composting manure offers farmers several advantages. Manure windrows dry down and decrease in volume by approximately 50 percent through the aerobic oxidation of organic materials. This practice provides greater flexibility in the timing and locations for land application, since compost contains less ammonia-nitrogen than raw manure and won't "burn" alfalfa. The final compost is often drier and easier to manage than raw manure, facilitating transport. Compost may also be marketable, as it is used by farmers, landscapers, nursery managers, greenhouses, engineers and road-building contractors to improve soil fertility, health and structure. Composting does require more handling than spreading raw manure.

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How can composting manure reduce runoff phosphorus losses from a farm?

Composting does not reduce the total amount of P in manure. However, this work shows that adopting composting can reduce runoff P losses across a farm through at least three mechanisms.

1. **Avoidance of winter spreading.** For this study, flexibility in timing compost applications provided the greatest potential for P reduction. Specifically, the windrows allowed farmers to avoid winter spreading. The P in manure spread when the soil is frozen has a much higher probability of running off than that spread at any other time of the year.

2. **Reduced erosion.** Runoff water carries P attached to sediment eroding from fields. Generally, adding organic material to soils helps reduce erosion. Compost, because it is more stable and takes longer to decay once applied, is expected to be more beneficial for reducing erosion over the long term than raw manure.

3. **Reduced dissolved P.** Phosphorus from manure applied to the soil surface dissolves into runoff water. Composting reduces the solubility of P in manure, leading to less dissolved P in runoff following compost application than if raw manure with the same amount of total P had been applied.

Methods

On the study farms, bedded pack manure came from housing for young and non-lactating livestock, where a combination of cornstalks, straw, wood shavings and sand were spread on the floor for bedding. As manure was added to these materials, additional bedding was applied in layers to maintain a healthy environment for the animals. After a large amount of material built up, it was removed from the barn and added to windrows to complete a controlled decomposition process.

Farm A composted the manure from 400 mixed-age heifers year-round in a new (2017) composting building with a roof and concrete floor. Estimated annual raw manure production from these heifers was 3,300 tons. Additionally, the pack contained 220 tons of corn stalks, straw or other organic bedding materials. The compost windrows were a combination of manure and bedding with different moisture contents cleaned from a variety of buildings. The farmer selected materials to add to the windrow to balance the moisture content of the starting windrow. Over the two years of the study, the farm used sawdust and ground corncobs both for bedding and windrow moisture control. The farm also sometimes used sand in bedding.

Farm B composted manure from about 200 steers and 25 dry cows outdoors, on dirt, on a farm several miles from the home farm. The farmer used corn stalks, straw and sand for bedding, and no additional materials were incorporated when windrows were formed. Over the duration of the study, the farm applied some bedded pack manure to fields immediately after clean out and stockpiled some manure, in addition to composting.

Researchers collected multiple samples of the raw (not composted) bedded pack manure, and collected composted manure samples at the beginning, middle and end stages of composting over two years. The samples were analyzed for total P and moisture content at the UW Soil and Forage Analysis Laboratory. The U.S. Dairy Forage Research Center analyzed the samples for water-soluble P. The chemical analysis of the compost and raw manure in the fall of 2017 were used for the modeling analysis because it was the most complete data set and it best represented the compost materials that would be available to the farms in the future.

In addition, in order to compare compost's impact on field annual erosion rates and runoff P losses to those of raw manure over several years, the researchers modeled P losses and soil erosion using the farms' SnapPlus nutrient management planning databases. The databases include records of crops grown, tillage operations, and fertilizer and manure applications. The researchers used SnapPlus to simulate current crop rotations into the future (from 2017 to 2023) and compared applications of raw manure and bedded pack materials to those of compost. The researchers assumed raw manure was always spread in the season it was generated, and compost was applied in the same year the manure was generated. Since composting does not remove phosphorus, the same amount of total phosphorus was distributed over the same farm's acres under both scenarios. For both manure and compost, the strategy was to apply to fields that were low in phosphorus whenever possible, but on both farms the majority of fields already had sufficient phosphorus to meet crop needs. Total application rates were determined by the nitrogen needs for crops such as corn and wheat per Wisconsin's nutrient management guidelines.

The researchers modeled seven years of data because manure and compost were applied to different crops in different years. A single-year analysis would have been affected by these variations and therefore less representative

Farm B composted in outdoor windrows.

of the overall impact of compost. The researchers also area-weighted the results so that values from bigger fields had a mathematically larger impact on the overall result.

In the raw manure scenario on Farm A, the material was spread equally in all months as it was cleaned from buildings, with approximately a third applied in winter (December through March). In the compost scenario on Farm A, manure was in windrows over the winter, so no winter applications took place. One thousand tons of composted manure were spread evenly across all other seasons. Summer compost was applied to established alfalfa; spring and fall applications were made before planting and after harvest. Farm A did not apply any commercial P fertilizer, so this was not included in the analysis. The compost scenario required additional corn stover to provide enough organic matter for the composting process, so P loss calculations included possible erosion due to this extra residue removal.

Two of Farm B's satellite farms, where the farmer applied bedded pack manure, were used for the forward-looking analysis. One of the satellite farms has sandy loam soils and the other has silt loams, and both have steep slopes of nine to 16 percent in all of the fields. No commercial P fertilization was included in the analysis for Farm B. Similar to Farm A, in the raw-bedded-pack scenario on Farm B a third of the manure was applied to corn fields in the winter and the rest was distributed in the other seasons avoiding applications to established alfalfa. Compost was not applied in the winter. Some compost was applied to alfalfa in the summer, averaging about 10 percent of the total. The remaining compost was applied in approximately equal amounts in spring and fall to row cropland and seeding alfalfa.

Results

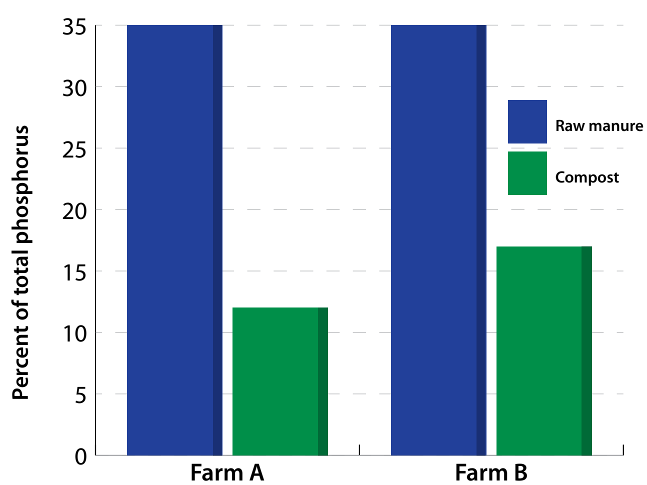
Compost weight. Researchers analyzed the raw manure and compost on each farm in the fall of 2017. The manure and bedding on Farm A was much lighter after composting, going from an average annual amount of 3,500 tons of raw material to 1,000 tons of compost. This was due to a drop in moisture content and the decomposition of organic matter during the composting process. The original pack material contained ground corncobs and relatively little sand. On Farm B, the raw manure and bedding weighed 4,500 tons annually, and the compost weighed 4,100 tons. There was less weight loss for this compost than on Farm A because of the high sand content of Farm B's bedding and the fact that moisture from rain can add to the weight of outdoor compost.

P water solubility. One of the primary determinants of how much P will run off from a manure application is the amount of water-soluble P the manure contains. For both farms, a much lower percentage of P in the compost was water soluble compared to the raw manure (see Figure 1). This means that, even though P was not removed in the composting process, less P was likely to dissolve into runoff from the compost than the raw manure.

P loading and erosion. The researchers used the P Index—a tool used to estimate runoff P delivered to surface waters—as an indicator of the risk of P runoff. P Index values are based on a variety of risk factors including soil P levels, erosion potential and weather patterns. Lower P Index values indicate a lower risk of P runoff; the maximum P Index value considered acceptable under Wisconsin agricultural runoff guidelines is 6, which equates to an estimated 6 pounds per acre per year (averaged over the years of the field's crop rotation) lost in runoff. The annual P Index values in Figure 2 on page 5 are averaged across crop rotations and area-weighted for the rotation average P Index value across all acres.

To estimate soil erosion, researchers used the Revised Universal Soil Loss Equation, or RUSLE2. This is a tool to predict long-term average annual soil erosion based on factors including slope, soil type, farming practices and precipitation.

Figure 1. Water soluble P as a percent of total P



Even though P Index values and erosion were already comparatively low when applying raw manure on Farm A, composting reduced estimated overall runoff P losses (Figure 2) and erosion (Figure 3) for the farm. The researchers found that 61 percent of the estimated runoff P reductions from composting on Farm A were from timing and placement of the compost applications; 38 percent came from less P in eroding sediment; and 11 percent came from the lowered P solubility of the compost. The amount of expected erosion decreased with compost applications because of the long-lasting effect of adding the stable organic matter in compost to the soil.

On Farm B, the use of compost cut expected average annual runoff P losses, as indicated by the P Index, by about a third (Figure 2). Compost resulted in a greater overall reduction in the P Index on Farm B than on Farm A because its original P index was higher, due to steep fields. The reasons for the P-loss reductions on Farm B were similar to those for Farm A, with 46 percent from timing and placement, 36 percent from reduced erosion due to compost stability, and 18 percent from lowered P solubility. As with Farm A, soil erosion losses were reduced on Farm B with compost applications (Figure 3).

Outdoor composting can result in nutrient transport from windrows into surface water through runoff. The researchers calculated runoff P losses from the windrows on Farm B by estimating average annual runoff volume using historical climate information, and the concentration of dissolved P in that runoff. They estimated runoff of 17 pounds of total dissolved P annually on Farm B. This amounts to four percent of the estimated reduction of cropland runoff P losses with composting on that farm. This loss is small in comparison to the overall benefit of composting. The researchers note that it is important to locate windrows away from surface flow channels that would direct upslope runoff into the piles. Although the researchers concentrated on the potential for surface runoff in this study, they caution that is also important to avoid areas with a high risk of windrow seepage leaching to groundwater.

The researchers offer one caveat with these results: the P Index equations may be overestimating P losses from winter applications of the raw heifer pack manure, so the runoff P loss reductions with compost may be overstated. More research is ongoing to better understand runoff from snowmelt and P release from solid manure. Additionally, the researchers did not measure the amount of ammonia volatilized into the atmosphere during the composting process versus during the application of raw manure and they suggest additional research is needed on this topic.

"This study found that composting can reduce the weight and volume of the original manure and bedding, concentrating nutrients and offering more flexibility in where and when it can be spread," said Good. Additional benefits of reduced erosion and lower levels of water-soluble P are also part of the compost story.

Figure 2. Average rotational P index (area weighted) on Farms A and B, 2017-2023

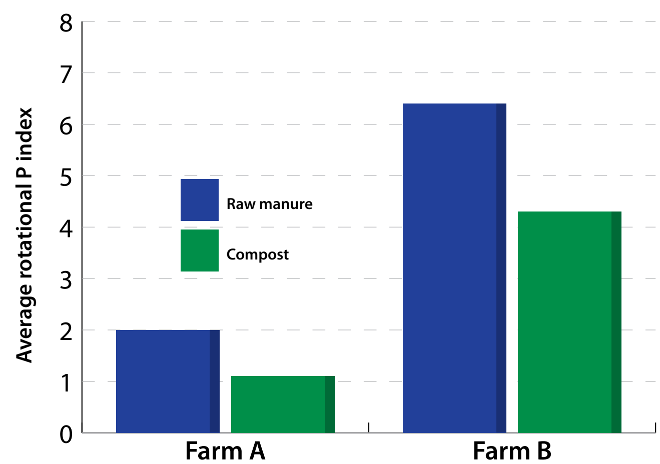
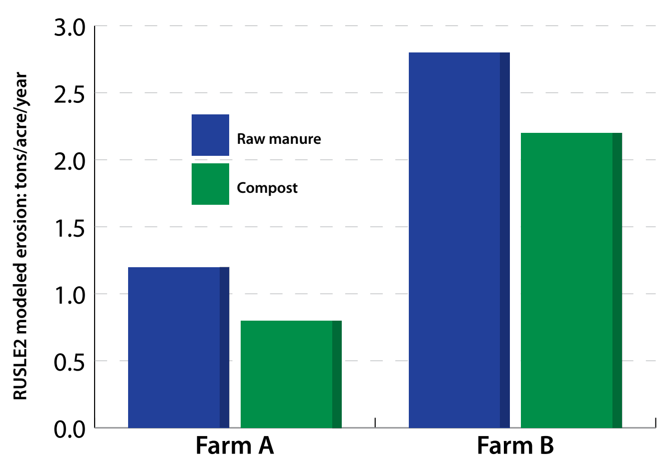


Figure 3. RUSLE2 modeled erosion tons/acre/year (area weighted) on Farms A and B, 2017-2023



Porter added, "Farmers are realizing the benefits of composting bedded pack manure and are devising composting techniques that make sense on their farms."

Farmer impressions of composting

Participating farmers reported a growing interest in composting bedded pack manure, especially because winter spreading of manure is operationally cumbersome and results in the loss of nutrients that could support crop production. Farmers cited several advantages to composting:

- Unlike unprocessed manure, composted manure can be applied to alfalfa and can increase yield.
- Composting can reduce pathogens in manure under certain conditions.
- Compost concentrates nutrients and weighs less than manure, mostly due to moisture loss.
- Compost can be used for animal bedding.
- Compost can be sold for a profit.
- The capital required for a composting facility can be less than what is required for a manure storage system.

On the downside, composting using windrows requires a large amount of space and an increase in labor for handling. Compost should be turned at least weekly to provide the oxygen that microorganisms need to produce higher temperatures for pathogen reduction. The farmers in this project rented a compost turner owned by a company that travels throughout Wisconsin. Weekly scheduling wasn't always possible, so windrows weren't turned as often as would be ideal. Despite this, all three farms did produce compost that had lowered P solubility. One participating farmer has since built his own compost turner. Composting costs vary, depending on a farm's existing facilities and handling expenses.

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