Optimizing Fall Nitrogen Management under Conditions of Extreme Moisture

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Executive Summary

Effective nitrogen management strategies using the 4R nutrient stewardship (right source, rate, timing and placement) can help to reduce nitrogen losses and optimize profitability. Soil moisture is at the nexus of, and plays an important role in many nitrogen form conversions and loss pathways. On a practical level, however, our inability to accurately forecast moisture conditions hampers our ability to decide if and when specific N management practices should be applied. The objective of this study was to develop a data-based decision support information to help farmers assess and manage the potential risks associated with fall nitrogen fertilizer management under extreme moisture conditions. The information will indicate when proactive measures to protect applied nitrogen are warranted, protecting yields and the fertilizer investment as well as reducing nitrogen in runoff, groundwater and greenhouse gasses. This represents a new approach for refining N management recommendations based on soil moisture conditions.

Fall precipitation data from 1961 – 2012 were analyzed at sixty-six locations in Manitoba. These locations were divided into five regions using the Manitoba Agriculture and Resource Development reporting delineation and analysis conducted for coarse, medium and fine textured soils. The amount of water filled pore space (WFPS) at the top 30 cm was used to determine the risk of nitrification and denitrification and the WFPS for the entire 130 cm depth was used for the leaching loss risk.

Likelihood of receiving a specific amount of precipitation was generated using a novel method of calculating 3-day sums rather than daily precipitation values. This was done to capture a wider window of precipitation that may be a more relevant timeframe to soil moisture than daily values. This method tends to inflate the influence of small precipitation on the likelihood of receiving a specific amount of precipitation but does help identify larger multi-day precipitation events.

Thresholds for identifying N transformations or losses (risk levels) were set at <40% WFPS for negligible nitrification and denitrification, 40-90% WFPS for nitrification but negligible denitrification and >90% for predominantly denitrification. Leaching thresholds are based on an estimated field capacity for each textural group of 20%, 30% and 40% volumetric moisture content for coarse, medium and fine textured soils, respectively. The range of soil moistures represented by the low, medium or high categories is defined based on the common moisture content of actual soil profiles within each group. Risk level is determined by adding precipitation to what is assumed to already be in the soil then determining if a threshold has been exceeded.

While there are a number of local nitrogen management studies that could be used for validation, very few of them reported the required information to validate the information generated by this study. Only two studies were able to be used for validation. In one study, all years were estimated to have a yellow level of risk and did not display any treatment effects that indicated N losses. In the other study, only one year was estimated to have elevated risk of N loss but also did not display any treatment effects that indicated N losses. Since cases indicating a red level of risk are not all expected to exhibit treatment effects or actual N losses, validation of the new information proved inconclusive. A larger number of site-years or feedback from users will be required to determine if the risk tables are performing adequately.

This study provides a good proof-of-concept that the combination of historical precipitation and the use of soil physical properties with defined thresholds can be used to determine the risk of nitrification and denitrification and leaching based on the amount of additional precipitation.

Introduction

Unlike regions with predictable weather patterns, Manitoba is subjected to conditions ranging from drought to flood. As a result, moisture extremes present a significant challenge for Manitoba's agricultural industry. In addition to the direct effects of erratic moisture conditions on crop yield and quality, one of the key questions from both a production and environmental standpoint is "How can growers best manage nitrogen (N) fertilizer under extreme moisture conditions to ensure that crop N demands are met and crop productivity is optimized while N losses are minimized?". The question of how best to manage risk to select an N management strategy that is a balance between effectiveness, profitability and environmental stewardship is complex. A vast body of research exists regarding N processes and management practices, which supports the underlying principles of the 4R fertilizer stewardship management framework: right source, right rate, right time, and right place (https://fertilizercanada.ca/nutrient-stewardship/). One of the challenges under Manitoba conditions is that the "right" best management practice (BMP) under a certain set of moisture conditions may not be the best approach under a different set of moisture conditions. As such, although the relationships among N processes, the relative efficacy of various N management practices, and environmental conditions are well-understood, in practical terms, it is difficult to select optimal N management practices without information about soil moisture.

As an example, moisture conditions may be an important consideration in decisions surrounding the use of conventional versus enhanced efficiency fertilizers (Grant, 2014). Enhanced efficiency fertilizers (EEF) chemically (e.g. nitrification inhibitors, urease inhibitors) or physically (e.g. coated N products) alter N transformation processes or movement following application. While use of these higher-cost fertilizers may reduce N losses via denitrification and leaching under wetter conditions, this may not be an important consideration under dry conditions where N losses are insignificant (Grant & Wu, 2008). In studies conducted across a range of environmental conditions at four locations across Canada, urea banded at seeding was generally found to be as effective or more effective than banded controlled release urea (CRU), split-applied urea, or a blend of conventional urea and CRU in increasing early season biomass and seed yield for canola, wheat and barley (Grant et al., 2012). In select cases only, typically under higher moisture conditions in the Aspen Parkland or Boreal Transition ecoregions, split application or a blend of urea and CRU increased yield compared to conventional urea. Conversely, CRU occasionally delayed early-season N release and growth to the extent that yield depression resulted. Economic analysis indicated that non-coated urea resulted in net revenues that were similar to or higher than CRU, split-applied urea, or a blend of conventional and CRU under the conditions of this study (Khakbazan et al., 2013).

Like EEF, split-application of N may assist in reducing N losses and enhancing yield under wetter conditions but provide no yield benefit under dry conditions (Grant et al., 2012; Malhi et al., 2010). Regardless, conducting an additional pass over the field to apply fertilizer in-season increases operational costs and labour. While split application may allow growers the opportunity to assess early-

season crop growth and “top up” N accordingly, in-season broadcast N applications may also be subject to stranding at the soil surface under dry conditions.

The relative efficacy of fall-applied versus spring-applied N may similarly be influenced by environmental conditions (Tiessen et al., 2005). The farther in advance of crop N uptake that fertilizer N is applied, the greater the potential for N losses especially under wetter conditions (Malhi et al., 2001).

While a trove of research has demonstrated the benefits of various N management practices under specific conditions, as the above examples outline, on a practical level our inability to accurately forecast moisture conditions hampers our ability to decide if and when specific N management practices are warranted. The lack of quantitative information regarding the risk of extreme moisture conditions means N management decisions are often based on general recommendations and the experience of the grower or advising agronomist.

The aim of the study is to provide producers and agronomists with data-based information to aid in optimizing fall N management decisions by pro-actively managing the moisture related risks associated with N fertilization, by linking the likelihood of extreme moisture conditions with N dynamics and well-established 4R BMPs. This task can be broken into several parts. The first is to determine the likelihood of extreme moisture conditions occurring during critical periods of the year when N management decisions are being made and implemented. The second is to determine the relative risk of N losses occurring as a result of moisture conditions. The final step is to develop guidance information to aid producers and advisors in making improved N management decisions under various moisture scenarios. To achieve this, historic precipitation data was used as an indicator for the likelihood of extreme moisture conditions occurring. A set of criteria was then developed to indicate how and when soil moisture is likely to affect N transformations and N losses. Producers and advisors can use this indicator of risk to apply 4R principles to improving N management decisions, proactively mitigating potential moisture related risks, when the risk for moisture related N losses is high.

Methods

Data processing

Data processing and table creation was scripted using python. Before processing, the large historical data files were split and organized to enable selective loading of specific station data based on region or other criteria. This step greatly reduced the memory and processing time required to process later steps.

Two main python scripts were used to generate the final tables. The first script uses daily volumetric moisture content (VMC) data and soil physical properties to determine the static parameters used to format all the final risk tables. This script outputs a text file containing appropriate soil moisture categories for each soil textural group as well as converted risk thresholds in mm of additional precipitation required to reach or exceed threshold values. Processing time is reduced substantially by using this output table rather than recalculating each time new risk tables are generated. The second script uses historical daily precipitation data to generate the likelihood of specific amounts of rainfall occurring and combines this with the previous output to apply the formatting for risk of N losses following an event.

Region

Precipitation data from 1961 – 2012 were analyzed from sixty-six locations in Manitoba. These locations were divided into five regions using the Manitoba Agriculture and Resource Development reporting delineations. Figure 1 shows the regions and locations used, these are Central (18 locations), East (11 locations), Interlake (10 locations), North West (10 locations) and South West (17 locations).

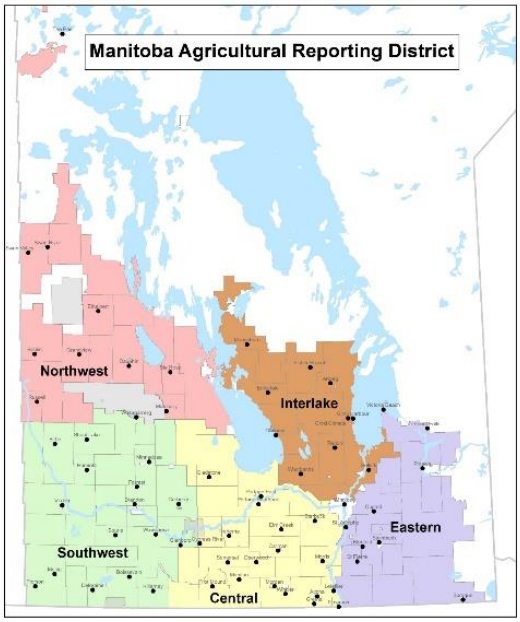


Figure 1. Manitoba Regions and Locations.

Calculating Likelihood of Precipitation

The longest period on the risk tables spans from September 1st to November 10th. Each successive period decreases by about two week intervals. The five Periods included on each table begin on 1-September, 15-September, 01-October, 15-October and 01-November. All Periods end on 10-November, the normal Manitoba deadline for fall applied N fertilizer. The Periods can be easily changed or expanded to include any part of the year.

Likelihood of a particular amount of rainfall occurring is generated using 52 years of historical weather data. First, only data from locations within the requested region are loaded. The data is then filtered to include only days within the Periods of interest. Precipitation is then converted into a series of three-day moving sums for each station-year. The three-day precipitation totals are then grouped into 12.7 mm (½") bins and the number of events in each bin is determined. Bin counts for each station are then converted to counts per year. Finally, the regional mean of all stations is found for each bin. Regional three-day precipitation counts are reported per year, per 10 years or per 100 years avoiding decimal values as numerators.

Calculating precipitation as a series of three-day moving sums was done for several reasons; receiving precipitation as large single day events may not allow time for the water to percolate into the soil, and soil moisture is also affected by precipitation received in previous days. This procedure should help capture the impact of longer slower precipitation events. Reporting the likelihoods as three-day moving sums tends to inflate the number of short duration precipitation events by a factor of roughly 3. Three-day sums seemed to be a good compromise between creating a measure of precipitation that

additionally accounts for recent rainfall and inflating the perceived likelihood of short duration rainfall events.

Textural Classes and Current Soil Moisture Ranges

Soil texture influences bulk density and porosity, affecting both field capacity and REDOX conditions. This makes soil texture an important parameter with respect to nitrification, denitrification and leaching. Separate tables were generated for three broad soil textural classes; Coarse, Medium and Fine.

Manitoba Agriculture soil moisture probe installations began in 2016 (Ojo and Manaigre, 2021). Although we do not have a soil moisture dataset of sufficient duration to compare directly to historical precipitation data, these data can be used to determine a reasonable range of soil moistures that would be commonly observed for each textural group. This provides a range of values for each textural class to be used as a convenient starting point for estimating and assessing the current field moisture.

Recent daily soil moisture data (2016 to 2020) from 106 locations with records for 5cm, 20cm, 50cm, and 100cm depths was used. These depths were assumed representative of soil layers from 0-10cm, 10-30cm, 30-70cm, and 70-130cm, respectively. Texture of each soil depth at each location was based on analysis using the pipette method performed by Maxxam labs. Textural classes were defined as groupings of sand and loamy sand for Coarse (n=78); loam, sandy loam, sandy clay loam, silty loam and silt for Medium (n=226); and clay, clay loam, heavy clay, silty clay loam, silty clay and sandy clay for Fine (n=128). Due to the limited number of location-depth-years in the daily soil moisture data, locations from all regions were used together to determine appropriate moisture ranges for soil textures at specific depths.

The minimum expected soil moisture content of a textural class at a specific depth was found as the mean of the 200-day non-winter minimum values of soil moisture. A minimum of 50 good records was required to include 200-day minimum values in the calculation. Saturation values were determined using pedotransfer functions from Saxton et al. (1986), the mean for a textural class at a specific depth was used as the maximum expected soil moisture content. A small downward adjustment was made to the expected minimum and maximum soil moisture values by multiplying by 0.9. This has the effect of slightly decreasing and narrowing the expected range of soil moisture values. The ability to apply adjustments was added to allow some flexibility and control over the moisture ranges.

The Current soil moisture categories on the risk tables (Low, Medium and High) were then determined by dividing the range between expected minimum and maximum for each texture class and depth into thirds. The values of soil moisture reported on the risk tables are in percent VMC for ease of use. Although unlikely, the actual moisture content of soil may fall outside of these ranges in extremely wet or dry situations.

Nitrification and Denitrification Risk Tables

Water filled pore space (WFPS) is a better indicator of microbial driven N transformations than VMC because it inherently includes a measure of air filled pores which can be an indicator of soil REDOX potential (Linn & Doran, 1984). Conversion between VMC and WFPS requires a measure of soil porosity (Equations 1 and 2), which was estimated using reasonable values of bulk density (Table 1) and particle density of 2.65 g cm^{-3}.

Table 1. Estimated bulk density by texture and depth.

	Estimated Bulk Density (g cm $^{-3}$)		
Depth (cm)	**Coarse**	**Medium**	**Fine**
0-10	1.55	1.20	1.35
10-30	1.55	1.20	1.35
30-70	1.60	1.20	1.40
70-130	1.60	1.20	1.40

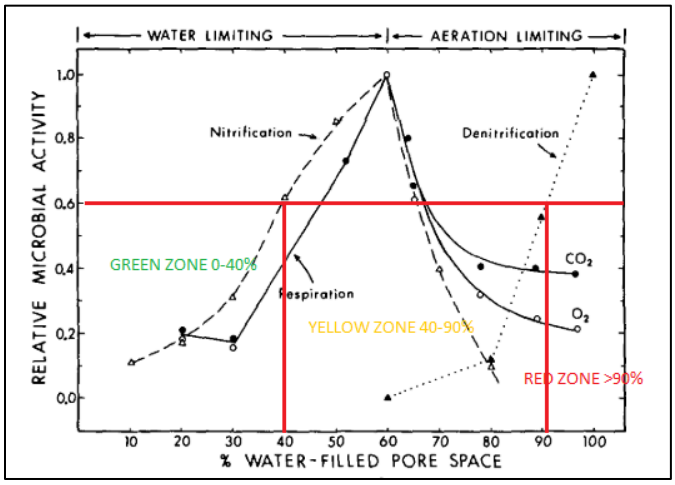
Porosity = 1-(Bulk Density/Particle Density) [1]

WFPS = VMC/Porosity [2]

Nitrification and denitrification are microbial processes, which are most active in the surface soil layers where most N, microbes and substrates for microbial growth are likely to be found (Huang et al., 2014). Therefore, only the 0 to 10 cm and 10 to 30 cm depth layers were used, simulating a 0-30 cm deep profile for nitrification and denitrification risk formatting. Formatting thresholds were set based on Linn and Doran (1984). Setting a relative microbial activity threshold of 60% yields WFPS formatting thresholds of 40% and 90%, which correspond to rapid increases in the rate of nitrification and denitrification, respectively (Figure 2). Ultimately, the choice of setting thresholds based on microbial activity of 60% was somewhat arbitrary and could be adjusted in the future to fit better with observations. This means colours on the nitrification and denitrification risk tables indicate:

- Green – negligible nitrification and denitrification are expected.
- Yellow – nitrification is expected, negligible denitrification is expected.
- Red – potential for substantial denitrification exists.

Where the center point of a soil moisture category (Low, Medium or High) is projected to be below 40% WFPS after adjusting for the additional precipitation in the column heading the colour formatting applied to risk table cell will be green (Figure 3). If the center point of a soil moisture category is projected to be between 40% WFPS and 90% WFPS, the cell will be formatted yellow. Lastly, if the center point of an initial soil moisture category is projected to be above 90% WFPS, the cell will be formatted red.



microbial nitrification, denitrification, respiration. Choice of nitrification and denitrification thresholds. (From Linn and Doran 1984)

Figure 2. The relationship between water-filled pore space and

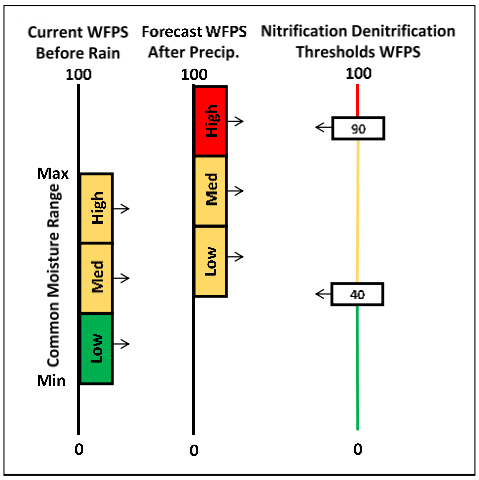


Figure 3. Nitrification and denitrification thresholds interacting with current and forecast soil moistures producing formatting colours for final nitrification and denitrification figure.

Leaching Tables

Leaching is a physical process that happens when excess moisture throughout the soil profile moves N beyond the rooting zone depth. All available depth layers are within the rooting zone and were used to simulate a 0-130 cm deep profile for the leaching risk tables. An estimate of field capacity was used as the soil moisture threshold above which excess moisture will drain to deeper soil layers. Reasonable VMC values for field capacity were chosen for each textural class based on expert opinion (Coarse 20%, Medium 30% and Fine 40% VMC). Specifically, leaching risk formatting colours indicate:

- Green – no leaching expected.
- Yellow – soil moisture is approaching field capacity, leaching possible.
- Red – soil moisture is above field capacity, leaching likely.
- Grey – low risk of leaching expected at any level of rainfall for fine textured soils; low hydraulic conductivity.

If all values of WFPS in soil moisture category (Low, Med or High) are projected to be below field capacity after adjusting for additional precipitation of the column, the cell will be formatted green (Figure 4). If an initial soil moisture category is projected to contain the value for field capacity, the cell will be formatted yellow. Lastly, if all values of WFPS are projected to be above field capacity, the cell will be formatted red. For fine textured soils that are not prone to leaching, all cells have been formatted grey regardless of the soil moisture or precipitation.

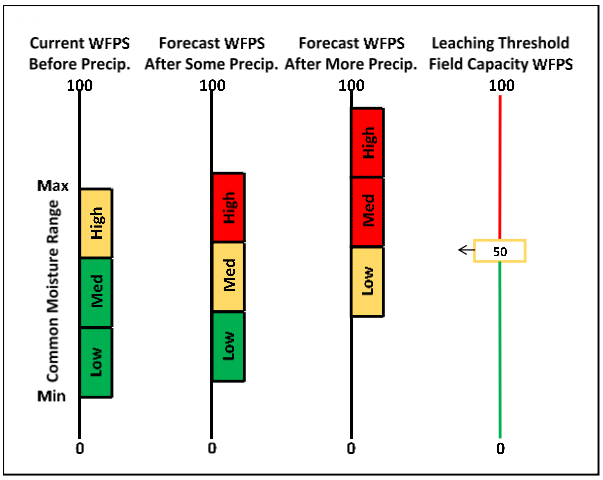


Figure 4. Leaching threshold (field capacity) interacting with current and forecast soil moistures producing formatting colours for final leaching figures.

Verification

Local N management research studies from Manitoba and Saskatchewan were compiled and used to validate that the risk tables can be used to identify high risk of N loss scenarios. Site-years that were likely to have experienced increased risk of N losses were then correlated with the effects of improved BMPs for fall applied N treatments. If the frequency of significant effects for treatments using improved 4R BMPs was higher where the risk of N loss was identified as elevated it would provide strong evidence that the risk tables are working as intended.

The ideal N management study should include:

- A known N application date,
- A known soil texture,
- Have onsite or nearby measures of soil moisture at the time of N application,
    - Nitrification and denitrification (0-30cm),
    - Leaching (0-130cm),
- Have onsite or nearby measures of daily fall precipitation,
- Nitrogen management treatments
    - At least one “basic” fall N management treatment,
    - At least one “improved” fall N management treatment,
- Measures of N loss or efficiency,
    - N losses and efficiency – yield, N uptake, residual N, NUE, volatilization, leaching, etc.
    - Greenhouse gasses – N_2O emissions (non-agronomic levels of N loss).
- Treatment effects reported for individual locations and years.

The risk level of a specific site year was determined by first finding the Period of the risk table that begins closest to the N application date. Next, the specific row of the table was found by categorizing the soil moisture level at the time of N application into Low, Medium, or High using the best available source. Lastly, using the best available source, precipitation that fell during the Period between N application and November 10th was converted into 3-day sums and the maximum value was used to select the column from the risk table. The corresponding level of risk can then be read from the table and compared with evidence of N losses from the study.

Results and Discussion

Use and Risk Levels

The risk tables (Appendix B to Appendix P) are designed to aid producers and advisors by indicating when the risk of losing applied nitrogen is elevated, proactively facilitating loss mitigation through improved nitrogen management practices. This can directly benefit producers by potentially reducing N losses and improving yields as well as provide the environmental benefits of reducing N in runoff, groundwater and greenhouse gasses.

To use the tables, first select the table for a specific region and texture, make a reasonable assumption of what the current soil moisture conditions are for the field, then use the likelihood of receiving precipitation to decide on a level of risk to assume. When high risk of N loss scenarios are likely, management decisions can be made to reduce the risk through the employment of improved management practices using 4R principles. For example, if "business as usual" includes fall broadcast incorporated urea or banded anhydrous ammonia, high risk of N losses might be mitigated by improving management by banding urea, using an N efficiency product or delaying N application several weeks or until spring. More information on recommended 4R BMPs can be found at https://fertilizercanada.ca/resources/4r-guidance-tables/ and https://gov.mb.ca/agriculture/crops/seasonal-reports/pubs/nitrogen-fertilizer-in-wet-fall.pdf for Manitoba specific resources. Detailed instructions and examples can be found in Appendix A.

Sound 4R N BMPs should be employed regardless of the indicated level of risk. The risk tables are only intended to indicate when additional precautions for preserving N with improved 4R BMPs might be warranted. Tables indicating Low risk should not be used as justification for poor N management. The green risk level for nitrification and denitrification does not always indicate low risk for all possible N management decisions. For example, although this is not a recommended practice, surface broadcasting untreated urea on dry soil with low likelihood of precipitation would be at higher risk of N loss from volatilization than the same activity under wetter conditions where surface-applied urea may be dissolved and moved into the soil. Likewise, the yellow risk level for nitrification and denitrification does not necessarily indicate more N losses than a green risk level. However, time spent under a yellow level of risk may "set the stage" for future losses. The yellow risk level indicates nitrification will be the dominant process leading Urea, NH_3 and NH_4^+ forms of N to become NO_3^-. Nitrate (NO_3^-) is much more mobile in soil increasing potential leaching losses; it can also be reduced to N_2 increasing potential denitrification losses. Both may contribute to further N losses if the conditions exist after spending time at the yellow level of risk.

Verification

Of the studies considered for verification, only 7 warranted closer investigation (approx. 38 site years) and only two included all the information required to verify the risk tables or had acceptable alternatives available (8 site years). A measure of on-site soil moisture at the time of N application for the depths required and on-site precipitation between N application and freeze were the most commonly missing information. Even studies that reported soil moisture and precipitation throughout the growing season often did not provide soil moisture or precipitation from the previous fall. The two studies used for verification were Wood (2018) and Grant et. al. (2012).

The Wood 2018 study compared various fall applied EEF treatments by measuring yield, protein and N_2O losses. It provided 4 site-years of useable data (Glenlea, LaSalle, Kelburn Farm and Ridge Road). Kelburn

is in the East region very near the border between the East and Central regions, all others were in the Central region. Nitrogen application dates ranged from October 20th to November 5th. Three site-years used locations with Fine textured soils and one (Ridge Road) had Coarse. Only three site-years had acceptable indicators of on-site soil moisture (0-5cm depth) and only one using a nearby weather station data at Glenlea. Of these four site-years, daily precipitation was available from nearby weather stations at Manitou and Glenlea. The "Current" soil moisture level at N application was estimated to be High for two site years (Glenlea and Kelburn), Medium in one (LaSalle) and Low in one (Ridge Road). Very little precipitation fell at Glenlea, LaSalle and Ridge Road ranging from 0 to 0.3" (0 to 6.4mm) during the Period of interest. Kelburn however, received 2.2" (55.3mm) of precipitation.

For nitrification and denitrification, the risk tables indicate Ridge Road should have a green level of risk while Glenlea and LaSalle should be yellow and Kelburn should be red. No significant difference between untreated urea and EEF were observed for yield, protein or N_2O losses for fall applied N treatments. Ridge Road was the only site with Coarse or Medium textured soil making it appropriate for testing the leaching risk tables. The soil moisture category and precipitation indicate a green level of risk at Ridge Road; no significant treatment effects were observed.

The Grant et al. 2012 study measured yield and protein in wheat and canola with fall banded urea or fall banded CRU. This study provided 4 site-years of data, all on Fine textured soils near Brandon Manitoba in the South West region. The exact N application date was not reported but was assumed mid-October. Soil moisture data was provided by the author for most of the site years and depths required but not specifically during N application. The "Current" soil moisture was estimated to be Low in two site-years and on the margin between medium and low for the other two. Precipitation data was provided by the author or received from Environment Canada Brandon and ranged from 0.3" to 1.0" (7.8 to 25mm).

For nitrification and denitrification, the risk tables indicate all site-years should have a yellow level of risk. No significant difference between untreated urea and CRU were observed for yield. There was a significant effect for protein in one site-year. All locations used in this study had Fine textured soils and are not appropriate for testing leaching risk.

While this verification method has the potential to indicate whether the risk tables are working with relatively few site-years, it will require a large number of site years to determine the expected frequency of effects for each risk level. Ultimately, with so few site-years of studies with complete data sets, the verification was inconclusive. Many more site-years could have been used for verification had a reliable measure of soil moisture been included in the studies. The addition of soil moisture at the time of N application would be a useful addition to future N management studies. The verification process was also completed using spring N risk tables and the same two studies (data not shown). The spring investigation, particularly for the Wood 2018 study, indicated N_2O might be a more sensitive indicator of N losses and/or transformations than yields.

Conclusion

We were able to develop a regional tool to help identify scenarios where the risk of N loss due to extreme moisture events might be elevated allowing producers to proactively adjust N management plans to compensate. However, the lack of a large number of N management studies reporting the required information prevented us from adequately validating the tools. In the future, the risk tables

may be validated or improved through alternative methods to the ones used in this study or by feedback from producers and advisors.

We identified that soil moisture measurements are commonly not included in N management studies and recommend the addition of soil moisture measurements to new N management studies with at least one date at the time of N application. Readings should be from the soil surface for all textures (30cm max) and for Medium and Coarse textured soils a measure of deep soil moisture would also be helpful.

We were not able to generate risk maps at this stage of the project but the information currently stored in tables could be used with a geospatial database to create the risk maps promised in the proposal. The limitation is currently how to map current soil moisture at the required depths to set the risk levels. An application or website might be a good solution to this issue since producers would be able to enter any missing information manually. It is currently possible to produce likelihoods of receiving precipitation on field-by-field basis by either interpolation between the best three nearest stations or simply the nearest station.

Next Steps

This study has provided a proof-of-concept that utilized historical weather data to determine the risk of extreme 3-day precipitation events, current soil moisture data for qualitative categorization of moisture status and soil textural class to determine the likelihood of fall applied N-loss to nitrification, denitrification and leaching. The tables generated from this study are useful tools for farmers to determine the risk of N-loss of fall-applied fertilizer. However, to make the results more accessible and relevant to farmers and policy makers, further studies are required in the following areas:

- Improved Accuracy and Reliability: A field study designed to comprehensively validate the N-loss risk is required to improve the reliability of the results presented in the tables. Specifically, the field experiment should review N loss under different water filled pore spaces to determine if the thresholds used in this study require adjustment.
- Integrated Web Application: The soil physical characteristics and regional delineations used in the study were generic. Manitoba currently has several resources that can be used to build an online tool that provides the likelihood of N-loss from fields. Information such as soil texture from AgriMaps, and current soil temperature and moisture from a network of 114 weather stations is available, as well as the potential to incorporate weather forecast into the online tool. This will assist farmers with making informed N-management decisions that reduces the risk of loss.

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Appendix A: How to Use the Nitrogen Risk Tables

These nitrogen loss risk tables are intended to indicate when additional time, effort and expense may be warranted to protect fall applied nitrogen from losses. An indication of elevated risk of nitrogen loss does not guarantee a return on investment.

1. Select the tables for the correct region and soil texture.
2. Select the period with a starting date closest to your intended fertilizer application date.
3. Determine the soil moisture category that is closest to the expected field moisture on the fertilizer application date (Low, Medium or High).
    a. Nitrification and denitrification tables use the average moisture in the 0-30 cm soil layer.
    b. Leaching tables use the average moisture in the full soil profile; 0-130 cm soil layer.

Moisture Category Limits (Volumetric Moisture Content)

Soil Texture	Moisture Category	0-30 cm	0-130 cm
Coarse	Low	<16%	<15%
	Medium	16-24%	15-23%
	High	>24%	>23%
Medium	Low	<23%	<25%
	Medium	23-32%	25-33%
	High	>32%	>33%
Fine	Low	<27%	<30%
	Medium	27-37%	30-39%
	High	>37%	>39%

4. The numeric values in the cells are the number of three-day precipitation events of a specific size that are expected (numerator) per number of years (denominator). Follow the row from left to right, the likelihood of events will decrease with each column. Stop when you reach the lowest likelihood that, in your opinion, has a reasonable chance of occurring.
   The heading for this column represents the largest amount of rainfall that has a “reasonable” likelihood of occurring over three consecutive days within the date range based on historic data.
5. The colour of the cell indicates the level of risk with respect to nitrogen losses.

Risk Levels

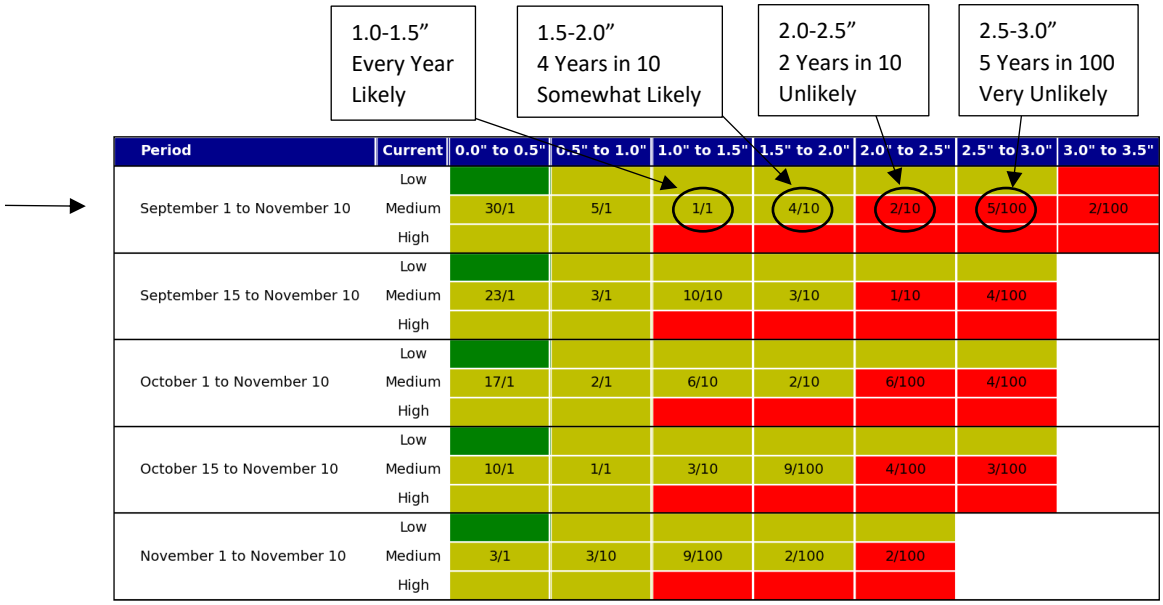
Table	Colour	Level	Interpretation
Nitrification and Denitrification	Green	Low	Negligible losses expected
	Yellow	Moderate	Potential for low to moderate losses. Nitrogen may become more susceptible to later leaching and denitrification losses.
	Red	High	Potential for moderate to high denitrification losses.
Leaching	Green	Low	No leaching expected
	Yellow	Moderate	Leaching possible
	Red	High	Leaching likely. More severe with each column above yellow.
	Grey	Not Applicable	Low soil moisture mobility

6. If yellow or red levels of risk are found it is an indicator that improved 4R management practices to preserve applied nitrogen may be warranted. For example, these may include actions such as choosing:

a. a different type of N fertilizer,
b. banding over broadcasting,
c. delaying N fertilizer application,
d. the use of an enhanced efficiency N fertilizer product,
e. or an alternative 4R practice not listed here. Visit https://fertilizercanada.ca/resources/4r-guidance-tables/ and https://gov.mb.ca/agriculture/crops/seasonal-reports/pubs/nitrogen-fertilizer-in-wet-fall.pdf for further information.

Increased likelihood of nitrogen losses should not be countered by increasing nitrogen application rates but whenever possible through improved retention using 4R management practices. It should also be noted that a green level of risk should not be used to justify poor fertilizer management practices.

Example: Nitrogen application date September 5th.



Period	Current	0.0" to 0.5"	0.5" to 1.0"	1.0" to 1.5"	1.5" to 2.0"	2.0" to 2.5"	2.5" to 3.0"	3.0" to 3.5"
September 1 to November 10	Low							
	Medium	30/1	5/1	1/1	4/10	2/10	5/100	2/100
	High							
September 15 to November 10	Low							
	Medium	23/1	3/1	10/10	3/10	1/10	4/100	
	High							
October 1 to November 10	Low							
	Medium	17/1	2/1	6/10	2/10	6/100	4/100	
	High							
October 15 to November 10	Low							
	Medium	10/1	1/1	3/10	9/100	4/100	3/100	
	High							
November 1 to November 10	Low							
	Medium	3/1	3/10	9/100	2/100	2/100		
	High							

The columns containing 1/1 or 4/10 would be good choices, 2/10 and further columns are more cautious options.

Using the 4/10 column (1.5” to 2.0”), soils with a low or medium current moisture content have a yellow level of risk. Soils with high current moisture have a red level of risk.

For low and medium moisture soils, nitrogen losses are possible but not expected to be severe. Improving nitrogen management may or may not be beneficial. Costly changes in nitrogen management are not likely to provide a return on investment. It should be noted, starting at the 4/10 column (1.5” to 2.0”), a full inch of additional moisture is required to bring low moisture soils to high risk while less than half an inch is needed for medium moisture soils. This may also affect management decisions.

For high moisture soils, nitrogen losses have the potential to be severe. Improving nitrogen management should be considered and may provide a return on investment.

Appendix B: Risk of N Losses* Based on Likelihood of Fall Rainfall and Soil Moisture for Coarse Textured Soils in the Central Region

Nitrification and Denitrification

Period	Current	0.0" to 0.5"	0.5" to 1.0"	1.0" to 1.5"	1.5" to 2.0"	2.0" to 2.5"	2.5" to 3.0"	3.0" to 3.5"
September 1 to November 10	Low							
	Medium	30/1	5/1	1/1	4/10	2/10	5/100	2/100
	High							
September 15 to November 10	Low							
	Medium	23/1	3/1	10/10	3/10	1/10	4/100	
	High							
October 1 to November 10	Low							
	Medium	17/1	2/1	6/10	2/10	6/100	4/100	
	High							
October 15 to November 10	Low							
	Medium	10/1	1/1	3/10	9/100	4/100	3/100	
	High							
November 1 to November 10	Low							
	Medium	3/1	3/10	9/100	2/100	2/100		
	High							

Fractions – number of three consecutive days of rainfall occurrence (numerator) per number of years (denominator).
Current – volumetric soil moisture in 0-12” depth (0-30 cm): Low <16%, Medium 16-24%, High >24%.
Green – negligible nitrification and denitrification expected.
Yellow – nitrification expected, negligible denitrification expected.
Red – potential for substantial denitrification.
* – nitrification (yellow) may not directly lead to N losses but may convert N to forms that are more easily lost if conditions for losses exist.

Leaching

Period	Current	0.0" to 0.5"	0.5" to 1.0"	1.0" to 1.5"	1.5" to 2.0"	2.0" to 2.5"	2.5" to 3.0"	3.0" to 3.5"
September 1 to November 10	Low							
	Medium	30/1	5/1	1/1	4/10	2/10	5/100	2/100
	High							
September 15 to November 10	Low							
	Medium	23/1	3/1	10/10	3/10	1/10	4/100	
	High							
October 1 to November 10	Low							
	Medium	17/1	2/1	6/10	2/10	6/100	4/100	
	High							
October 15 to November 10	Low							
	Medium	10/1	1/1	3/10	9/100	4/100	3/100	
	High							
November 1 to November 10	Low							
	Medium	3/1	3/10	9/100	2/100	2/100		
	High							

Fractions – number of three consecutive days of rainfall occurrence (numerator) per number of years (denominator).
Current – soil moisture in 0-50” depth (0-130 cm): Low <15%, Medium 15-23%, High >23%.
Green – no leaching expected.
Yellow – soil moisture is approaching field capacity, leaching possible.
Red – soil moisture is above field capacity, leaching likely.

Appendix C: Risk of N Losses* Based on Likelihood of Fall Rainfall and Soil Moisture for Medium Textured Soils in the Central Region

Nitrification and Denitrification

Period	Current	0.0" to 0.5"	0.5" to 1.0"	1.0" to 1.5"	1.5" to 2.0"	2.0" to 2.5"	2.5" to 3.0"	3.0" to 3.5"
September 1 to November 10	Low							
	Medium	30/1	5/1	1/1	4/10	2/10	5/100	2/100
	High							
September 15 to November 10	Low							
	Medium	23/1	3/1	10/10	3/10	1/10	4/100	
	High							
October 1 to November 10	Low							
	Medium	17/1	2/1	6/10	2/10	6/100	4/100	
	High							
October 15 to November 10	Low							
	Medium	10/1	1/1	3/10	9/100	4/100	3/100	
	High							
November 1 to November 10	Low							
	Medium	3/1	3/10	9/100	2/100	2/100		
	High							

Fractions – number of three consecutive days of rainfall occurrence (numerator) per number of years (denominator).
Current – volumetric soil moisture in 0-12” depth (0-30 cm): Low <23%, Medium 23-32%, High >32%.
Green – negligible nitrification and denitrification expected.
Yellow – nitrification expected, negligible denitrification expected.
Red – potential for substantial denitrification.
* – nitrification (yellow) may not directly lead to N losses but may convert N to forms that are more easily lost if conditions for losses exist.

Leaching

Period	Current	0.0" to 0.5"	0.5" to 1.0"	1.0" to 1.5"	1.5" to 2.0"	2.0" to 2.5"	2.5" to 3.0"	3.0" to 3.5"
September 1 to November 10	Low							
	Medium	30/1	5/1	1/1	4/10	2/10	5/100	2/100
	High							
September 15 to November 10	Low							
	Medium	23/1	3/1	10/10	3/10	1/10	4/100	
	High							
October 1 to November 10	Low							
	Medium	17/1	2/1	6/10	2/10	6/100	4/100	
	High							
October 15 to November 10	Low							
	Medium	10/1	1/1	3/10	9/100	4/100	3/100	
	High							
November 1 to November 10	Low							
	Medium	3/1	3/10	9/100	2/100	2/100		
	High							

Fractions – number of three consecutive days of rainfall occurrence (numerator) per number of years (denominator).
Current – soil moisture in 0-50” depth (0-130 cm): Low <25%, Medium 25-33%, High >33%.
Green – no leaching expected.
Yellow – soil moisture is approaching field capacity, leaching possible.
Red – soil moisture is above field capacity, leaching likely.

Appendix D: Risk of N Losses* Based on Likelihood of Fall Rainfall and Soil Moisture for Fine Textured Soils in the Central Region

Nitrification and Denitrification

Period	Current	0.0" to 0.5"	0.5" to 1.0"	1.0" to 1.5"	1.5" to 2.0"	2.0" to 2.5"	2.5" to 3.0"	3.0" to 3.5"
September 1 to November 10	Low							
	Medium	30/1	5/1	1/1	4/10	2/10	5/100	2/100
	High							
September 15 to November 10	Low							
	Medium	23/1	3/1	10/10	3/10	1/10	4/100	
	High							
October 1 to November 10	Low							
	Medium	17/1	2/1	6/10	2/10	6/100	4/100	
	High							
October 15 to November 10	Low							
	Medium	10/1	1/1	3/10	9/100	4/100	3/100	
	High							
November 1 to November 10	Low							
	Medium	3/1	3/10	9/100	2/100	2/100		
	High							

Fractions – number of three consecutive days of rainfall occurrence (numerator) per number of years (denominator).
Current – volumetric soil moisture in 0-12” depth (0-30 cm): Low <27%, Medium 27-37%, High >37%.
Green – negligible nitrification and denitrification expected.
Yellow – nitrification expected, negligible denitrification expected.
Red – potential for substantial denitrification.
* – nitrification (yellow) may not directly lead to N losses but may convert N to forms that are more easily lost if conditions for losses exist.

Leaching

Period	Current	0.0" to 0.5"	0.5" to 1.0"	1.0" to 1.5"	1.5" to 2.0"	2.0" to 2.5"	2.5" to 3.0"	3.0" to 3.5"
September 1 to November 10	Low							
	Medium	30/1	5/1	1/1	4/10	2/10	5/100	2/100
	High							
September 15 to November 10	Low							
	Medium	23/1	3/1	10/10	3/10	1/10	4/100	
	High							
October 1 to November 10	Low							
	Medium	17/1	2/1	6/10	2/10	6/100	4/100	
	High							
October 15 to November 10	Low							
	Medium	10/1	1/1	3/10	9/100	4/100	3/100	
	High							
November 1 to November 10	Low							
	Medium	3/1	3/10	9/100	2/100	2/100		
	High							

Fractions – number of three consecutive days of rainfall occurrence (numerator) per number of years (denominator).
Current – soil moisture in 0-50” depth (0-130 cm): Low <30%, Medium 30-39%, High >39%.
Grey – low risk of leaching expected at any level of rainfall for fine textured soils; low hydraulic conductivity.

Appendix E: Risk of N Losses* Based on Likelihood of Fall Rainfall and Soil Moisture for Coarse Textured Soils in the East Region

Nitrification and Denitrification

Period	Current	0.0" to 0.5"	0.5" to 1.0"	1.0" to 1.5"	1.5" to 2.0"	2.0" to 2.5"	2.5" to 3.0"	3.0" to 3.5"
September 1 to November 10	Low							
	Medium	32/1	5/1	2/1	5/10	2/10	5/100	4/100
	High							
September 15 to November 10	Low							
	Medium	26/1	4/1	1/1	3/10	1/10	3/100	
	High							
October 1 to November 10	Low							
	Medium	18/1	2/1	8/10	2/10	8/100	2/100	
	High							
October 15 to November 10	Low							
	Medium	11/1	1/1	4/10	6/100	5/100	2/100	
	High							
November 1 to November 10	Low							
	Medium	4/1	3/10	1/10	2/100	2/100	2/100	
	High							

Fractions – number of three consecutive days of rainfall occurrence (numerator) per number of years (denominator).
Current – volumetric soil moisture in 0-12” depth (0-30 cm): Low <16%, Medium 16-24%, High >24%.
Green – negligible nitrification and denitrification expected.
Yellow – nitrification expected, negligible denitrification expected.
Red – potential for substantial denitrification.
* – nitrification (yellow) may not directly lead to N losses but may convert N to forms that are more easily lost if conditions for losses exist.

Leaching

Period	Current	0.0" to 0.5"	0.5" to 1.0"	1.0" to 1.5"	1.5" to 2.0"	2.0" to 2.5"	2.5" to 3.0"	3.0" to 3.5"
September 1 to November 10	Low							
	Medium	32/1	5/1	2/1	5/10	2/10	5/100	4/100
	High							
September 15 to November 10	Low							
	Medium	26/1	4/1	1/1	3/10	1/10	3/100	
	High							
October 1 to November 10	Low							
	Medium	18/1	2/1	8/10	2/10	8/100	2/100	
	High							
October 15 to November 10	Low							
	Medium	11/1	1/1	4/10	6/100	5/100	2/100	
	High							
November 1 to November 10	Low							
	Medium	4/1	3/10	1/10	2/100	2/100	2/100	
	High							

Fractions – number of three consecutive days of rainfall occurrence (numerator) per number of years (denominator).
Current – soil moisture in 0-50” depth (0-130 cm): Low <15%, Medium 15-23%, High >23%.
Green – no leaching expected.
Yellow – soil moisture is approaching field capacity, leaching possible.
Red – soil moisture is above field capacity, leaching likely.

Appendix F: Risk of N Losses* Based on Likelihood of Fall Rainfall and Soil Moisture for Medium Textured Soils in the East Region

Nitrification and Denitrification

Period	Current	0.0" to 0.5"	0.5" to 1.0"	1.0" to 1.5"	1.5" to 2.0"	2.0" to 2.5"	2.5" to 3.0"	3.0" to 3.5"
September 1 to November 10	Low							
	Medium	32/1	5/1	2/1	5/10	2/10	5/100	4/100
	High							
September 15 to November 10	Low							
	Medium	26/1	4/1	1/1	3/10	1/10	3/100	
	High							
October 1 to November 10	Low							
	Medium	18/1	2/1	8/10	2/10	8/100	2/100	
	High							
October 15 to November 10	Low							
	Medium	11/1	1/1	4/10	6/100	5/100	2/100	
	High							
November 1 to November 10	Low							
	Medium	4/1	3/10	1/10	2/100	2/100	2/100	
	High							

Fractions – number of three consecutive days of rainfall occurrence (numerator) per number of years (denominator).
Current – volumetric soil moisture in 0-12” depth (0-30 cm): Low <23%, Medium 23-32%, High >32%.
Green – negligible nitrification and denitrification expected.
Yellow – nitrification expected, negligible denitrification expected.
Red – potential for substantial denitrification.
* – nitrification (yellow) may not directly lead to N losses but may convert N to forms that are more easily lost if conditions for losses exist.

Leaching

Period	Current	0.0" to 0.5"	0.5" to 1.0"	1.0" to 1.5"	1.5" to 2.0"	2.0" to 2.5"	2.5" to 3.0"	3.0" to 3.5"
September 1 to November 10	Low							
	Medium	32/1	5/1	2/1	5/10	2/10	5/100	4/100
	High							
September 15 to November 10	Low							
	Medium	26/1	4/1	1/1	3/10	1/10	3/100	
	High							
October 1 to November 10	Low							
	Medium	18/1	2/1	8/10	2/10	8/100	2/100	
	High							
October 15 to November 10	Low							
	Medium	11/1	1/1	4/10	6/100	5/100	2/100	
	High							
November 1 to November 10	Low							
	Medium	4/1	3/10	1/10	2/100	2/100	2/100	
	High							

Fractions – number of three consecutive days of rainfall occurrence (numerator) per number of years (denominator).
Current – soil moisture in 0-50” depth (0-130 cm): Low <25%, Medium 25-33%, High >33%.
Green – no leaching expected.
Yellow – soil moisture is approaching field capacity, leaching possible.
Red – soil moisture is above field capacity, leaching likely.

Appendix G: Risk of N Losses* Based on Likelihood of Fall Rainfall and Soil Moisture for Fine Textured Soils in the East Region

Nitrification and Denitrification

Period	Current	0.0" to 0.5"	0.5" to 1.0"	1.0" to 1.5"	1.5" to 2.0"	2.0" to 2.5"	2.5" to 3.0"	3.0" to 3.5"
September 1 to November 10	Low							
	Medium	32/1	5/1	2/1	5/10	2/10	5/100	4/100
	High							
September 15 to November 10	Low							
	Medium	26/1	4/1	1/1	3/10	1/10	3/100	
	High							
October 1 to November 10	Low							
	Medium	18/1	2/1	8/10	2/10	8/100	2/100	
	High							
October 15 to November 10	Low							
	Medium	11/1	1/1	4/10	6/100	5/100	2/100	
	High							
November 1 to November 10	Low							
	Medium	4/1	3/10	1/10	2/100	2/100	2/100	
	High							

Fractions – number of three consecutive days of rainfall occurrence (numerator) per number of years (denominator).
Current – volumetric soil moisture in 0-12” depth (0-30 cm): Low <27%, Medium 27-37%, High >37%.
Green – negligible nitrification and denitrification expected.
Yellow – nitrification expected, negligible denitrification expected.
Red – potential for substantial denitrification.
* – nitrification (yellow) may not directly lead to N losses but may convert N to forms that are more easily lost if conditions for losses exist.

Leaching

Period	Current	0.0" to 0.5"	0.5" to 1.0"	1.0" to 1.5"	1.5" to 2.0"	2.0" to 2.5"	2.5" to 3.0"	3.0" to 3.5"
September 1 to November 10	Low							
	Medium	32/1	5/1	2/1	5/10	2/10	5/100	4/100
	High							
September 15 to November 10	Low							
	Medium	26/1	4/1	1/1	3/10	1/10	3/100	
	High							
October 1 to November 10	Low							
	Medium	18/1	2/1	8/10	2/10	8/100	2/100	
	High							
October 15 to November 10	Low							
	Medium	11/1	1/1	4/10	6/100	5/100	2/100	
	High							
November 1 to November 10	Low							
	Medium	4/1	3/10	1/10	2/100	2/100	2/100	
	High							

Fractions – number of three consecutive days of rainfall occurrence (numerator) per number of years (denominator).
Current – soil moisture in 0-50” depth (0-130 cm): Low <30%, Medium 30-39%, High >39%.
Grey – low risk of leaching expected at any level of rainfall for fine textured soils; low hydraulic conductivity.

Appendix H: Risk of N Losses* Based on Likelihood of Fall Rainfall and Soil Moisture for Coarse Textured Soils in the Interlake Region

Nitrification and Denitrification

Period	Current	0.0" to 0.5"	0.5" to 1.0"	1.0" to 1.5"	1.5" to 2.0"	2.0" to 2.5"	2.5" to 3.0"	3.0" to 3.5"
September 1 to November 10	Low							
	Medium	32/1	5/1	1/1	3/10	1/10	5/100	2/100
	High							
September 15 to November 10	Low							
	Medium	25/1	4/1	10/10	2/10	5/100	4/100	2/100
	High							
October 1 to November 10	Low							
	Medium	17/1	2/1	6/10	10/100	3/100	3/100	2/100
	High							
October 15 to November 10	Low							
	Medium	11/1	1/1	4/10	4/100	2/100	3/100	2/100
	High							
November 1 to November 10	Low							
	Medium	3/1	3/10	7/100	2/100			
	High							

Fractions – number of three consecutive days of rainfall occurrence (numerator) per number of years (denominator).
Current – volumetric soil moisture in 0-12” depth (0-30 cm): Low <16%, Medium 16-24%, High >24%.
Green – negligible nitrification and denitrification expected.
Yellow – nitrification expected, negligible denitrification expected.
Red – potential for substantial denitrification.
* – nitrification (yellow) may not directly lead to N losses but may convert N to forms that are more easily lost if conditions for losses exist.

Leaching

Period	Current	0.0" to 0.5"	0.5" to 1.0"	1.0" to 1.5"	1.5" to 2.0"	2.0" to 2.5"	2.5" to 3.0"	3.0" to 3.5"
September 1 to November 10	Low							
	Medium	32/1	5/1	1/1	3/10	1/10	5/100	2/100
	High							
September 15 to November 10	Low							
	Medium	25/1	4/1	10/10	2/10	5/100	4/100	2/100
	High							
October 1 to November 10	Low							
	Medium	17/1	2/1	6/10	10/100	3/100	3/100	2/100
	High							
October 15 to November 10	Low							
	Medium	11/1	1/1	4/10	4/100	2/100	3/100	2/100
	High							
November 1 to November 10	Low							
	Medium	3/1	3/10	7/100	2/100			
	High							

Fractions – number of three consecutive days of rainfall occurrence (numerator) per number of years (denominator).
Current – soil moisture in 0-50” depth (0-130 cm): Low <15%, Medium 15-23%, High >23%.
Green – no leaching expected.
Yellow – soil moisture is approaching field capacity, leaching possible.
Red – soil moisture is above field capacity, leaching likely.

Appendix J: Risk of N Losses* Based on Likelihood of Fall Rainfall and Soil Moisture for Medium Textured Soils in the Interlake Region

Nitrification and Denitrification

Period	Current	0.0" to 0.5"	0.5" to 1.0"	1.0" to 1.5"	1.5" to 2.0"	2.0" to 2.5"	2.5" to 3.0"	3.0" to 3.5"
September 1 to November 10	Low							
	Medium	32/1	5/1	1/1	3/10	1/10	5/100	2/100
	High							
September 15 to November 10	Low							
	Medium	25/1	4/1	10/10	2/10	5/100	4/100	2/100
	High							
October 1 to November 10	Low							
	Medium	17/1	2/1	6/10	10/100	3/100	3/100	2/100
	High							
October 15 to November 10	Low							
	Medium	11/1	1/1	4/10	4/100	2/100	3/100	2/100
	High							
November 1 to November 10	Low							
	Medium	3/1	3/10	7/100	2/100			
	High							

Fractions – number of three consecutive days of rainfall occurrence (numerator) per number of years (denominator).
Current – volumetric soil moisture in 0-12” depth (0-30 cm): Low <23%, Medium 23-32%, High >32%.
Green – negligible nitrification and denitrification expected.
Yellow – nitrification expected, negligible denitrification expected.
Red – potential for substantial denitrification.
* – nitrification (yellow) may not directly lead to N losses but may convert N to forms that are more easily lost if conditions for losses exist.

Leaching

Period	Current	0.0" to 0.5"	0.5" to 1.0"	1.0" to 1.5"	1.5" to 2.0"	2.0" to 2.5"	2.5" to 3.0"	3.0" to 3.5"
September 1 to November 10	Low							
	Medium	32/1	5/1	1/1	3/10	1/10	5/100	2/100
	High							
September 15 to November 10	Low							
	Medium	25/1	4/1	10/10	2/10	5/100	4/100	2/100
	High							
October 1 to November 10	Low							
	Medium	17/1	2/1	6/10	10/100	3/100	3/100	2/100
	High							
October 15 to November 10	Low							
	Medium	11/1	1/1	4/10	4/100	2/100	3/100	2/100
	High							
November 1 to November 10	Low							
	Medium	3/1	3/10	7/100	2/100			
	High							

Fractions – number of three consecutive days of rainfall occurrence (numerator) per number of years (denominator).
Current – soil moisture in 0-50” depth (0-130 cm): Low <25%, Medium 25-33%, High >33%.
Green – no leaching expected.
Yellow – soil moisture is approaching field capacity, leaching possible.
Red – soil moisture is above field capacity, leaching likely.

Appendix J: Risk of N Losses* Based on Likelihood of Fall Rainfall and Soil Moisture for Fine Textured Soils in the Interlake Region

Nitrification and Denitrification

Period	Current	0.0" to 0.5"	0.5" to 1.0"	1.0" to 1.5"	1.5" to 2.0"	2.0" to 2.5"	2.5" to 3.0"	3.0" to 3.5"
September 1 to November 10	Low							
	Medium	32/1	5/1	1/1	3/10	1/10	5/100	2/100
	High							
September 15 to November 10	Low							
	Medium	25/1	4/1	10/10	2/10	5/100	4/100	2/100
	High							
October 1 to November 10	Low							
	Medium	17/1	2/1	6/10	10/100	3/100	3/100	2/100
	High							
October 15 to November 10	Low							
	Medium	11/1	1/1	4/10	4/100	2/100	3/100	2/100
	High							
November 1 to November 10	Low							
	Medium	3/1	3/10	7/100	2/100			
	High							

Fractions – number of three consecutive days of rainfall occurrence (numerator) per number of years (denominator).
Current – volumetric soil moisture in 0-12” depth (0-30 cm): Low <27%, Medium 27-37%, High >37%.
Green – negligible nitrification and denitrification expected.
Yellow – nitrification expected, negligible denitrification expected.
Red – potential for substantial denitrification.
* – nitrification (yellow) may not directly lead to N losses but may convert N to forms that are more easily lost if conditions for losses exist.

Leaching

Period	Current	0.0" to 0.5"	0.5" to 1.0"	1.0" to 1.5"	1.5" to 2.0"	2.0" to 2.5"	2.5" to 3.0"	3.0" to 3.5"
September 1 to November 10	Low							
	Medium	32/1	5/1	1/1	3/10	1/10	5/100	2/100
	High							
September 15 to November 10	Low							
	Medium	25/1	4/1	10/10	2/10	5/100	4/100	2/100
	High							
October 1 to November 10	Low							
	Medium	17/1	2/1	6/10	10/100	3/100	3/100	2/100
	High							
October 15 to November 10	Low							
	Medium	11/1	1/1	4/10	4/100	2/100	3/100	2/100
	High							
November 1 to November 10	Low							
	Medium	3/1	3/10	7/100	2/100			
	High							

Fractions – number of three consecutive days of rainfall occurrence (numerator) per number of years (denominator).
Current – soil moisture in 0-50” depth (0-130 cm): Low <30%, Medium 30-39%, High >39%.
Grey – low risk of leaching expected at any level of rainfall for fine textured soils; low hydraulic conductivity.

Appendix K: Risk of N Losses* Based on Likelihood of Fall Rainfall and Soil Moisture for Coarse Textured Soils in the North West Region

Nitrification and Denitrification

Period	Current	0.0" to 0.5"	0.5" to 1.0"	1.0" to 1.5"	1.5" to 2.0"	2.0" to 2.5"	2.5" to 3.0"	3.0" to 3.5"	3.5" to 4.0"	4.0" to 4.5"	4.5" to 5.0"	5.0" to 5.5"	5.5" to 6.0"
September 1 to November 10	Low												
	Medium	31/1	4/1	1/1	4/10	9/100	6/100	5/100	2/100	3/100	2/100	2/100	2/100
	High												
September 15 to November 10	Low												
	Medium	25/1	3/1	7/10	2/10	8/100	5/100	6/100	2/100	3/100	2/100	2/100	2/100
	High												
October 1 to November 10	Low												
	Medium	17/1	2/1	4/10	1/10	4/100	4/100						
	High												
October 15 to November 10	Low												
	Medium	11/1	1/1	2/10	8/100	4/100	4/100						
	High												
November 1 to November 10	Low												
	Medium	4/1	3/10	4/100	2/100								
	High												

Fractions – number of three consecutive days of rainfall occurrence (numerator) per number of years (denominator).
Current – volumetric soil moisture in 0-12" depth (0-30 cm): Low <16%, Medium 16-24%, High >24%.
Green – negligible nitrification and denitrification expected.
Yellow – nitrification expected, negligible denitrification expected.
Red – potential for substantial denitrification.
* – nitrification (yellow) may not directly lead to N losses but may convert N to forms that are more easily lost if conditions for losses exist.

Leaching

Period	Current	0.0" to 0.5"	0.5" to 1.0"	1.0" to 1.5"	1.5" to 2.0"	2.0" to 2.5"	2.5" to 3.0"	3.0" to 3.5"	3.5" to 4.0"	4.0" to 4.5"	4.5" to 5.0"	5.0" to 5.5"	5.5" to 6.0"
September 1 to November 10	Low												
	Medium	31/1	4/1	1/1	4/10	9/100	6/100	5/100	2/100	3/100	2/100	2/100	2/100
	High												
September 15 to November 10	Low												
	Medium	25/1	3/1	7/10	2/10	8/100	5/100	6/100	2/100	3/100	2/100	2/100	2/100
	High												
October 1 to November 10	Low												
	Medium	17/1	2/1	4/10	1/10	4/100	4/100						
	High												
October 15 to November 10	Low												
	Medium	11/1	1/1	2/10	8/100	4/100	4/100						
	High												
November 1 to November 10	Low												
	Medium	4/1	3/10	4/100	2/100								
	High												

Fractions – number of three consecutive days of rainfall occurrence (numerator) per number of years (denominator).
Current – soil moisture in 0-50" depth (0-130 cm): Low <15%, Medium 15-23%, High >23%.
Green – no leaching expected.
Yellow – soil moisture is approaching field capacity, leaching possible.
Red – soil moisture is above field capacity, leaching likely.

Appendix L: Risk of N Losses* Based on Likelihood of Fall Rainfall and Soil Moisture for Medium Textured Soils in the North West Region

Nitrification and Denitrification

Period	Current	0.0" to 0.5"	0.5" to 1.0"	1.0" to 1.5"	1.5" to 2.0"	2.0" to 2.5"	2.5" to 3.0"	3.0" to 3.5"	3.5" to 4.0"	4.0" to 4.5"	4.5" to 5.0"	5.0" to 5.5"	5.5" to 6.0"
September 1 to November 10	Low												
	Medium	31/1	4/1	1/1	4/10	9/100	6/100	5/100	2/100	3/100	2/100	2/100	2/100
	High												
September 15 to November 10	Low												
	Medium	25/1	3/1	7/10	2/10	8/100	5/100	6/100	2/100	3/100	2/100	2/100	2/100
	High												
October 1 to November 10	Low												
	Medium	17/1	2/1	4/10	1/10	4/100	4/100						
	High												
October 15 to November 10	Low												
	Medium	11/1	1/1	2/10	8/100	4/100	4/100						
	High												
November 1 to November 10	Low												
	Medium	4/1	3/10	4/100	2/100								
	High												

Fractions – number of three consecutive days of rainfall occurrence (numerator) per number of years (denominator).
Current – volumetric soil moisture in 0-12" depth (0-30 cm): Low <23%, Medium 23-32%, High >32%.
Green – negligible nitrification and denitrification expected.
Yellow – nitrification expected, negligible denitrification expected.
Red – potential for substantial denitrification.
* – nitrification (yellow) may not directly lead to N losses but may convert N to forms that are more easily lost if conditions for losses exist.

Leaching

Period	Current	0.0" to 0.5"	0.5" to 1.0"	1.0" to 1.5"	1.5" to 2.0"	2.0" to 2.5"	2.5" to 3.0"	3.0" to 3.5"	3.5" to 4.0"	4.0" to 4.5"	4.5" to 5.0"	5.0" to 5.5"	5.5" to 6.0"
September 1 to November 10	Low												
	Medium	31/1	4/1	1/1	4/10	9/100	6/100	5/100	2/100	3/100	2/100	2/100	2/100
	High												
September 15 to November 10	Low												
	Medium	25/1	3/1	7/10	2/10	8/100	5/100	6/100	2/100	3/100	2/100	2/100	2/100
	High												
October 1 to November 10	Low												
	Medium	17/1	2/1	4/10	1/10	4/100	4/100						
	High												
October 15 to November 10	Low												
	Medium	11/1	1/1	2/10	8/100	4/100	4/100						
	High												
November 1 to November 10	Low												
	Medium	4/1	3/10	4/100	2/100								
	High												

Fractions – number of three consecutive days of rainfall occurrence (numerator) per number of years (denominator).
Current – soil moisture in 0-50" depth (0-130 cm): Low <25%, Medium 25-33%, High >33%.
Green – no leaching expected.
Yellow – soil moisture is approaching field capacity, leaching possible.
Red – soil moisture is above field capacity, leaching likely.

Appendix M: Risk of N Losses* Based on Likelihood of Fall Rainfall and Soil Moisture for Fine Textured Soils in the North West Region

Nitrification and Denitrification

Period	Current	0.0" to 0.5"	0.5" to 1.0"	1.0" to 1.5"	1.5" to 2.0"	2.0" to 2.5"	2.5" to 3.0"	3.0" to 3.5"	3.5" to 4.0"	4.0" to 4.5"	4.5" to 5.0"	5.0" to 5.5"	5.5" to 6.0"
September 1 to November 10	Low												
	Medium	31/1	4/1	1/1	4/10	9/100	6/100	5/100	2/100	3/100	2/100	2/100	2/100
	High												
September 15 to November 10	Low												
	Medium	25/1	3/1	7/10	2/10	8/100	5/100	6/100	2/100	3/100	2/100	2/100	2/100
	High												
October 1 to November 10	Low												
	Medium	17/1	2/1	4/10	1/10	4/100	4/100						
	High												
October 15 to November 10	Low												
	Medium	11/1	1/1	2/10	8/100	4/100	4/100						
	High												
November 1 to November 10	Low												
	Medium	4/1	3/10	4/100	2/100								
	High												

Fractions – number of three consecutive days of rainfall occurrence (numerator) per number of years (denominator).
Current – volumetric soil moisture in 0-12” depth (0-30 cm): Low <27%, Medium 27-37%, High >37%.
Green – negligible nitrification and denitrification expected.
Yellow – nitrification expected, negligible denitrification expected.
Red – potential for substantial denitrification.
* – nitrification (yellow) may not directly lead to N losses but may convert N to forms that are more easily lost if conditions for losses exist.

Leaching

Period	Current	0.0" to 0.5"	0.5" to 1.0"	1.0" to 1.5"	1.5" to 2.0"	2.0" to 2.5"	2.5" to 3.0"	3.0" to 3.5"	3.5" to 4.0"	4.0" to 4.5"	4.5" to 5.0"	5.0" to 5.5"	5.5" to 6.0"
September 1 to November 10	Low												
	Medium	31/1	4/1	1/1	4/10	9/100	6/100	5/100	2/100	3/100	2/100	2/100	2/100
	High												
September 15 to November 10	Low												
	Medium	25/1	3/1	7/10	2/10	8/100	5/100	6/100	2/100	3/100	2/100	2/100	2/100
	High												
October 1 to November 10	Low												
	Medium	17/1	2/1	4/10	1/10	4/100	4/100						
	High												
October 15 to November 10	Low												
	Medium	11/1	1/1	2/10	8/100	4/100	4/100						
	High												
November 1 to November 10	Low												
	Medium	4/1	3/10	4/100	2/100								
	High												

Fractions – number of three consecutive days of rainfall occurrence (numerator) per number of years (denominator).
Current – soil moisture in 0-50” depth (0-130 cm): Low <30%, Medium 30-39%, High >39%.
Grey – low risk of leaching expected at any level of rainfall for fine textured soils; low hydraulic conductivity.

Appendix N: Risk of N Losses* Based on Likelihood of Fall Rainfall and Soil Moisture for Coarse Textured Soils in the South West Region

Nitrification and Denitrification

Period	Current	0.0" to 0.5"	0.5" to 1.0"	1.0" to 1.5"	1.5" to 2.0"	2.0" to 2.5"	2.5" to 3.0"	3.0" to 3.5"	3.5" to 4.0"
September 1 to November 10	Low								
	Medium	29/1	4/1	1/1	4/10	8/100	5/100	6/100	2/100
	High								
September 15 to November 10	Low								
	Medium	22/1	3/1	8/10	2/10	6/100	3/100	4/100	2/100
	High								
October 1 to November 10	Low								
	Medium	16/1	1/1	5/10	1/10	4/100			
	High								
October 15 to November 10	Low								
	Medium	10/1	8/10	2/10	8/100	4/100			
	High								
November 1 to November 10	Low								
	Medium	3/1	2/10	3/100	2/100				
	High								

Fractions – number of three consecutive days of rainfall occurrence (numerator) per number of years (denominator).
Current – volumetric soil moisture in 0-12” depth (0-30 cm): Low <16%, Medium 16-24%, High >24%.
Green – negligible nitrification and denitrification expected.
Yellow – nitrification expected, negligible denitrification expected.
Red – potential for substantial denitrification.
* – nitrification (yellow) may not directly lead to N losses but may convert N to forms that are more easily lost if conditions for losses exist.

Leaching

Period	Current	0.0" to 0.5"	0.5" to 1.0"	1.0" to 1.5"	1.5" to 2.0"	2.0" to 2.5"	2.5" to 3.0"	3.0" to 3.5"	3.5" to 4.0"
September 1 to November 10	Low								
	Medium	29/1	4/1	1/1	4/10	8/100	5/100	6/100	2/100
	High								
September 15 to November 10	Low								
	Medium	22/1	3/1	8/10	2/10	6/100	3/100	4/100	2/100
	High								
October 1 to November 10	Low								
	Medium	16/1	1/1	5/10	1/10	4/100			
	High								
October 15 to November 10	Low								
	Medium	10/1	8/10	2/10	8/100	4/100			
	High								
November 1 to November 10	Low								
	Medium	3/1	2/10	3/100	2/100				
	High								

Fractions – number of three consecutive days of rainfall occurrence (numerator) per number of years (denominator).
Current – soil moisture in 0-50” depth (0-130 cm): Low <15%, Medium 15-23%, High >23%.
Green – no leaching expected.
Yellow – soil moisture is approaching field capacity, leaching possible.
Red – soil moisture is above field capacity, leaching likely.

Appendix O: Risk of N Losses* Based on Likelihood of Fall Rainfall and Soil Moisture for Medium Textured Soils in the South West Region

Nitrification and Denitrification

Period	Current	0.0" to 0.5"	0.5" to 1.0"	1.0" to 1.5"	1.5" to 2.0"	2.0" to 2.5"	2.5" to 3.0"	3.0" to 3.5"	3.5" to 4.0"
September 1 to November 10	Low								
	Medium	29/1	4/1	1/1	4/10	8/100	5/100	6/100	2/100
	High								
September 15 to November 10	Low								
	Medium	22/1	3/1	8/10	2/10	6/100	3/100	4/100	2/100
	High								
October 1 to November 10	Low								
	Medium	16/1	1/1	5/10	1/10	4/100			
	High								
October 15 to November 10	Low								
	Medium	10/1	8/10	2/10	8/100	4/100			
	High								
November 1 to November 10	Low								
	Medium	3/1	2/10	3/100	2/100				
	High								

Fractions – number of three consecutive days of rainfall occurrence (numerator) per number of years (denominator).
Current – volumetric soil moisture in 0-12” depth (0-30 cm): Low <23%, Medium 23-32%, High >32%.
Green – negligible nitrification and denitrification expected.
Yellow – nitrification expected, negligible denitrification expected.
Red – potential for substantial denitrification.
* – nitrification (yellow) may not directly lead to N losses but may convert N to forms that are more easily lost if conditions for losses exist.

Leaching

Period	Current	0.0" to 0.5"	0.5" to 1.0"	1.0" to 1.5"	1.5" to 2.0"	2.0" to 2.5"	2.5" to 3.0"	3.0" to 3.5"	3.5" to 4.0"
September 1 to November 10	Low								
	Medium	29/1	4/1	1/1	4/10	8/100	5/100	6/100	2/100
	High								
September 15 to November 10	Low								
	Medium	22/1	3/1	8/10	2/10	6/100	3/100	4/100	2/100
	High								
October 1 to November 10	Low								
	Medium	16/1	1/1	5/10	1/10	4/100			
	High								
October 15 to November 10	Low								
	Medium	10/1	8/10	2/10	8/100	4/100			
	High								
November 1 to November 10	Low								
	Medium	3/1	2/10	3/100	2/100				
	High								

Fractions – number of three consecutive days of rainfall occurrence (numerator) per number of years (denominator).
Current – soil moisture in 0-50” depth (0-130 cm): Low <25%, Medium 25-33%, High >33%.
Green – no leaching expected.
Yellow – soil moisture is approaching field capacity, leaching possible.
Red – soil moisture is above field capacity, leaching likely.

Appendix P: Risk of N Losses* Based on Likelihood of Fall Rainfall and Soil Moisture for Fine Textured Soils in the South West Region

Nitrification and Denitrification

Period	Current	0.0" to 0.5"	0.5" to 1.0"	1.0" to 1.5"	1.5" to 2.0"	2.0" to 2.5"	2.5" to 3.0"	3.0" to 3.5"	3.5" to 4.0"
September 1 to November 10	Low								
	Medium	29/1	4/1	1/1	4/10	8/100	5/100	6/100	2/100
	High								
September 15 to November 10	Low								
	Medium	22/1	3/1	8/10	2/10	6/100	3/100	4/100	2/100
	High								
October 1 to November 10	Low								
	Medium	16/1	1/1	5/10	1/10	4/100			
	High								
October 15 to November 10	Low								
	Medium	10/1	8/10	2/10	8/100	4/100			
	High								
November 1 to November 10	Low								
	Medium	3/1	2/10	3/100	2/100				
	High								

Fractions – number of three consecutive days of rainfall occurrence (numerator) per number of years (denominator).
Current – volumetric soil moisture in 0-12” depth (0-30 cm): Low <27%, Medium 27-37%, High >37%.
Green – negligible nitrification and denitrification expected.
Yellow – nitrification expected, negligible denitrification expected.
Red – potential for substantial denitrification.
* – nitrification (yellow) may not directly lead to N losses but may convert N to forms that are more easily lost if conditions for losses exist.

Leaching

Period	Current	0.0" to 0.5"	0.5" to 1.0"	1.0" to 1.5"	1.5" to 2.0"	2.0" to 2.5"	2.5" to 3.0"	3.0" to 3.5"	3.5" to 4.0"
September 1 to November 10	Low								
	Medium	29/1	4/1	1/1	4/10	8/100	5/100	6/100	2/100
	High								
September 15 to November 10	Low								
	Medium	22/1	3/1	8/10	2/10	6/100	3/100	4/100	2/100
	High								
October 1 to November 10	Low								
	Medium	16/1	1/1	5/10	1/10	4/100			
	High								
October 15 to November 10	Low								
	Medium	10/1	8/10	2/10	8/100	4/100			
	High								
November 1 to November 10	Low								
	Medium	3/1	2/10	3/100	2/100				
	High								

Fractions – number of three consecutive days of rainfall occurrence (numerator) per number of years (denominator).
Current – soil moisture in 0-50” depth (0-130 cm): Low <30%, Medium 30-39%, High >39%.
Grey – low risk of leaching expected at any level of rainfall for fine textured soils; low hydraulic conductivity.

Equipment Purchased - none

Project Photos – N/A

Public Information Materials

Oral Presentations at Conferences

Fraser, T., Ojo, E.R., Bullock, P.R., Mohr, R. and Heard, J. Frequency of Extreme Precipitation and Associated Risk of Soil Nitrogen Losses. 65th Annual Manitoba Soil Science Society Meeting, Winnipeg, MB, February 2022

Web Infographic

Under development, hosted by the University of Manitoba

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Publications - none