USING MANURE AS A FERTILIZER FOR CROP PRODUCTION

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Interpretive Summary:
Integrating manure as a fertilizer for crop production is the primary accepted mechanism for disposal of manure from animal feeding operations. Successfully using manure as a fertilizer requires assessing the available nutrients in manure, calculating the appropriate rate to provide the needed nutrients to the crop and applying the manure uniformly across the field at the target rate.

Efficient use of manure as a fertilizer is complicated by the imbalance of nutrients in manure, variability in many sources of manure, difficulties in estimating nutrient availability, and the relatively low nutrient concentration limiting the distances manure can profitably be transported for use as a fertilizer. Manure management is most likely to be profitable on farms with a manure source with a relatively high nutrient concentration (like slurry manure) applying manure to fields near the operation and to a crop or crop rotation that can fully utilize all the applied nutrients.

Research has shown that disposal applications of manure that fail to use the fertilizer value of manure for crop production greatly increase the potential for nutrient loss from land receiving manure. Potential losses from nitrogen applied at or below optimum rates are much less than losses from nitrogen applied in excess of crop utilization capacity. Raising soil test above agronomically optimal levels increases the phosphorus concentration in runoff and the phosphorus content of eroded soil particles with no benefits in improved crop productivity.

There is ample crop capacity to utilize excess manure nutrients to replace fertilizer. In 1997, 24.7 billion tons of nitrogen and 4.06 billion tons of phosphorus were purchased as fertilizer. A Natural Resource Conservation Service (NRCS) study estimated confined livestock in the US generated 2.58 billion pounds of nitrogen and 1.44 billion pounds of phosphorus available for land application in the same year (<15% of purchased nitrogen and phosphorus).

The NRCS study concluded that over 60% of the manure nutrients were in excess of crop nutrient capacity of the farms where they were produced and poultry operations were the farm type with the most excess nutrients. The same report indicated that at least 165 US counties were likely to have difficulties utilizing all manure nitrogen generated in the county and 364 counties would have trouble utilizing all the manure phosphorus generated in the county. This implies that improved utilization of manure as a fertilizer will require transporting manure substantial distances and applying to fields not owned by the farmer that generated the manure in many instances. This describes perfectly the situations most difficult for a manure producer to offset manure application costs with the fertilizer value of the manure.

There is some opportunity for existing operations to pay for improved manure utilization by better capturing its fertilizer value in local crop production. The bigger challenge is in areas with

regional excess manure production. In these areas it will be much more difficult to use fertilizer value of the manure to significantly offset transportation costs to fields with fertilizer need.

There are excellent opportunities to make money with manure as fertilizer by closely linking new facilities with nearby row crop production ground. In a Missouri assessment, a 4800 grow finish hog operation using modern diets could use manure from the facility to meet the fertilizer needs of two sections of land in corn-bean rotation while increasing net income at least $25,000 with a return on assets greater than 15%.

Introduction:

<u>The role of nutrient management planning in protecting water quality.</u>

Fertilizing agricultural land with the nutrients nitrogen and phosphorus often improves productivity resulting in greater yields. Unfortunately these same nutrients can impair water quality if they move off agricultural land into sensitive water resources.

Agriculture frequently is a significant contributor of nutrients to water resources. The *National Water Quality Inventory* (USEPA, 2002), a state-by-state biennial inventory of water quality impairment, typically lists agriculture among the top sources of nutrients in impaired streams and lakes in most states.

Manure is often linked to water quality problems. While nutrients from manure are not inherently more likely to cause water quality problems than nutrients from commercial fertilizers, some characteristics of manure make it more likely that nutrients can be over-applied to some fields.

Movement of nutrients from agricultural land to water resources is a complex process controlled by many factors. Nutrients can leach through the soil profile into ground water or reemerge as seeps, springs or from tile drains to enter surface waters. Runoff can carry nutrients as dissolved ions and in particulate matter. The amount of nutrient loss from a field or farm is affected by a diverse range of farm management practices including animal feeding strategies, manure storage and handling technology, cropping systems, and timing and rate of nutrient application.

The primary water quality concern from phosphorus is its impact on surface freshwater resources such as streams and lakes. Frequently, additions of phosphorus to surface freshwater resources increases algal growth, increases the cost of water treatment and reduces aesthetics and some recreational uses. Excess nitrate nitrogen in drinking water can pose health risks to babies and young livestock. Excess nitrogen in rivers can contribute to the degradation of marine coastal areas such as the Gulf of Mexico.

Nutrient management planning is the primary mechanism being used in the US to reduce the movement of nutrients from agricultural land to surface and ground water. There have been extensive efforts to encourage nutrient management planning by farmers, particularly operations with confined livestock. Two national initiatives to improve nutrient management planning in the past decade are:

- The NRCS 590 nutrient management policy released in 2001.

- The revised Concentrated Animal Feeding Operation (CAFO) rules released by USEPA in 2003.

The nutrient management planning process is an opportunity to work with a farmer to consider options for improving the efficiency of nutrient use on the farm. The nutrient management planning process can educate farmers about practices that will improve water quality and, in many cases, improve the profitability of their operation.

<u>Comparison of manure characteristics with other fertilizer sources.</u>
The value of manure as a fertilizer source has been recognized for thousands of years. However in modern agricultural systems manure sources often are under utilized as fertilizer resources for crop production. This is directly due to physical and chemical characteristics of manure that reduce its value as a fertilizer compared to other fertilizer sources commonly used by crop producers. Most manure sources have the following liabilities as a fertilizer:

- Nutrient concentration: Total fertilizer nutrient concentration rarely exceeds 10% in most manure sources and frequently is a fraction of that. For example nitrogen, phosphate and potash are approximately 8.5% of the weight of poultry litter, 1.5% of the weight of hog slurry and 0.2% of the weight of hog lagoon effluent. Most commercial grade fertilizers exceed 30% nutrient concentration by weight. Low nutrient concentration increases the time and cost of transportation and land application.
- Nutrient ratio: Modern fertilizer production practices allow the blending of fertilizer constituents providing custom fertilizers that meet the specific nutrient requirements of a crop and field. Manure nutrient ratios are a product of animal nutritional considerations and manure storage and frequently do not match the crop requirements. For example applying poultry litter to meet the nitrogen needs of a corn crop applies over five times more phosphate than the crop removes in the grain. It has been clearly documented that long-term use of unbalanced manure fertilizers leads to high soil test phosphorus and potassium levels.
- Nutrient availability: Most commercial fertilizers are designed to be rapidly available to crops when applied to the soil. The organic nitrogen fraction of manure reduces the availability and predictability of the manure as a nitrogen source because the availability of organic nutrients are dependent on microbial activity in the soil. The chemistry of manure makes inorganic nitrogen in manure prone to volatilization losses when it is surface applied. Successful use of manure fertilizer requires adjusting application rates to account for reduced nutrient availability. Sometimes manure management strategies can take advantage of the slow release characteristics of organic nitrogen and phosphorus in manure to help reduce nutrient losses from fertilizer applications.
- Uniformity: Most states have legal requirements for guaranteed analysis of products sold as commercial fertilizers. Nutrient concentrations in manure typically vary spatially and over time within the manure storage making it difficult to meet fertilizer law requirements. Farmers also are challenged when calculating application rates of highly variable sources of manure. Should they apply a rate that *on average* supplies the target fertilizer rate or select a rate that *guarantees* the whole field gets at least the target fertilizer rate? The first strategy insures portions of the field will have nutrient deficits, an economic liability to the farmer; the second strategy maximizes yield but also insures that part of the field will have nutrient excess, a water quality liability.

- Timing: Manure may have to be applied at times that are not ideal for maximizing availability of nutrients. This is especially true for manure storages with an inflexible cleanout schedule such as liquid manure from storages with less than one-year capacity. Manure application decisions are frequently driven by the need to empty a manure storage structure to reduce the risk of overflow or to meet animal management concerns, not to meet crop fertilization requirements.

Utilizing manure as a fertilizer for crop production can be a key component of the economic success of an animal feeding operation. Successful application of any fertilizer requires correctly estimating the nutrient concentration and availability, properly calibrating the application equipment and obtaining an optimal spreading pattern on the field. Manure has some characteristics that make it more difficult to meet these basic requirements. Failure to appropriately account for the unique attributes of manure as a fertilizer can lead to over estimating its value to the farmer. The objective of this paper is to help the reader to better understand the characteristics of manure and the value of manure as a fertilizer source.

Potential

Use of manure does not require that nutrient losses from agricultural systems increase compared to commercial fertilizer systems. There is extensive research showing that when equivalent rates of nutrients are applied as manure or commercial fertilizers that nutrient losses from manure applications are similar or below those associated with chemical fertilizers. For example, Arkansas research showed a 55% reduction in phosphorus concentration in runoff seven days after surface application of poultry litter to fescue compared to a similar rate of inorganic phosphorus. In another example, a Wisconsin study demonstrated that surface-applied dairy slurry reduced total phosphorus loss from a tilled field because the manure reduced losses of particulate phosphorus.

Manure management is associated with greater potential losses of nutrients because the fertilizer characteristics of manure promote over application of nutrients. Failure to account for nutrient imbalances in manure, applying conservatively high rates to insure sufficient available nutrients or failure to properly account for the fertilizer value of manure (e.g. waste applications) all lead to over-application of nutrients. There is extensive research demonstrating that mismanagement of manure leads to over-application of nutrients and to accumulation of nutrients in excess of crop needs, which in turn, leads directly to greater nutrient losses from agricultural systems.

Excessive nutrient application rates typically lead to linear increases in potential nutrient losses. For example, Minnesota research showed linear increases in residual nitrate in the soil profile associated with over application of manure nitrogen to corn following alfalfa. Numerous studies have shown that soil test values increase linearly with increasing over-application of manure phosphorus and potassium. Increasing soil test phosphorus typically results in linear increases in phosphorus concentrations in runoff. Similarly, phosphorus concentration in runoff in the days after manure application often is linearly related to the soluble phosphorus concentration in the applied manure.

Efforts to improve manure management through nutrient management planning will reduce nutrient losses by reducing excess nutrient applications and identifying other changes in crop management practices that will reduce the potential for transport of nutrients from agricultural fields to water resources. Other papers in this publication will address nutrient transport and management practices to limit nutrient loss from agricultural fields.

Important factors

Manure nutrient characteristics

An estimate of manure nutrient concentrations is the starting point for any effort to use manure as a fertilizer yet obtaining a good estimate of nutrient content in manure can be surprisingly difficult.

Tabular values are often used for planning purposes (see examples in Table1). Publications such as *Manure Characteristics* (MWPS-18, 2004) provide book values for many animal types and specialized manure handling systems. Despite this specificity, book values should be judged as rough estimates. Location-specific characteristics such as rainfall, water use, feed composition and animal performance limit the utility of book manure nutrient values relative to manure test results from a properly sampled manure storage.

Table 1. Estimated nutrient concentration in manure for selected animal types and manure storage and handling systems. Data is adapted from *Manure Characteristics* (MWPS-18, 2004).

Livestock system	Units	Total nitrogen (N)	Ammonium N	Phosphate (P_2O_5)	Potash (K_2O)
Pig, nursery, pit slurry	lbs/1000 gal.	25	14	19	12
Pig, grow-finish, deep-pit slurry	lbs/1000 gal.	50	33	42	30
Pig, farrow-finish, pit slurry	lbs/1000 gal.	28	16	24	23
Dairy cow, pit slurry	lbs/1000 gal.	31	6	15	19
Layer hen, pit slurry	lbs/1000 gal.	57	37	52	33
Pig, grow-finish, lagoon water	lbs/acre-in	113	113	56	85
Pig, farrow-finish, lagoon water	lbs/acre-in	127	113	81	102
Dairy cow, lagoon water	lbs/acre-in	114	102	47	82
Broiler, dry litter	lbs/ton	46	12	53	36
Turkey, dry litter	lbs/ton	40	8	50	30

Sampling manure storages is an essential part of using manure as a fertilizer. Unfortunately it can be challenging to obtain representative samples of manure storages at the time of manure application. Slurry tanks are best sampled after they are fully agitated which limits the optimum time for sampling to the time of application. Sampling dry litter in poultry houses is more difficult with birds and feeders in place so they are frequently sampled at the time of building cleanout. Lagoons can be easily sampled a week or so before pumping to provide results representative of lagoon water if no agitation is planned. Current methods to sample lagoon sludge in the bottom of the lagoon are inadequate and the resulting estimates of lagoon sludge nutrient concentrations are unreliable.

Manure testing strategies ideally rely on using manure test records to estimate the nutrient content at the time of application. For example, in slurry operations, rates should be calculated based on the average of previous tests or the most recent past test. A new sample taken during application is then added to the test records and used to confirm the accuracy of the current manure application rate and to help calculate the next manure application rate.

When test results do not exist for a manure storage, results from a similarly managed storage will typically be superior to book values. In poultry operations litter test results from other buildings affiliated with the same integrator often will have similar nutrient concentrations; these buildings typically have similar design, management, bird type and feed. Missouri research showed little variation in average nutrient concentration in buildings on the same farm and phosphorus and total nitrogen concentration in any building were within 10% of the grand mean of all the buildings sampled within the same integrator complex.

An emerging approach is to estimate manure nutrient content based on animal feed and engineering design criteria of the storage facility. This approach has the most potential for covered slurry storages where water inputs are predictable, nitrogen volatilization is limited and all excreted phosphorus and potassium is applied annually. These independent estimates of manure nutrient content can be particularly valuable to validate that an operation's manure test results are accurate.

More research is needed on feed- and animal performance-based approaches for estimating manure nutrient concentrations, predicting seasonal and site-to-site variations in nutrient content in manure, developing more efficient sampling strategies for similarly managed buildings and sampling lagoon sludge. Current regulations and standards suggest sampling every manure storage at least annually. There is potential to develop sampling strategies that require less extensive sampling and provide more reliable estimates of manure nutrient concentration.

Use state and regional extension publications for guidance on how to sample specific types of manure storages and how to handle and ship manure samples.

<u>Manure nutrient availability to crops</u>

Manure differs from most commercial fertilizers in that it typically includes a diverse mix of organic nitrogen compounds that require conversion to inorganic nitrogen by microorganisms (a process called mineralization) to make them available to plants. One of the challenges of manure management is to estimate the rate of nitrogen release from manure organic material and the fraction of organic nitrogen that ultimately is available to crops.

Because mineralization is a biological process it only occurs when soil conditions are suitable for biological activity. The same conditions that promote crop growth also promote mineralization of manure organic nitrogen. Conversely, cold, dry or water logged soil conditions all limit nutrient release from manure.

Inorganic nitrogen in manure is dominantly in the ammonium form (NH_4-N) because there is little oxygen in most manure storages preventing formation of nitrate (NO_3-N). Manure also typically has a pH of at least 7. This combination of ammonium nitrogen a neutral pH makes inorganic nitrogen prone to volatilization. Significant amounts of nitrogen are lost from manure storages as ammonia and these losses generally continue at greater rates than those associated with commercial fertilizers when manure is surface applied to fields.

To accurately estimate nitrogen availability of manure to a crop requires accurately estimating the fraction of organic nitrogen that is mineralized during the growing season and the fraction of inorganic manure nitrogen that is retained by the soil and available for plant uptake. A further complication is that some of the organic nitrogen can be released by the manure one and two years after application.

Most states have developed equations to estimate nitrogen availability in manure. These vary significantly in their approach from state-to-state. For example:

- Missouri calculations require estimates of both organic nitrogen and ammonium nitrogen in manure. Available organic nitrogen is calculated based on organic nitrogen in the manure sample multiplied by an availability factor. The mineralization factor varies based on animal type and storage type. Available ammonium nitrogen is calculated by multiplying manure ammonium nitrogen by a retention factor that varies based on manure placement.
- Minnesota calculations require only an estimate of total nitrogen in manure. The fraction of total nitrogen available is based on multiplying total nitrogen by an availability factor that varies based on animal type and manure placement.

There are significant differences among states in estimated available nutrients, particularly in estimates of nitrogen availability (Table 2). Some differences may be expected due to differences in climate; cool or dry environments may limit the rate of nitrogen mineralization. State-to-state variation also reflects differences in philosophy and approach to calculating nutrient availability in manure.

Table 2. First-year plant available nutrients in 1000 gallons of surface-applied grow-finish pig slurry for selected north-central states. Based on a manure analysis of 50 lbs total nitrogen, 33 lbs ammonium-nitrogen, 42 lbs phosphate and 30 lbs potash per 1000 gallons. State specific nutrient availability calculated using Purdue University's *Manure Nutrient Availability Calculator* (Joern and Hess, 2004).

	Available nutrients		
State	Nitrogen	Phosphate	Potash
	lbs per 1000 gallons		
Illinois	30	42	30
Indiana	27	42	30
Iowa	38	42	30
Kansas	9	42	30
Michigan	9	42	30
Minnesota	18	34	27
Missouri	26	42	30
Nebraska	9	42	30
Ohio	27	42	30
Wisconsin	25	25	24

State-to-state differences have dramatic impacts on the amount of manure that can be applied to a field. An Iowa farmer seeking to apply 150 lbs/acre of available nitrogen can apply 3,950 gallons/acre of slurry, a Minnesota farmer 8,350 gallons/acre and a Michigan farmer 16,650 gallons/acre. Most states are in agreement that manure phosphorus and potassium is at least as available as commercial fertilizer sources. Farmers in states with a lower estimate of manure phosphorus availability may have a lesser restriction on phosphorus-based manure application rates.

Predicting nitrogen availability in manure is difficult because it is so dependent on local climate and soil conditions. However a more integrated, equitable and accurate system of determining nitrogen availability that accounts for regional differences in temperature and moisture is within capabilities of the state of the science.

Manure value

The value of manure nutrients is a topic fraught with misconceptions and over-simplifications. Many casual observers wonder why so many farmers apparently act against their own self-interest and ignore what seems to be a gold mine of nutrients in their manure storage. A more careful analysis demonstrates that the value and importance of manure to the operation's bottom line varies significantly among farms.

An earlier section of this paper outlined potential liabilities of manure compared to other fertilizer sources: nutrient concentration, nutrient ratio, nutrient availability, uniformity and timing. All these factors can have a significant impact on manure value.

Nutrient concentration affects manure value through its impact on the time and volume of material that needs to be managed. Consider a farmer wanting to apply 150 lbs/acre nitrogen. One option could be injected anhydrous ammonia with a guaranteed analysis of 82% nitrogen requiring injection of 185 lbs of product per acre to meet crop need. If the farmer uses poultry litter it would require over four tons of manure to provide the same amount of available nitrogen and if the farmer used lagoon effluent it would require 110 tons of manure (27,000 gallons). Low nutrient concentration increases the time needed for nutrient application and limits the distance manure can be economically hauled.

Fixed nutrient ratio also can affect manure value. We have already discussed how repeated applications of some types of manure to meet the nitrogen needs of a crop will lead to over-application of phosphorus and high soil test phosphorus levels.   The value of additional manure phosphorus to high phosphorus testing fields is zero limiting manure value to nitrogen and perhaps potassium content. Valuing all of the nutrients in manure often overestimates the economic value of manure. A farmer buying nutrients values the nutrients he needs, not necessarily what the manure happens to contain.

An analysis of nitrogen-based manure management on 36 hog operations (17 lagoon operations and 18 slurry operations) in five states demonstrated that factors such as manure management system, size of operation and ownership structure affected manure application costs and net value. Extracting manure value was a more important element of profitability on slurry operations. Manure value represented 2% of net income on lagoon operations compared to 16% on slurry operations. Manure value exceeded application costs on nearly 60% of slurry operations compared to 15% of lagoon operations. Why are lagoons favored by some farmers over slurry tanks if they depress manure value? Farmers with lagoons need less land for manure application and were less dependent on land not owned by the operation. It also took more time per animal unit to apply manure on slurry operations. Most importantly, investment in slurry storage and handling systems did not increase return on assets on these operations; it was more profitable to invest money in raising more hogs then extracting more value from manure.

Limitations

Land needs for phosphorus-based application rates

Concerns about water quality are forcing some farmers to limit manure applications to the phosphorus removal capacity of the crops harvested from a field. Animal feeding operations are unlikely to need to immediately convert to a phosphorus-based application rate because of the revised rules. An estimate of the phosphorus land base requirement does provide farmers an idea of the long-term sustainable land base for manure management. Equation 1 can be used to estimate the change in land needs when converting from nitrogen-based to phosphorus-based land base:

$$\text{Land increase (\%)} = \left(\left(\text{crop need N:}P_2O_5\text{ ratio} \div \text{manure available N:}P_2O_5\text{ ratio}\right)-1\right) \times 100\% \qquad \text{Eq. 1}$$

This equation emphasizes that both the nutrient ratio of crop receiving manure and the nutrient ratio of manure affect the conversion from nitrogen-based to a phosphorus-based application strategy. There will less impact on fields with crops that have low nitrogen to phosphate removal ratio such as wheat (1.9) or corn (2.2) than on a crop with a higher ratio such as alfalfa (4.2) or cool season pasture (15). Conversion will also have less impact on fields receiving manure with a high nitrogen-to-phosphate ratio such as injected lagoon effluent (3.4) compared to manures with low ratios such as surface-applied hog slurry (0.7) or poultry litter (0.6).

A farmer applying hog slurry to a corn field in Missouri will have a 210% ((2.4)/(0.7)-1)X100) increase in land needs; if the operation used 100 acres for nitrogen-based application rates it will need 210 additional acres to apply based on phosphorus. Another operation that is injecting lagoon effluent on corn would need no additional land to adopt phosphorus-based application rates ((2.4)/(3.4)-1)X100<0). Phosphorus rules also will have a greater impact on farms with less productive land because increased land needs are proportional to current land needs. Actual changes in land needs also may be greater if no manure can be applied on some of the phosphorus limited land.

Feasibility of P-based application rates

There are two strategies that farmers can use to implement phosphorus-based application rates on phosphorus limited land:

- Phosphorus rotation is the practice of applying manure to meet the nitrogen need of this year’s crop (a nitrogen-based application rate) and then refraining from additional manure applications until subsequent crops have removed the excess applied phosphorus.
- Annual phosphorus is the practice of limiting manure application rate to the annual crop need for phosphorus.

Both approaches require similar increases in land needs to meet phosphorus-based land application requirements. The difference is that the annual approach requires applying a reduced rate of manure on all acres every year whereas the phosphorus rotation allows application to a fraction of the land base but rotates which land receives manure each year.

An analysis of 39 US swine operations (19 slurry and 20 lagoon operations) indicated that annual phosphorus limit approach posed significant feasibility issues for farmers spreading slurry manure. Annual limits required slurry operations to reduce manure application rates an average of 77% for the 19 slurry operations. To attain such reductions with their current manure application equipment would require some combination of increased travel speed, increased swath width and reduced discharge rate. The study found that:

- None of the 19 operations could attain the reduction in application rate only through increasing travel speed.
- Reduced discharge rate was necessary to meet annual phosphorus application rates on 14 of the operations. Reducing discharge rate increases application time.
- On two of 19 operations annual phosphorus rates were infeasible with the current manure applicator.

Rotational phosphorus rates avoid issues of equipment feasibility because manure is applied at the nitrogen-based rate in the year of manure application. It has the further benefit that manure is a complete nitrogen and phosphorus fertilizer in the year of manure application.

Annual phosphorus limits were not a feasibility problem on operations applying unagitated lagoon effluent. These operations typically make multiple passes to attain nitrogen based rates and annual phosphorus limits were obtainable by reducing the number of passes over the field.

The results of this study imply that operations applying poultry litter will have feasibility issues more similar to slurry operations because of the low nitrogen to phosphorus ratio in both types of manure.

One challenge associated with rotational phosphorus limits is to determine the maximum number of years allowed for a manure rotation. In some pasture-based systems a nitrogen-based rate of poultry litter can apply over 15 years of phosphorus. On permitted animal feeding operations records must be kept for five years suggesting that no more than five-years of phosphorus ever be applied in a single phosphorus-based application rate.

Another question is whether phosphorus rotation application strategy is a greater risk to water quality compared to annual limits. Phosphorus losses in the year of application certainly are greater on land receiving manure using a nitrogen-based limit. This is offset by the balance of the land in rotation receiving no manure so the net loss of phosphorus from the land base may be similar in both approaches. The phosphorus rotation has the further benefit that it requires less time for manure application (no reduction in discharge rate) and does not require applying manure to every acre every year. The flexibility gained with reduced time for application and the opportunity to not apply on marginal land in wet years has the potential to reduce phosphorus losses from rotational strategies.

Summary

Nutrient management planning is an opportunity to help farmers identify ways to increase the value of manure for their farm and protect water quality. One of the challenges of manure management is that decisions are driven by more than the fertilizer value of the nutrients in the manure. These include:

- Manure storage concerns such as ensuring the level of the storage is sufficiently low to prevent overflow.
- Feasibility concerns such as how much land is needed and how much time it will take to apply the manure.
- Economic concerns such as does it pay to invest in upgraded manure equipment compared to adding to other aspects of animal production.
- Manure value concerns such as does it pay to haul manure to a particular field and will the manure provide the needed nutrients for crop production.

Manure has a positive impact on the bottom line of many agricultural operations. To fully understand what motivates manure management decisions requires a full understanding of the challenges associated with using manure as a fertilizer.

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