Natural Resources Conservation Service

CONSERVATION PRACTICE STANDARD

NUTRIENT MANAGEMENT

CODE 590

(ac)

DEFINITION

Managing the amount (rate), source, placement (method of application), and timing of plant nutrients and soil amendments.

PURPOSE

This practice is used to accomplish one or more of the following purposes–

- To budget, supply, and conserve nutrients for plant production
- To minimize agricultural nonpoint source pollution of surface and groundwater resources
- To properly utilize manure or organic by-products as a plant nutrient source
- To protect air quality by reducing odors, nitrogen emissions (ammonia, oxides of nitrogen), and the formation of atmospheric particulates
- To maintain or improve the physical, chemical, and biological condition of soil

CONDITIONS WHERE PRACTICE APPLIES

This practice applies to all lands where plant nutrients and soil amendments are applied. This standard does not apply to one-time nutrient applications to establish perennial cover.

CRITERIA

General Criteria Applicable to All Purposes

Use of this standard requires compliance with all applicable federal, state, and local laws and regulations.

The overriding objective of nutrient management is to ensure that, as practical as possible, nutrients are applied with the right placement, in the right amount, at the right time, and from the right source to optimize profitability and to minimize nutrient losses to our air and water resources.

A nutrient budget for nitrogen (N), phosphorus (P), and potassium (K) will be developed that considers all potential sources of nutrients including, but not limited to:

- Plant available soil nutrients,
- legume credits and green manures,
- commercial fertilizer,
- animal manure,
- waste water,
- irrigation water,
- biosolids,

- other nutrient containing materials (e.g. compost, organic by-products, etc.).

Land where nutrients are applied will be evaluated for site sensitivity or potential vulnerability including, but not limited to:

- proximity to perennial water bodies,
- proximity to surface inlets,
- areas of concentrated flow,
- shallow depths to ground water,
- working or abandoned wells,
- Karst terrain,
- recharge areas for sole source aquifers,
- Public Water Supply System Wellhead Protection Area,
- Surface Water Drinking Reservoir Watershed,
- and, other conditions that make the land prone to flooding, leaching, or runoff, including frozen, snow/ice-covered, and/or saturated soils.

Soil pH will be maintained in a range that is adequate for crop nutrient availability and utilization based on Purdue University (Purdue) fertilizer recommendations.

All manure applications will be consistent with minimum application setbacks. Refer to *Table* 1 – *Manure Application Setback Distances*. To decrease a manure application setback from Table 1, a properly designed and maintained buffer of at least 50 feet, or the design criteria to address water quality as appropriate, whichever is greater, must be established according to the IN NRCS eFOTG Standard (393) Filter Strip or (390) Riparian Herbaceous Cover when the site meets the conditions of these standards; otherwise (327) Conservation Cover will be used. Manure must not be applied to the buffer.

To avoid salt damage, the rate and placement of applied N and K in starter fertilizer must be consistent with Purdue guidelines, or industry practice recognized by Purdue.

Applications of irrigation water must minimize the risk of nutrient loss to surface and groundwater based on the water holding capacity of the soil. Refer to IN NRCS (449) Irrigation Water Management.

On organic operations, nutrient sources and management must be consistent with the USDA's National Organic Program.

Soil, Manure, and/or Tissue Sampling and Laboratory Analyses (Testing)
Nutrient planning must be based on current soil, manure, and (where used as supplemental information) tissue test results developed in accordance with the most current Purdue and/or other land grant university guidance or industry practice, if recognized by Purdue.

Current soil tests are those that are no older than 4 years. The maximum area represented by a soil test must not be greater than 20 acres. Collect a minimum of 12 cores per composite sample.

Soil tests must include, at a minimum, pH, buffer pH, organic matter, phosphorus (Bray P_1 or Mehlich 3), potassium (ammonium acetate, pH 7.0 or Mehlich 3), cation exchange capacity (CEC) by summation of basic cations (NCR, 1998).

Soil test analyses will be performed by laboratories successfully meeting the requirements and performance standards of the North American Proficiency Testing Program under the auspices of the Soil Science Society of America (SSSA) or the Agricultural Laboratory Proficiency Program (ALP).

Nutrient values of manure, organic by-products and biosolids will be determined prior to land application. The nutrient value used can be a rolling average from 3 or more years of analysis from the same nutrient source.

Manure analyses will include, at a minimum, total N, ammonium N (NH_4-N), total P or P_2O_5, total K or K_2O, and percent moisture or percent solids.

Manure, biosolids and other organic by-products samples will be collected and analyzed at least annually, if a three (3) year rolling average isn't used. For manure, more frequent sampling will be needed if changes in manure nutrient content are expected due to uncovered outdoor storages or operational changes including feed management, animal type, manure handling strategy, etc.

Samples will be collected, prepared, stored and shipped following Purdue guidance or industry practice, if recognized by Purdue.

When planning for new or modified livestock operations, acceptable "book values" recognized by the NRCS (e.g., NRCS Agricultural Waste Management Field Handbook, Chapter 4) or analyses from similar operations in the geographical area will be used if they accurately estimate nutrient output from the proposed operation.

Manure testing analyses will be performed by laboratories successfully meeting the requirements and performance standards of the Manure Analysis Proficiency program (MAP) under the auspices of the Minnesota Department of Agriculture.

Table 1 – Manure Application Setback Distances (in feet)

Known Feature	Liquid - Injection or Single Pass Incorporation (liquid/solid)	Liquid – Incorporation*; Surface Application (solid or compost); or Surface Application to Pasture	Liquid - Surface Application	
			≤ 6% Slope; or Residue Cover	> 6% Slope
Public Water Supply Wells & Surface Intake Structures	500	500	500	500
Surface Waters of the State	25 [1,2)]	50 [1,2)]	100 [1,2)]	200 [1,2)]
Sinkholes	25 [1,2)]	50 [1,2)]	100 [1,2)]	200 [1,2)]
Wells	50 [1,2)]	50 [1,2)]	100 [1,2)]	200 [1,2)]
Drainage Inlets, including Water & Sediment Control Basins	5 [1)]	50 [1,2)]	100 [1,2)]	200 [1,2)]
Property Lines & Public Roads	0	10	50	50

*****Liquid incorporation of manure in Table 1 means only manure that has been incorporated into the soil within twenty-four (24) hours of placement on the land.

All setback distances will be measured from the edge of the area of actual placement of manure on the land.

[1)] If a properly designed and maintained buffer is located between the application site and: surface waters of the state; any known well; the surficial opening or lowest point on any sinkhole; or any drainage inlet, including water and sediment control basins; then the setback is the width of the buffer. The minimum width of the buffer will be 50 feet or wider (see FOTG 393, 390, or 327).

Known Feature	Liquid - Injection or Single Pass Incorporation (liquid/solid)	Liquid – Incorporation*; Surface Application (solid or compost); or Surface Application to Pasture	Liquid - Surface Application	
			≤ 6% Slope; or Residue Cover	> 6% Slope
[2)] The setback is ten (10) feet if a gradient barrier (such as a berm or spoil bank) is located between the application site and: surface waters of the state; any known well; the surficial opening or lowest point on any sinkhole; or any drainage inlet, including water and sediment control basins. Note: The application setbacks for Concentrated Animal Feeding Operations (CAFOs) may be different. CAFO operators are required to use the most restrictive setback distance that applies to the Known Feature and the applicable method of application.				

Nutrient Application Rates
Planned nutrient application rates for commercial fertilizer N, P_2O_5, and K_2O will not exceed Purdue guidelines or industry practice, if recognized by Purdue. Lower than recommended nutrient application rates are permissible if the grower's objectives are met and crop yield goals are not compromised.

All nutrient application rates will follow the guidance within this document ± 10%.

At a minimum, nutrient application rates will be based on crop/cropping sequence, current soil test results and realistic yield goals (where applicable).

When applicable, realistic yield goals will be established based on historical yield data, soil productivity information, climatic conditions, nutrient test results, level of management, and local research results considering comparable production conditions.

For new crops without current Purdue fertilizer recommendations, industry demonstrated yield response and nutrient utilization information will be used until Purdue recommendations are available.

Nutrient and Sediment Transport Risk Assessment
The **Nutrient and Sediment Transport Risk Assessment Tool (NASTRAT)** will be conducted to assess the potential for nutrient and sediment losses from each field or management unit. The NASTRAT can be found in the FOTG Section IV - Water Quantity and Quality Interpretations. All nutrient management plans will include:

- A record of the NASTRAT assessment for each field or management unit for every crop year in the plan, and
- A written statement about how the producer will reduce (e.g. through conservation practices or agronomic management activities) potential offsite nutrient and sediment movement for all of the following conditions for each field or management unit:
  - Soil erosion is above "T" for any crop year, or
  - Surface runoff class is high or very high, or
  - Nitrate leaching index is > 10, or
  - The Bray P_1/Mehlich 3 soil test is > 50 ppm, or
  - Distance from field to water is < 30 feet, or
  - The field has identified or designated nutrient related water quality impairment.

Once these issues have been addressed, the following will be used to guide nutrient application rates to each field or management unit.

Nitrogen Applications

- Commercial fertilizer N application rates will not exceed Purdue fertilizer recommendations or

industry practice, if recognized by Purdue, for the current or planned crop.

- Animal manure N application rates will not exceed Purdue fertilizer recommendations or industry practice, if recognized by Purdue, for the current or planned crop and will account for planned starter N applications. The Estimated Available N (EAN) content of manure will be based on the time and method of application relative to crop N utilization. However, over application of N based on losses due to timing and method of application is not allowed and the maximum allowable manure application rate will be based on the potentially available N (PAN) content of the manure. The PAN is the amount of N that could be realistically taken up by the crop under optimum management and is calculated as the sum total of 90 percent of the ammonium N and a percentage of the organic N that will mineralize in one (1) growing season (refer to the most current PU recommendations).
    - Application rates for legume crops are as follows:
      Soybean – Up to 150 lbs. N/ac/yr.

      Legume Hay – Up to 75 lbs. N/ac/harvest of hay, not-to-exceed 300 lbs. N/ac/yr.

Supplemental N applications for manured fields or management units will be based on the following equation:

Supplemental N = (Fertilizer N recommendation) – (EAN from manure) – (starter fertilizer N)

Alternatively, for corn, the Pre-Sidedress Soil Nitrate Test (PSNT) is allowed to be used to determine supplemental N needs in accordance with Purdue recommendations.

Phosphorus Applications

- Commercial fertilizer, animal manure from livestock farms, biosolid and other P-containing material application rates will not exceed the crop rotation recommended rates based on Purdue fertilizer recommendations or industry practice, if recognized by Purdue, or P removed by the harvested portion of planned crops up to a soil test P (STP) level of 50 ppm. Starter fertilizers (injected) that contain 25 lbs. P_2O_5/ac/yr. are approved at STP levels up to 75 ppm. No other commercial P fertilizer will be applied to soils with a STP level > 50 ppm.
- Application rates for animal manures applied to livestock farms only, will be based on *Table 2 - Organic Nutrient Application Guidelines Based on Soil Test Phosphorus*.

Table 2. Organic Nutrient Application Guidelines Based on Soil Test Phosphorus

Soil Test Phosphorus Level (Bray P_1/Mehlich 3 ppm)	Basis for Nutrient Application
≤50 ppm	**Nitrogen Based**
51 – 100 ppm	**1.5 x Crop P_2O_5 Removal[1)]**
101 – 200 ppm	**Crop P_2O_5 Removal[1)]**
> 200 ppm	**No P Application**

[1)] Found in Table 3

Table 2 Explanation. The nutrient application guidelines in Table 2 are meant to address longer-term P loading to the soil. For example, if STP levels are £ 50 ppm (Bray P_1/Mehlich 3), then the P applications are based on this year's planned or current crop nitrogen needs. If the STP is 51 – 100 ppm and a corn (160 bu./acre) – soybean (40 bu./acre) rotation removes an average of 50 lbs P_2O_5/acre/yr (60 lbs P_2O_5/acre/yr for corn and 40 lbs P_2O_5/acre/yr for soybean), then the long-term P_2O_5 application rate will not exceed 75 lbs/acre/yr (50 x 1.5 = 75). If the STP is 101-200 ppm, and the previous example crop rotation is used, then the long- term P2O5 application rate will not exceed 50 lbs/acre/yr. Using Table 2, there will be no application of P if the Bray P_1/Mehlich 3 soil test is > 200 ppm.

When single year organic nutrient application rates are N-based, the longer-term P-based limits in Table 2 will be met by reducing the frequency of application. A single application of manures, biosolids or other organic nutrient sources may be made at a rate equal to, but not to exceed, the crop N needs for that crop year, as long as the STP is ≤ 200 ppm and all of the following conditions are met.

- The slope is less than two percent (2%), or the application site has at least forty percent (40%) crop residue, or a vegetated crop cover is present on the land application site and;
- surface applications will not be closer than two hundred (200) feet from any surface water or tile riser and;
- applications are not allowed in a flood plain and;
- applications are not allowed to frozen, snow/ice-covered, and/or saturated soils.

Table 3. Approximate Nutrients Removed by Crops (Lbs/Unit) [2)]

Crop	Unit	P_2O_5
Alfalfa (hay)	Ton	13
Grasses - Cool Season (hay)	Ton	17
Corn (Grain)	Bushel	0.37
Corn (Stover)	Bushel	0.19
Corn Silage [1)]	Ton	3.3
Oats (Grain)	Bushel	0.25
Oats (Straw)	Bushel	0.15
Sorghum (Grain)	CWT	0.39
Sorghum (Stover)	CWT	0.66
Soybean	Bushel	0.8
Tobacco (leaf)	CWT	0.83
Tobacco (Stem and Suckers)	CWT	0.75
Wheat (Grain)	Bushel	0.63
Wheat (Straw)	Bushel	0.09

[1)] 6 bushels of grain = 1 ton of silage

[2)] Sources - Tri-State Fertilizer Guide, Ohio Agronomy Guide, National Plant Food Institute and others.

Nutrient Sources

Nutrient sources utilized will be compatible with the cropping and planting system, soil properties, including drainage, and local climate to minimize the risk of nutrient and sediment loss to the environment.

Nutrient Application Timing and Placement
Timing and placement of all nutrients will correspond as closely as practical with plant nutrient uptake and consider nutrient source, cropping and planting system limitations, soil properties, including drainage, and local climate to minimize the risk of nutrient and sediment loss to the environment.

With the exception of topdress applications on winter wheat, no surface applications of manure, biosolids or other organic by-products or P containing commercial fertilizers are allowed:

- on frozen and/or snow/ice-covered soils, or
- when the top 2 inches of soil are saturated from rainfall or snow melt, or
- on a flood plain during months expected to flood (current Web Soil Survey data).

Additional Criteria to Minimize Agricultural Nonpoint Source Pollution of Surface and Groundwater
The following practices to improve nutrient use efficiency and to minimize nutrient losses to surface- and ground-water will be used, as applicable:

- coordinate nutrient applications with optimum crop nutrient uptake,
- incorporate or inject manure and commercial fertilizers,
- optimize the timing and number of nutrient applications,
- reduce nutrient application rates to economic optimum rates rather than agronomic optimum rates,
- utilize nitrification and urease inhibitors,
- utilize the Pre-Sidedress Soil Nitrate Test (PSNT),
- utilize tissue testing, chlorophyll meters, and other optical/spectral analysis technologies,
- utilize the Corn Stalk Nitrate Test (CSNT).

Additional Criteria Applicable to Properly Utilize Manure or Organic By-Products as a Plant Nutrient Source
All liquid manure applications will avoid ponding, runoff and loss to subsurface tile drains. When liquid manures are applied, known subsurface tile drains will be monitored during application and remediation measures to plug tile outlets will be made in advance. In addition, the single application rate of liquid manure will not exceed the lesser of:

- 13,500 gallons per acre or,
- the soil's water holding capacity for the potential crop rooting zone at the time of application.

Additional Criteria to Protect Air Quality by Reducing Odors, Nitrogen Emissions and the Formation of Atmospheric Particulates
To address air quality concerns caused by odor, N, sulfur, and/or particulate emissions; the source, timing, amount, and placement of nutrients will be adjusted to minimize the negative impact of these emissions on the environment and human health. One or more of the following will be used, as applicable:

- injection,
- no-till or strip-till,
- residue and tillage management,
- incorporation,
- nitrification inhibitors,
- urease inhibitors,
- other technologies that minimize the impact of these emissions.

Do not apply poultry litter, manure, or organic by-products of similar dryness/density when there is a high probability that wind will blow the material offsite.

Additional Criteria to Improve or Maintain the Physical, Chemical, and Biological Condition of the Soil to Enhance Soil Quality for Crop Production and Environmental Protection

Use no-till/strip-till in combination with cover crops to sequester nutrients, increase soil organic matter, increase aggregate stability, reduce compaction, improve infiltration, and enhance soil biological activity to improve nutrient use efficiency.

Time the application of nutrients to avoid periods when field activities will result in soil compaction.

Use an adaptive approach to adjust nutrient rate, timing, form, and placement over time as soil biology function and carbon:nitrogen ratio changes over time.

Periodically soil test at various vertical depths and adapt nutrient management to minimize vertical stratification of nutrient buildup and pH.

Ensure STP does not exceed agronomic needs.

To avoid detrimental impacts to soil biota, minimize the use of gaseous ammonia as a nitrogen source and nitrification inhibitors.

In areas where salinity is a concern, select nutrient sources that minimize the buildup of soil salts.

CONSIDERATIONS

Use nutrient management strategies such as cover crops, crop rotations, and crop rotations with perennials to improve nutrient cycling and reduce energy inputs.

Use variable rate for N, P_2O_5 and K_2O applications based on site-specific variability in crop yield, soil characteristics, soil test values, and other soil productivity factors.

Use variable-rate N applications based on chlorophyll meters and other optical/spectral analysis technologies.

Develop site-specific yield maps using a yield monitoring system. Use the data to further diagnose low and high yield areas, or zones, and make the necessary management changes.

Use conservation practices to further limit nutrient losses.

Apply manure at a rate that will result in an “improving” Soil Conditioning Index (SCI) without exceeding acceptable risk of N or P loss.

Use legume crops and cover crops to increase soil available N through biological fixation and improved nutrient recycling.

Modify animal feed diets to reduce the nutrient content of manure following guidance contained in Conservation Practice Standard (CPS) Code 592, Feed Management.

Collect new soil tests when developing new plans.

Avoid excessively high soil test levels as some nutrients can induce deficiencies of other nutrients. For example high STP levels can cause zinc deficiencies.

Use soil tests, plant tissue analyses, and field observations to check for secondary and micronutrient deficiencies or toxicities that may impact plant growth or the availability of other nutrients.

Use the adaptive nutrient management learning process to improve nutrient use efficiency on farms. Strive for a balanced fertility program to avoid nutrient imbalances in crops or forages.

Workers should be protected from and avoid unnecessary contact with plant nutrient sources. Extra caution will be taken when handling anhydrous ammonia or when dealing with organic by-products stored in non-ventilated enclosures.

Material generated from cleaning nutrient application equipment should be utilized in an environmentally safe manner. Excess material should be collected and stored or field applied in an appropriate manner.

Nutrient containers should be recycled in compliance with State and local guidelines or regulations.

Considerations to Minimize Agricultural Nonpoint Source Pollution of Surface and Groundwater

Use conservation practices that slow runoff, reduce erosion, and increase infiltration (e.g., cover crops, no-till). These practices can also reduce the loss of nitrates or soluble P.

Use application methods and timing strategies that reduce the risk of nutrient losses to ground- and surface-waters, such as:

- side-dress or split N applications to improve crop N uptake and use efficiency,
- band-apply N and P to improve nutrient uptake and use efficiency,
- avoid surface applications of manures, biosolids and other organic by-products if precipitation capable of producing runoff or erosion is forecast within the time of planned application,
- utilize drainage water management, blind inlets, denitrifying bioreactors and constructed wetlands to reduce nutrient discharge through drainage systems.

Properly store and handle nutrients to protect air, soil, and water quality.

Conditions to Protect Air Quality by Reducing Nitrogen and/or Particulate Emissions to the Atmosphere

Avoid applying manures, biosolids and other organic by-products upwind of inhabited areas.

Use high-efficiency irrigation technologies (e.g., reduced-pressure drop nozzles for center pivots) to reduce the potential for nutrient losses.

PLANS AND SPECIFICATIONS

The following components will be included in the nutrient management plan:

- aerial site photograph(s)/imagery or site map(s), and a soil survey map of the site,
- soil information including: soil type, surface texture, pH, drainage class, permeability, available water holding capacity, depth to seasonal high water table, depth to restrictive layers, and flooding and/or ponding frequency,
- location of designated sensitive areas and the associated nutrient application setbacks,
- for manure applications, location of nearby residences, or other locations where humans may be present on a regular basis, and any identified meteorological (e.g., prevailing winds at different times of the year), or topographical influences that may affect the transport of odors to those locations,
- results of the NASTRAT for each field or management unit for each cropping period,
- documentation of how the producer will reduce (e.g. through conservation practices or agronomic management activities) potential offsite nutrient and sediment movement for all applicable NASTRAT components.
- current and/or planned plant production sequence or crop rotation,
- analytical results of nutrient tests for soils, manures, biosolids and other organic by-products, and water and plant tissue sample analyses applicable to the plan,
- realistic yield goals for the crops,

- complete nutrient budget for N, P_2O_5 and K_2O for 4 years or the crop production sequence or rotation, whichever is greater,
- listing and quantification of all nutrient sources and forms,
- planned nutrient application source, timing, amount and placement of plant nutrients for each field or management unit, and
- plan for implementation, operation and maintenance, and recordkeeping.

In addition, the following components will be included in a precision/variable rate nutrient management plan:

- documentation of the geo-referenced soil sampling locations and soil test report data where collected that were processed and analyzed as a GIS layer or layers to generate nutrient or soil amendment recommendations.
- documentation of the nutrient recommendation guidance and recommendation equations used to convert the GIS base data layer or layers to a nutrient source material recommendation GIS layer or layers.
- documentation if a variable rate nutrient or soil amendment application was made.
- records per management zone or an as applied map within individual field boundaries that document the source, timing, method and rate of all applications that resulted from use of the precision agriculture process for nutrient or soil amendment applications. These records must be maintained for five (5) years.

If increases in STP levels are expected (i.e., when N-based rates are used), the nutrient management plan will document:

- the STP levels at which it is desirable to convert to phosphorus based planning, and
- management activities or techniques used to reduce the potential for nutrient transport and loss.

OPERATION AND MAINTENANCE

Conduct periodic plan reviews to determine if adjustments or modifications to the plan are needed. At a minimum, plans will be reviewed and revised, as needed with each soil test cycle, or earlier due to major change in manure volume or analysis, crops, or crop management.

Fields receiving biosolids will be monitored for the accumulation of heavy metals in accordance with IDEM 503 Rule.

Calibrate application equipment to ensure accurate distribution of material at planned rates.

Document the nutrient application rate. When the applied rate differs from the planned rate, provide appropriate documentation for the change.

Records will be maintained for at least 5 years to document plan implementation and maintenance. As applicable, records include:

- analytical results for soils, manures, biosolids, other organic by-products, plant tissues and water used to generate nutrient recommendations,
- quantities, analyses and sources of all nutrients applied,
- sources, dates, rates and methods of all nutrient applications,
- weather conditions and soil moisture at the time of application; lapsed time to manure incorporation; rainfall or irrigation event,
- crops planted, planting and harvest dates, yields, nutrient analyses of harvested biomass, and crop residues removed, and
- dates of plan review, name of reviewer, and recommended changes resulting from the review.

Additional records for precision/variable rate sites will include:

- maps identifying the variable application source, timing, amount and placement of all plant nutrients applied, and

GPS-based yield maps for crops where yields can be digitally collected.

REFERENCES

Offsite Risk Index (ORI) and Nitrate Leaching Index – NRCS (FOTG Section II – Water Quality and Quantity Interpretations).

Agricultural Waste Management Field Handbook – Part 651, “National Engineering Handbook”, USDA-NRCS, March 2008.

Confined Feeding Rules & CAFO Regulations, Indiana Department of Environmental Management.

Purdue University Manure Management Planner (MMP) software – current version.

E-2567, 1995, Tri-State Fertilizer Recommendations for Corn, Soybeans, Wheat and Alfalfa. Nitrogen Management Guidelines for Corn in Indiana, Purdue University, latest edition.

AY-277, 1993, Calculating Manure and Manure Nutrient Application Rates.

AY-278, 1993, Estimating Manure Spreader Capacity.

AY-281, 1994, Soil Sampling for P, K and Lime Recommendations.

CES 227, 1990, updated 2001, How and Where to Get a Livestock Manure Analysis.

ID-101, 1994, Animal Manure as a Plant Nutrient Resource.

ID-179, Corn & Soybean Field Guide, latest edition.

ID-198, Crop Production Recordkeeping System.

Association of American Plant Food Control Officials (AAPFCO). 2011. AAPFCO Official Publication no. 64. AAPFCO Inc., Little Rock, AR.

Follett, R.F. 2001. Nitrogen transformation and transport processes. *In* Nitrogen in the environment; sources, problems, and solutions, (eds.) R.F. Follett and J. Hatfield, pp. 17-44. Elsevier Science Publishers. The Netherlands. 520 pp.

Schepers, J.S., and W.R. Ruan, (eds.) 2008. Nitrogen in agricultural systems. Agron. Monogr. no. 49, American Society of Agronomy (ASA), Crop Science Society of America (CSSA), Soil Science Society of America (SSSA). Madison, WI.

Sims, J.T. (ed.) 2005. Phosphorus: Agriculture and the environment. Agron. Monogr. no. 46. ASA, CSSA, and SSSA, Madison, WI.

Stevenson, F.J. (ed.) 1982. Nitrogen in agricultural soils. Agron. Series 22. ASA, CSSA, and SSSA, Madison, WI.

U.S. Department of Agriculture, Natural Resources Conservation Service. 2010. Agronomy Technical Note, (TN) 190-AGR-3, Precision Nutrient Management Planning. Washington, DC.

U.S. Department of Agriculture, Natural Resources Conservation Service. Jan. 2012. Title 190, General Manual, (GM), Part 402, Amend. 26, Nutrient Management. Washington, DC.

U.S. Department of Agriculture, Natural Resources Conservation Service. Feb. 2017, Title 190, National Instruction (NI), Part 313 1st Ed., Amend. 20, Nutrient Management Policy Implementation. Washington, DC.