Research Update: December 2014

Judith River Watershed Nitrogen Project

Newsletter #2: Process and Timing of Nitrate Leaching

This is the second in a newsletter series designed to provide residents of Judith Basin and Fergus Counties with information about what we've learned from working with local farmers on this project. Newsletter #1 included results from 2013 studies that documented advantages of replacing fallow with pea. This newsletter describes what we've learned about the drivers of nitrate leaching on farm fields. We hope this information can help farmers develop management practices that will put more nitrogen into their crops and less into groundwater.[1]

- Soil nitrate can come from N fertilizer or soil organic matter.
- To leach soil nitrate, rainfall has to exceed plant uptake, evaporation, and soil water storage.

Where is nitrate leaching coming from?

When organic matter decomposes or fertilizer dissolves, a form of nitrogen called ammonium is released. Ammonium is available to plants and microorganisms, and because it carries the opposite charge as soils, it sticks to soil and doesn't leach much. In the presence of oxygen and moisture, however, ammonium gets converted to nitrate. This process can take a few hours to even months – but is much faster when the soil is warm and moist. Unlike ammonium, nitrate has the same charge as soil surfaces so tends to move with soil water and much more easily leached to groundwater. Plant uptake of nitrate reduces the amount that can move to groundwater.

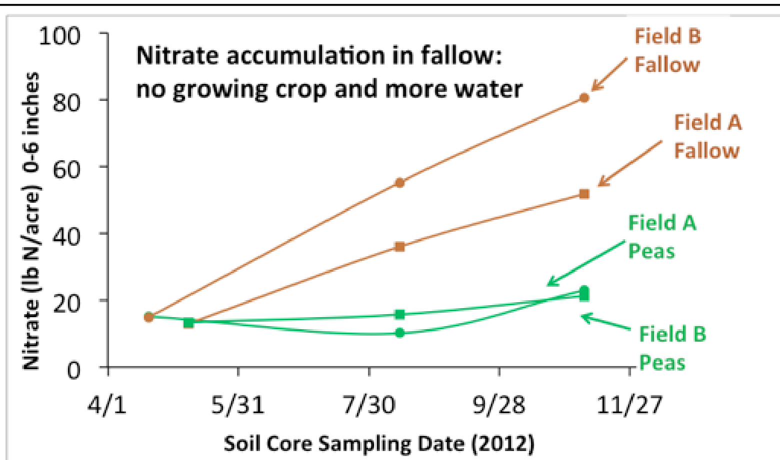

Fig. 1 Fallow fields enter winter with far more nitrate than cropped fields, increasing the chance for of nitrate leaching. The use of nitrate by a growing crop (and lower mineralization rates) results in relatively little nitrate buildup and limits nitrate available for leaching by winter and spring rainfall.

SOIL VS. FERTILIZER NITROGEN: We have seen that in the Judith River Watershed, soil mineralization processes tend to produce as much or more available nitrate in the soil as added fertilizers. Figure 1 illustrates how we see this in fallow soils, which are moister than cropped soils, promoting more organic matter decomposition and nitrate formation. All of the growth in soil nitrate levels in the fallow fields comes from decomposing organic matter and conversion to nitrate, since no fertilizer is being added and no crops are using available nitrogen. We observed that even peas will take up quite a bit of soil nitrate before 'fixing' their own from nitrogen gas.

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[1] Copies of newsletters and other information can be found at: waterquality.montana.edu/docs/judith.shtml

RAINFALL AND SOIL WATER STORAGE: For leaching to occur, there must be enough rainfall to fill the soil beyond its capacity (and crop uptake) – it is this excess water that pushes nitrate from the upper layers of soil (where crops can use the nitrogen) down into areas that have contact with groundwater. Depending on the pattern of precipitation in any water year, nitrate in the soil may or may not be leached below the levels where crop roots can reach. Because fallow soils have higher moisture and nitrate levels going into winter and spring, they have the strongest potential for nitrate leaching, despite fallow's known advantages for the next year's crop yield, protein, and weed control.

Downward water movement in soil

Cultivated soils in this area have gravel contacts at depths of about 6 to 36 inches, averaging about 18 inches on the fields in this study. This limits their water storage capacity. At the end of a growing season, soils contain only a small amount of water, as shown under "recrop" in Fig. 2, generally around 10% in this region's clay loam soils, or 1 inch of water in 10 inches of soil. Water doesn't move downward in a soil until water fills its larger pores as shown under "fallow". In this region's soils, this doesn't occur until the moisture content is above about 30%, meaning about 3 inches of water in 10 inches of soil. This means that if more than 2 inches (3 minus 1) of precipitation falls on a soil with 10 inches to gravel, and a crop is not there to take it up, soil water (and available nitrate) will begin to move out of the root zone. If there are 20 inches of soil above gravel, that soil could hold about 4 inches of rainfall.

Evapotranspiration (evaporation plus transpiration from plant leaves) can prevent or minimize water movement below the root zone if it occurs at a faster rate than precipitation, generally mid-June to August on cropped fields. Evapotranspiration is generally not high enough to keep up with precipitation in the Judith River watershed in the wet late April to early June period, especially on fallow fields and spring grains.

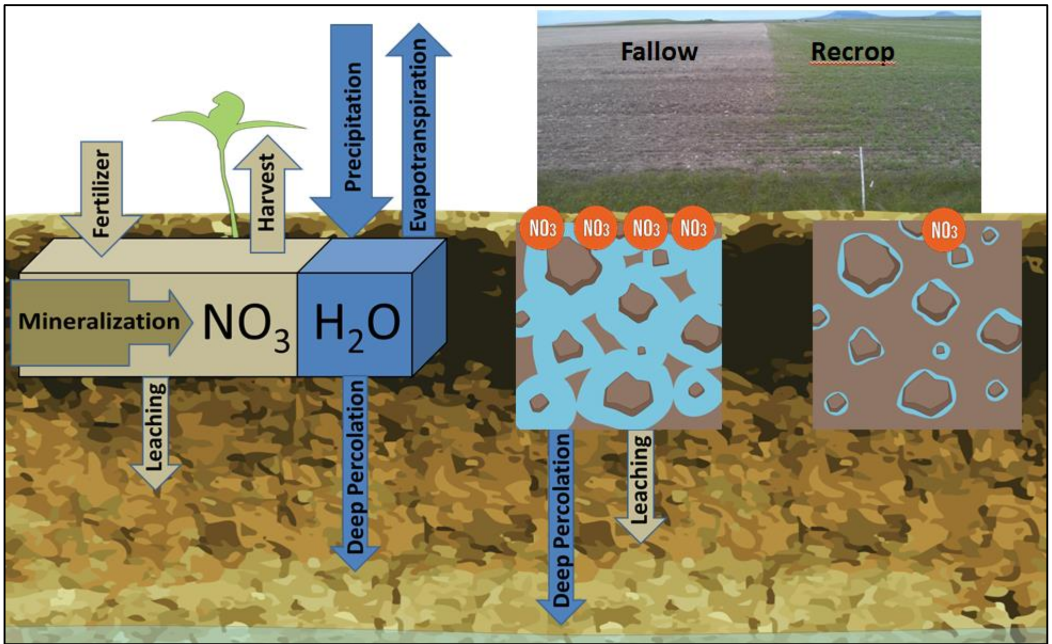

Fig. 2. Nitrate accumulates when release from soil (mineralization) plus N fertilizer are greater than plant uptake + other losses (to atmosphere). Water accumulates when precipitation is greater than moisture losses to the air. Annual cropping, especially fallow, accumulates more nitrate and water than perennial or recrop.

Bottom line: Nitrate leaching is highest when deep percolation occurs simultaneously with high soil nitrate levels.

Look for next month's newsletter which will answer the question: "Do alternative management practices affect my net profit?"