Soil Nitrate Survey of Agricultural Fields in the Hullcar Valley in 2021

Final Report

BRITISH COLUMBIA

Ministry of Agriculture and Food

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Short title: 2021 Soil Nitrate Study: Hullcar Valley

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June 2022

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Acknowledgements

Thanks to the producers who volunteered their fields for soil sampling. Doug Macfarlane and Ruth McDougall helped with soliciting producer cooperation, sampling the fields, and arranging soil testing. Greg Rekken provided editorial comments.

Summary

The nitrate (NO_3-N) left in the soil profile after harvest is susceptible to leaching to groundwater during cooler months when precipitation exceeds plant evapotranspiration. By measuring the amount of nitrate in soil following crop harvest, some agronomic inferences can be made about N management over the course of the growing season. Additionally, this measurement can also be used as an environmental tool to determine how much soil nitrate may be at risk of leaching loss to groundwater.

In 2021, soil sampling was completed on 50 fields lying above Aquifer 103 in the Hullcar Valley of the North Okanagan to a 90-cm depth. Several new fields were introduced to the sampling area while others were removed. Overall, the area-weighted average soil nitrate value for the entire sampling area in 2021 was greater than 2020 (99 and 72 kg NO_3-N ha^{-1}, respectively), as was the median soil nitrate value (82 and 73 kg NO_3-N ha^{-1}, respectively). From 2020 to 2021, the area-weighted average and median soil nitrate value increase for fields cropped with silage corn. Additionally, the area-weighted average soil nitrate value increased for alfalfa/grass while the median soil nitrate value decreased during the same time period.

Among the fields sampled, 58% of the nitrate in the sampled 90 cm of soil was found in the 0-30 cm layer on average, while 23% and 19% was found in the 30-60 and 60-90 cm layers, respectively.

Table of Contents

List of Tables

1 Introduction

In recent years, the water quality of Aquifer 103, located in the Hullcar Valley in the North Okanagan of British Columbia, has had elevated concentration of nitrate (NO3-N). Some environmental impact studies have suggested that the elevated concentration of NO_3-N is due to over-application of nitrogen (N) on agricultural fields, as this region of British Columbia is dominated by forage crops grown for livestock feed (Associated Environmental 2016, Associated Environmental 2017a, Associated Environmental 2017b, Poon and Code 2017). However, it has not yet been established the rate at which NO_3-N moves from the crop rooting zone to the aquifer, which may range from a few years to several decades. Therefore, it is prudent for agricultural producers to minimize the amount of NO_3-N remaining in the soil after crop harvest, as this NO_3-N may contribute to contamination of the underlying aquifer (Andrews 2020b). Several studies have been conducted over the past few years to monitor residual soil nitrate after crop harvest in the Hullcar Valley above Aquifer 103 (Andrews 2020a, Andrews 2020b, Andrews 2021, Poon and Code 2017, Poon and Code 2018). The results reported for residual soil nitrate in the 0-90 cm of soil after the 2021 crop harvest in this study are a continuation of this work.

Sampling for soil nitrate (NO_3-N) after crop harvest can be used as both an agronomic and an environmental tool. When sampled to a 30-cm depth, the amount of soil nitrate can be used to evaluate the balance between N supply and crop uptake, commonly referred to as a post-harvest nitrate test (PHNT) (B.C. Ministry of Agriculture 2020, Sullivan et al. 2021). In the coastal regions of B.C., the amount of soil nitrate represents NO_3-N susceptible to leaching due to humid, mild winters (Kowalenko 2000). However, recent reports for the Okanagan show that, unlike in coastal regions, not all soil nitrate is susceptible to leaching during the following non-growing season (Andrews 2020a, Andrews 2020b, Poon and Code 2017, Poon and Code 2018).

Sampling in this study includes the zone of soil recommended for agronomic PHNT and deeper zones to monitor presence of nitrate down to 90 cm. The sampling and analysis employed do not allow for the determination of the origin or fate of nitrate.

The objective of this report is to determine the amount and distribution of soil nitrate after crop harvest in sampled fields in the Hullcar Valley in order to inform area producers' decisions on N management.

Primary Questions

1. Overlying Aquifer 103 and the nearby area, how many agricultural fields had elevated levels of soil nitrate in the 0-90 cm layer of soil after crop harvest in 2021?
2. How is nitrate distributed throughout the three soil sampling depths (0-30, 30-60, and 60-90 cm) in 2021?
3. How did soil nitrate levels compare between 2020 and 2021 in fields that had the same crop type?

Hypotheses

1. Most agricultural fields in the area had less than 100 kg ha^{-1} of soil nitrate (0-90 cm soil layer) in 2021.
2. The majority (>50%) of nitrate was found in the 0-30 cm soil layer for each crop type in 2021.
3. The area-weighted average and median soil nitrate values of the entire study area did not increase from 2020.

Out of Scope

- Measuring nitrate leaching during the growing season, possibly due to over-irrigation or quantities of rainfall significant enough to cause leaching
- Measuring nitrate leaching from non-cropped areas, such as manure storage areas
- Measuring N transformations, such as mineralization or denitrification, that influence soil and water nitrate concentrations
- Measuring N uptake or N use efficiency of harvested crops
- Measuring soil water movement or retention
- Updating nutrient management plans, including assessing relationships between nitrogen management practices and post-harvest soil nitrate testing results

2 Materials and Methods

Study area

The study area was mostly overlying Aquifer 103 in the Hullcar Valley of the North Okanagan, located south of Grindrod, B.C. The agricultural activity, crops, and soils of the region have previously been described by Poon and Code (2017). The average annual precipitation of the study area is 480 mm and the daily mean temperature ranges from a low of -2.3C in January to a high of 20.2C in July (Andrews 2020b).

The period of N application and management as well as post-harvest sampling ranged from April through October 2021. During this time, the area received 169 mm of cumulative precipitation, which may be inaccurate due to data collection errors at the weather station in May, September, and October 2021 (Table 1). This amount of cumulative precipitation, while inaccurate, is well below the long-term average (LTA; 1981-2010) of 292 mm during the same time period. Despite the low amount of precipitation, some fields in the study area did receive supplemental irrigation. Air temperature exceeded the LTA air temperature for five of the seven selected months.

Table 1. Cumulative precipitation and average temperature for spring through fall of 2019 - 2021 and the long-term average (LTA; 1981-2010) values at the Silver Creek station (approximately 7 km from the study area).

	Cumulative precipitation (mm)				Temperature (°C)			
Month	2019	2020	2021	LTA	2019	2020	2021	LTA
April	23.4	12.0	2.2	29.9	7.5	6.9	8.4	8.4
May	29.8	54.4	10.8[a]	48.7	14.5	12.9	12.6[a]	12.6
June	39.4	75.8	26.0	51.4	17.0	15.2	19.7	16.1
July	67.5	17.6	5.7	44.8	18.5	18.6	22.3	19.1
August	23.4	11.6	13.9	33.8	18.8	18.7	18.9	18.4
September	79.8	20.2	39.4[a]	34.0	14.3	15.6	13.8[a]	13.5
October	33.6	82.1	71.2[a]	49.1	5.8	6.7	7.1[a]	6.7
Total	296.9	273.7	169.2[a]	291.7	-	-	-	-

Data: Environment Canada 2022.

[a] Incomplete data

Field Selection and Sampling Methodology

Fifty agricultural fields above Aquifer 103 were selected for sampling in 2021. Field delineation was based on consistent N management within the area and to keep total field size under 25 hectares. The total study area was 775 hectares, with 332 hectares of the area cropped with alfalfa/grass and 443 hectares of the area cropped with silage corn.

While the sampling area in 2021 was similar to 2020, several fields were removed from the sampling area while others were introduced (Table 4). Overall, there were 22 fields (332 ha) cropped with alfalfa/grass in 2021, compared to 21 (327 ha) in 2020. Twenty-eight fields (443 ha) were cropped with silage corn in 2021, while 24 fields (396) were cropped with silage corn in 2020. There were no fields cropped with nursery trees in 2021, while there were 3 (68 ha) in 2020. All fields were given new identifiers to protect producer privacy, and exact location of each field is unknown to the Ministry of Agriculture and Food.

The soil sampling methodology was consistent with those used previously from 2016 to 2020 (Andrews 2020a, Andrews 2020b, Andrews 2021, Poon and Code 2017, Poon and Code 2018). For each sampling area, one composite soil sample was taken at the 0-15, 15-30, 30-60, and 60-90 cm depths from twenty random locations throughout each field. In 2021, fields were sampled throughout October, and each field was sampled within 10 days of harvest.

Analyses

The laboratory and data analyses were the same as in previous years (Andrews 2020a, Andrews 2020 b, Andrews, 2021, Poon and Code 2017, Poon and Code 2018). After sampling, soil samples were refrigerated during delivery to prevent changes in nitrogen concentrations through microbial activity. Samples were then air-dried, sieved, extracted with potassium chloride, and analyzed by A&L Laboratories (London, ON).

The concentrations of extractable soil nitrate-nitrogen was converted to kg NO_3-N ha^{-1} using soil bulk densities of 1300 kg m^{-3} for the 0-15 and 15-30 cm soil layers and 1500 kg m^{-3} for the 30-60 and 60-90 cm soil layers. The total amount of nitrate-nitrogen found in the 0-90 cm soil layer was categorized into four categories (modified from Kowalenko et al. 2009): Low (0-49 kg NO_3-N ha^{-1}), Medium (50-99 kg NO_3-N ha^{-1}), High (100-200 kg NO_3-N ha^{-1}), and Very High ($\geq$200 kg NO_3-N ha^{-1}).

The environmental risk categories originally described by Kowalenko et al. (2007, 2009) classified total nitrate-nitrogen for the 0-60 cm sampling depth. However, the category names and ranges used in this study are based on a 0-90 cm sampling depth, which may increase the total measured amount of NO_3-N for each field and increase the likelihood of a field being placed into a higher NO_3-N category.

3 Results and Discussion

Overall, 22% of the total sampled land area had a 'Low' rating (11 fields), 35% had a 'Medium' rating (18 fields), 31% had a 'High' rating (15 fields), and 12% had a 'Very High' rating (6 fields). 57% of the total sampled land area, a total of 29 fields, had less than 100 kg NO_3-N ha^{-1}, which supports the hypothesis (Hypothesis 1) that the majority of fields had soil nitrate values below 100 kg NO_3-N ha^{-1}.

There were differences in average soil nitrate (0-90 cm) between the two crop types in 2021 (Table 2). Silage corn had the highest area-weighted average soil nitrate value of 117 kg NO_3-N ha^{-1} and accounted for the greatest proportion of sampled land area, 57%. Alfalfa/grass accounted for the remaining 43% of the sampled land area and had an area-weighted average soil nitrate value of 75 kg NO_3-N ha^{-1}.

Table 2. Sampling area and soil nitrate test statistics for the 2021 post-harvest sampling period.

Crop type	No. of sampling areas	Area sampled	Area-weighted average PHNT[a]	Maximum PHNT	Median PHNT	Minimum PHNT
	-	(ha)	------------------kg NO_3-N ha^{-1} ------------------			
Alfalfa/grass	22	332	75	240	50	15
Silage corn	28	443	117	284	109	47
All crops	50	775	99	284	82	15

[a] In an area-weighted average, sampling areas that were larger in size contributed more to the average PHNT value comparted to areas that were smaller. In contrast, all areas contribute equally to a simple average regardless of the size of the area.

In 2021, 58% of the total area-weighted average soil nitrate for each field was found in the uppermost 0-30 cm sampling zone (Table 3), supporting the hypothesis (Hypothesis 2) that the majority of nitrate would be found in this sampling zone. At lower depths, 23% and 19% of the total area-weighted average soil nitrate was found at the 30-60 and 60-90 cm depths, respectively.

Table 3. The proportion of all nitrate found in the 0-30 cm, 30-60 cm, and 60-90 cm sampling depths for the 2021 sampling period.

Crop	0-30 cm	30-60 cm	60-90 cm
Alfalfa/grass	60%	25%	15%
Silage corn	57%	22%	21%
All crops	58%	23%	19%

To interpret the results, the difference between the agronomic N and crop N removal rates needs to be understood. The agronomic N rate is the N application rate at which crop growth and yield is not limited. This rate is always greater than the crop N removal rate, which is the amount of N that the crop removes from the soil. Since no crop uses all N in the soil, a certain amount of post-harvest nitrate is expected. The amount depends on several factors, including crop, soil type, and weather.

The amount of nitrate found in the soil after crop harvest can be used to make inferences about N application rates and use (Sullivan et al. 2021). Based on the range of soil nitrate values it appears that most fields had a greater N uptake than the typical assumption of 50% of applied N (Hermanson et al. 2000) or did not receive significant amounts of supplemental N. This indicates for these fields that N was applied at an agronomic rate and were managed for optimal crop uptake (Sullivan et al. 2021).

Kowalenko et al. (2009) cautions against the use of PHNT values alone to describe the risk of nitrate leaching in the Okanagan. Recent studies during the non-growing season in the Hullcar Valley show that movement of NO_3-N through the soil is fairly limited, and that NO_3-N can expected to be present at planting the following year (Poon and Code 2017, Poon and Code 2018, Andrews 2020a, Andrews 2020b). In this area, producers should expect some soil NO_3-N to be present at the beginning of the growing season and incorporate it into their N management strategies for the next season. Monitoring PHNT values, crop yield, and crop quality on an annual basis provides information to minimize excess nitrate over time without compromising crop production goals (Poon and Code 2017).

Comparisons between years

The area-weighted average and median soil nitrate value for the study area was somewhat higher in 2021 in comparison to 2020 (Table 4). In 2020, the area-weighted average and median soil nitrate value was 72 and 73 kg NO_3-N ha^{-1}, respectively. In 2021, these values were 99 and 82 kg NO_3-N ha^{-1}, respectively. This represents a 27 kg NO_3-N ha^{-1} increase in the area-weighted average soil nitrate value from 2020 to 2021, and a 9 kg NO_3-N ha^{-1} increase in the median soil nitrate value from 2020 to 2021. However, it should be noted that there was also an increase in the number of fields and amount of land cropped with both silage corn and alfalfa/grass from 2020 to 2021, both of which typically receive greater application amounts of N. Nonetheless, these increases do not support the hypothesis that area-weighted average median soil nitrate did not increase from 2020 to 2021 (Hypothesis 3).

From 2020 to 2021, the area-weighted average soil nitrate value increased for alfalfa/grass, from 66 to 75 kg NO_3-N ha^{-1}, while the median value decreased from 63 to 50 kg NO_3-N ha^{-1} (Table 4). In the same time period, both the area-weighted average and median soil nitrate value increase for silage corn, from 84 and 85 kg NO_3-N ha^{-1}, to 117 and 109 kg NO_3-N ha^{-1}, respectively. Increases observed from 2020 to 2021 may be due to several factors, such as an increased N application rate for crops with greater N requirements (such as silage corn), application of N over the agronomic rate, or late-season mineralization of organic N due to conditions that were warmer and wetter than normal (Table 2).

4 Conclusions

The 2021 area-weighted average and median soil nitrate values of the study area were greater than 2020 values. Both silage corn and alfalfa/grass had greater area-weighted average soil nitrate values than 2020, while alfalfa/grass had a lower median soil nitrate value. Increases in soil nitrate measures may be due to several factors, such as greater N application rates for an increased number of N-demanding crops or late-season mineralization of soil organic N. However, due to the position of the fields above the aquifer, soil nitrate and N management practices should continue to be monitored to ensure the efficient uptake of applied N and minimize the amount of nitrate vulnerable to leaching loss.

Table 4. Sampling area and post-harvest nitrate test statistics for the 2020 and 2021 post-harvest sampling periods.

	2020				2021			
Crop type	No. of sampling areas	Area sampled	Area-weighted average PHNT[a]	Median PHNT	No. of sampling areas	Area sampled	Area-weighted average PHNT[a]	Median PHNT
	-	(ha)	---kg NO_3-N ha^{-1}---		-	(ha)	---kg NO_3-N ha^{-1}---	
Alfalfa/grass	21	327	66	63	22	332	75	50
Silage corn	24	396	84	85	28	443	117	109
Nursery trees	3	68	34	28	-	-	-	-
All crops	48	791	72	73	50	775	99	82

[a] In an area-weighted average, sampling areas that were larger in size contributed more to the average PHNT value comparted to areas that were smaller. In contrast, all areas contribute equally to a simple average regardless of the size of the area.

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6 Supplemental Materials

Supplemental Table 1. Post-harvest nitrate by soil layer (depth) in sampling areas that were silage corn in 2021.

Depth (cm)	NO_3-N (ppm)	kg NO_3-N ha^{-1}	Depth (cm)	NO_3-N (ppm)	kg NO_3-N ha^{-1}
0-15	30	58	0-15	22	43
15-30	15	30	15-30	9	18
30-60	9	41	30-60	5	23
60-90	8	37	60-90	4	18
0-15	12	24	0-15	20	39
15-30	5	10	15-30	11	21
30-60	6	28	30-60	7	33
60-90	2	9	60-90	10	47
0-15	8	16	0-15	42	83
15-30	6	12	15-30	20	39
30-60	2	9	30-60	9	42
60-90	2	9	60-90	12	55
0-15	15	30	0-15	20	40
15-30	6	12	15-30	15	28
30-60	2	9	30-60	8	37
60-90	2	9	60-90	5	23
0-15	13	26	0-15	19	38
15-30	7	14	15-30	12	22
30-60	3	14	30-60	4	19
60-90	2	9	60-90	7	33
0-15	12	24	0-15	37	72
15-30	5	10	15-30	14	27
30-60	2	9	30-60	7	33
60-90	2	9	60-90	5	23
0-15	21	40	0-15	20	39
15-30	9	18	15-30	7	14
30-60	3	14	30-60	3	14
60-90	4	18	60-90	2	9
0-15	17	34	0-15	38	73
15-30	5	10	15-30	18	35
30-60	2	9	30-60	10	47
60-90	1	5	60-90	13	60

Supplemental Table 2. Post-harvest nitrate by soil layer (depth) in sampling areas that were silage corn in 2021 (continued).

Depth (cm)	NO_3-N (ppm)	kg NO_3-N ha^{-1}	Depth (cm)	NO_3-N (ppm)	kg NO_3-N ha^{-1}
0-15	40	77	0-15	27	53
15-30	18	34	15-30	13	26
30-60	5	23	30-60	6	28
60-90	10	46	60-90	2	9
0-15	25	48	0-15	23	44
15-30	11	22	15-30	8	16
30-60	4	18	30-60	6	28
60-90	4	18	60-90	3	14
0-15	25	48	0-15	11	22
15-30	13	26	15-30	6	12
30-60	8	37	30-60	5	23
60-90	10	46	60-90	5	23
0-15	32	62	0-15	13	26
15-30	12	24	15-30	8	16
30-60	3	14	30-60	2	9
60-90	3	14	60-90	1	5
0-15	41	81			
15-30	17	32			
30-60	12	56			
60-90	8	37			
0-15	25	48			
15-30	10	20			
30-60	7	32			
60-90	3	14			
0-15	21	40			
15-30	9	18			
30-60	4	18			
60-90	2	9			
0-15	11	22			
15-30	39	75			
30-60	21	96			
60-90	20	91			

Supplemental Table 3. Post-harvest nitrate by soil layer (depth) in sampling areas that were alfalfa/grass in 2021.

Depth (cm)	NO_3-N (ppm)	kg NO_3-N ha^{-1}	Depth (cm)	NO_3-N (ppm)	kg NO_3-N ha^{-1}	Depth (cm)	NO_3-N (ppm)	kg NO_3-N ha^{-1}
0-15	10	20	0-15	16	32	0-15	10	20
15-30	6	12	15-30	25	48	15-30	9	18
30-60	2	9	30-60	14	64	30-60	9	41
60-90	2	9	60-90	5	23	60-90	4	18
0-15	1	2	0-15	9	18	0-15	13	26
15-30	6	12	15-30	6	12	15-30	9	18
30-60	4	18	30-60	2	9	30-60	6	27
60-90	3	14	60-90	2	9	60-90	3	14
0-15	5	10	0-15	5	10	0-15	35	68
15-30	3	6	15-30	3	6	15-30	39	76
30-60	1	5	30-60	2	9	30-60	9	42
60-90	1	5	60-90	1	5	60-90	5	23
0-15	9	18	0-15	4	8	0-15	56	110
15-30	4	8	15-30	2	4	15-30	32	62
30-60	2	9	30-60	1	5	30-60	9	41
60-90	2	9	60-90	1	5	60-90	6	28
0-15	2	4	0-15	5	10	0-15	16	32
15-30	1	2	15-30	3	6	15-30	6	12
30-60	1	5	30-60	2	9	30-60	3	14
60-90	1	5	60-90	1	5	60-90	1	5
0-15	4	8	0-15	6	12	0-15	25	48
15-30	4	8	15-30	11	22	15-30	8	16
30-60	2	9	30-60	2	9	30-60	7	32
60-90	2	9	60-90	2	9	60-90	7	32
0-15	3	6	0-15	11	22			
15-30	5	10	15-30	15	30			
30-60	3	14	30-60	3	14			
60-90	1	5	60-90	3	14			
0-15	8	16	0-15	12	24			
15-30	8	16	15-30	9	18			
30-60	3	14	30-60	4	18			
60-90	1	5	60-90	2	9			