Alternative Management Tool (AMT)
Precision Agriculture: Precision Nitrogen Management

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Alternative Management Tools (AMTs) *are specific agricultural practices and solutions, other than nitrogen fertilizer best management practices, to address groundwater nitrate problems. AMTs are described in the Groundwater Protection Rule and approved by the Commissioner of Agriculture.*

Introduction

In areas where the groundwater is vulnerable to nitrate contamination and in highly vulnerable drinking water supply management areas (DWSMAs), an effective strategy for reducing nitrate leaching is precision nitrogen management where the supply of nitrogen (N) applied is matched to when the crop needs it. Precision nitrogen management falls within the broader scope of precision agriculture.

The precision nitrogen management practices described below meet the definition of alternative management tools (AMTs) in the Groundwater Protection Rule (MR 1573.0010). Specifically, the practices align the nitrogen (N) application rate, source, placement, and timing, to better match crop uptake needs. This document outlines options and rate exceedances that allows higher than the MDA published N fertilizer rate to be applied for soils with high yield potential in DWSMAs.

There are two options under precision nitrogen management:

- A basic option where an up to **30 lb. N/ac** exceedance above the MDA published rate is allowed for conditions as outlined, and
- An advanced option reflecting advanced N management **without a limit** for the N application.

Definition of Precision Agriculture

Precision agriculture relies on geospatial technology to manage the variability of soil and crop parameters and aid decisions on production inputs. According to the international Society of Precision Agriculture, this practice is defined as "*a management strategy that gathers, processes and analyzes temporal, spatial and individual data and combines it with other information to support management decisions according to estimated variability for improved resource use efficiency, productivity, quality, profitability and sustainability of agricultural production.*"

Precision nitrogen management means the 4R principles of nutrient management is followed - the Right source, Right rate, Right time, and the Right placement. Precision nitrogen management often include site specific nutrient management and variable rate nitrogen (VRN) application.

AMT substitution for a Nitrogen Fertilizer Best Management Practice (BMP)

See BMP/AMT matrix (www.mda.state.mn.us/nitrogenamts) for more information about how this AMT substitutes for nitrogen fertilizer BMPs.

Water Quality Benefits

Precision nitrogen management can reduce nitrate leaching loss by spatially and temporally matching crop requirement and nitrogen fertilizer application. It is becoming an increasingly common practice (Agvise, 2020). This can be accomplished by mapping within-field spatial variability of crop N need using either grid or management zone approaches (Khosla et al., 2002) with N management zones (Mulla, 1991). For further improvement in N management, delaying N application and completing an in-season assessment of crop N need to better match crop uptake requirements is used. This is especially important in Minnesota where a substantial amount of nitrogen can be lost via leaching in the spring (Zak and Grigal, 2001). Wilson et al. (2017) compared nitrate leaching loss under variable rate nitrogen management to that of conventional N management on coarse textured soils and estimated a 13% reduction in N loss when using VRN. This result was later confirmed by Wilson et al. (2020) in three other agro-ecoregions in Minnesota.

The MDA has identified two options, using precision nitrogen management, for applying N fertilizer above the MDA published rate for the DWSMA:

Option #1: Basic Variable Rate Nitrogen

Following these requirements will allow for up to 30 lb. N/ac exceedance above the MDA published N fertilizer rate for the DWSMA. The 30 lb. N/ac exceedance is calculated as the average rate for the field.

To qualify for the 30 lb. N/ac exceedance, these two requirements must be met:

1) Justification showing a reasonable expectation of improved yields to substantiate the higher N rate, and
2) N fertilizer must be applied using variable rate technology.

To justify this higher N rate for a given field, it must be demonstrated that a field as a whole can be considered to have high productivity. Examples include:

- The last three-year average yields must be more than 15% higher than the USDA County average[1], or
- Working with a 4R Stewardship certified crop production retailer and using adaptive management practices accepted by the Minnesota 4R Nutrient Stewardship program (see appendix A).

The second requirement is the use of variable rate N fertilizer prescription (VRN). MDA has included this option to encourage the use of VRN. The following are examples of practices that would fulfill this requirement.

[1] County yield averages from the actuarial information browser (AIB) from the USDA Risk Management Agency, https://webapp.rma.usda.gov/apps/ActuarialInformationBrowser2022/CropCriteria.aspx should be used. The County average is found by selecting commodity, year, insurance plan (Area Revenue Protection (05), State and County and click Get Report. Select the Prices and Yields tab and scroll down to find the county average for non-irrigated and irrigated crops. For example, for Dakota County the 2021 yields were 151 bu/ac for non-irrigated corn and 223.6 bu/ac for irrigated corn.

- Conduct precision soil sampling (zone or grid based) for nitrate-nitrogen with a minimum of two zones that correspond to a minimum of two nitrogen application rates. Sampling should consider the following:
    - Current soil sample nitrate analysis
    - On large uniform fields, one or more composite samples must be taken per 20 acres, or per 40 acres if previous sampling showed little in-field variability
    - On smaller fields or hilly/rolling ground, one or more composite samples must be taken per 5 acres, or per 20 acres if previous sampling showed little in-field variability
    - Each sample must be composite consisting of multiple cores (e.g., 15-20 cores)
- Develop management zones or grid based on relevant information, such as soil organic matter, Lidar DEM, yield maps, digital soil survey information, remote sensing, proximal sensing or other geospatial data.
- Develop prescriptions for in-season application of nitrogen where no more than 50% of the MRTN can be applied before sidedress and the remaining is applied in-season as a variable rate application.
- The variable rate nitrogen prescription must account for the field spatial variability characterized in the above-mentioned steps (e.g., based on management zones or grid or other site-specific information). The total nitrogen rate applied during the entire growing season (including all sources of nitrogen including manure, credits from previous legume crop) may not exceed the N rate established for the DWSMA by more than 15 lb. N/ac on average for the field.

Option #2: Utilizing Advanced Technology for In-Season Nitrogen Management

The MDA will accept nitrogen fertilizer application rates above the MDA published rate if there is a documented need for additional nitrogen to meet crop needs. The need must be determined annually in-season based on advanced nitrogen management and monitoring technologies. **The technology being used must have documentation and be verified by MDA to prove it provides accurate estimates of additional N need under Minnesota crop production conditions**. See appendix 2 for more information about technology verification.

To qualify for the N rate exceedance, these two requirements must be met:

1) Use of applicable in-season precision nitrogen technology showing a need for additional N, and
2) N fertilizer must be applied using variable rate technology.

Examples of applicable precision nitrogen technology that can be used in-season to justify higher N rates after they have been verified by MDA include but are not limited to:

- **Pre-sidedress soil test** (PSNT) that is grid or zone based. Follow University of Minnesota guidance for precision soil sampling (extension.umn.edu/nutrient-management/testing-and-analysis),
- **Precision tissue testing** that is grid or zone based,
- **Chlorophyll readers** that is grid or zone based,
- **Advanced crop models** with a spatial component to account for within-field spatial variability,
- **Remote sensing**-based estimates of normalized difference vegetation index (NDVI) or other vegetation indices including the thermal, near-infrared, visible and other spectral wavelengths,
- Other **proximal, aerial, or satellite**-based sensing of plant N status, or

- Third party N recommendation that is science-based, and that documents the technology and information used to develop the variable prescription.

This information should be used to develop variable rate prescription maps which must be used when applying the in-season N fertilizer, and the following requirements must be followed:

- Develop prescriptions for in-season application of nitrogen where no more than 50% of the MRTN can be applied before sidedress and the remaining is applied in-season as a variable rate application.
- The variable rate nitrogen prescription must account for the field spatial variability characterized in the above-mentioned precision nitrogen technologies. The total nitrogen rate applied during the entire growing season (including all sources of nitrogen including manure, credits from previous legume crop) must be documented as part of the recordkeeping.

Recordkeeping

Records to document N fertilizer rates above the MDA published rate must be kept. The records must provide clear documentation of the method that was used, the data and other information utilized, how that data was interpretated and the as-applied maps of N fertilizer. Examples of records include:

- Soil sampling map (zone or grid based): to document use of precision soil sampling.
- Soil test nitrate result from an MDA certified lab.
- Yield maps from a combine yield monitor to establish yield potential and demonstrate the high productivity of the field.

References

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Appendix A

Adaptive management practices accepted by the Minnesota 4R Nutrient Stewardship program

The adaptive management practices accepted by the Minnesota 4R Nutrient Stewardship program are:

- Literature review from peer-reviewed papers with similar conditions that supports the increased nutrient application,
- Studies showing rates above and below the optimum with regression analysis,
- Self-designed projects to quantify water results at the edge of field and or in-field. The control comparison will be the land grant university recommendation compared to the adaptive management practice,
- Consultation with a water quality expert willing to provide the documentation. University of Minnesota Agricultural Extension, Soil & Water Conservation Districts, or Land Grant institutions can assist, or
- Documenting advanced nitrogen BMP for rate with a goal of nitrogen use efficiency of less than 1.0 pound per bushel of corn or Nitrogen Use Efficiency of 0.6 - 0.8. On-farm nitrogen rate response trials using source, timing, and placement BMPs within reasonable proximity to farm are acceptable data sets.

For more information, please see https://4rcertified.org/minnesota-about/

Appendix B

Evaluation process for advanced technologies for in-season nitrogen management

For each proposed technology, the MDA will assess the accuracy of the technology for predicting nitrogen application. MDA will produce a short report with a discussion of limitations, uncertainties, or specific conditions under which the technology must be used.

The evaluation is based on relevant or pertinent information including but not limited to:

- Technical information from the technology provider
- Review of scientific literature
- Computer modeling
- Consultation with University of Minnesota or other regional agricultural research experts
- Input from agricultural industry and commodity group leaders
- Other relevant sources of information, such as research trial data

Relevant technical information is required to evaluate claims and/or to provide evidence of accuracy for nitrogen recommendation when the technology is used as recommended or directed. Any experimental evidence provided to MDA must relate to conditions in this state (environmental, application rates, soil, crop etc.) for which the technology is intended and must correspond to the actual technology intended to be evaluated. Technical report(s) will typically include at a minimum the materials and methods, results, an appropriate statistical analysis, and discussion. Other information sources including but not limited to; abstracts, incomplete articles, literature reviews of similar but different technologies, testimonials, news articles, pictures and fact sheets are generally insufficient as evidence for evaluating benefits.