NATURAL RESOURCES CONSERVATION SERVICE

CONSERVATION PRACTICE STANDARD

NUTRIENT MANAGEMENT

(Acre)

CODE 590

DEFINITION

Managing the amount, source, placement, form, and timing of the application of nutrients and soil amendments.

PURPOSES

- To budget and supply nutrients for plant production.
- To properly utilize manure or organic by-products as a plant nutrient source.
- To minimize agricultural non-point source pollution of surface and ground water resources.
- To protect air quality by reducing nitrogen emissions (ammonia and NO_x compounds) 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.

CRITERIA

General Criteria Applicable to All Purposes

A nutrient budget for nitrogen, phosphorus, and potassium shall be developed that considers all potential sources of nutrients including, but not limited to animal manure and organic by-products, waste water, commercial fertilizer, crop residues, legume credits, and irrigation water. Organic and inorganic fertilizer recommendation budgets will be developed using New Mexico State University's (NMSU) fertilizer recommendation software **NMSU Soil Test Interpretation software** (Excel workbook) or other NRCS approved software.

Realistic yield goals shall be established based on soil productivity information, historic yield data, climatic conditions, level of management and/or local research on similar soil, cropping systems, and soil and manure/organic by-products tests. For new crops or varieties, industry yield recommendations may be used until documented yield information is available. The NRCS state agronomist and NMSU shall establish yield goals and nutrient requirements for new crops as soon as possible.

Plans for nutrient management shall specify the source, amount, timing and method of application of nutrients on each field to achieve realistic production goals, while minimizing movement of nutrients to surface and/or ground waters.

Areas contained within established minimum

application setbacks (e.g. sinkholes, wells, gullies, ditches, surface inlets or rapidly permeable soil areas) shall not receive direct application of nutrients.

Erosion, runoff, and water management controls shall be installed, to meet Section III of the FOTG, on fields that receive nutrients. Irrigated fields must have an Irrigation Water Management practice developed (Practice Code 449).

Agricultural waste shall not be land-applied on soils that are frequently flooded, as defined by the National Cooperative Soil Survey, during periods when flooding is expected.

Soil Testing

Nutrient planning shall be based on a current soil test developed in accordance with NMSU guidance or industry practice if recognized by NMSU. Current soil tests are those that are no older than five years. Annually cropped fields will have a soil test taken the first year of a new plan or rotation, thereafter once in five years as a minimum. Hayland, rangeland and pasture can be tested once in five years. If organic sources of fertilizers are used, annual soil testing is required.

On fields that do not receive organic nutrients, after a baseline of two sampling periods, similar fields (rotation, soil series, slope, and irrigation type) can use a composite or aggregate (combined) sample to represent the group of fields. Nutrient recommendations for each crop can be made according to the results of the composite soil test.

Soil samples shall be collected and prepared according to the NMSU Extension guidance (Guide A-114). Fields must have 10-15 sub-samples taken to make up the composite sample to be analyzed.

Soil test analyses shall be performed by laboratories that are accepted in one or more of the following programs:

- The North American Proficiency Testing Program (Soil Science Society of America), or
- Laboratories whose tests are accepted by the NMSU.

Soil testing shall include analysis for any nutrients for which specific information is needed to develop the nutrient plan. Request analyses specified in NMSU Extension guide A-122. These analyses will include: **pH**, **electrical conductivity** (EC), **soil organic matter** (OM), **nitrate nitrogen** (N), **phosphorus** (P), **potassium** (K), **magnesium**, **calcium,** and **sodium** (SAR). Many soils and crops in NM also show a need for sulfur, zinc, manganese, and other micronutrients. If the pH is greater than seven, an Olsen (Sodium Bicarbonate) P-test will be done. At a pH of less than seven, the Bray P-test will be done. K-test will be done using the water extraction method. Ammonium acetate extractable K is also acceptable. Soil pH and electrical conductivity will be determined by saturation extract (salinity assessment). Exchangeable calcium, magnesium, and sodium, shall also be determined during salinity assessment to assess the sodium adsorption ratio and exchangeable sodium percentage.

Low Nitrate Soil Tests

If a soil test comes back from the lab with a test value for N at less than 1 ppm, the sample shall be rerun at the lab (same sample). If the rerun of the first sample is still less than 1 ppm, then a new sample will be taken in the field, and re-tested.

Plant Tissue Testing

Tissue sampling and testing, if used, shall be done in accordance with NMSU standards or recommendations. See NMSU Extension Guide A-123. Additional nutrients above the budget amounts may be added if interpretation of the tissue testing shows a need.

Nutrient Application Rates

Recommended nutrient application rates shall be based on NMSU recommendations (see Fertilizer Guide Extension A-128) and/or industry practice when recognized by NMSU that consider current soil test results (see above), realistic yield goals and management capabilities. NMSU Fertilizer Interpretation software (Excel workbook) or other NRCS approved software may be used to generate a nutrient budget for a given crop.

The planned rates of nutrient application, as documented in the nutrient budget, shall be determined based on the following guidance:

- **Nitrogen Application** - Planned nitrogen (N) application rates shall match the recommended rates, except when manure or other organic by-products are a source of nutrients. When manure or other organic by-products are a source of nutrients, see "Additional Criteria" below.
- **Phosphorus Application -** Planned phosphorus (P_2O_5) application rates shall match the recommended rates, except when manure or other organic by-products are a source of nutrients. When manure or other organic by-products are a source of nutrients, see "Additional Criteria" below.
- **Potassium Application** - Excess potassium shall not be applied in situations in which it causes unacceptable nutrient imbalances in crops or forages. When forage quality is an issue associated with excess potassium application, state standards shall be used to set forage quality guidelines.
- **Other Plant Nutrients -** The planned rates of application of other nutrients shall be consistent with NMSU guidance or industry practice if recognized by the NMSU.
- **Starter Fertilizers** - Starter fertilizers containing nitrogen, phosphorus, potassium, and/or micronutrients may be applied in accordance with NMSU recommendations or industry practice if recognized by NMSU. When starter fertilizers are used, they shall be included in the nutrient budget.
- **Soil amendments** can be applied, as needed, to adjust soil pH to the specific range of the crop for optimum availability and utilization of nutrients. Most conditions will not require a pH change. NM soils range from pH 6 to 8.5. Many soils have large amounts of free lime which prevents pH adjustment with amendments such as sulfur.

Nutrient Application Timing

Timing and method of nutrient application shall correspond as closely as possible with plant nutrient uptake characteristics, while considering cropping system limitations, weather and climatic conditions, and field accessibility.

Nutrient Application Methods

Nutrient applications associated with irrigation systems shall be applied in

accordance with the requirements of the Irrigation Water Management practice (Practice Code 449). Fertigation must not exceed the water holding capacity of the soil.

Additional Criteria Applicable to Manure or Other Organic By-Products Applied as a Plant Nutrient Source

Nutrient Values

Nutrient values of manure and other organic by-products shall be determined prior to land application based on laboratory analysis, acceptable "book values" recognized by the NRCS and/or NMSU, or historic records for the operation (two or three years of no operational change), if they accurately estimate the nutrient content of the materials. At a minimum, manure analyses shall identify nutrient and specific ion concentrations, percent moisture, and percent organic matter. Salt concentration shall be monitored so that manure applications do not cause plant damage or negatively impact soil quality.

Book values recognized by NRCS may be found in the Agricultural Waste Management Field Handbook (AWMFH), Chapter 4 – Agricultural Waste Characteristics. Acceptable values for NM can be found in the NM Nutrient Management specification. Heavy metals in biosolids have additional criteria.

Additional Soil Testing Requirements

Nitrogen soil testing for permitted Confined Feeding Operations will have the following additional requirements. Total soil nitrogen levels will be determined by Kjeldahl methods. Exchangeable nitrate will be determined by the Keeney and Nelson method using KCl.

Additional Soil Sampling Requirements

Land with a history of different application rates within the field may be required to have separate soil testing and different application rates. The New Mexico Environment Department (NMED) may require additional sampling to determine the extent of the variability and what applications can be made to zones in the field.

Nutrient Application Rates

The application rate (in/hr) for material applied through irrigation shall not exceed the soil intake/infiltration rate. The total application of water shall not exceed the water holding capacity of the soil root zone. See the Irrigation Guide in the NM Field Office Technical Guide (FOTG, Sec I) for local soil water holding capacities and soil intake rates. Application rates must be adjusted to match the soil intake rate.

The planned rates of nitrogen and phosphorus application recorded in the specification shall be determined based on the following guidance:

Nitrogen Application –

Normal N test – When the application rate is based on N (P Index <27) and the preplant/preapplication soil nitrate reading is less than 30 ppm, the **normal agronomic rates of application will be used** (as explained under Nutrient Application Rates).

High N test – When the soil N test is between 30-200 ppm nitrate, **additional testing will be done** to determine when more manure can be added. Additional testing will be done 25% of the way into

the growth period of the crop (120 day corn would be tested 30 days after planting). If the preapplication (crop growing) soil test is less than 80 ppm, a maximum rate of 30 lbs/ac of N can be applied.

Excessive N test – When the soil N test is greater than 200 ppm nitrate, **no more organic nutrient sources containing N can be applied** until the level drops below 80 ppm. Additional testing will be done 25% of the way into the growth period of the crop (120 day corn would be tested 30 days after planting). If the preapplication (crop growing) soil test is less than 80 ppm, a maximum rate of 30 lbs/ac of N can be applied.

P index >27 – When the practice is being implemented on a phosphorus standard (when the Phosphorus Index is High, Very High, or Excessive), manure or other organic by-products shall be applied at rates consistent with budgeting for P as described below under Phosphorus Application. In such situations, an additional nitrogen application, from non-organic sources, may be required to supply the recommended amounts of nitrogen.

N Applied to Legumes - Manure or other organic by-products may be applied on legumes at rates equal to 60 percent of the estimated removal of nitrogen in harvested plant biomass. See NM Nutrient Management Specification and the NMSU Soil Test Interpretation workbook.

Phosphorus Application - When manure or other organic by-products are used, the planned rates of phosphorus application will use the NM Phosphorus Index as follows:

- **Phosphorus Index (PI) Rating.** On **Very Low, Low or Medium risk sites**, application rates will be based on nitrogen crop need. On **Very High risk sites**, application rates will be based on phosphorus crop need. On **Excessive risk sites**, no phosphorus application is allowed. On **High risk sites**, the application rate will be based on 1.5 times the crop removal rate. The PI for NM is found in Agronomy Technical Note 41, and is available as a MS-Excel spread sheet found on NRCS's NM website. http://www.nm.nrcs.usda.gov/techserv/TechNotes/agro.htm

A single application of phosphorus applied as manure may be made at a rate equal to the recommended phosphorus application or estimated phosphorus removal in harvested plant biomass for the crop rotation or multiple years in the crop sequence. This can only be done when the PI is **Very-Low, Low, or Medium**. When such applications are made, the application rate shall:

- not exceed the recommended nitrogen application rate during the year of application, or
- not exceed the estimated nitrogen removal in harvested plant biomass during the year of application when there is no recommended nitrogen application.
- not be made on sites considered vulnerable to off-site phosphorus transport unless appropriate conservation practices, and management activities are used to reduce the vulnerability. Leaching and runoff practices must be included in the resource management plan.

Timing of application

Manure shall not be applied on frozen, flooded, or saturated soil.

Apply at the times when crops will use the most nutrients. This is when the most growth is expected for the crop.

In times when crops are not actively growing, apply only as much pond effluent as can be held in the planned crop root zone. For example: if the root zone profile can hold 4 inches of water (Total Water Holding Capacity (TWHC)) and the soil moisture is at 75% TWHC, then a 1-inch application is the most that can be applied.

Animal Feeding Operations-Setback Requirements

Setbacks are required for application of manure, litter, and lagoon or pond waste water. No application can be made closer than 100-feet to any down gradient surface open tile line intake structure, sink holes, well heads, or other conduits to surface or ground water.

A vegetated buffer (grass, no shrubs) 35-feet wide or more will allow organic application adjacent to the buffer.

Field Risk Assessment

When animal manures or other organic by-products are applied, a field-specific assessment of the potential for phosphorus transport from the field shall be completed. This assessment will be done using the **NM Phosphorus Index** (PI). In such cases, plans shall include:

- a record of the PI rating for each field or sub-field, and
- information about conservation practices and management activities that can reduce the potential for phosphorus movement from the site. Practices will be listed in the Comment section on the worksheet.

When such assessments are done the results of the assessment and recommendations shall be discussed with the client as the practice is planned. The client will initial the review on the PI worksheet.

Heavy Metals Monitoring

When biosolids are applied, the accumulation of potential pollutants (including arsenic, cadmium, copper, lead, mercury, selenium, and zinc) in the soil shall be monitored in accordance with the US Code, Reference 40 CFR, Parts 403 and 503.

Where municipal wastewater and solids (biosolids) are applied to agricultural lands as a nutrient source, the single application (annual limit) or lifetime limits of heavy metals shall not be exceeded. The concentration of salts shall not exceed the level that will impair seed germination or plant growth.

Maximum Annual and Lifetime Heavy Metal Additions to the Soils[1]

Metal (name/sym.)	**Annual Limit** (lbs/ac/yr)	**Lifetime Limit** (lbs/ac)
Arsenic (As)	2.2	46.0
Cadmium (Cd)	2.3	33.0
Copper (Cu)	84.0	1500.0
Lead (Pb)	17.0	336.0
Mercury (Hg)	0.95	19.0
Nickel (Ni)	24.0	19.0
Selenium (Se)	5.6	112.0

Zinc (Zn)	157.0	3136.0

[1]From the Code of Federal Regulations, Title 40, Vol 3, Part 503, Sec. 13, July 1 , 1999

Biosolids Applications

Biosolids shall not be applied to land that is closer than 100 feet to any water course.

Biosolids shall not be applied to land that is flooded, frozen, snow-covered or saturated soil.

Animals shall not be allowed to graze on the land for 30 days after the application of biosolids.

Food crops with harvested parts that touch applied biosolids and are totally above the soil surface shall not be harvested for 14 months after the application. Food crops with harvested parts below the surface of the land shall not be harvested for 20 months after application of biosolids, when the application remains on the land surface for four months or longer prior to incorporation into the soil. Food crops with harvested parts below the surface of the land shall not be harvested for 38 months after application of biosolids when the application remains on the land surface for less than four months.

Additional Criteria to Minimize Agricultural Non point Source Pollution of Surface and Ground Water Resources

An assessment shall be completed of the potential for nitrogen and/or phosphorus transport from the field if any waters of concern may be affected. Waters of concern include but are not limited to waters of the US, 303d listed steams, wells, other streams, high ground water, ponds, arroyos that flow part of the year, and lakes. The **Leaching Index (LI)** and/or **Phosphorus Index (PI)**, or other recognized assessment tools, may be used to make these assessments. The results of these assessments and recommendations shall be discussed with the client and included in the practice planning.

Nutrient Management practices developed to minimize agricultural non-point source pollution of surface or ground water resources shall include practices and/or management activities that can reduce the risk of nitrogen or phosphorus movement from the field.

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

In areas with an identified or designated nutrient management related air quality concern, any component(s) of nutrient management (i.e., amount, source, placement, form, timing of application) identified by risk assessment tools as a potential source of atmospheric pollutants shall be adjusted, as necessary, to minimize the loss(es).

When tillage can be performed, surface applications of manure and fertilizer nitrogen formulations that are subject to volatilization on the soil surface (e.g., urea) shall be incorporated into the soil within 24 hours after application.

When manure or organic by-products are applied to grassland, hayland, pasture or minimum-till areas the rate, form and timing of application(s) shall be managed to minimize volatilization losses.

When liquid forms of manure are applied with irrigation equipment, operators will select weather conditions during application that will minimize volatilization losses.

Operators will handle and apply dry types of animal manures when the potential for wind-driven loss is low and there is less potential for transport of particulates into the atmosphere.

Weather and climatic conditions during manure or organic by-product application(s) shall be recorded and maintained in accordance with the operation and maintenance section of this standard.

Additional Criteria to Improve the Physical, Chemical, and Biological Condition of the Soil.

Nutrients shall be applied and managed in a manner that maintains or improves the physical, chemical and biological condition of the soil. Use of nutrient sources with high salt content relative to the nutrient value will be minimized to prevent damage to plants. Salt levels will be monitored by soils testing to see that they do not exceed the permissible EC rate for the crop to be grown. See Table 4 in the NM Irrigation Guide in Sec. 1 of the FOTG for the maximum allowable salt levels by crop.

Nutrients shall not be applied to flooded or saturated soils by ground equipment when the potential for soil compaction and creation of ruts is high.

Additional Criteria for Subsurface Drip Irrigation

If nutrients are added to subsurface drip irrigation systems (SDI), a jar test must be done to determine if any of the material being added to the system will cause solids to precipitate out causing the system to plug and fail. The jar test is simply a mixture of the fertilizers (at the field concentration) applied to the water and left to stand to see if any of material settles out. See Agronomy Tech Note 71.

CONSIDERATIONS

During the planning process, consider the relationship between nitrogen and phosphorus transport and water quality impairment. Consider the potential for nitrogen leaching into shallow ground water and potential health impacts. Consider the potential for phosphorus accumulation in the soil, the increased potential for phosphorus transport in soluble form, and the types of water quality impairment that could result from phosphorus movement into surface water bodies.

Consider the intent of this practice to prevent the nutrients (nitrogen and phosphorus) supplied for production purposes from contributing to water quality impairment.

Consider additional practices such as Conservation Cover (327), Grassed Waterway (412), Contour Buffer Strips (332), Filter Strip (393), Irrigation Water Management (449), Riparian Forest Buffer (391A), Conservation Crop Rotation (328), Cover and Green Manure (340), and Residue Management (329A, 329B, or 329C, and 344) to improve soil nutrient and water storage, infiltration, aeration, tilth, diversity of soil organisms and to protect or improve water quality.

When applicable, plans shall include other practices or management activities as determined by specific regulation, program requirements, or client goals.

Consider induced deficiencies of nutrients due to excessive levels of other nutrients.

Consider cover crops whenever possible to utilize and recycle residual nitrogen.

Consider application methods and timing that reduce the risk of nutrients being transported to ground and surface waters,

or into the atmosphere. Suggestions include:

- split applications of nitrogen to provide nutrients at the times of maximum crop utilization,
- avoid winter nutrient application for spring seeded crops,
- avoid winter plow out of alfalfa to release nitrate when plants can use it in the spring,
- band apply phosphorus near the seed row,
- use precision agricultural techniques to apply nutrient materials uniformly
- incorporation of applied manure or organic by-products immediately
- delay field application of animal manures or other organic by-products if precipitation capable of producing runoff and erosion is forecast within 24 hours of the time of the planned application.
- Ammonia based N fertilizers should be incorporated the same day applied.

Consider minimum application setback distances from environmentally sensitive areas, such as sinkholes, wells, gullies, ditches, surface inlets or rapidly permeable soil areas. See NRCS Practice standard 633 for guidance.

Consider the potential problems from odors associated with the land application of animal manures, especially when applied near or upwind of residences.

Consider nitrogen volatilization losses associated with the land application of animal manures. Volatilization losses can become significant, if manure is not immediately incorporated into the soil after application. Consider using soil test information no older than one year, particularly if organic nutrients are used.

Consider annual reviews to determine if changes in the nutrient budget are desirable (or needed) for the next planned crop. If livestock numbers change up or down 20%, or land area increases or decreases by 20%, or the crop rotation changes a review of the nutrient budget is needed.

On sites on which there are special environmental concerns, consider other sampling techniques. (For example: Soil profile sampling for nitrogen, Pre-Sidedress Nitrogen Test (PSNT), or soil surface sampling for phosphorus accumulation or pH changes.)

Consider ways to modify the chemistry of animal manure, including modification of the animal's diet to reduce the manure nutrient content, to enhance the client's ability to manage manure effectively.

For rapidly growing crops, apply waste in a manner that should cover no more than 25% of the leaf surface with solids.

To prevent leaf burn for some crops, apply liquids according to local climatic conditions or the NRCS irrigation guide. Application rate should vary according to the salt content (electrical conductivity for the liquid and the salt tolerance of the crop). See Table 4 in the Irrigation Water Quality section of the Irrigation Guide in Section I of the FOTG.

Avoid applying manure and organic byproducts upwind of occupied structures when residents are likely to be home (evenings, weekends and holidays).

When applying manure with irrigation equipment, modifying the equipment can reduce the potential for volatilization of nitrogen from the time the manure leaves the application equipment until it reaches

the surface of the soil (e.g. reduced pressure, drop down tubes for center pivots). N volatilization from manure in a surface irrigation system will be reduced when applied under a crop canopy.

Plan nutrient applications and tillage operations to promote soil carbon buildup and decrease greenhouse gas emissions (e.g. nitrous oxide, N_2O, carbon dioxide, CO_2).

CAFO operations seeking permits under USEPA regulations (40CFR Parts 122 and 412) should consult with the permitting authority for additional criteria.

PLANS AND SPECIFICATIONS

Plans and specifications shall be in keeping with this standard and shall describe the requirements for applying the practice to achieve its intended purpose(s), using nutrients to achieve production goals and to prevent or minimize resource impairment. See **New Mexico Nutrient Management Specification 590** for required components.

OPERATION AND MAINTENANCE

The owner/client is responsible for safe operation and maintenance of this practice including all equipment. **Operation and maintenance will address the following:**

- Periodic specification review to determine if adjustments or modifications to the practice are needed. **As a minimum**, the specification will be reviewed and revised with each soil test cycle.
- Protection of fertilizer and organic by-product storage facilities from weather and accidental leakage or spillage.
- Calibration of application equipment to ensure uniform distribution of material at planned rates.
- Documentation of the actual rate at which nutrients were applied. When the actual rates used differ from or exceed the recommended and planned rates, records will indicate the reasons for the differences.

Maintaining records to document practice implementation. As applicable, records include:

- soil test, water, plant, and organic by-product test results and recommendations for nutrient application,
- quantities, analyses and sources of nutrients applied,
- dates and method of nutrient applications,
- crops planted, planting and harvest dates, yields, and crop residues removed,
- dates of review and person performing the review, and recommendations that resulted from the review.

Records should be maintained for five years; or for a period longer than five years if required by other Federal, state, or local ordinances, or program or contract requirements.

Workers should be protected from and avoid unnecessary contact with chemical fertilizers and organic by-products. Protection should include the use of protective clothing when working with plant nutrients. Extra caution must be taken when handling ammonia sources of nutrients, or when dealing with organic wastes stored in unventilated enclosures.

The disposal of material generated by the cleaning nutrient application equipment should be accomplished properly. Excess material should be collected and stored or field applied in an appropriate manner.

Excess material should not be applied on areas of high potential risk for runoff and leaching.

The disposal or recycling of nutrient containers should be done according to state and local guidelines or regulations.

REFERENCES

Extension publications mentioned above are available on the NMSU website, http://www.cahe.nmsu.edu/pubs/_a/

The Animal Waste Management Field Handbook is available in most NRCS County Field Offices. It can also be accessed from the NRCS National website, http://www.ncg.nrcs.usda.gov/awmfh.html

NMSU Fertilizer Interpretation software, Phosphorus Assessment Tool, and other technical information is available on the NM NRCS website, http://www.nm.nrcs.usda.gov/technical/fotg/section-4/jobsheets/js590.xls and http://www.nm.nrcs.usda.gov/technical/tech-notes/agro/ag57.xls

The Code of Federal Regulations can be accessed from the website, http://www.access.gpo.gov/nara/cfr/index.html. State regulations may be accessed from the New Mexico Environment Department website, http://www.nmenv.state.nm.us.

Bremner, J.M. and C.S. Mulvaney. 1982. Nitrogen – Total. *In* Methods of Soil Analysis Part 2. Page, A.L. (ed.) American Society of Agronomy and Soil Science Society of Agronomy, Madison, WI. Pp 595 – 624.

Follett, R.F. 2001. Nitrogen Transformation and Transport Processes. pp. 17-44, In R.F. Follett and J. Hatfield. (eds.). 2001. Nitrogen in the Environment; Sources, Problems, and Solutions. Elsevier Science Publishers. The Netherlands. 520 pp.

Keeney, D.R., and D.W. Nelson. 1982. Nitrogen – Inorganic Forms. In Methods of Soil Analysis Part 2. Page, A.L. (ed.) American Society of Agronomy and Soil Science Society of Agronomy, Madison, WI. Pp 643 - 698.

Sims, J.T. (ed.) 2005. Phosphorus: Agriculture and the Environment. Agron. Monogr. 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.