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MontGuide

Crop and Fertilizer Management Practices to Minimize Nitrate Leaching

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Use nitrogen fertilizer and crop management practices to minimize nitrate leaching, benefit crop production and protect groundwater quality.

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THIS MONTGUIDE BRIEFLY DESCRIBES THE agronomic contributions to nitrate leaching into groundwater and suggested management practices on both cropland and gardens to minimize this issue. For more detailed information based on regional research, please see *Minimizing Nitrate Leaching from Cropland.*

Is nitrate leaching a problem in Montana?

Nitrate is a form of nitrogen (N) that is plant-available. It can come from fertilizer or decomposition of organic matter and manure, and is highly soluble and easily lost to leaching as it moves with water below the root zone.

High amounts of nitrate in drinking water can be harmful, especially to infants and pregnant women. They also represent a direct financial loss to Montana agriculture. It is estimated Montana groundwaters contain over one billion dollars worth of leached N. In addition, nitrate leaching contributes to soil acidification, an emerging issue in parts of Montana. While most groundwater in Montana has nitrate levels below the drinking water standard (10 mg nitrate-N/liter or parts per million), high nitrate levels have been found in certain areas (Figure 1).

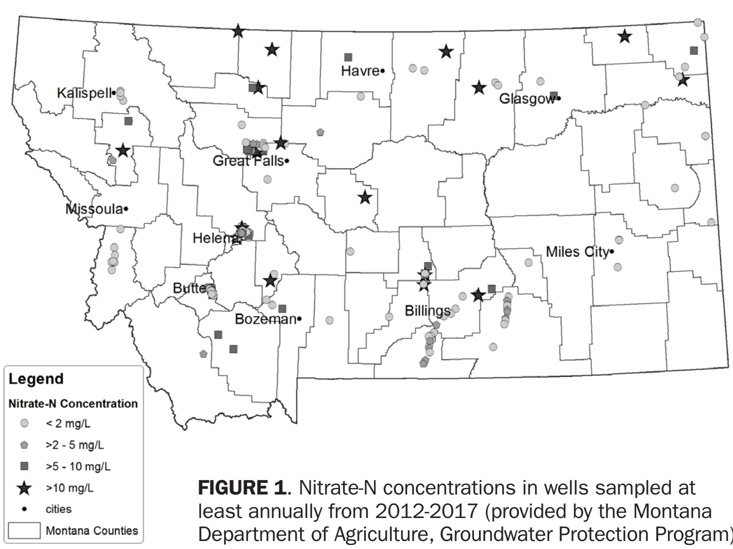


FIGURE 1. Nitrate-N concentrations in wells sampled at least annually from 2012-2017 (provided by the Montana Department of Agriculture, Groundwater Protection Program).

Whether leached nitrate ends up in groundwater depends on many factors, including the depth to a gravel layer, depth to groundwater, soil texture, and rooting depths. Fortunately, in Montana, soil texture is often fine and deep-rooted crops such as winter wheat and alfalfa are common, which minimize leaching, and drinking water often comes from uncontaminated deep wells. Yet there are locations in the state that have a high potential for leaching and groundwater contamination.

Soil and water factors that increase leaching potential

Soil texture influences a soil's ability to retain water (Table 1, page 2). Sandy soils and shallow soils have low water holding capacity. Cracks and other vertical channels (e.g., from worms or roots) that extend from the soil surface to below the root zone allow water to move nitrate downwards. There is little producers can do to change these soil properties.

Precipitation contributes to nitrate leaching, even in drier parts of Montana. In dryland conditions, leaching is likely insignificant during much of Montana's growing season because plant uptake of water usually exceeds precipitation. However, from fall to early spring, water input exceeds plant uptake, resulting in increased potential for leaching *(1, MT).*

Irrigated fields have the highest potential for leaching, especially on coarse soil. Sprinkler systems have lower leaching risk than furrow and flood irrigation systems. Irrigation should be managed to meet the crop need, but not exceed the soil's water holding capacity (Table 1). Montana State University has several resources to guide irrigation practices (http://waterquality.montana.edu/farm-ranch/irrigation/) and Colorado State University offers specific guidelines for irrigation management to retain soil N *(2).*

TABLE 1. Plant available water holding capacity for various soil textures.

Soil Texture	Inches Water per Foot of Soil
Sand, fine sand	0.72
Loamy sand	0.96
Sandy loam	1.44
Loam, silt loam, silt, sandy clay, silty clay, clay	2.04
Sandy clay loam, clay loam, silty clay loam	2.16

If the soil is 1-foot sandy loam over 2-feet sandy clay loam, it would take (1.44) + (2 x 2.16) = 5.8 inches of water to refill the dry soil to a 3-foot depth. More precipitation or irrigation could leach nitrate.

Crop management

In dryland cropping systems, reducing fallow is likely the most important strategy to reduce water and nitrate movement below the root zone. Fallow fields build up nitrate through organic matter decomposition and have no crop in place to take up N. They have higher leaching potential because if they reach field capacity (the amount of water a particular soil can hold against drainage) additional precipitation is likely to push soil water below the rooting zone, taking nitrate with it. As cropping frequency increases, nitrate leaching decreases (*3, SK*).

Annual legumes such as field pea can substantially reduce nitrate leaching compared to fallow *(1, MT).* In addition to using soil water, they are good scavengers of available N in the upper 2-3 feet of soil and do not need N fertilizer as long as sufficient phosphorus, potassium, sulfur and the correct inoculants are available for N fixation. The benefit of an annual legume-wheat system compared to fallow-wheat appears to be more an effect of capturing water than reduced N fertilizer rates. In a Montana study, the amount of nitrate in the 4th foot of soil after wheat increased with increasing N rates in the fallow-wheat system, but was minimally affected by N rate in the legume grain-wheat system (Table 2). It is highly likely any nitrate in the 4th foot of soil in the spring after a winter wheat year would not be scavenged by wheat planted the following growing season and will eventually be lost to groundwater.

Cereal forages, green manures and cover crops can be used to manage crop available water in areas with insufficient precipitation for continuous cropping, but with more precipitation than can be used by crop fallow. Cover crops can scavenge N and water in intensively managed systems with high N inputs and extended overwinter/early spring bare periods (e.g., corn, sugarbeet, vegetables). Non-legume cover crops in such systems reduced leaching by an average 70%, while legume cover crops reduced leaching by 40%, with little to no reduction in yields *(5).* Cover crops are likely underused to catch N in home and market gardens which are often close to residential wells.

In fallow systems, fall-planted crops are ideal to take up some N before the late April – early June rainy season. Planting perennials or deep rooted annual crops, such as sunflower, canola, safflower and winter wheat, helps use water and N that escapes shallow rooted crops. While alfalfa is an excellent scavenger of soil nitrate, the large supply of N remaining after alfalfa is terminated can release nitrate. To avoid leaching loss of this nitrate, fields should be recropped rather than fallowed after alfalfa termination, and N from alfalfa residue credited in fertilizer N rate calculations (~40 lb N/acre) to avoid over fertilization.

Selecting seeding rates and row spacing for optimal plant density can increase yields and optimize resource use, which will decrease potential for N leaching. For example, spring wheat had a higher efficiency of N fertilizer use at 6-inch row spacing than at 12-inch spacing *(6, MT)*, which should translate into less N leaching loss.

Residual soil nitrate levels tend to be lower in no-till and minimum till than conventional-tilled fallow or recrop systems, presumably because tillage increases the rate of organic matter decomposition *(7, ND)*. Increasing annual crop diversity and including perennials is more important in tilled than no-till systems *(8, SK)*.

What to do on high leaching potential soils:

- Recrop rather than fallow
- Diversify to include perennial and/or deep rooted annual crops
- Reduce tillage
- Space rows for optimal resource use and plant yield
- Sprinkle rather than flood irrigate
- Irrigate to meet but not exceed crop needs

Fertilizer management

A major goal is to reduce residual soil nitrate, because if the crops don't use it, the field can lose it. Annual soil testing and realistic yield goals should help producers calculate fertilizer N rates to avoid over-fertilization. When calculating fertilizer rates, credit all sources of N available to the crop, including legume input, organic matter and soil nitrate-N (see *Developing Fertilizer Recommendations for Agriculture* for details). Spring soil tests are a better measure of available N than fall soil tests because they account for overwinter

TABLE 2. March soil nitrate in the 4th foot of soil, after wheat in fallow-wheat and legume grain-wheat systems at four available-N rates applied during the wheat rotation *(4, MT)*.

	Soil Nitrate (lb N/acre)	
Available N[1] (lb N/bu)	Fallow-wheat	Legume grain-wheat
0.0	10	9
1.5	15[2]	6
3.0	20	6
4.5	25	11

1. Available N is soil N plus fertlizer N; 2. Soil nitrate was higher in fallow-wheat than legume grain-wheat systems at 1.5, 3.0, and 4.5 lb N/bu, with 90% confidence.

changes to soil nitrate levels. For example, nitrate-N increased an average 18 lb N/acre annually from late summer to early spring in a 3-year Montana study *(9)*. Early fall samples are especially likely to underestimate soil nitrate following a cover crop, pulse crop, or brassica crop and could lead to over-fertilization.

Soil test annually, and sample deeper than 2 feet where soils allow, to learn how much N is in the root zone. Credit all available soil N at the 2-3 foot depth if planting a deep rooted crop, but only half of that N if planting a shallow rooted crop. See *Soil Sampling and Laboratory Selection* for more details.

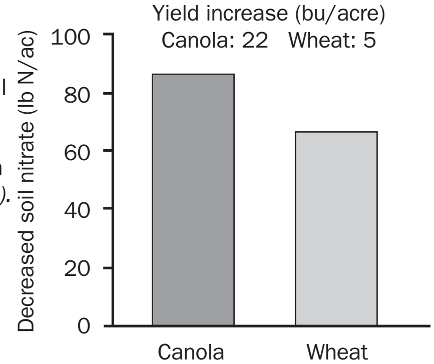
Ideally, conventional N fertilizer is applied right before the plants need it most, which is from seedling to late tillering stages in cereal grains and seedling to early branching in oilseeds *(Nutrient Uptake Timing by Crops: to assist with fertilizing decisions)*. Fertilizer topdress applications should be timed based on plant demand or growth stage, rather than calendar date. By matching N rates to plant needs and using split applications, there is less risk of over-fertilizing, leaving less unused N in the soil. Nitrogen release from crop residue better matches the timing of crop growth and N uptake than any N fertilizer and results in less N lost to leaching *(10, CO)*. In addition, legume crop residue can reduce the need for N fertilizer.

There are advances in fertilizer and application technology that help increase the amount of applied fertilizer actually used by the crop. Some enhanced efficiency fertilizers slowly release their nutrients over time due to coatings, others slow the conversion of N fertilizer to nitrate, thereby possibly decreasing leaching. Polymer-coated urea has reduced leaching in potato, corn and turfgrass production *(11, UT)*. Enhanced efficiency fertilizers deserve consideration, especially if the price difference compared to conventional N fertilizers decreases. But, they are not the best fertilizer choice for all situations and timing of application is different than with conventional fertilizer. For discussion of the properties of these fertilizers, their effectiveness and suggested management see *Enhanced Efficiency Fertilizers.*

Variable-rate fertilizer application methods help ensure N is applied where it is needed most and not in places where it will be lost. Often, most nitrate leaching comes from only a fraction of the total area of a field *(12)*. Low productivity zones contribute more to nitrate leaching than high productivity zones *(13, CO)*. To limit N loss, identify areas of a field that are limited by factors other than N and apply just enough N to meet that area's production potential.

A deficiency in other nutrients such as phosphorus, potassium, or sulfur can result in less crop growth, less water uptake and more N left in the ground, especially after fallow *(3, SK)*. Sulfur can be especially critical for N uptake and yield, thereby reducing N susceptible to leaching (Figure 2). See *Developing Fertilizer Recommendations for Agriculture* for assistance with fertilizer rate calculations.

FIGURE 2. Addition of 13 to 18 lb S/acre on sulfur deficient soil increased yields (bu/acre) and decreased residual soil nitrate in the top 2-feet *(14, SK)*.



By using available technology and best management practices, producers can make sure their fertilizer dollars are spent growing a crop and reducing the potential for groundwater nitrate contamination. The 4R nutrient stewardship approach involves selecting the right source-rate-time-place combination from practices validated by research (www.ipni.net/4r). The Natural Resources Conservation Service's (NRCS) Environmental Quality Incentives Program (EQIP) provides farmers with financial and technical assistance on protecting environmental quality. Programs offered by the NRCS do change, so get current information from www.nrcs.usda.gov/wps/portal/nrcs/main/mt/programs/ or a local NRCS office.

What to do on high leaching potential soils:

- Know your soil type
- Soil sample annually in the spring to 3 feet or more in deeper soils
- Base N rate on soil tests and reasonable yield potential
- Credit N from all sources, such as manure and previous legume crops
- Apply N in spring or use a slow release fertilizer before spring
- Apply conventional N fertilizers close to peak crop N uptake
- Split applications – use conservative pre-plant N rate and in moist years topdress before rapid growth stage
- Retain crop residue and include legumes in rotation
- Use variable rate/zone specific technology
- Provide other nutrients for optimal yields

Conclusion

Producers and their advisers cannot easily control some factors that affect soil nitrate leaching, such as soil properties and climate. However, they can control other factors, such as crop rotations, fertilization amount and timing, and irrigation. Many agronomic management practices can be used to minimize N leaching losses and potential groundwater contamination. These practices help ensure that fertilizer dollars are optimally spent on growing the crops while keeping our groundwater safe.

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Extension Materials

For a range of information from well testing to irrigation management, contact the MSU Extension Water Quality Program at http://waterquality.montana.edu/ or phone (406)994-7381.

The following can be found by title at http://landresources.montana.edu/SoilFertility/publications.html.

Developing Fertilizer Recommendations for Agriculture (MT200703AG)

Enhanced Efficiency Fertilizers (EB0188)

Minimizing Nitrate Leaching from Cropland (EB0226), available Winter 2018

Nutrient Management Modules (#4449-1 to 4449-15)

Nutrient Uptake Timing by Crops: to assist with fertilizing decisions (EB0191)

Soil and Water Management Modules (#4481-1 to 4481-5).

Soil Sampling and Laboratory Selection (Nutrient Management Module No. 1 4449-1)

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