Using an Exchange Frequency Index to Identify Sites at Risk of Over-Winter Leaching

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Introduction

Variable soil nitrate-nitrogen (NO_3-N) accumulation following summer crops is common in dryland cropping systems due to variable precipitation patterns and the consequent challenges of matching N rate to the season. Tools to characterize N loss potential at a farm and regional scale are important to minimize environmental impacts from agriculture, for example by targeting cover cropping to high risk sites. The soil solution exchange frequency, proposed by Hölting, *et al*. (1995), was evaluated as a potential leaching index for well-drained Mid-Atlantic soils over the winter-wheat growing season.

Methods

Soils:

- The NRCS soils database was used to estimate the 60 cm deep available water holding capacities (AWHC) of each field site's soil series, which contained textures of loamy sand to silt loam and AWHCs ranging from 66 to 136 mm.

Nitrate loss:

- Soil samples were take to a 60 cm depth at 8 sites and NO_3-N was measured in the fall and again in the late-winter or early-spring (Fig. 1) using standard Cd reduction methods.

Fig. 1 Collecting 60 cm soil samples from experiments

Fig. 2 Lysimeter construction Palmer *et al.* (2011)

Bromide loss

A series of field and lysimeter studies provided Br loss data.

- A fall surface-application of KBr was made to replicated plots at 14 field sites in Maryland.
- Soil cores to 60 cm were collected during the fall-winter season to monitor Br loss from these field sites.
- Soil-column lysimeter studies also measured Br loss in the leachate over 3 years during defined fall-winter periods.
- Br analysis of soils and leachate was by ion chromatography.

Exchange Frequency Index (EFI) of the soil solution

A simple leaching risk index was calculated by:

$EFI = (\text{Precipitation, mm})_{\Delta t} * (\text{soil AWHC, mm})^{-1}$

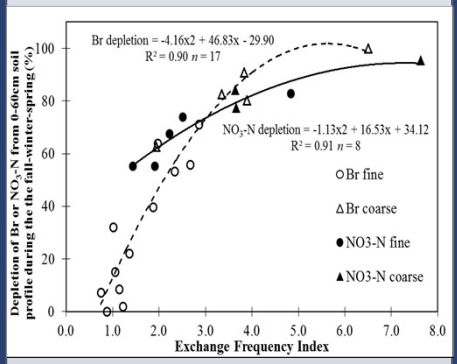
Assumptions or approximations in using this simple index

1. $\text{Precipitation}_{\Delta t}$ estimates potential drainage through the soil, i.e., precipitation over Δt is much > runoff and evapotranspiration.
2. Soil AWHC approximates the active volume of soil participating in solute movement.
3. Soil moisture at winter wheat planting is near FC, so all the precipitation over Δt is available for leaching.

Results & Discussion

- The EFI was highly correlated with NO_3-N and Br depletion to 60 cm depth (Fig. 3) because it effectively combines two major drivers of leaching: soil AWHC and precipitation.
- For EFI ≥ 2.5 the % decrease in non-reactive Br which has minor plant uptake was >60% and >65% for NO_3-N (Fig. 3). The NO_3-N decreases can be attributed to leaching, denitrification, immobilization, and wheat N uptake.

Fig. 3 Depletion of NO_3-N (solid line) and Br (dashed line) 0-60 cm during the fall-winter-spring groundwater recharge period under winter wheat cropping.



- However, the similar pattern of Br and NO_3-N reductions vs. EFI, for comparable EFI ranges (i.e., EFI >1.4) in Fig. 4, is consistent with the view that leaching is a major avenue of fall-winter NO_3-N loss in well-drained Mid-Atlantic soils.
- Table 1 summarizes EFI estimated leaching risks for three soil textures. A loamy-sand represents a "high" or "very high" risk in 58% of years, compared to 18% of years for a silt loam soil.

Fig. 4 The combined percent reduction in NO_3-N and Br vs. EFI, for EFI >1.4, were not statistically different (P= 0.36), Kleinbaum and Kupper (1978).

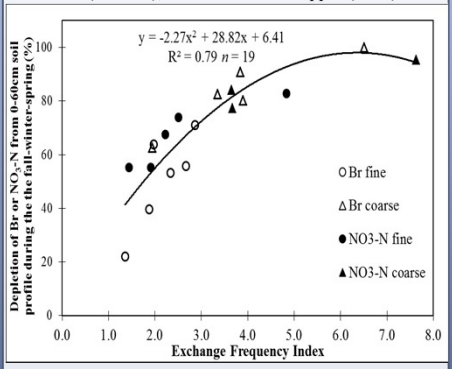


Table 1: The EFI for three soil textures based on 141 years precipitation data from Baltimore, MD during the post wheat-planting period (15 Oct.-30 Nov.).

Soil Texture	Soil AWHC	EFI and Leaching Risk			
		<0.5	0.5 – 1.5	1.5 – 2.5	≥2.5
	mm	Low	Moderate	High	V. High
		% of Years in Leaching Risk Category			
Loamy sand	66	0.7	41.1	37.6	20.6
Sandy loam	95	7.1	59.6	31.9	1.4
Silt loam	119	12.1	69.5	18.4	0

Conclusions

- Nitrogen leaching is driven by soil physical characteristics, variable precipitation patterns, and the presence of NO_3-N.
- The EFI is a simple and effective indicator of NO_3-N loss potential that is suitable for use at field scales, in well-drained soils in the Mid-Atlantic region.
- Over-winter N losses are site and year specific, thus these factors should be integrated into the development of future fall NO_3-N conservation strategies.

References

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