Soil Testing for Manure Management

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Introduction

Many livestock operations in Arkansas use nutrient-rich animal waste as fertilizer on pastures. Soil testing is a useful tool for determining the kinds and rates of nutrients and/or animal wastes required to maximize and sustain profitable forage production. The soil test phosphorus (STP) concentration of pasture soils has become a serious issue for livestock producers who use animal manure as fertilizer. To determine the STP of soil, Arkansas residents can submit soil samples for free analysis through the local county Extension office.

Proper soil sampling is critical to ensure that soil test results accurately characterize the soil chemical properties that influence nutrient availability to plants. Step-by-step recommendations for soil sampling pastures amended with animal manures are listed in Table 1. Soil test results may be influenced by the time of year, soil depth and field locations (spatial variability of soils within any given field) where soil samples are collected. The objectives of this publication are to help clients take samples in a manner that reduces variability due to sampling method to help ensure that the collected soil samples are representative of the field(s) from which they are taken.

Soil Test Recommendations

Soil tests use a mixture of chemicals to extract some proportion of nutrients from the soil that are deemed “plant-available nutrients.” Routine soil test methods (extractants) provide no information on the soil’s total nutrient content. Although soil test results are often reported with units of pounds nutrient/acre,

Table 1. Recommendations for Collecting Soil Samples From Soils Used for Pasture and Forage for Hay Production

1. Identify representative sampling areas/zones that are uniform in soil and previous management history. Each sample area should represent < 20 acres. Avoid livestock loafing and feeding areas.

2. If a representative area has been determined, proceed to Step 3. If a representative area has not been determined, refer to the section entitled “Defining Multiple Sampling Areas Within a Pasture.”

3. Using a clean soil probe, collect 25 to 35 individual subsamples to a 4-inch depth per sample area or composite sample in a random zigzag pattern.

4. Combine individual subsamples in a clean plastic bucket and mix thoroughly. Place a subsample of the mixed composite in a clean soil box and label with the field name and grower information.

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this value should not be considered as the total amount of plant-available nutrients. Soil nutrient concentrations should be considered only as an index of relative nutrient availability. Different extractants vary in their ability to remove nutrients and often produce different soil test nutrient concentrations and fertilizer recommendations for the same soil because the index of nutrient availability scale differs. For this reason, soil test nutrient concentrations from different labs should not be compared unless the same extraction method and identical analytical procedures are used.

Extractants do not perfectly mimic the plant's ability to remove nutrients from the soil. To overcome this, soil test results must be correlated to crop growth and/or yield through field research for the soil test information to be meaningful. Fertilizer recommendations are subsequently developed based on crop response. Check with your county agent regarding questions about recommendations.

The University of Arkansas Soil Test Lab uses the Mehlich-3 extractant and uses a quality assurance program to ensure that errors due to laboratory analysis are minimized. A check soil sample (sample with known nutrient concentrations) is analyzed every 12 samples to help detect and correct laboratory errors.

Soil Testing for Manure Management

Testing soil for nutrients is an integral part of nutrient management planning for the use of animal manure as fertilizer. Nutrient management planning has been adopted as a requirement in virtually all the state and federal environmental laws related to confined livestock operations in Arkansas. These include the following:

- Arkansas State Regulation 5 – This law, enacted in 1994, requires all livestock and poultry operations with liquid manure handling systems to obtain a nutrient management plan as partial requirement of receiving a permit for operation. The Arkansas Department of Environmental Quality (ADEQ) has the responsibility of overseeing this law.
- The Federal Animal Feeding Operation (AFO/CAFO) Regulation – This Environmental Protection Agency regulation requires all states to permit confined animal feeding operations of a given size (Table 2). This regulation has been incorporated into State Regulation 6 and is overseen by the ADEQ. Regulation 6 mandates that permitted CAFOs must implement a nutrient management plan that meets EPA specifications, which are very similar to NRCS's definition of Comprehensive Nutrient Management Plan.
- Arkansas Acts 1059 and 1061 identify nutrient-sensitive areas in the state, designate them as Nutrient Surplus Areas and require all nutrient applications (whether manure or commercial fertilizer or agricultural or residential) to be done according to a nutrient management plan or an approved protective use rate. These new laws will be carried forth by the Arkansas Soil and Water Conservation Commission (ASWCC).

Table 2. Animal Requirements Necessary for Confined Livestock Operations to Be Considered a Concentrated Animal Feeding Operation (CAFO). A CAFO is required to obtain a permit from the Arkansas Department of Environmental Quality (ADEQ) to legally operate.

Animal	Number Requirements*
Chickens other than laying hens (operations with other than a liquid manure handling system)	At least 125,000 chickens other than laying hens and **does not** use a liquid manure handling system
Chickens operating with a liquid manure handling system	At least 30,000 chickens and uses a liquid manure handling system
Cattle (other than mature dairy cows) grown in confinement	At least 1,000 cattle, dairy, heifers, cow/calf pairs, or veal calves
Swine (55 pounds or more)	At least 2,500 swine weighing 55 pounds or more
Swine (55 pounds or less)	At least 10,000 swine weighing 55 pounds or less
Horses	At least 500 horses
Sheep or lambs	At least 10,000 sheep or lambs
Turkeys	At least 55,000 turkeys
Laying hens (operations with other than a liquid manure handling system)	At least 82,000 laying hens and **does not** use a liquid manure handling system

*Confinement must be for 45 days (non-consecutive) for any 12-month period.

Soil Testing and Environmental Quality

Soil test phosphorus can be one of several factors associated with phosphorus movement from fields treated with animal manure. Phosphorus is generally considered the nutrient most limiting eutrophication in most fresh, clear-water streams and lakes. A very small increase in phosphorus concentration can result in excessive algae growth in water bodies.

Historically, recommended animal waste application rates have been based on the nitrogen content of the waste because nitrogen is generally the nutrient that most limits plant growth and is required in the greatest amount. The phosphorus (P_2O_5) and nitrogen content of many animal wastes are nearly equal. Unfortunately, the application of enough animal manure to meet crop nitrogen needs may result in applying more phosphorus than the crop needs. Repeated, long-term animal waste applications based on nitrogen can lead to elevated STP levels.

Some states have proposed basing animal waste application rates on phosphorus rather than nitrogen. The general concept used in these states is to apply animal waste at rates that do not exceed crop requirements for phosphorus as determined by soil test recommendations. Phosphorus-based application rates imply 1) that crop nitrogen requirements will not be met by animal manure applications and supplemental nitrogen fertilizers will be needed to maintain forage production and 2) more land will be needed to use the same amount of waste as compared to nitrogen-based rates.

In Arkansas, manure application rates based on phosphorus are determined by using vulnerability assessments known as the "P-Index." In this approach, many factors associated with phosphorus movement, including STP, are used to determine a manure application rate that does not pose an unacceptable risk of phosphorus leaving the field. A considerable amount of research is being conducted nationally to further develop the concept of phosphorus indexing.

Soil test phosphorus is a key consideration for any of these proposed strategies. Collecting representative soil samples to ensure accurate results is critical in light of these proposed environmental protection strategies.

Recommendations for Collecting Soil Samples

The first step in soil testing is to collect a representative sample from a defined sampling area. **Sampling procedures can influence the accuracy of results more than any other step of soil testing.** The objective is to obtain a small sample of soil that accurately describes the entire area that it represents. This can be difficult since soil nutrient concentrations can vary across time, space and soil depth. Variability in soil nutrient concentrations occurs naturally but can be increased by agricultural practices such as grazing, fertilizing, liming and land application of animal wastes.

To obtain an accurate sample, follow the recommendations in Table 1. The logic behind these recommendations is explained in the following sections.

Soil Test Phosphorus, lbs/A

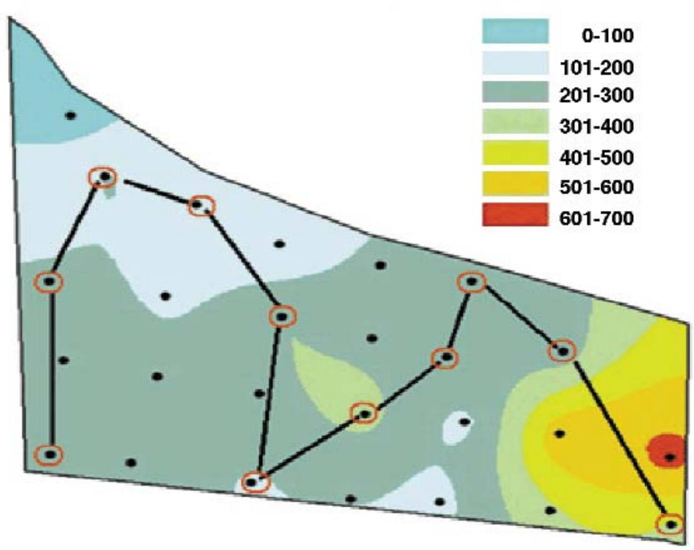

Figure 1. Soil phosphorus map for a 6-acre pasture developed from 26 separate samples taken at grid points (●). Black line indicates zigzag pattern where grid points encircled in red were composited into one sample to represent the entire field.

Defining a Sampling Area

To reduce variability, a sampling zone or area should be chosen that is relatively uniform in soil and management properties. Fenced areas, hillsides (i.e., land differing in slope), creek bottoms or other well-defined features should be sampled separately for accurate and representative soil sampling.

Individual pastures should be further subdivided if more than one soil type (i.e., series, texture or both) exists or the pasture has been managed differently on greater than 25 percent of the area. Differences in soil types can be detected by either using the NRCS county soil survey report or by delineating observed differences in soil properties such as color, texture, slope or plant growth.

If differences in management or soil properties are known or suspected to exist, then refer to the section below entitled "Defining Multiple Sampling Areas Within a Pasture" for instructions on how to further subdivide the area.

Sampling Pattern

The zigzag sampling pattern (Figure 1) generally provides the most representative composite soil sample with the fewest individual subsamples (soil cores). For example, the average STP of all individual samples in Figure 1 is 265 lbs/A compared to 257 lbs/A for selected samples representing a zigzag pattern.

Other zigzag patterns may produce different results, but generally these differences are not large enough to affect the resulting recommendation. However, any sampling pattern can include individual locations with high or low soil test values. These can bias a sample, particularly if only a few locations are sampled.

Adjusting for Extreme High or Low Values

Individual samples from each grid location in Figure 1 were analyzed separately so that the spatial distribution of STP concentrations across the pasture could be shown on a map. Soil test results reflect how the pasture has been managed over years of use. The area containing STP values > 500 lbs/A, next to the eastern boundary, was an area where cattle had been fed for many years because it was the only dry location during most winters. The area with < 100 lbs STP/A, in the extreme northwest corner, was usually too wet for the litter spreader truck and had not received as much phosphorus as other parts of the field.

Both of these areas represent less than 5 percent of the field. However, because their STP results represent extreme high or low values as compared to the rest of the pasture, subsamples collected from these areas can influence the STP value that represents the entire sampling area. Therefore, separate soil samples should be collected from these areas, even though they represent a small area of the entire field.

For example, including subsamples from locations within the area > 500 lbs/A result in a mean field value of 306 lbs STP/A, while the same zigzag pattern that excludes these values results in a mean field value of 244 lbs STP/A. Although this difference is relatively small, inclusion of the high areas resulted in a STP value that exceeds a potential STP threshold of 300 lbs/A.

Exclude known livestock feeding or loafing areas near gates from the zigzag pattern if this area represents less than 10 percent of the total sampling area. When areas like this are sampled accidentally in a zigzag pattern, they can bias the results towards the extreme value.

Closely following soil sample collection guidelines regarding the number of subsamples (i.e., cores) reduces the influence of any one sample location with high or low soil test nutrient values. As the number of individual subsamples decreases, the influence of an extremely high or low soil nutrient concentration for any single soil core increases and will bias the STP result if included in the sampling pattern. The influence that a single soil core with extremely high or low nutrient concentrations has on the final soil nutrient concentrations becomes greater as the number of soil subsamples decreases. Most research shows that a composite soil sample should be comprised of a minimum of 25 to 35 soil cores. The number of soil subsamples should increase as the spatial variability of the sampled field area increases. From each sampling area, individual soil cores should be placed in a clean plastic bucket. Once all subsamples have been taken, the soil cores should be mixed thoroughly and then a subsample should be placed in the soil box for analysis. Galvanized buckets or other containers that may be contaminated with nutrients from animal feeds, manures or fertilizers should be avoided. Also, avoid taking soil samples when soils are too moist. High soil moisture content prevents adequate mixing of soil subsamples.

Defining Multiple Sampling Areas Within a Pasture

Although a zigzag pattern generally produces a representative sample, it does not identify differences in soil test results within a sampling area. If you suspect that an area of pasture has higher or lower STP values compared to the remainder of the pasture, it may be best to sample it separately. Use of grid soil sampling, where separate samples from each grid point are collected and tested separately (Figure 1), is appropriate to identify uniformity of soil nutrient concentrations within a sampling area. It is

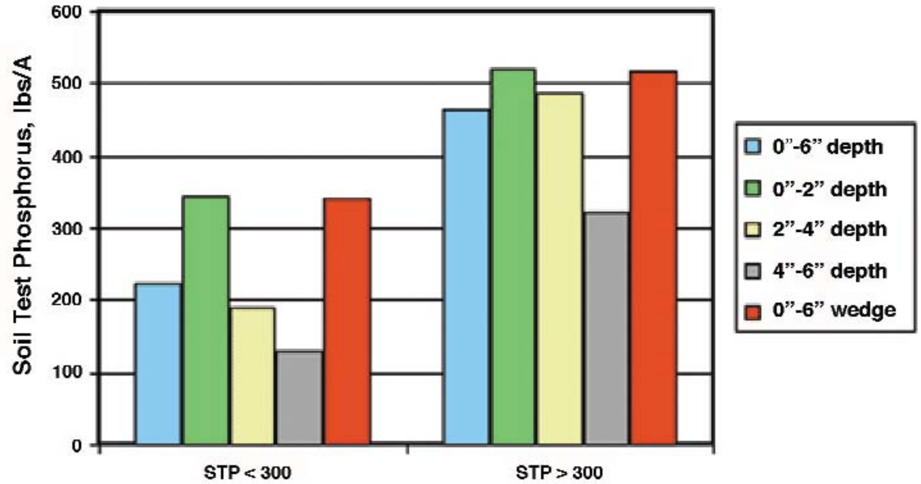

Figure 2. Distribution of soil phosphorus with depth as compared to a 6-inch sample collected with a cylindrical soil sampler and a 6-inch sample collected in a wedge shape with a shovel. STP < 300 represents the average of samples whose 6-inch sample (collected with cylindrical soil sampler) was less than 300 pounds per acre soil test phosphorus. STP > 300 represents the average of samples whose 6-inch sample was greater than 300 pounds per acre soil test phosphorous.

necessary to do grid sampling only once to show obvious differences that help subdivide the field into more uniform sampling areas. Apply the zigzag pattern separately to each newly defined sampling area.

Sample Depth and Size

The depth of sampling can significantly affect soil test results. Nutrients are generally stratified in soils that are not tilled annually and have low to medium soil nutrient levels, with the highest soil nutrients occurring near the soil surface and decreasing with soil depth (Figure 2). The University of Arkansas now bases its pasture and forage production fertilizer and lime recommendations on soil samples collected from the 0- to 4-inch soil depth. The 4-inch soil depth represents a large portion of the active root zone for forages and most accurately depicts surface soil pH on soils that are seldom tilled. This depth refers to the mineral portion of the soil. Remove all surface debris, such as thatch and other plant material, from the soil surface before inserting the soil probe to collect the sample. Surface soil samples should be collected once every two to four years to monitor soil nutrients for accumulation or depletion, unless specified by nutrient management plans or crop production recommendations.

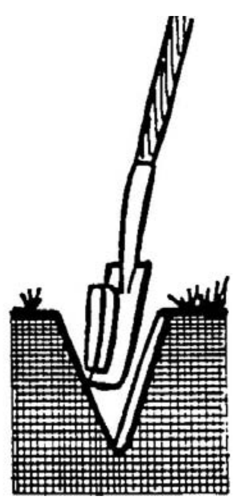

Figure 3. Illustration of wedge-shaped soil sample volume created with a shovel.

Occasionally, once every six to eight years for established forages or when pastures will be renovated, soil samples should also be collected from the 0- to 4-inch plus the 4- to 8- or 10-inch depth to monitor subsoil pH and nutrient concentrations.

The previous recommendation for soil sample depth (0- to 6-inch depth) was changed for a number of reasons including monitoring of soil pH and ease of sampling in rocky soils. For some soils, the STP may be slightly greater in a soil sample taken from the 0- to 4-inch depth compared with the 0- to 6-inch depth. Research has shown that when STP is relatively high, soil sample depth will have little influence on STP. Phosphorus applied to the soil surface tends to be adsorbed by soil particles at the surface. However, when the adsorption sites become saturated with phosphorus, the phosphorus will move deeper into the soil profile until unoccupied adsorption sites are encountered. It should be noted that phosphorus adsorption capacities vary with different soil textures. For example, sandy-textured soils adsorb much less phosphorus than clayey soils.

The tool used to collect a soil sample can also affect soil test results if a uniform volume of soil is not collected. A cylindrical soil sampling tube collects a uniform volume of soil with depth and helps control the depth of sampling. The use of a shovel can create a wedge-shaped sample (Figure 3) that can bias the soil test results. In soils with stratified P levels, wedge-shaped samples taken with a shovel had P levels closer to the 2-inch sample than the full 6-inch sample (Figure 2). Soil sample probes can be purchased from a number of different suppliers for a reasonable price. Although a number of common tools can be used to collect soil samples, soil probes made of stainless steel (to minimize contamination) are highly recommended. Auger-type soil samplers may facilitate collection of more uniform soil samples in rocky soils.

Sample Time

The time of year that a sample is taken affects the mobile nutrients (nitrate and sulfate) more than the less mobile nutrients (P and K). To reduce seasonal differences, samples should be taken from the same sampling area during the same time of year, especially if the samples will be used to monitor soil nutrient concentrations across a number of years.

The best time of year to soil sample also depends on the forage species/growth habit (cool- or warm-season forage) and time of nutrient applications. For cool-season forages, soil samples should be taken in late spring or early summer. For warm-season forages and legume mixtures, soil samples should be taken in late fall or winter. These sample times correspond to the forage's dormant period and allow for timely collection of samples and laboratory analysis as well as planning of nutrient management strategies that maximize forage production.

Other factors related to time of year such as weather and rainfall can affect how easy it is to collect samples, as well as soil nutrient concentrations. In rainy periods, soils can be waterlogged and difficult to sample. During summer months, soils can be difficult to sample due to dry conditions. Soil pH values are also affected by time of year and environmental conditions near the time of sampling.

Summary

Following proper soil sampling procedures will increase the reliability of the laboratory's results and, in turn, increase the value of the resulting recommendations. Sampling procedures are important for sound agronomic and environmentally sustainable nutrient management strategies. For more information, contact your local county Extension office. Refer to fact sheets FSA1029, *Soil Phosphorus Levels: Concerns and Recommendations,* and FSA2144, *Managing Soil Phosphorus Levels in Pasture Soils,* for more information about soil phosphorus management and water quality.

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This publication was completed as part of an EPA 319(h) project. For the entire project, 56 percent was provided by the Environmental Protection Agency. The University of Arkansas Cooperative Extension Service provided 44 percent. The Arkansas Soil and Water Conservation Commission administered the federal funds.

The authors would like to express thanks to John Langston, former Extension agricultural engineer, and Dr. Stan Chapman, former Extension soils specialist, for their contributions to this publication.

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FSA1035-2.5M-9-05RV