The Soil Management Series

Manure Management

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THE SOIL MANAGEMENT SERIES:

Publications to help you get more from your soil

Whether you grow a few acres of vegetables for local markets, or two thousand acres of corn and soybeans for international markets, you depend on top performance from your soil. The Soil Management series is aimed at improving soil performance. Because each farm is unique, the series will not tell you the "best way" to manage your soil. Only you can decide that. Instead, it will help you make more effective use of recommendations from the university, consultants, and other advisors.

Agronomic recommendations are typically made for broad climatic regions or soil types, but farmers are increasingly interested in fine-tuning and customizing management practices to fit their unique situation and variability across the land. One example of this trend is precision agriculture technology. The goals of a "fine-tuning" approach to land management are to use resources more efficiently, improve profits, and preserve the profitability and health of the land into the future. To fine-tune agronomic practices, farmers need to monitor the variation across the land from year to year, treat different parts of each field differently, and perhaps run personalized experiments to learn what works best on an individual farm.

This series will help by providing the background science needed to monitor soil and to understand how you can modify general recommendations to suit the needs of your farm. Each publication consists of the following sections that feature basic information, practical applications, and places to look for more help:

THE SOIL MANAGER —explains management options for improving your soil.

THE SOIL SCIENTIST —reviews the soil science principles that are important to production agriculture.

YOUR FARM —helps you apply what you are reading to your own farm.

WHAT'S NEXT? —wraps up the chapter by helping you assess your operation and soil.

FURTHER RESOURCES —lists people and publications to consult for more information.

Titles in the Soil Management Series include:

1) Soil Management (BU-7399)
2) Compaction (BU-7400)
3) Manure Management (BU-7401)
4) Organic Matter Management (BU-7402)
5) Soil Biology and Soil Management (BU-7403)

Copies of the individual titles and the complete series (PC-7398) can be ordered from the University of Minnesota Extension Service Distribution Center, 405 Coffey Hall, 1420 Eckles Avenue, St. Paul, MN 55108-6068. To order by e-mail: order@extension.umn.edu
or by credit card: (800) 876-8636.

Manure Management

WASTE DISPOSAL OR SOIL ENHANCEMENT?

Do you think of manure as waste or an asset? Why do some farmers spend valuable time planning a manure management system? Here are some reasons to treat manure as an asset and examine your manure management system.

Enhancing crop growth. Ron Tobkin, a dairy and crop farmer in northwestern Minnesota, appreciates the improved growth he sees in his edible beans. Ron applied 90 pounds of nitrogen as urea to one plot of beans, and 90 pounds of nitrogen as hog manure to another. The manured beans yielded at least as well as those receiving urea; their roots were better developed and less diseased; and the manure application cost Ron less than the fertilizer. Increased biological activity or other manure characteristics may explain the lower disease rates.

Reducing costs. Other farmers manage their manure carefully so they can reduce fertilizer costs. Manure from a 60-head dairy herd is enough to fertilize 200 acres of cropland in an oats-alfalfa-alfalfa-corn-corn rotation. If bedding and a solid manure handling system is used, the dollar value of the N, P, and K produced may be over $10,000. Nitrogen alone would be worth over $4,000 each year. (Data from the MDA *Manure Management Planning Guide,* p. 3.)

Being a good neighbor. Effective manure management prevents odors and keeps nitrogen and phosphorus out of surface and groundwater.

Making livestock production possible. Recently, leaders in Rice County, Minnesota decided that existing manure management regulations did not adequately control odor and protect water quality. They established an ordinance limiting livestock operations to 1500 animal units. Rice County is just one example of a growing number of places around the country where farmers who want the right to raise animals must explain and justify how they are handling manure.

In this publication

What is your manure management system?

Are you getting the maximum benefit from your manure and adequately preventing pollution? This publication describes how your manure management system affects your farm nutrient cycles, and outlines ways to improve your system.

COMPONENTS OF GOOD MANURE MANAGEMENT

1) Planning your system.
2) Testing manure.
3) Crediting nutrients.
4) Applying manure evenly.

Manure management planning is whole farm planning

The goal of manure management is to handle manure in a way that improves soil quality, avoids pollution, and protects your profitability. Manure management is not just about designing storage facilities. Manure handling decisions impact many aspects of a farm operation. Decisions to raise livestock (and choice of livestock) impact your crop rotation options. How you choose to house your animals (such as conventional confinement systems, deep bedded system, pasture, etc.) limits possible collection and storage systems. The design of your cropping system and seasonal labor availability limits when manure can be spread. Feed type affects the quality of the manure. All of these aspects are part of manure planning.

Want to know more?

See Further Resources for contact information

About manure testing
A list of testing labs is in the *Feedlot and Manure Management Directory*

About planning a system
The *Manure Management Planning Guide* provides information about permitting, building and equipment options, and cost share assistance.

Both are available from the Minnesota Department of Agriculture.

How do I make a manure management plan?

Manure planning happens in two ways: making long-term plans for your system, and making annual plans for nutrient management.

Long-term system planning. Several issues about manure handling were raised at the beginning of this section. Consider the goals of your whole operation as you study options for each of the components of manure handling: manure production, collection, storage, treatment, transfer, and utilization. Ask yourself about start-up and maintenance costs, amount and timing of labor, nutrient loss, and the potential for soil, water, and air pollution.

Annual nutrient management planning. Soil and Water Conservation Districts have computer programs and worksheets to help farmers estimate the amount of manure produced on their farm, and develop a plan for applying it to fields based on crop needs. MAP (The Manure Application Planner) is a computer program that will generate an application plan and nutrient credit report, and estimate the costs of using manure compared with using only commercial fertilizer. MAP can also be used to compare different manure management systems.

THE SOIL MANAGER

Manure testing

Manure testing is essential for proper crediting of nutrients. A basic test consists of total N, P, and K and percent solids. Tests are also available to determine the level of salts, and the level of inorganic or ammonium N (the form available to plants). Taking a representative sample of manure when it is on its way to the field ensures maximum mixing or agitation of the manure, and eliminates the need to estimate nutrient losses during storage. You will not be able to use test results to determine application rates that day, but if you record the application rate, test results can be used later to credit the manure nutrients before applying other fertilizers.

Why test manure?

The nutrient content of manure varies tremendously from farm to farm for many reasons (see p. 11). Minnesota researchers have found manure analyses ranging from 25% to 300% of the average values. With that much variability, published averages are of little use in estimating the nutrient value of manure on your farm.

The good news is that manure from a single farm does not vary much from year to year, so manure tests are meaningful and cost effective.

Nutrient crediting

There are two approaches to using manure as fertilizer.

Before manure application, calculate the appropriate application rate to meet crop needs.

After manure application, calculate the nutrient value of your manure and reduce fertilizer applications by that amount.

In either case, you need to test your manure and soil, and calibrate your spreader so you know how much you are applying. Read on for more information about fertilizing with manure.

Applying manure evenly

Most of the information in this unit assumes that manure is spread uniformly over the fields. *Spreading manure evenly over the land may be the most important step farmers can take toward good manure management*. It also can be difficult. Uniform application means starting a load where the last load left off, avoiding spaces between spreader rows, dispensing manure evenly, and applying manure over all fields rather than only those closest to the livestock.

Want to know more?

About calibrating spreaders

Fertilizing Cropland with Manure series.

QUESTIONS AND ANSWERS

How much manure is too much?

That depends on the manure and the soil. Most manure application rates are based on the nitrogen needs of crops because nitrogen is usually the most expensive part of the fertilizer bill.

However, manure contains large amounts of phosphorus relative to nitrogen, and phosphorus can build up if manure application rates are based solely on nitrogen. You may want to base application rates on phosphorus levels if soil P tests are high or if erosion into surface water is a problem.

Use the MAP computer program or University of Minnesota Extension Service's *Developing a Manure Management Plan* (described at the end of this publication)

If you take only one step towards better manure management...

Apply manure evenly.

This is the most significant thing you can do to get the benefits of manure and to prevent pollution.

to calculate manure application rates based on crop nutrient needs. By not making these calculations, you run the risk of over-application.

Every situation is different, but as an illustration, the typical application rates of dairy manure are 10 to 30 tons fresh weight or 4,000 to 11,000 gallons of liquid manure per acre. This could supply 50 to 150 pounds of nitrogen to the current crop, and the equivalent of 30 to 50 pounds of phosphate and 180 to 200 pounds of potash.

Your Farm

Keeping records is helpful for good manure management—so make it easy on yourself. Have many copies of your farm base map on hand (see *Soil Management,* BU-7399 in this series, for directions on how to make a base map). Then you can quickly sketch exactly where you spread, where you stopped, and the rate of application or total amount applied. Keep manure test results in the same file.

Potential problems from excess manure application rates:

- More *nitrogen* than plants can use at any point in the year may leach into groundwater or concentrate in leaves. Nitrate in drinking water is known to be a serious concern for infant health. High nitrogen can cause excess vegetative growth, but poor seed growth. Excess nitrate in leaves can be bad for human health and seems to attract insect pests.
- Erosion from high *phosphorus* soils and runoff of *ammonium* from manure can damage water quality by triggering algae blooms and decreasing the dissolved oxygen in water.
- The ammonia in *fresh manure* can retard germination and plant growth if not allowed to decompose for a few weeks before planting. This is especially a problem if manure is not spread evenly over the soil. Salt damage is a particular problem with poultry manure. Seedbed tillage will alleviate this potential problem.
- Large amounts of *liquid manure* may cause aeration problems in poorly drained soils.
- *Pathogens* in manure may run off into surface water and threaten human and animal health.
- If manure is washed into surface water, microbes decomposing the manure will use up the water's dissolved oxygen, and fish and other organisms in the water will die.

Can I reduce my fertilizer applications?

If you have results from manure and soil tests, you can credit manure nutrients or calculate an application rate.

Credit manure nutrients:

Multiply the amount of nutrients in the manure times the amount of manure applied times the proportion of the manure nutrients available. In other words:

test value: Pounds of nutrients per ton or per 1000 gallons of manure
X application rate: Tons or 1000 gallons of manure applied per acre
X % availability: % of nutrient available in first year (see below)

= nutrient credit: pounds of nutrient per acre available in first growing season.

Subtract this number from the fertilizer recommendation based on your soil test and crop needs.

Want to know more?

About the fertilizer value of manure

Estimating Manures' Fertilizer Replacement Value. University of Minnesota Extension Service, FO-7197.

Calculate an application rate:

1) Decide whether the application rate will be based on the N or P needs of the crop.
2) Multiply the manure test value of that nutrient times the % available (see below).
3) Divide the fertilizer recommendation for the nutrient (in lbs/acre) by the amount available in the manure (in lbs/ton or 1000gal).
4) The result is the application rate in tons or gallons per acre.

In other words: $\frac{\text{fertilizer recommendation}}{\text{manure test value X \% available}}$ = manure application rate

What proportion of manure P and K is available?

70% to 80% of the phosphorus and 70% to 90% of the potassium in animal wastes is available to plants during the first year.

What proportion of manure N is available?

Percent of nitrogen in applied manure that is available to crops:

SWINE	Broadcast			Injection		**POULTRY**	Broadcast		
	NI*	<4d	<12hr	sweep	knife		NI	<4d	<12hr.
Available 1st yr	35%	55%	75%	80%	70%		45%	55%	70%
Available 2nd yr	15%	15%	15%	15%	15%		25%	25%	25%
Total N lost	50%	30%	10%	5%	15%		30%	20%	5%

DAIRY	Broadcast			Injection		**BEEF**	Broadcast			Injection	
	NI	<4d	<12 hr	sweep	knife		NI	<4d	<12hr	sweep	knife
Available 1st yr	20%	40%	55%	55%	50%		25%	45%	60%	60%	50%
Available 2nd yr	40%	40%	35%	40%	40%		35%	35%	35%	35%	40%
Total N lost	40%	20%	10%	5%	10%		40%	20%	5%	5%	10%

*NI = not incorporated
<4d = incorporated within 4 days after application
<12hr = incorporated within 12 hours after application

Source: Michael Schmitt, personal communication.

A couple of notes. . .

The table above shows nitrogen availability for only the first two years after manure application. In reality, residual nitrogen from manure may continue to elevate soil nitrogen in subsequent years. This is best quantified by using the residual nitrogen soil test.

The calculations that generated this table are based on the climate in Minnesota. Decomposition rates and nitrogen availability will differ elsewhere.

Is fall better than spring?

There is no single answer to the question of when to apply manure. On sandy soils, fall application can lead to significant nitrogen losses and groundwater contamination. On other soils, nitrogen losses after fall application are similar to losses after spring application. Practical concerns, such as time and equipment availability, usually determine when you apply manure. Large storage systems or composting give you more flexibility in timing an application.
Below are some considerations about each season.

Spring

Because there is less time for decomposition, a smaller proportion of nutrients will be available in the first year. Total losses over several years may be somewhat lower than with fall application. Spring is a tight time for labor, so manure application may delay other fieldwork. Soil compaction is a serious risk when applying manure on fine-textured or wet soils.

Fall

Fall application gives microbes time to decompose the manure—making nutrients more available to crops and preventing germination concerns. On the other hand, there is more time for nitrogen loss. Avoid fall application on coarse-textured soils or in karst (limestone sinkhole) areas.

Winter

Labor is generally available and compaction is not a concern in the winter. Because incorporation is impossible, nutrient losses can be high. Nutrient runoff from snow melt or rain is a serious problem when manure is applied to frozen, sloping soil. However, some farmers have found that the mulch created by a manure crust prevents wind erosion.

Summer

Summer application requires a crop rotation that leaves a field available for manure. This could be a fallow field, a pasture, or a crop that is planted late or harvested early. High biological activity and plant growth in the summer reduce the loss of nutrients from the rooting zone.

Is it worthwhile to compost manure?

Composting manure has several advantages that may make it worth the extra effort, especially for organic growers.

- Composting raises the pH of manure and reduces odor.
- Nutrients are released more steadily over several years.
- Composting substantially reduces the bulk of manure. Its low water content and high nutrient concentration make compost easier to handle than uncomposted manure.
- Weed seeds, fly eggs, and pathogens can be reduced if high temperatures are generated during the composting process.
- Compost does a better job of encouraging the growth of the soil organisms that improve nutrient cycling and soil structure. The low pH and high salt level of fresh manure can disrupt soil life.

Want to know more?

About composting

See the list of references at the end of this publication.

THE SOIL SCIENTIST

This section contains basic information about what manure does in the soil and why manure nutrient content varies so much from farm to farm.

WHAT IS MANURE?

Manure is not just the urine and feces from livestock, but also the bedding, runoff, spilled feed, parlor wash, and anything else mixed with it.

Use of livestock manure is one of the major methods (along with crop rotation and green manure) used throughout history to maintain soil fertility. Since World War II, there have been remarkable developments in the use of inorganic, manufactured fertilizers. Yet manure can still contribute to soil fertility and tilth. In addition to nutrients, manure provides carbon and other constituents that affect soil humus content, biological activity, and soil physical structure.

WHAT DOES MANURE DO IN THE SOIL?

Manure is an invaluable way to improve soil, but it can be a major pollutant if you do not pay attention to how it works in the soil.

Manure has several effects when added to the soil system:

Immediate supply of nutrients. Manure contains nitrogen (as ammonium), phosphorus, potassium, and micronutrients that can be used directly by plants. This is the most commonly recognized value of manure.

Delayed supply of nutrients. Other nutrients in manure are part of organic (carbon-containing) compounds. These compounds trigger biological activity which makes nutrients in the manure and other organic matter available to plants.

Lowered pH. Regular manure application lowers soil pH. The acidifying effect of manure is less than that of inorganic fertilizers.

Salt and ammonia toxicity. Manure contains high levels of salts that burn leaves when applied to growing plants. Once in the soil, though, salts are not a concern in Minnesota because of adequate rainfall levels. High levels of ammonia or ammonium in fresh manure can be detrimental to germinating seeds.

Improved soil structure. The increased biological activity and organic matter improve soil structure by binding soil into aggregates. In the words of S. W. Fletcher in 1910, "When incorporated with the soil, [manure] greatly improves the texture, loosening a heavy compact soil and binding together a light leachy one; making the soil more friable, warmer, more retentive of moisture and more congenial to plants in every way." (S. W. Fletcher, 1910. *Soils: How to Handle and Improve Them*. Garden City Doubleday, Page & Company, p. 348.)

In some situations, manure can serve as a protective mulch on soils vulnerable to erosion.

Want to know more?

About nitrogen in the soil

See *Soil Biology* (BU-7403 in this series) for a description of what bacteria do to nitrogen.

See *Soil Management* (BU-7399 in this series) for a description of the soil solution and how plants get nutrients from the soil.

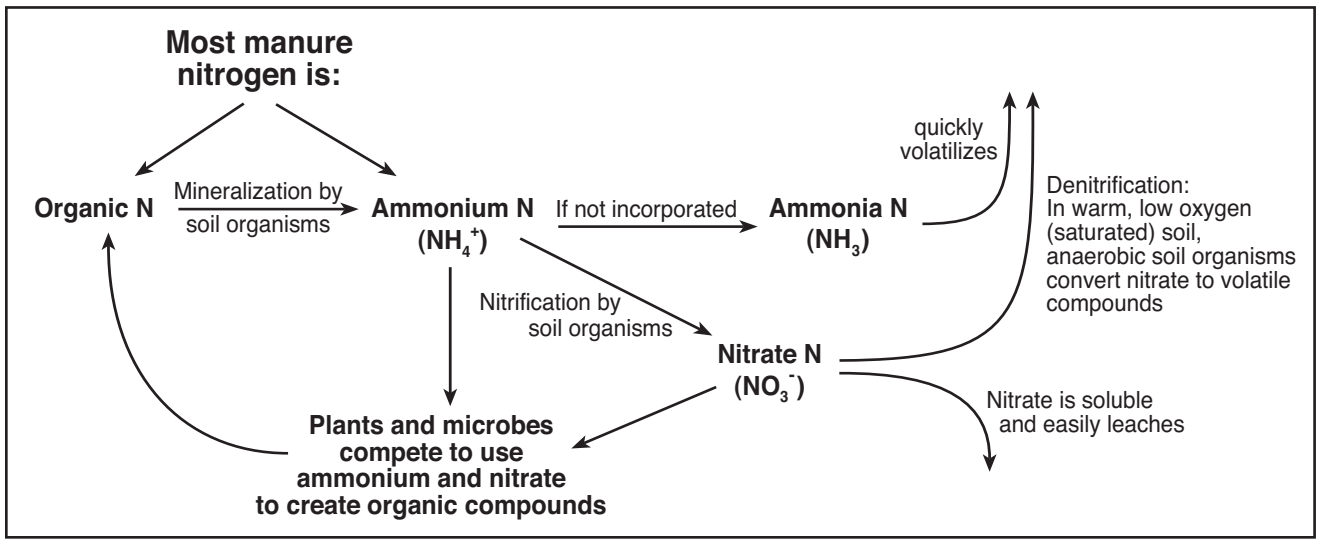
Enhanced biological activity. Manure affects the mix of organisms in soil, but these changes are poorly studied. Manure may affect pest and nutrient cycles by changing the diversity of soil organisms that compete with pests and that transform plant nutrients.

What kind of nitrogen does manure supply?

As the figure below shows, about half of the nitrogen in manure is in the form of ammonium and about half is in the form of organic material. Microbes that consume the organic compounds excrete ammonium. One of four things will happen to the ammonium–regardless of whether it comes directly from the manure or from microbes consuming the organic compounds. The ammonium may be:

1. *used by plants immediately*,
2. *converted to ammonia* and lost to the air,
3. *converted to nitrate* which will be used by plants or microbes, leached out of the soil, or denitrified and evaporated,
4. *used by microbes*. Microbes convert the nutrients to organic compounds which cannot be used by plants or easily lost from the soil. These "immobilized" nutrients become available to plants when the microbes are consumed by other organisms that release ammonium as a waste product.

In the warmth of summer, plants and microbes are growing vigorously and use ammonium and nitrate quickly. Losses of nitrate to leaching is greater in spring and fall when fewer plants and microbes can turn it into organic matter. More complex ecosystems (e.g., a pasture with many plant species, a rotation that includes cover crops, or a weedy field,) are more likely to have some plants and microbes active at all times of the year, preventing the loss of nitrogen from the root zone.



WHAT DETERMINES THE NUTRIENTS IN MANURE?

- **Type of animal and age of herd/flock**
- **Feed and feed supplements**
- **Bedding**
- **Collection and storage system**
- **Application method**
- **Timing of application**
- **Soil texture and weather**

Anytime you change one of these factors, you can expect your manure nutrient test to change. Each of the factors are described below.

Type of animal

Different animal species produce different types of manure. A ton of fresh manure from most species contains roughly 10 to 20 pounds of nitrogen, 5 to 10 pounds of phosphorus, and 10 to 15 pounds of potassium. However, nitrogen and phosphorus levels are even higher in poultry manure, and sheep manure contains greater potassium levels.

Feed

Typically, 75% to 90% of the nutrients in feed is not used by animals for growth and is excreted in urine and feces. So it is not surprising that the nutrient content of manure changes when a farmer changes feed sources or when pasture plants change over the seasons. The level of protein and inorganic salts in feed (sodium, calcium, potassium, magnesium, phosphate, and chloride) will be reflected in the characteristics of the manure, and the proportion of available versus organic nitrogen may change.

Innovations in feeding practices are dramatically affecting the nutrient value of manure. As you carefully balance feeds for optimal nutrient use by the animals, the nutrients excreted in manure will change. For example, the use of phytase in feed and the use of low phytate corn varieties will improve animal use of phosphorus and will substantially lower the level of phosphorus in manure.

Bedding

Bedding material absorbs urine, somewhat reducing nitrogen losses. Bedding is more important for changing the rate at which nutrients are available than for changing the nutrient content of manure. Compared to manure alone, the higher carbon content of manure-plus-bedding makes less nutrients available in the first year after application (but more in subsequent years).

Want to know more?

About the importance of carbon and nitrogen content

See *Organic Matter Management* (BU-7402 in this series).

Collection and storage system

Manure exposed to sun and wind will lose nitrogen through evaporation. Rain and runoff will leach soluble nitrogen. Phosphorus and potassium losses are negligible in storage except in open systems in which runoff and leaching can cause losses of 20 to 50 percent.

The table below compares nitrogen losses under some conventional storage systems.

	N loss (compared to fresh manure)
Solid systems	
Daily scrape and haul	15-35%
Manure pack	20-40%
Open lot	40-60%
Deep pit (poultry)	15-35%
Liquid systems	
Anaerobic deep pit	15-30%
Above ground storage	15-30%
Earthen storage pit	20-40%
Lagoon	70-80%

(Source: Utilization of Animal Manure as Fertilizer, 1983. Purdue University Cooperative Extension Service.)

Application method

Incorporating manure into the soil immediately after application minimizes nitrogen loss to the air and allows soil microorganisms to start decomposing the organic matter, making nutrients available more quickly to the crop. In manure in which half of the nitrogen is in the form of ammonium, about 25% of the nitrogen is lost within the first 24 hours after surface application. Another 20% may be lost in the next 3 days. Nitrogen loss to the air (as ammonia) is greater on dry, windy days, and from the manures of poultry and veal calves. Losses are reduced if it rains shortly after application, and if application is done as the air temperature is dropping (such as in the late afternoon).

Phosphorus and potassium are not lost to the air, but they can be carried away in runoff.

Solid manure that is allowed to settle out of the liquid may contain 50%-80% of the phosphorus. This may be important if the liquid is applied separately from the solids.

Soil and weather characteristics

Decomposition occurs faster under warm, moist conditions, making nutrients available to plants more quickly. Rain after application reduces volatile losses of nitrogen.

On *coarse textured soils,* decomposition is rapid, so nutrients are available more quickly. Coarse soils have a low CEC (cation exchange capacity, or nutrient holding capacity) and low water-holding capacity, so it may be necessary to limit the amount of manure applied to coarse soils to prevent nutrient leaching.

Fine-textured soils retain nutrients longer in the rooting zone. Infiltration is slower than on coarse-textured soils. To prevent runoff, the amount of liquid manure applied to fine soils may have to be limited.

INTENSIVE GRAZING AND OTHER "DIRECT DEPOSIT" APPROACHES

One important manure management system that is often neglected is direct deposit of manure onto land by grazing or herded animals. Because animals manage the storage and application components of this system, labor savings are significant. However, nutrients can be lost to runoff and to nitrogen evaporation. These losses can be minimized by mechanically incorporating manure into the soil after herding animals on a plot, or by maintaining a vigorous biological community (e.g., beetles, earthworms, chickens, wild turkeys) that can chop, bury, and decompose the manure so it is quickly fixed into forms that are not easily leached or volatilized. The greatest nitrogen losses are from urine spots because the nitrogen is in an inorganic form and overwhelms the soil's ability to buffer and immobilize the nitrogen.

A "direct deposit" approach to manure management can be used on pastures, hayland, cover crops, and crop fields where livestock clean up residues, weeds, sprouted grains, etc. This strategy is especially suited to areas that will be tilled after the manure is deposited.

Two important factors to consider when planning a direct deposit system are irregular distribution and the freshness of the manure. Inevitably, more manure is deposited near watering, feeding, and bedding areas. Urine (with its different mix of nutrients), is typically separated from dung. For these reasons, grazing will greatly increase the variation of nitrogen in the soil across the field. The salt and acid content of fresh urine and manure can have a temporarily dramatic effect on soil and plants. Consider that a urinating cow is applying nitrogen at a rate of 1100 pounds per acre; sheep are applying nitrogen at 250 pounds per acre. Most urine nitrogen is lost to the atmosphere or leaching, in part, because plant growth is reduced by urine scorch.

Want to know more?

About rotational grazing

Many local groups of rotational graziers meet regularly to share information. To find one in your area, call the Land Stewardship Project at (507) 523-3366. Grazing publications are listed at the end of this publication.

WHAT'S NEXT?

ASSESSING YOUR SYSTEM

Is manure an expensive waste product or an integral part of nutrient cycling and an asset to your soil quality? Is your manure management system where you want it to be? Here are some questions to help you decide.

Review all the places where nitrogen is lost from manure—collection, storage, and application. (See pages 9-11.) Where are your major N losses? Are they acceptable? What would it take to make improvements?

- ✔ How close is your manure storage to surface water? Is that water protected from run-off and spillage? Is erosion under control on all parts of your farm where manure is applied?
- ✔ Is the cost of the system acceptable? Is the timing of labor requirements acceptable or do they compete with other operations?
- ✔ Is manure spread over your whole farm and not concentrated in small areas?
- ✔ Think about your soil problem areas. (You may have created a list of these areas in *Soil Management,* BU-7399 in this series.) If these areas are not receiving manure, it may be a useful treatment for poor tilth, disease, or generally poor productivity.
- ✔ Is it worth rethinking your whole system for housing animals and handling manure, or can you make adjustments to your existing system?

THE ECONOMICS AND POLITICS OF MANURE

Manure management decisions are linked to many parts of your farm operation. But how are manure management decisions linked to the larger food production system?

In the past, nearly every farm in the country had a few animals. Now, livestock are concentrated in a few regions and in large herds. There have always been some poor manure managers, but the costs of poor manure management are rising as the size of herds and flocks grow.

Non-farmers are becoming concerned about these costs as manure spills increasingly make the news. Farmers' pocket books and the quality of soil are affected as nutrients are carried farther and farther from their original field. For example, nutrients may be taken from a field in Minnesota (in the form of corn), fed to hogs in South Carolina, and deposited hundreds of miles from the source of those nutrients.

The modern system of livestock production is not just changing the distribution of nutrients across the land. It is also changing the markets for manure and forages. How has livestock production changed in your area in the last 20 years? If a farmer without livestock wanted to grow a forage crop, would it be easier or harder now to find a market for that crop? Could that farmer buy manure? The answers to these questions are quickly changing for many farmers, and are changing the way farmers manage their soil.

FURTHER RESOURCES

MANURE SPECIALISTS

Phil Nesse, Extension educator, Manure Management. Staples, MN. Phone: 218-894-2610.

Dennis Busch, Extension educator, Manure Management. Waseca, MN. Phone: 507-835-3422.

PUBLICATIONS

Composting

The Composting Council, 114 South Pitt Street, Alexandria, VA 22314, 703-739-2401.
The Composting Council is a trade association supporting the needs of the composting industry. Members include compost producers, equipment manufacturers, academic institutions, non-profit groups, and others interested in maximizing the use of organic materials. Their publications focus on the commercial production of compost and its use. Call for a list of publications.

Farm-Scale Composting. 1994. Donna Doel. Appropriate Technology Transfer for Rural Areas (ATTRA). This free booklet can be ordered from ATTRA at 800-346-9140, or on their web site at http://www.attra.org.

Manure Management Alternatives. 1995. Minnesota Department of Agriculture.
Pages 3-12 contain information on composting. Visit the MDA web page at http://www.mda.state.mn.us for the most current edition or call MDA at 651-285-6830.

Organic Field Crop Handbook. 1992. Canadian Organic Growers Inc.
See pages 32-43 for practical information on how to compost manure. Available from Faye Jones, Education Outreach Coordinator, Wisconsin OCIA, N7834 Co. Rd. B, Spring Valley WI 54767.

The Passively Aerated Windrow System of Composting – A Guide for Farmers. 1995. Jon Nilsson and others. A free handbook available from the Pickering Creek Environmental Center in Easton, MD. Call Alan Girard, Jr. at 410-822-4903.

The Rodale Book of Composting. 1992. D. Martin and G. Gershuny. Rodale Press.
Order from Rodale at 800-914-9363.

Manure Management

Developing a Manure Management Plan. 1997. Dennis Busch, Lowell Busman, and Phil Nesse. University of Minnesota Extension Service BU-6957.
A pencil-and-paper alternative to the MAP computer program. Use it to calculate manure application rates based on the nutrients in manure and crop nutrient needs. Contact your local University of Minnesota Extension educator, or call the Distribution Center at 1-800-876-8636. These publications and other manure management information are available at the Manure Education and Research home page at http://www.bae.umn.edu/extens/manure/manure.html

Estimating Manures' Fertilizer Replacement Value. D. Busch, P. Nesse, L. Busman. University of Minnesota Extension Service FO-7197.
Provides a starting point, through examples and worksheets, to determine a reasonable value for manure purchases. For livestock producers, consultants, and potential manure buyers. Contact your local University of Minnesota Extension educator, or call the Distribution Center at 1-800-876-8636. These publications and other manure management information are available at the Manure Education and Research home page at http://www.bae.umn.edu/extens/manure/manure.html

FURTHER RESOURCES

Feedlot and Manure Management Directory. 1997. Minnesota Department of Agriculture.
See **Manure Management Planning Guide for Livestock Operators,** below.

The Fertilizing Cropland with Manure series. Michael Schmitt and George Rehm. University of Minnesota Extension Service.
Contact your local University of Minnesota Extension educator, or call the Distribution Center at 1-800-876-8636. These publications and other manure management information are available at the Manure Education and Research home page at http://www.bae.umn.edu/extens/manure/manure.html
Fertilizing Cropland with Beef Manure. FO-5882.
Fertilizing Cropland with Dairy Manure. FO-5880.
Fertilizing Cropland with Poultry Manure. FO-5881.
Fertilizing Cropland with Swine Manure. FO-5879.

Integrated Animal Waste Management. 1996. Council for Agricultural Science and Technology (CAST). Task Force Report No. 128.
An 80-page summary of manure management policy issues and system options written to educate the public. Copies available for $20 from CAST, 4420 West Lincoln Way, Ames, IA 50014-3447, (515)292-2125, cast@cast-science.org

Livestock Manure Sampling and Testing. Tim Wagar, Mike Schmitt, Chuck Clanton, and Fred Bergsrud. University of Minnesota Extension Service FO-6423.
Contact your local University of Minnesota Extension educator, or call the Distribution Center at 1-800-876-8636. These publications and other manure management information are available at the Manure Education and Research home page at http://www.bae.umn.edu/extens/manure/manure.html

MAP (Manure Application Planner). Center for Farm Financial Management, University of Minnesota.
MAP is a computer program that can be used to assess the economic viability and environmental soundness of your current practices, or to design a new manure application plan. It is available for use at Soil and Water Conservation District offices, University of Minnesota Extension Service offices, and Pollution Control Agency offices. For more information, or to purchase the program, contact the Center for Farm Financial Management at 1-800-234-1111, or at http://www.cffm.umn.edu/cffm/map.htm
To prepare for an efficient and productive session when using the MAP software, fill out *Manure Application Planning Input Form*. 1996. M. A. Schmitt, R. A. Levins, and D. W. Richardson. University of Minnesota Extension Service FO-6691.

Manure Management Alternatives. 1995. Minnesota Department of Agriculture.
See **Manure Management Planning Guide for Livestock Operators,** below.

Manure Management for Open Lot Livestock Production. 1995. Natural Resouces Conservation Service, Iowa State University, and Iowa Department of Natural Resources.
A 16-page booklet about choosing the right management system, storing manure, releasing liquids, treating runoff, and applying nutrients to the land. Cost: $2. Distributed by the Conservation Technology Information Center, 317-494-9555, hopper@ctic.purdue.edu.

Manure Management in Minnesota. Michael Schmitt. University of Minnesota Extension Service FO-3553.
A summary of manure management issues, including the application of manure to alfalfa or soybeans. Contact your local University of Minnesota Extension educator, or call the Distribution Center at 1-800-876-8636. These publications and other manure management information are available at the Manure Education and Research home page at http://www.bae.umn.edu/extens/manure/manure.html

FURTHER RESOURCES

Manure Management Planning Guide for Livestock Operators. 1995. Minnesota Department of Agriculture. 60 pgs. Two supplements are also available: *Manure Management Alternatives* (1995), and *Feedlot and Manure Management Directory* (1997).
These three publications are a comprehensive guide to the technical aspects of manure handling systems. They are less useful in planning nutrient management. The *Manure Management Planning Guide* includes chapters on permitting, neighbor relations, system options, environmental considerations, utilization and application of manure, and cost share assistance. The *Manure Management Alternatives* book explains composting, vegetative filter strips, mechanical separation, anaerobic digestion, gasification, and odor control methods. The *Feedlot and Manure Management Directory* lists contacts for permitting, financial assistance, planning and engineering assistance, testing labs, custom applicators, crop consultants, and private engineers. For the most up-to-date version of the directory visit the MDA web page at http://www.mda.state.mn.us. For a free copy, call the MDA Ag Marketing and Development Division at 651-285-6830.

Running your Feedlot for Farm Economy and Water Resource Protection. 1993. Minnesota Pollution Control Agency.
This 16-page publication is available by calling PCA at 651-296-6300.

Turkey Manure Handling. Sally Noll. University of Minnesota Extension Service FO-5653.
Provides information about storage, use as a fertilizer, use as a feed source, financial value, transportation, regulations, public relations, and resources. Contact your local University of Minnesota Extension educator, or call the Distribution Center at 1-800-876-8636. These publications and other manure management information are available at the Manure Education and Research home page at http://www.bae.umn.edu/extens/manure/manure.html

Rotational Grazing

Controlled Grazing Guidelines. 1991. Carl Fredericks. Wisconsin Department of Agriculture.
Eight pages on pasture management, free from the Wisconsin Department of Agriculture. Call Jane Larson, 608-273-6408.

Grass-Based and Seasonal Dairying. 1996. Alice E. Beetz. Appropriate Technology Transfer for Rural Areas (ATTRA).
A free booklet from ATTRA. Call 800-346-9140, or see their web site at http://www.attra.org

Knee Deep in Grass: A survey of twenty-nine grazing operations in Minnesota. 1996. B. Loeffler, D. Johnson, E. Fuller. Minnesota Institute for Sustainable Agriculture and University of Minnesota Extension Service (BU-6693).
Offers detailed descriptions of dairy grazing operations and their effect on farm families, labor needs, production and business management. Contact the Distribution Center at 612-625-8173 or 1-800-876-8636 or on the Web at http://www.extension.umn.edu.

Managed Grazing (Video). 1995. Jim Russell and others. Iowa State University.
A five-tape series demonstrating improved grazing practices in the Midwest. From the Iowa State University Department of Animal Science. Call Barb Magnuson, 515-294-2240.

Pastures for Profit: A Guide to Rotational Grazing. 1993. University of Wisconsin.
Provides basic information about setting up rotational grazing on the farm. Available from the University of Minnesota Extension Service (FO-6145) at 612-625-8173 or 1-800-876-8636; or from University of Wisconsin Cooperative Extension Publications (A3529) at 608-262-3346.

Pasture Talk Magazine.
A publication dedicated to grazing published by Greenbull Press, P.O. Box 620732, Middleton, WI 53562.

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This publication is part of a series developed through the Sustainable Agriculture Information Exchange, a clearinghouse of sustainable agriculture information and materials in Minnesota. These informational materials are accessible to the public by phone (toll-free), fax, e-mail, or World Wide Web.

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