BALANCING AGRONOMY AND ENVIRONMENT: N RECOMMENDATIONS IN ONTARIO FOR THE 21ST CENTURY

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Introduction

The goal of a fertilizer program may be to maximize yields from each field, or to maximize profit, or to minimize environmental impact. Recent instances of groundwater contamination with nitrate have focused attention on the need for source water protection, and agriculture has been implicated as one of the sources of nitrate contamination. This has lead to concerns that environmental rules could reduce the profitability of crop production, by limiting fertilizer use and hence, crop yields.

Additional pressure is being felt by crop producers for the upcoming spring, because of the widening gap between fertilizer prices and crop returns. This has an impact on the fertilizer rates that should be used to ensure maximum profitability. The relative price of fertilizer and crops can also have an impact on the environmental impact of crop fertilization.

Ontario Approach to N Recommendations

Nitrogen recommendations for field crops in Ontario have been developed based on the Maximum Economic Rate of Nitrogen (MERN) concept, where the target rate is the rate which provides the greatest profit per acre from nitrogen application. General N recommendations are developed from the mean results of the MERNs from a number of plots. In the case of corn, the N recommendations are adjusted based on yield, soil type, previous crop, application timing, maturity zone and fertilizer price (Janovicek and Stewart, 2004). For other crops, with less extensive response databases, there might be single recommendation for the province, or adjustments for fertilizer price only.

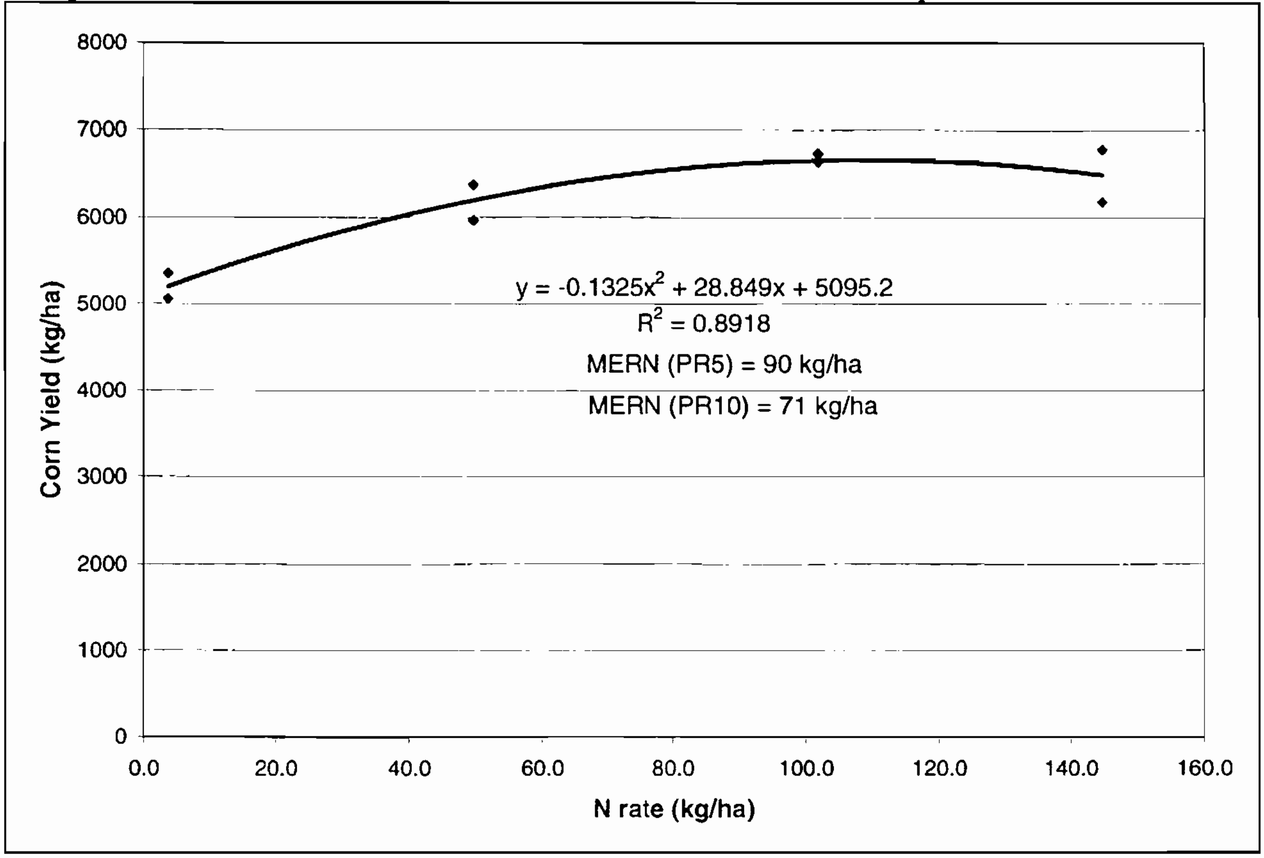
MERN Calculations – a review

The process of calculating the MERN for a particular plot starts with the results of a nitrogen rate trial, where a "best-fit" curve is fitted to the data to describe the relationship between nitrogen rate and yield (Black, 1993). The most common function used in this process is the quadratic equation (Yield = $a + b*N - c*N^2$), or the quadratic-plateau where the yield response levels out at higher rates of fertilizer. The Mitscherlich or square-root functions can also be used, but the quadratic generally fits the data quite well, and I am more familiar with the math so I will limit my discussions to this function.

The yield response curve for a field plot is shown in Figure 1, along with the equation for the fitted curve. The N rate to provide the maximum yield can be calculated by using calculus, taking the first derivative of the equation so that $N_{max} = b/2*c$. In this example, $N_{max} = 28.849/(2*0.1325) = 109$ kg/ha.

This relation does not take into account the cost of the nitrogen fertilizer needed to reach the maximum yield. At low N rates. the value of the yield increase for each increment of fertilizer will be greater than the cost of the fertilizer, but near the top of the curve it will cost more for each increment of fertilizer than the extra yield that is generated. The point where the greatest economic return to fertilizer occurs is the point where the value of the yield increase exactly equals the cost of the fertilizer. Mathematically, this is the point where the slope of the curve is tangent to the ratio between the price of fertilizer and the price of corn (Price Ratio, PR). For the past several decades, the price ratio has hovered around 5; in other words, it took 5 pounds of corn to pay for one pound of N. We can use this value by modifying the equation for the first derivative of the quadratic, subtracting the price ratio from the "b" coefficient. The equation then becomes MERN = (b-PR)/(2*c). In this example, MERN = (28.849 – 5)/(2*0.1325) = 90 kg/ha. If this rate of nitrogen had been applied to the entire field, it would have provided the greatest profit to the grower.

Figure 1: Example of corn response to nitrogen fertilizer rates. The quadratic equation fit to the data points is used to determine the MERN values for different N:corn price ratios.



Impact of N:Crop Price Ratio

General nitrogen fertilizer recommendations for corn have assumed a price ratio of 5. Projections for the spring of 2006, however, are for significantly higher nitrogen fertilizer prices, while the price of corn is not expected to rise significantly. The current list price for urea is around $500 (Can), which translates to $1.09 per kg of nitrogen, or almost 50 cents per pound.

The market price for new crop corn at the elevator is around $2.85 per bushel, or about 5 cents per pound. This gives a price ratio of 10, rather than the traditional ratio of 5.

The impact of this higher ratio is that the economically optimum rate of nitrogen (or MERN) is reduced. For this particular example, the MERN at a price ratio of 10 is reduced by 19 kg/ha. The math to get to this number is: MERN = (28.849 – 10)/(2*0.1325) = 71 kg/ha.

This example is for a single plot, and the actual impact of the change in price ratio will vary depending on how responsive the field is. Fields with a large yield increase with nitrogen fertilizer additions (large "b" value) will be less affected by differences in the price ratio than fields that are less responsive. In practice, this means that fields with a history of livestock manure or forage legumes will likely show a greater drop in MERN than fields in long term cash grain rotations.

The average reduction in optimum fertilizer N rate across the 582 plots that made up the Ontario Nitrogen Database was 7 kg/ha for each unit increase in the price ratio. This means that the optimum fertilizer rates for 2006 should be reduced by 35 kg/ha from the rates calculated for a price ratio of 5.

There are several factors that complicate calculation of the price ratio for a given year. The first is determining the price of fertilizer N, which will vary with the form of nitrogen used. I have used urea in these calculations, but anhydrous ammonia generally costs less per pound of N, so will have a narrower ratio. To be fair, the application cost should be included in the calculations, so the cost used to determine the ratio should be calculated as the material cost per acre plus the application cost per acre, divided by the number of pounds of N applied. The second variable is the price of corn that is used in the calculation, which must be projected into the next selling season. If corn is pre-sold, these prices can be used, otherwise we are using estimates. When calculating the price, any subsidies or deficiency payments should be included in the total value of the corn.

The calculations of price ratios shown here were for Ontario, but the issue is still relevant in the U.S. Corn Belt. Using a projected price for U.S. corn of $2.25/bushel, which includes the market price plus any stabilization or loan deficiency payments, gives a price for corn of just over $0.04/lb. Urea fertilizer, at a price of $370/ton, gives a price per pound of nitrogen of just over $0.40. This results in a price ratio of 10, which is very similar to the situation in Ontario for the coming year. This indicates that, for maximum profitability, the N fertilizer rates across the Corn Belt should decline by a similar amount.

Environmental Impacts of N rates

Excessive nitrogen applications, from fertilizer, manure, forage legume plowdowns, or a combination of sources, have been implicated in elevated nitrate concentrations in groundwater, and in nitrous oxide emissions which are linked to climate change. The easiest response to this perceived threat is to call for reductions in nitrogen fertilizer rates across the board, but this may not provide the desired benefits.

Throughout Ontario, and much of the eastern part of the Corn Belt in the U.S., there is more loss of moisture through evapotranspiration through the growing season than is replenished by precipitation. This means that there is little or no net downward movement of soil moisture during the growing season, and hence low risk of nitrate leaching. The opposite situation occurs, however, during the late fall to early spring period, when precipitation exceeds evapotranspiration. Residual soil nitrogen (RSN) that is present in the soil following crop harvest is at greatest risk for leaching to groundwater. There is also some research to suggest that nitrous oxide emissions are also greater with elevated RSN that results from fertilizer applications above the MERN for a field (Claudia Wagner-Riddle, personal communication).

Measurements of nitrate leaching below the rooting zone, or of nitrous oxide emissions, are difficult and expensive to collect. The risk of these losses, however, will be increased by elevated levels of nitrate in the soil prior to the winter season. The mineral N content following harvest can be measured relatively easily and cheaply, to provide an indicator of the risk of nitrogen losses to the environment.

As part of the Greenhouse Gas Mitigation Program for Canadian Agriculture – Demonstration and Awareness Activities, soil samples were collected following harvest on livestock farms that had received nitrogen rate strips. This allowed the correlation of RSN with deviation from MERN.

Materials and Methods

Ten on-farm demonstration sites were established across the corn producing regions of Ontario in 1994. Nine of these sites had received uniform applications of manure during the late summer or fall of the previous year, and the tenth site received side-dressed liquid hog manure in June of that year. Corn was planted in early to mid-May at each of the sites, using normal farm management practices with the exception of fertilizer N application. Four rates of nitrogen fertilizer (0, 50, 100 and 150 kg N/ha) were established by side-dressing the appropriate rate of UAN solution (28-0-0) during June. The yields from the fertilizer N strips were used to estimate the maximum economic rate of N (MERN) for each site (Deen *et al*, 2005).

Table 1: Description of location, manure history and yields for sites included in this study.

County	Manure Type and Rate	Last Applied	MERN (kg/ha)	MEY (kg/ha)
S,D&G*	L. Beef, 6000 gal/ac	Fall 2003	0	11682
Huron	S. Broiler, 4 t/ac	Fall 2003	145	10620
S,D&G*	L. Dairy, 8000 gal/ac	Fall 2003	4	9100
Huron	L. Swine, 5000 gal/ac	Summer 2003	130	10413
Perth	L. Swine, 6000 gal/ac	Fall 2003	93	10406
Perth	L. Dairy, 6500 gal/ac	Fall 2003	93	9768
Wellington	S. Broiler, 5.25 t/ac	Fall 2003	59	9639
Wellington	L. Swine, 2900 gal/ac	Fall 2003	86	9344
Durham	L. Dairy, 6000 gal/ac	Fall 2003	32	10725
Perth	L. Swine, 4000 gal/ac	Side-dress 2004	133	10231

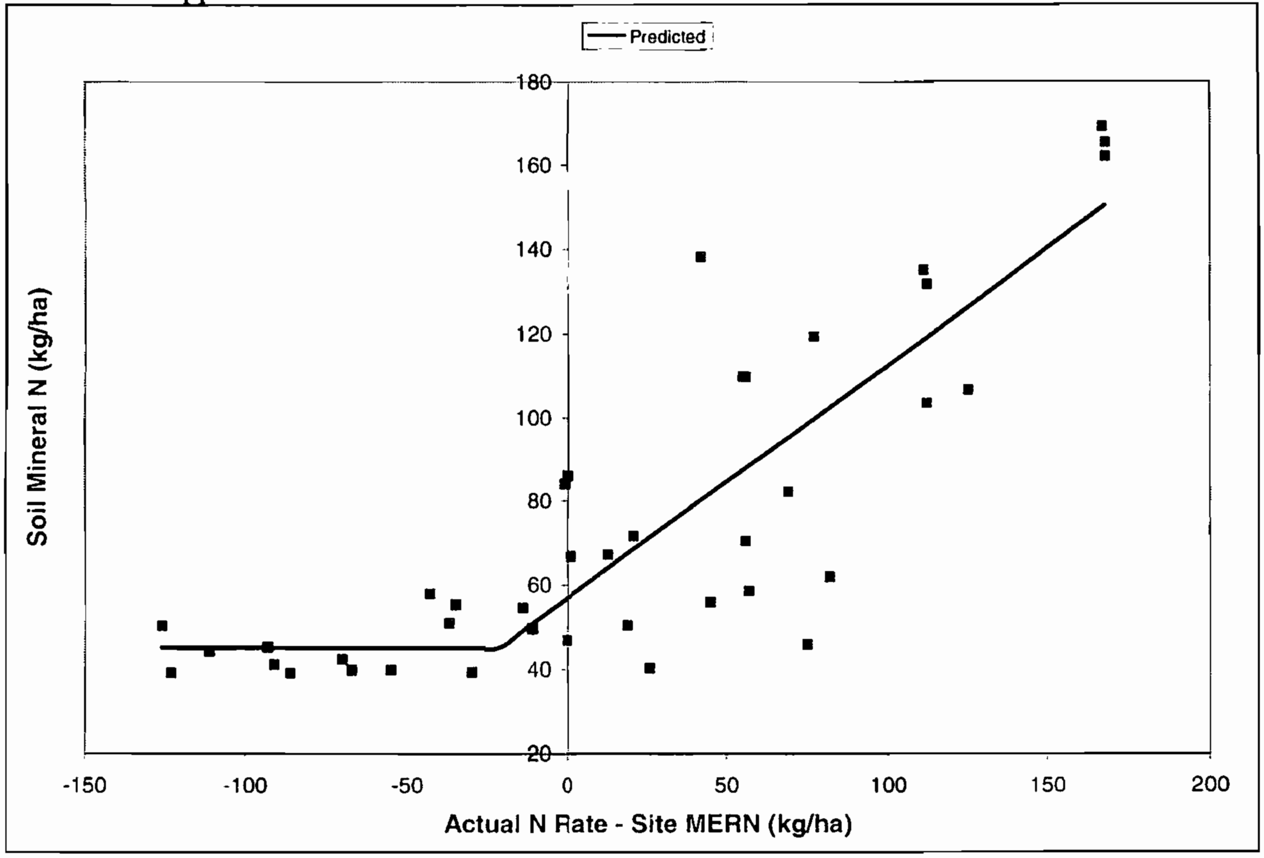
*United Counties of Stormont, Dundas and Glengarry

Soil samples to a depth of 30 cm were collected immediately following corn harvest from the various nitrogen treatments, and analyzed at a commercial soil test lab for nitrate- and ammonium-N concentrations.

Results and Discussion

Figure 2 illustrates the trend of residual soil mineral N (NH_4-N + NO_3-N) following corn harvest with different fertilizer application rates. On rate strips where the nitrogen fertilizer application was less than the economic optimum for the site (negative values on the x-axis), the residual soil mineral N content was relatively constant, averaging about 42 kg/ha. As the application rates exceeded the economic optimum, the average mineral N content in the surface 30 cm increased from about 55 kg/ha to 150 kg/ha.

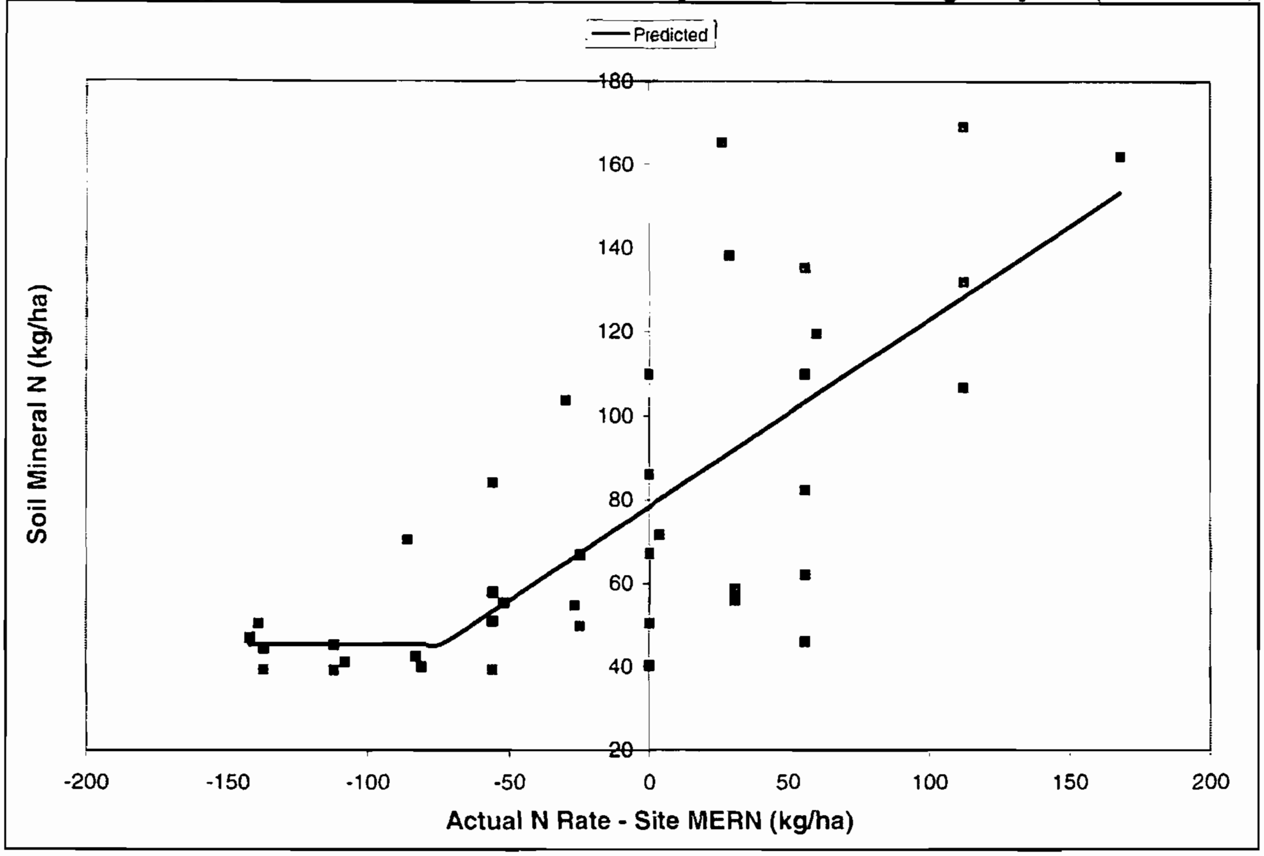
Figure 2: Residual Soil Mineral N (NH_4-N + NO_3-N) following corn harvest, relative to the deviation of applied N from MERN for each site. MERN were calculated for a PR=5.



Clearly, applying nitrogen in excess of economic requirements contributes to increased mineral N concentrations in the soil at the end of the growing season. This soil N is subject to environmental losses, including leaching to groundwater, or conversion to nitrous oxide which is a greenhouse gas.

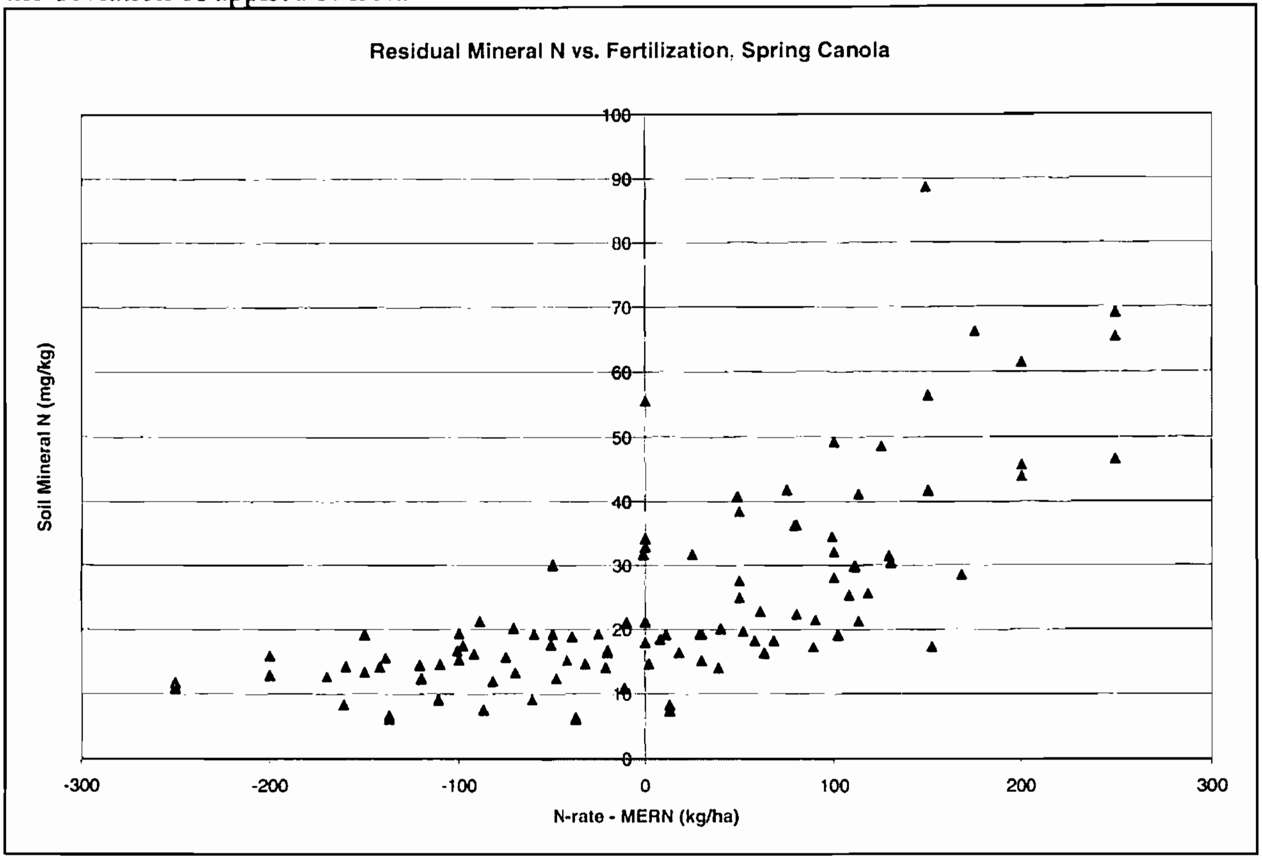
Some farmers, and some state fertilizer recommendations, target the nitrogen rate which provides the maximum corn yield, rather than the maximum economic return. This can increase the risk of environmental impacts, since the levels of residual mineral N at the point of maximum yield have already begun to climb. Figure 3 illustrates the relation of post-harvest soil mineral N concentrations with fertilizer application rates targeting maximum yield.

Figure 3: Residual Soil Mineral N (NH_4-N + NO_3-N) following corn harvest, relative to the deviation of applied N from the lowest N rate that provided maximum grain yield (i.e. PR = 0)



The discussion to this point has focused on the nitrogen response of corn. There are, however, many other field crops that are equally, or more responsive to nitrogen fertilization, including cereal crops, canola, and most horticultural crops. A recent re-assessment of general nitrogen recommendations for spring canola included post-harvest soil sampling of some of the sites (Rowsell *et al*, 2005). The impact of N fertilizer rates in spring canola on residual soil mineral N is shown in Figure 4. The pattern of constant soil N concentrations up to the economic N application rate, and increasing beyond this point, is very similar to the pattern in corn.

Figure 4: Residual Soil Mineral N (NH_4-N + NO_3-N) following spring canola harvest, relative to the deviation of applied N from MERN for each site. MERN were calculated for a PR=3.



Summary

Nitrogen fertilizer management is a key component of both economic and environmental sustainability of field crop production. Increasing nitrogen fertilizer costs, when not accompanied by rising crop prices, mean that the economically optimum nitrogen rates for crop production are reduced. At projected fertilizer and crop prices for 2006, the average reduction in nitrogen recommendations for corn is 35 kg/ha from "normal" values.

Environmental impacts from nitrogen fertilizer application are more closely related to excessive N application, than to total N application. This is reflected in the amount of residual soil nitrogen in the surface 30 centimeters following crop harvest. Nitrogen fertilizer rates that exceeded the economic optimum for the crop increased the amount of mineral N remaining in the soil at the end of the growing season, and therefore increased the risk of nitrate leaching or nitrous oxide emissions.

The challenge for growers is to predict the optimum N rates for a given year early in the growing season. This prediction will never be completely accurate, because of the variability in weather, but tools are available to help the grower come relatively close in most cases. The good news is that the target rate for this prediction will provide maximum economic benefits to the grower, while not compromising environmental health.

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