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SUBJECT: Nitrate leaching research proposal.

TO: Bob Naerebout

FROM: Dave Bjorneberg

The following is a research proposal from the Agricultural Research Service at Kimberly, ID to study the potential leaching from agriculture in southern Idaho. We have proposed a three-year project to 1) Estimate nutrient budgets for dairy farms in southern Idaho, 2) Estimate nutrient budgets for crop fields in southern Idaho, 3) Use simulation models to estimate nitrogen losses from agricultural sources, and 4) Monitor water quality in select springs and wells in southern Idaho. This project is slightly different from what we originally discussed with you about one year ago. We decided to measure nutrient budgets on-farm in crop fields rather than installing lysimeters to measure leaching under controlled, but artificial, conditions. We will also measure nutrient budgets for dairy farms. All of the on-farm information will be used to validate two simulation models that will be used to predict nutrient losses from typical agricultural practices in southern Idaho.

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Quantify Potential Nitrate Leaching to Groundwater from Agriculture in Southern Idaho

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Introduction.

Increasing nitrate concentrations have been noted in various springs along the Snake River and wells in southern Idaho (IDEQ, 2008 and 2009). The main focus of this research project is to estimate potential nitrogen (N) losses from the soil root zone from crop fields and potential nutrient loads from dairy farms. This information will be used to identify the relative magnitude of various nitrogen sources so management practices can be appropriately applied to reduce nitrogen losses. Research will concentrate in the Jerome and Gooding county areas where agricultural practices potentially impact water flowing in springs along the Snake River.

Most N applied to soil as either inorganic or organic fertilizer does not remain in its original form. Under certain conditions, N can be converted to a gas and lost to the atmosphere. Microorganisms can immobilize soil N in their body tissue. Other microorganisms can convert inorganic or organic fertilizer N to forms that are readily available for plant growth such as ammonium (NH_4^+) and nitrate (NO_3^-).

The ecological risk associated with NO_3 leaching is due to NO_3 moving below the rootzone where it cannot be used by plants (McNeal et al., 1995; Woodard et al., 2002, 2003). Leaching occurs because NO_3 is water-soluble and negatively charged; thus, it moves with water and is repelled by negatively charged soil particles (unlike NH_4^+ which can be attracted and retained by soil particles). Nitrate that has leached below the crop root zone is a wasted resource because it can no longer be used by plants and ultimately can reach groundwater and potentially surface water contamination through subsurface drainage. The risk has been noted worldwide (China: Gui-Hua et al., 2011; Portugal: Yevenes and Mannaerts, 2011; UK: Howden et al., 2011) due to anthropogenic agricultural intensification.

Nitrate leaching is affected by the amount of water percolating through the soil and the amount of soil NO_3 available to leach. Kohler et al. (2006) applied increasing inorganic N fertilizer rates to a sugarbeet-spring barley-potato-rye rotation grown in sandy soil. Crop yields responded to increasing fertilizer application rate, yet NO_3 leaching losses were the same for all rates because high crop water use limited water movement through the soil profile. Agyin-Birikorang et al. (2012) applied increasing N fertilizer rates to a bermudagrass pasture established on a sandy soil. They showed that N fertilizer rates less than half the recommended rate of 90 kg ha^{-1} did not result in NO_3 leachate above drinking water standards, yet rates greater than 70 kg ha^{-1} caused substantial leaching losses. Schepers et al. (1991) found that Nebraska producers who exceeded fertilizer N recommendations had the highest groundwater NO_3 concentrations in an area with shallow groundwater (2 to 12 m below soil surface). Spalding et al. (2001) measured significant leaching beneath sprinkler irrigated alfalfa even though the alfalfa was not fertilized. Suggested recommendations for reducing leaching losses are careful water management, split fertilizer applications, slow release N fertilizer application, or reducing the current recommended fertilizer application rate.

Using animal manure to fertilize crops is a good way to recycle nutrients but it can be difficult to estimate the amount of nutrients available after application. Askegaard et al. (2011) applied animal manure (up to an equivalent of 70 kg total N ha^{-1} yr^{-1}) to several sandy soils but did not measure an increase in NO_3 leaching as compared to controls (i.e. no manure added), likely due to the manure N application rates being lower than crop demand. However, in cropping systems where animal manures are utilized, N mineralization continues after crop harvest with potentially significant N leaching losses occurring if the soil is left uncropped (Russelle and Jokela, 2007). This is especially true in well-drained sandy soils with low water holding capacity (Simmelsgaard, 1998). Moore and Ippolito (2009) stated that manures left to overwinter on fallow soils may slowly mineralize to form NO_3, which might be taken up by the following crop or could possibly be leached below the rootzone. Read et al. (2008) showed that applying swine effluent to bermudagrass (grown in sandy soil) during peak growth periods did not result in soil N accumulation. However, manure application near the end of the cropping season increased the potential for excess soil N and represented a source for NO_3 leaching to groundwater. Similar observations were made by Eriksen et al. (1999), who in addition found that fall plowing could further increase leaching losses by incorporating additional mineralizable organic N sources (e.g. green manures, crop residues, etc.).

Although it may be difficult to achieve zero NO_3-N leaching losses, especially when crops are grown on sandy soils (e.g. Kohler et al., 2006), proper N fertilizer (be it from inorganic fertilizer or manures) and irrigation management should reduce NO_3 leaching while maintaining crop yield (McNeal et al., 1995; Zotarelli et al., 2007). Simulation models can be used to predict nitrate leaching from various management practices and field conditions. Two such models are the Root Zone Water Quality Model (RZWQM) and the Integrated Farm System Model (IFSM). The RSWQM is a comprehensive model of physical, chemical and biological processes in the soil that influence water quality and soil water movement (Ahuja et al., 2000). It was developed by ARS in Fort Collins, CO. RZWQM has been widely applied in non-irrigated crop production scenarios such as simulating long-term crop production and N losses (Ma et al., 2007), N mass balances in soil (Nolan et al., 2010), $NO3^{-1}$ losses to tile drains (Malone et al., 2007), and effects of fertilizer application practices on N losses (Malone et al., 2010). Once calibrated for an area, the RZWQM can simulate the effects of management scenarios on crop production and N losses. The IFSM is a process-based simulation of dairy, beef, and crop farming systems (http://www.ars.usda.gov/ Main/docs.htm?docid=8519). This farm model was developed by ARS in University Park, PA and provides a tool for evaluating the long term performance, economics, and environmental impacts of production systems over many years of weather. Environmental impacts include volatile N losses, $NO3^{-1}$ loss to groundwater, erosion, soluble and sediment phosphorus losses to surface water and greenhouse gas emissions.

Project Description.

The proposed research has four objectives.

1. Estimate nutrient budgets for dairy farms in southern Idaho.
2. Estimate nutrient budgets for crop fields in southern Idaho.
3. Use simulation models to estimate nitrogen losses from agricultural sources.
4. Monitor water quality in select springs and wells in southern Idaho.

Objectives 1 and 2 will involve data collection from dairy farms and crop fields. This information will be used to estimate nutrient loads and validate simulation models. Simulation models used in Objective 3 will predict N losses for various conditions and practices to provide a more comprehensive estimate of N losses from agriculture in southern Idaho. Water quality monitoring in springs and wells will be used to identify current water quality trends and establish a baseline to assess the impacts of future management practices.

1. Estimate nutrient budgets for dairy farms in southern Idaho.

Nutrient budgets will be calculated for four dairy farms. Nutrient inputs and outputs will be measured or estimated for two dairies in 2013 and two dairies in 2014. The budgets will include the dairy production facility, including waste storage, but not crop land associated with the dairy. Farm inputs and outputs are listed below.

Inputs	Outputs
Feed (total mixed ration)	Milk
Bedding	Wastewater
Water	Manure/Compost
Cows	Emissions
	Cows

Feed, water, fresh manure and wastewater samples will be collected once a month. Feed samples will be collected from the mixed ration, not individual feed ingredients stored on the farm. Milk production and the number of animals (cows, heifers, calves) entering or leaving the farm will be provided by the cooperator. Bedding brought to the farm and manure/compost leaving the farm will also be provided by the cooperator. In addition, the volume of manure and bedding stored on-farm will be estimated monthly when feed and manure samples are collected. Although water provides minimal nutrients, meters on water supply wells will be read monthly for a water budget. Wastewater will either be measured as it enters the storage pond or when it is pumped from the pond depending on the specific situation at each farm. Nutrient losses in air emissions will be estimated based on previous ARS research.

We propose to calculate the nutrient budget at the dairy scale. Fresh manure samples and estimated excretion amounts will allow pen-scale nutrient budgets also (Feed and water input, milk and manure output). Cooperation from the dairy farm owner/manager will be essential to successfully achieve this objective. Although the target area for this project is Jerome and Gooding counties, dairies outside of this area may be selected based on the willingness of the cooperator to be part of this study.

2. Estimate nutrient budgets for crop fields in southern Idaho.

Nutrient budgets will be measured on four fields in 2013 and possibly six to eight fields in 2014 and 2015. Fields with and without a history of manure application will be selected for monitoring. Each field may have more than one monitoring location depending on the variability within the field (soil type, bedrock depth, etc.). Fewer fields will be monitored if measurements are collected from multiple locations in each field.

Field nutrient budgets will involve continuous measurement of soil water content in the root zone with periodic soil and plant sampling (approximately quarterly) to measure nutrient changes. Irrigation and precipitation will be measured with a rain gage in each field. Crop water use will be calculated using potential evapotranspiration (ET) from a Agrimet station (US Bureau of Reclamation) that is adjusted for crop growth in the specific fields.

Cooperation from the farmer is also important for achieving this objective. Sprinkler irrigated fields with sandy soil in Jerome and Gooding counties will be primarily considered. An alternative to measuring nutrient budgets on-farm is using percolation lysimeters, as we originally proposed. Percolation lysimeters allow exact measurements of leaching because all water, nutrients and crop roots are contained within the lysimeter, which is particularly useful for measuring effects of management practices. However, lysimeters provide an artificial environment that can limit root growth that may affect water and nutrient uptake. We decided to measure nutrient budgets on production fields rather than make the major investment in collecting and installing undisturbed soil cores for the lysimeters.

<u>3. Use simulation models to estimate nitrogen losses from agricultural sources.</u>
Information from Objective 1 will be used to validate IFSM for southern Idaho. IFSM will then be used to simulate nutrient losses from various dairy production systems common to southern Idaho to estimate the potential magnitude of losses in Jerome and Gooding counties.

The RZWQM will be initially calibrated with data from research studies at Kimberly and field data from a cooperating farmer east of Jerome. Crop growth and soil nutrient and water data from objective 2 will be used to validate the model for simulating irrigated crop production scenarios for southern Idaho.

Initial RZWQM simulations will compare the potential changes in $NO3^{-1}$ leaching due to changes in crops grown in Jerome and Gooding counties during the last 30 years. Corn has increased from 22,000 acres to 78,000 acres from 1980 to 2009. During the same time period, wheat has decreased from 65,000 acres to 28,000 acres and dry bean has decreased from 37,000 acres to 8,000 acres. Alfalfa crop area was not available until 1988, and has increased from 55,000 acres to 71,000 acres. Later RZWQM simulations will predict NO_3 leaching and crop production for alternate crop production and fertilizer application practices, such as split applications, slow release fertilizer or cover crops, to identify potential reductions in $NO3^{-1}$ leaching and effects on crop yield.

<u>4. Monitor water quality in select springs and wells in southern Idaho.</u>
Starting in October 2012, weekly water samples have been collected from four springs at Clear Springs Foods' Snake River Farm. Historical data show that all springs exhibit a seasonal trend with high NO_3 concentrations in the fall (October) and low concentrations in the spring (May). The four springs occur within 300 ft and NO_3 concentrations vary from 3 to 15 mg/L.

Weekly sampling will continue on these four springs until NO_3 concentrations begin to steadily decline. Samples will be collected biweekly until irrigation water starts flowing in the Northside Canal Company in April, when samples will be collected weekly again. Water samples will be analyzed for pH, EC, NO_3, NH_4, total N, and total soluble elements. Where possible, flow rate of the springs will be measured to determine nutrient loads (mass per time).

Idaho Power and Idaho Department of Water Resources are planning to conduct groundwater tracer studies near Snake River Farms. I cooperation with these studies, 5-10 wells will be identified for monthly water quality sampling. Additional springs in the area may also be monitored.

After the seasonal trends are clearly identified, water samples will be collected from monitored wells and springs for isotope analysis. Isotope analysis will be used to potentially identify water age (tritium: ^3H) and source of NO_3 (^{15}N-NO_3; ^{18}O-NO_3). Samples for isotope analysis will be collected multiple times per year to determine if isotope signatures change seasonally, indicating source water changes during the year. Approximately 80 samples total will be collected in 2014 and 2015.

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