Virginia Cooperative Extension
Virginia Tech • Virginia State University
Publication 442-305

Nutrient Management for Small Farms

Jactone Arogo Ogejo, Extension Specialist, Biological Systems Engineering, Virginia Tech
Rory Maguire, Extension Specialist, School of Plant and Environmental Sciences, Virginia Tech

Introduction

The basic principles of nutrient management on small farms are similar to those of large farms. However, small farms may have a greater challenge with managing manure nutrients because of (1) the different characteristics of manure from the multiple animal species they keep, (2) the limited land area available to apply manure, and/or (3) a lack of equipment for manure management and spreading. The purpose of this publication is to outline how to quantify and determine use of manure nutrients in small farms as a crop fertilizer in order to prevent environmental damage that may be caused by nutrient losses.

What Is a Small Farm?

Small farms are diverse, ranging from retirement and residential farms with few off-farm sales to commercially oriented farms with annual sales approaching $250,000.

What Is Nutrient Management?

Nutrient management is the process used to handle the application of nutrients to crops, including their quantity, form, placement, and timing. On most farms, the nutrients predominantly come from manure and commercial fertilizer, but other sources, such as compost, can also be important. The purpose of nutrient management is to supply sufficient plant nutrients for optimum forage and crop yields, and thus prevent excess applications that can contaminate water quality. A nutrient management plan (NMP) documents the source, rate, method, and timing of nutrient applications.

Movement of Nutrients on a Farm

To manage manure effectively, it is important to consider the entire farm's nutrient balance. Figure 1 provides an overview of nutrient cycling on a farm. Usually, there is a tendency to focus on manure management alone, which may only account for a small part of the total nutrients. Nutrient dynamics include inputs, outputs, what is lost, and what is stored on the farm. It is necessary to consider the big picture in order to understand and identify the sources of nutrients potentially associated with environmental issues and how to develop solutions to deal with the problems they create.

Farm nutrient inputs include purchased animals, feed, fertilizer, legume nitrogen, and bedding. **Farm nutrient outputs** are products that are moved out of the farm through sales or given away, including animals, milk, meat, eggs, manure, and crops. Recycling of nutrients occurs on the farm when manures from livestock are used for crop fertilizer, and then the crops are harvested and fed to the livestock. The optimal goal is to have a situation whereby the farm can balance the inputs with crop and animal needs to minimize risk of environmental damage.

The major nutrients of interest are nitrogen (N) and phosphorus (P). Losses of N occur via leaching of nitrates to groundwater, volatilization of ammonia to the atmosphere, and phosphorus (P) runoff into the surface water. Phosphorus may also accumulate in the soil to levels greater than crop needs and cause excessive losses in runoff. Nutrients may leave the farm when manure is used for off-site energy generation (thermal and biological processes) and composting.

Estimating Manure Quantity and Nutrients on a Farm

In general, the quantity and nutrient content of manure depend on the species, breed, and age of the animal and the composition of feed in their diet. Table 1 presents quantity and nutrient content of freshly excreted manure from different animal species, usually referred to "as excreted."

Produced by Virginia Cooperative Extension, Virginia Tech, 2018

VT/1218/442-305(BSE-241P)

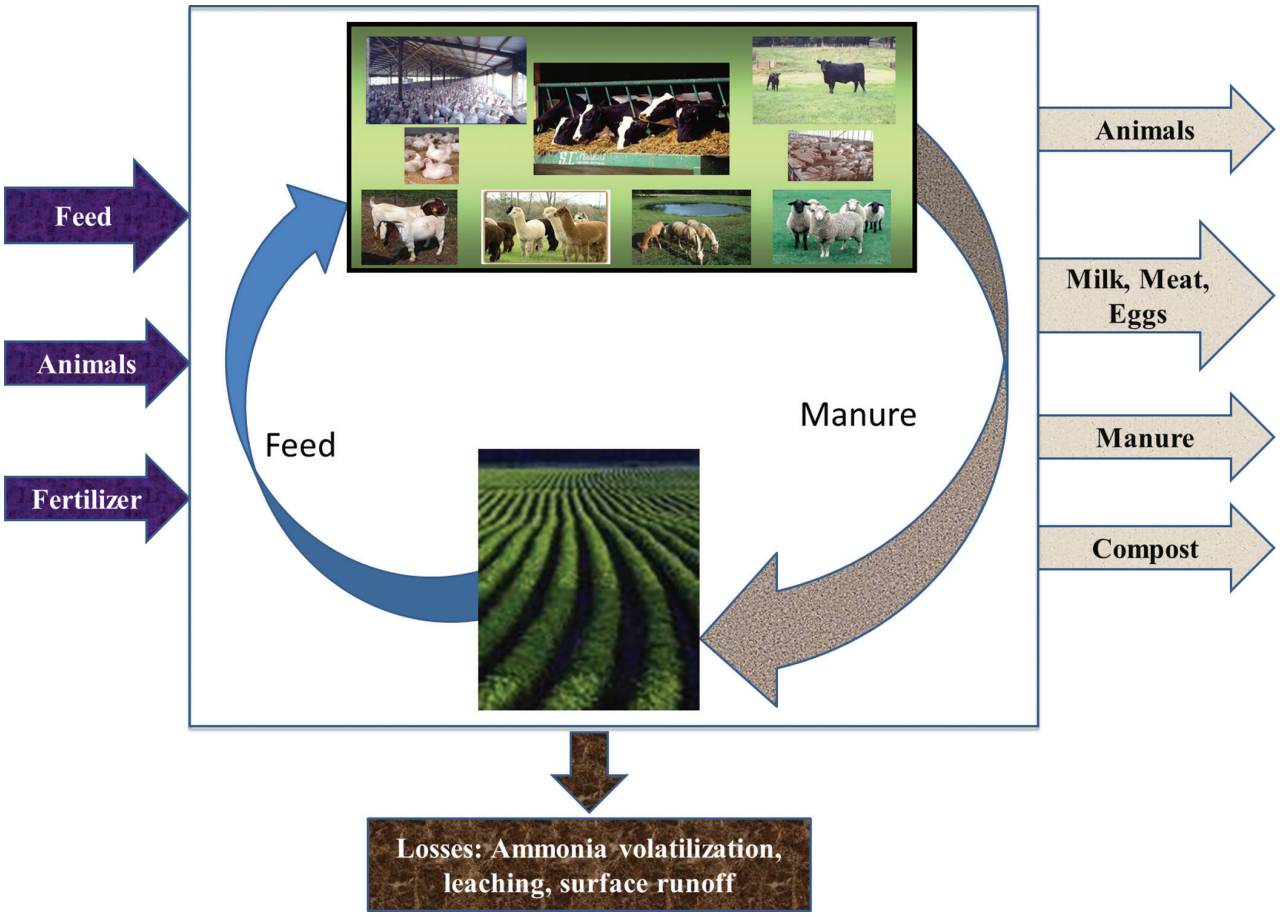

Figure 1. Nutrient cycling on a farm operation

The composition of manure applied to cropland is usually different from that of freshly excreted manure because of decomposition and losses during storage. The amount of loss depends on the climate, transformation of nutrients, storage period, and type of manure handling system used. Major losses are from N volatilization and leaching of soluble nutrients. Some studies have indicated that as much as 50 to 70 percent of N may be lost from manure (depending on how it is stored), due to ammonia volatilization and denitrification to dinitrogen gas (N_2). Phosphorus and potassium (K) losses are less likely except for manure not contained properly. Tables 2 and 3 present the nutrient content of stored manure for the common animal species in Virginia.

Manure quantities in table 1 are suitable for planning short-term storage and nutrient application where there is no manure storage on the farm. Tables 2 and 3 are useful in estimating the amount of nutrients that will be available for application to cropland after storage. The data in tables 2 and 3 also include standard deviations, which show how the nutrients in manure vary and how close individual manure samples are to the average value. These values should be used as a guide and only when manure analyses for your farm are not available.

Manure composition can vary widely, so testing is the most accurate way to determine nutrient content. Taking a representative sample from your manure is important because manure composition is not consistent. For example, manure on the surface of a pile will contain less N because of ammonia loss than that deeper in the pile. To learn how to take a representative sample, see the publication by Maguire, Hodges, and Crouse (2009).

Also, all phosphorus in manure is considered plant-available. This is not the case for N because it is so mobile and exists in many forms. The total N and ammonium-N in manure are used to calculate the plant-available component, as described in *Soil Test Note No. 5: Fertilizing with Manures*, Virginia Cooperative Extension (VCE) publication 452-705 *(https://pubs.ext.vt.edu/content/dam/pubs_ext_vt_edu/452/452-705/452-705_pdf.pdf)*. The example below shows how to estimate the nutrients on a farm with several animal species.

Table 1. Quantity of manure produced daily and nutrient concentrations as excreted by different animals.

Animal type	Weight (lb)	Quantity produced per day: Weight (lb)	Quantity produced per day: Volume (gal)	Moisture content (%)	Nutrients (lb/day per animal): Total N	Nutrients (lb/day per animal): Total P (P_2O_5)	Nutrients (lb/day per animal): Potassium (K_2O)
Dairy							
Lactating	Mature	150	18.00	87	0.99	0.39	0.28
Dry	Mature	83	9.72	87	0.50	0.15	0.40
Heifer	970	48	5.83	83	0.26	0.10	0.33
Calf	250	22	2.60	87	0.11	0.04	0.09
Beef							
Finishing	975	58	6.9	88	0.36	0.11	0.30
Cow (confined)	Mature	64	7.80	88	0.42	0.22	0.36
Calf (confined)	500	29	3.5	88	0.29	0.13	0.23
Horses	1,100	57	6.80	85	0.34	0.17	0.25
Poultry							
Broilers	2.5	0.2290	0.0265	74	0.0025	0.0017	0.0017
Layers	2.5	0.1900	0.0232	75	0.0035	0.0025	0.0016
Turkey							
Male (toms)	17	0.5850	0.0730	74	0.0090	0.0062	0.0051
Female (hens)	10	0.3620	0.0430	74	0.0054	0.0034	0.0029
Sheep	63	3.1800	0.4190	70	0.0319	0.0089	0.0316
Goats	64	3.4200	0.3800	64.5	0.0412	0.0092	0.0367

Source: ASABE 2005; MWPS 1993; Barker, Zublena, and Walls 2001.

Table 2. Average nutrient content (± standard deviation) of liquid manure for different animal species at the time of application in Virginia.

Animal	Samples (#)	Moisture content (%)	Nutrient (lb/1,000 gal): Total N	Nutrient (lb/1,000 gal): Ammonium-N	Nutrient (lb/1,000 gal): Total P (P_2O_5)	Nutrient (lb/1,000 gal): Potassium (K_2O)
Beef	59	93.1 (±2.3)	22.11 (±3.30)	9.51 (±1.52)	12.50 (±3.51)	19.61 (±3.42)
Dairy	1,181	94.0 (±1.3)	21.19 (±3.94)	9.18 (±0.52)	9.18 (±1.11)	21.25 (±9.79)
Swine	617	98.9 (±0.5)	9.06 (±0.93)	6.61 (±0.73)	4.20 (±1.32)	12.28 (±0.98)

Source: Virginia Department of Conservation and Recreation.

Table 3. Average nutrient content (± standard deviation) of solid manure for different animal species at the time of application in Virginia.

Animal	Samples (#)	Moisture content (%)	Nutrient concentration (lb/ton): Total N	Nutrient concentration (lb/ton): Ammonium-N (NH_4-N)	Nutrient concentration (lb/ton): Total P (P_2O_5)	Nutrient concentration (lb/ton): Potassium (K_2O)
Dairy	384	65.8 (±2.6)	19.78 (±10.94)	2.99 (±0.72)	7.93 (±1.58)	17.98 (±9.87)
Beef	142	59.6 (±4.8)	23.81 (±10.98)	2.34 (±0.43)	12.71 (±2.50)	26.08 (±11.69)
Swine	6	46.1 (±27.1)	29.45 (±13.04)	7.80 (±1.98)	24.35 (±18.34)	10.75 (±5.93)
Broiler	2,025	27.8 (±0.6)	66.58 (±3.49)	11.05 (±0.61)	48.09 (±8.50)	54.25 (±2.26)
Layer (breeders)	436	30.7 (±2.0)	48.68 (±3.98)	8.45 (±0.54)	57.85 (±8.92)	44.77 (±2.72)
Turkey	1,017	29.5 (±1.0)	66.54 (±6.44)	13.5 (±0.41)	49.74 (±7.42)	41.73 (±5.31)
Turkey (breeders)	107	24.4 (±2.6)	59.18 (±5.60)	11.91 (±1.76)	57.45 (±9.72)	38.02 (±6.12)

Source: Virginia Department of Conservation and Recreation.

Example: Estimating Quantity and Nutrients in Manure

A farm has 50 lactating cows, five dry cows, 45 heifers, 40 goats (1-year-olds), 1,000 broilers, and five horses. Estimate (1) the amount of manure generated per year; (2) the nutrient content (nitrogen, phosphorus, and potassium) in manure excreted by each of the animals; and (3) the total nitrogen, phosphorus, and potassium produced on the farm annually.

The answers to this example can be obtained by using table 1.

1. Estimate the amount of manure generated in a year.For each animal species, estimate by multiplying "volume of manure produced per day" by the number of animals on the farm and the number of days in a year.

Lactating cows:
18 gal/animal-day × 50 animals × 365 days/year = 328,500 gal

Dry cows:
9.72 gal/animal-day × 5 animals × 365 days/year = 17,739 gal

Heifers:
5.83 gal/animal-day × 45 animals × 365 days/year = 95,758 gal

Goats:
0.38 gal/animal-day × 40 animals × 365 days/year = 5,548 gal

Broilers:
0.00265 gal/bird-day ×1,000 birds × 365 days/year = 9,673 gal

Horses:
6.8 gal/animal-day × 5 animals × 365 days/year = 12,410 gal

2. Estimate the amount of nutrients in the manure that are generated in a year.

   For each animal species, estimate each nutrient — nitrogen, phosphorus, and potassium — by multiplying pounds of the nutrient in manure produced per day by the number of animals on the farm and the number of days in a year. The calculations for nitrogen values are presented below. You can estimate phosphorus and potassium using the same method and compare with the answers given in table 4.

Lactating cows:
0.99 lb N/animal-day × 50 animals × 365 days/year = 18,608 lb N

Dry cows:
0.5 lb N/animal-day × 5 animals × 365 days/year = 913 lb N

Heifers:
0.26 lb N/animal-day × 45 animals × 365 days/year = 4,271 lb N

Goats:
0.0412 lb N/animal-day × 40 animals × 365 days/year = 602 lb N

Broilers:
0.0025 lb N/bird-day ×1,000 birds × 365 days/year = 913 lb N

Horses:
0.34 lb N/animal-day × 5 animals × 365 days/year = 621 lb N

3. Estimate the total amount of manure and nutrients in the manure generated in a year.The total amount of manure and nutrients generated on the farm in a year is the sum of all the manure produced by each species, as shown in table 4.

Table 4: Total manure and nutrient production in a year.

Animal	Manure (gal)	N (lb)	P_2O_5 (lb)	K_2O (lb)
Dairy: lactating	328,500	18,608	7,118	5,293
Dairy: dry	17,739	913	274	730
Dairy: heifers	95,758	4,271	1,643	5,417
Goats	5,548	602	134	536
Broilers	9,673	913	621	621
Horses	12,410	621	310	456
Total	469,628	25,385	10,009	10,052

How To Decide Location and Nutrient Application Rates

Conduct a farm risk assessment using a farm map to determine appropriate areas for spreading. Consider slope, distance to water sources, erosion potential of the land where manure might be applied, and soil nutrient tests. Soil testing is the basis of good nutrient management, and soil samples should be taken regularly. Details regarding sampling procedures and laboratory methods are available at *www.soiltest.vt.edu*.

A soil sample should be taken every three to five years. From the soil test data, knowledge of the soil type, and the crop to be grown, nutrient and lime application rates can be determined for optimum crop growth. A three-year sampling interval is recommended for row crops and hay systems where nutrients are removed in harvested crops; a five-year sampling interval is acceptable for forage systems where grazing animals return nutrients to the soil through their manure. Soil pH must be kept within a specific range for each crop, and your soil test report will include the lime requirement (if any) along with nutrient recommendations. Lime supplies calcium, but the main benefit is to increase the pH of the predominantly acidic soils we have in Virginia.

Source of Nutrients

Once your soil test tells you the quantity of nutrients required in each field, the next step is to decide what source of nutrients to use. If you have manure on the farm, it is normally cheapest to use this before purchasing any commercial fertilizer. The problem with manure is that its ratio of nitrogen to phosphorus is low compared to crop requirements, so applying manure to meet crop nitrogen needs overapplies phosphorus (unless soil test phosphorus is low) and applying to meet crop phosphorus needs underapplies nitrogen. The solution to this is either (1) apply manure according to crop phosphorus needs or supplement with commercial nitrogen fertilizer; or (2) apply according to crop nitrogen needs once every three years, track soil test phosphorus, and use no phosphorus fertilizer or manure in the intervening two years.

Once you have decided where to use your manure, the remaining nutrient needs can be made up through commercial fertilizers. There are various fertilizers available that can be mixed to provide the correct quantities of the primary nitrogen, phosphorus, potassium, and other secondary and micronutrients. Common commercial fertilizers and how to calculate application rates are covered in *Fertilizer Types and Calculating Application Rates*, VCE publication 424-035 (*https://pubs.ext.vt.edu/content/dam/pubs_ext_vt_edu/424/424-035/424-035_pdf.pdf*).

Summary

Step 1: Estimate the total nutrients on your farm. Use manure analysis data for your farm if available. Otherwise, use local book values or general book values provided by professional organizations whose work involves manure.

Step 2: Test soils in the fields where manure is to be applied. This test will tell you the amount of nutrients needed for the planned crops for that field.

Step 3: Determine how much of the nutrients required by the crops in step No. 2 will come from manure. Plan use of manure based on the nutrient (phosphorus or nitrogen) that limits manure application.

Step 4: Determine how much supplemental commercial fertilizer is needed to meet crop nutrient needs for optimum production.

When and How to Apply

Lime takes time to react in the soil, so it should be applied several months in advance of planting or at the start of the growing season for perennials, if possible. Nutrients — especially nitrogen, which is very mobile in soil — should be applied as close to planting as possible or at the start of the growing season for perennials. This will maximize nutrient use by the crop and minimize unwanted losses through runoff and leaching that can be economically and environmentally damaging.

When deciding how to apply the nutrients, there are several factors to take into consideration, including manure and equipment availability and cropping system. Losses of nutrients in runoff are generally less if they can be placed under the soil surface, either through injection or incorporation. However, special equipment is needed for injection, while incorporation through tillage conflicts with forage and no-till systems and can increase soil erosion. Therefore, surface applications of manure or fertilizer are most common.

Record Keeping

Keeping good nutrient management plan records is critical for demonstration of good environmental stew-

ardship. Records should include the necessary items to help with proper development/improvement and implementation of the nutrient management plan. The records may be kept in various ways, ranging from a simple handwritten logbook to a detailed, computer-based spreadsheet. Records should document the quantity and location of nutrients on the farm.

The basic components of a record book consist of:
- Number and type of animals.
- Manure generated and inventory.
- Manure applied to land or used on the farm.
- Any manure (excess or otherwise) moved off the farm through sales or given away.
- Any other change that affects quantity of manure produced on the property that is not listed above.

Records should be maintained for a period of five years for other beneficial uses, which include making important business decisions that affect farm income; improving efficiency of production by evaluating the yields, soil tests, manure nutrients, and usage as a fertilizer; and using other commercial fertilizers. Although not a desirable situation, records provide the potential to reduce liability for producers should they be accused of environmental mismanagement. The records will help document responsibility and show the practices in place on the farm to manage nutrients.

Manure Records

Where animals are housed or confined, manure accumulation will occur, making manure collection and storage necessary. It is important to know the quantity and nutrient content of the manure to plan for its use. It is a good practice to collect and send manure samples for analysis.

Manure records should include:
- Sampling date.
- Sampling protocol.
- Name of the person who took the samples.
- Name of the analytical laboratory.
- Analytical results.

If manure is to be moved off the property, the records to keep include:
- Amount (volume or weight) of manure produced or handled.
- Date of manure transfer.
- Volume or weight of manure transferred.
- Name and address of person to whom manure is given or sold.

Storage

The two critical issues or questions one should consider about storage structures are their capacity and maintenance. Manure storage structures should have enough capacity to allow for the environmentally safe utilization of the manure and wastewater generated by an operation. “Environmentally safe utilization” means that manure and wastewater are not land-applied at times or under conditions that increase the likelihood of nutrients to enter surface water.

These conditions or periods include:
- High precipitation.
- Frozen or snow-covered ground.
- Saturated soil (with water and nutrients).
- Floods.
- Near the end of or after the growing season, when crops cannot take up applied nutrients.

Adequate capacity will provide the operator with the flexibility to make changes to the NMP, especially if manure storage for a longer time is required. Details on how to site, size, and maintain a storage structure can be found in *Selection and Location of Poultry and Livestock Manure Storage*, VCE publication 442-307*(https://pubs.ext.vt.edu/content/dam/pubs_ext_vt_edu/442/442-307/442-307_pdf.pdf)*; and *Poultry and Livestock Manure Storage: Management and Safety*, VCE publication 442-308 (http://pubs.ext.vt.edu/content/dam/pubs_ext_vt_edu/442/442-308/442-308_pdf.pdf).

Specific records to keep for manure storage are:
- Animal numbers (monthly or weekly).
- Storage capacity.
- Storage volumes or levels recorded weekly.
- Any changes to the storage structure.
- Dates and quantities of any discharges from storage and corrective measures taken to manage the discharges.
- Notes on weekly or regular inspections of the storage structure’s integrity, including the liquid depth marker.
- Other information.

Land Application

Records concerning land application activities that the farmer is to maintain should be specified in the plan. Land application records are critical because they enable farmers to demonstrate that they are applying manure and wastewater in accordance with a site-specific NMP. Land application records will demonstrate that the manure and wastewater are being applied in

accordance with the requirements of the NMP.

Specific records for land application include:
- Location and description of land where manure is applied.
- Area of land where manure is applied.
- Date the manure is applied.
- Volume or weight of manure applied.
- Application rates of manure nutrients and fertilizer by field and year.
- Manure incorporation methods.
- Weather conditions at the time of application and 24 hours before and after application.
- Explanation of the basis for determining manure application rates.
- Calculations showing the total nitrogen and phosphorus to be applied to each field, including sources other than manure, litter, or process water.
- Total amount of nitrogen and phosphorus actually applied to each field, including documentation of calculations for the total amount applied.
- Methods used to apply the manure, litter, or process water.
- Dates of manure application equipment inspection.
- Expected crop yields.
- Soil test results.
- Conservation practices to reduce nutrient losses.

Other Records

- Mortality management.
- Manure and wastewater analysis.
- Soil tests.
- Crop yields.
- Equipment inspections and calibrations.
- Handling, use, and management of chemicals on the farm.

Resources

ASABE. 2005. *Manure Production and Characteristics*. Standard ASABE D384.2. American Society of Agricultural and Biological Engineers. St. Joseph, Mich.: ASABE.

Barker, J. C., J. P. Zublena, and F. R. Walls. 2001. *Animal and Poultry Manure Production and Characterization*. Raleigh: North Carolina State University Cooperative Extension.

Maguire, R. O., S. C. Hodges, and D. A. Crouse. 2009. Residual materials and manures: Sampling techniques for nutrient analysis of animal manures. In *Methods for Phosphorus Analysis for Soils, Sediments, Residuals and Waters*, 2nd ed. Edited by J. L. Kovar and G. M. Pierzynski, 72-75. Southern Cooperative Series Bulletin No. 408. Southern Extension/Research Activity-Information Exchange Group 17.

MWPS, 1993. Livestock Waste Management, 3rd ed. Midwest Plan Service. Ames, Iowa. *https://www-mwps.sws.iastate.edu/*

Natural Resources Conservation Service. 2014 *Nutrient Management*. Conservation Practice Code 590. *https://efotg.sc.egov.usda.gov/references/public/va/VA_590.*

U.S. Department of Agriculture, Economic Research Service. The Economics of Food, Farming, Natural Resources, and Rural America. *www.ers.usda.gov* (accessed March 2010).

U.S. Environmental Protection Agency. Ag 101. Crop Production: Nutrient Management. *www.epa.gov/oecaagct/ag101/cropnutrientmgt.html* (accessed November 2018).

Virginia Cooperative Extension. *Fertilizer Types and Calculating Application Rates*. VCE publication 424-035. *https://pubs.ext.vt.edu/content/dam/pubs_ext_vt_edu/424/424-035/424-035_pdf.pdf*.

Manure Management and Environmental Stewardship. VCE publication 442-309. *http://pubs.ext.vt.edu/content/dam/pubs_ext_vt_edu/442/442-309/442-309_pdf.pdf*

Poultry and Livestock Manure Storage: Management and Safety. VCE publication 442-308. *http://pubs.ext.vt.edu/content/dam/pubs_ext_vt_edu/442/442-308/442-308_pdf.pdf*

Selection and Location of Poultry and Livestock Manure Storage. VCE publication 442-307. *https://pubs.ext.vt.edu/content/dam/pubs_ext_vt_edu/442/442-307/442-307_pdf.pdf*

Soil Test Note No. 5: Fertilizing with Manures. VCE publication 452-705. *https://pubs.ext.vt.edu/content/dam/pubs_ext_vt_edu/452/452-705/452-705_pdf.pdf.*

Acknowledgements

The authors would like to express appreciation for the review and comments made by Michael Westendorf, associate Extension specialist, animal sciences, Rutgers University; Brian Jones, Extension agent, agriculture and natural resources, crop and soil sciences, Virginia Cooperative Extension Augusta County Office; and Charles Stallings, Extension specialist, dairy science, Virginia Tech.