Soil Nitrate Survey of Agricultural Fields in the Hullcar Valley in 2020

Final Report

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Disclaimer

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 2020, soil sampling was completed on 39 fields lying above Aquifer 103 in the Hullcar Valley of the North Okanagan to a 90-cm depth. The area-weighted average soil nitrate value for the entire sampling area in 2020 was similar to 2019 (72 and 78 kg NO_3-N ha^{-1}, respectively), as was the median soil nitrate value for the overall sampling area (73 and 70 kg NO_3-N ha^{-1} for 2020 and 2019, respectively). From 2019 to 2020, the area-weighted average soil nitrate value and median soil nitrate value decreased for fields cropped with silage corn and alfalfa/grass, which represent 91% (29 fields) of the total sampled land area.

Among the fields sampled, 56% of the nitrate in the sampled 90 cm of soil was found in the 0-30 cm layer on average, while 24% and 20% was found in the 30-60 and 60-90 cm layers, respectively.

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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, Poon and Code 2017, Poon and Code 2018). The results reported for residual soil nitrate in the 0-90 cm of soil after the 2020 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 2020?
2. How is nitrate distributed throughout the three soil sampling depths (0-30, 30-60, and 60-90 cm) in 2020?

3. How did soil nitrate levels compare between 2019 and 2020 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 2019.
2. The majority (>50%) of nitrate was found in the 0-30 cm soil layer for each crop type in 2020.
3. The area-weighted average and median soil nitrate values of the entire study area did not increase from 2019.

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 2020. During this time, the area received 274 mm of cumulative precipitation, slightly below the long-term average (LTA; 1981-2010) of 292 mm during the same time period. However, some fields in the study area did receive supplemental irrigation. Air temperature exceeded the LTA air temperature for three of the seven selected months.

Table 1. Cumulative precipitation and average temperature for spring through fall of 2018 - 2020 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	2018	2019	2020	LTA	2018	2019	2020	LTA
April	44.8	23.4	12.0	29.9	7.4	7.5	6.9	8.4
May	25.6	29.8	54.4	48.7	16.2	14.5	12.9	12.6
June	66.4	39.4	75.8	51.4	16.2	17.0	15.2	16.1
July	32.4	67.5	17.6	44.8	19.4	18.5	18.6	19.1
August	24.0	23.4	11.6	33.8	17.9	18.8	18.7	18.4
September	87.6	79.8	20.2	34.0	12.3	14.3	15.6	13.5
October	49.6	33.6	82.1	49.1	6.0	5.8	6.7	6.7
Total	330.4	296.9	273.7	291.7	-	-	-	-

Data: Environment Canada 2021.

Field selection and Sampling Methodology

All thirty-nine fields that were sampled in 2019 for post-harvest nitrate were sampled again in 2020. Field delineation was based on having consistent N management within the area. Additionally, all of the original nine fields that were split in 2017, 2018, and 2019 were also split in 2020. These fields were split either due to differences in soil types or to keep the total field size under 25 ha. In summary, there were 39 fields and 48 sampling areas in 2020.

As no field changes were made from 2019 to 2020, the total study area remained 791 hectares. From 2019 to 2020, there were three more sites in which alfalfa/grass was grown, an increase in the total cropped area of alfalfa/grass in the study area from 302 hectares to 327 hectares. Silage corn was grown three fewer sites from 2019 to 2020, a decrease in total cropped area from 421 to 396 hectares. The same sampling areas were grown with nursery trees in 2020 as in 2019, so there was no change in the number of sampling areas or the total cropped area.

The soil sampling methodology was consistent with those used previous from 2016 to 2019 (Andrews 2020a, Andrews 2020b, 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 2019, fields were sampled from 9 October through 29 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, 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 (≥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, 27% of the total sampled land area had a 'Low' rating (9 fields), 50% had a 'Medium' rating (20 fields), and 23% had a 'High' rating (10 fields). No fields had 200 kg NO_3-N ha^{-1} or more, the threshold for a 'Very High' rating. Therefore, 77% of the total sampled land area, a total of 29 fields, had less than 100 kg NO_3-N ha^{-1}. This 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 crop types in 2020 (Table 2). Silage corn had the highest area-weighted average soil nitrate value of 84 kg NO_3-N ha^{-1} and accounted for the greatest proportion of sampled land area, 50%. Alfalfa/grass had an area-weighted average soil nitrate value of 66 kg NO_3-N ha^{-1} and accounted for 41% of the total sampled land area. Nursery tress had the lowest area-weighted average soil nitrate value, 34 kg NO_3-N ha^{-1}, but only accounted for 9% of the total sampled land area.

Table 2. Sampling area and soil nitrate test statistics for the 2020 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	21	327	66	160	63	29
Silage corn	24	396	84	154	85	23
Nursery trees	3	68	34	54	28	27
All crops	48	791	72	160	73	23

[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 2020, 56% 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. In fact, the majority of the total area-weighted average soil nitrate was found in the 0-30 cm sampling zone for all crop types in 2020. At lower depths, 24% and 20% 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 2020 sampling period.

Crop	0-30 cm	30-60 cm	60-90 cm
Alfalfa/grass	60%	21%	19%
Silage corn	53%	27%	20%
Nursery trees	56%	22%	22%
All crops	56%	24%	20%

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, as well as the area-weighted average soil nitrate value for each crop type, 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 similar in 2020 in comparison to 2019 (Table 4). In 2019, the area-weighted average and median soil nitrate value was 78 and 70 kg NO_3-N ha^{-1}, respectively. In 2020, these values were 72 and 73 kg NO_3-N ha^{-1}, respectively. This represents a 6 kg NO_3-N ha^{-1} decrease in the area-weighted average soil nitrate value from 2019 to 2020 and a 3 kg NO_3-N ha^{-1} increase in the median soil nitrate value. While there was a decrease in the area-weighted average soil nitrate value, the small increase in the median soil nitrate value does not support the hypothesis that both of these measures did not increase from 2019 to 2020 (Hypothesis 3).

While there were small differences in the area-weighted average and median soil nitrate values for the entire study area, these measures both decreased in fields cropped with alfalfa/grass and silage corn (Table 4). However, nursery trees had an increase in both measures but remained relatively low overall. This increase may be due to an increased N application rate, reduced N uptake, or more than expected N mineralization during the growing season.

Year-to-year trends in soil nitrate values for a given field can only be compared if the crop is the same between years. From 2019 to 2020 in such fields, 9 silage corn fields had no change in soil nitrate values (± 25 kg NO_3-N ha^{-1}), 3 fields had an increase in soil nitrate values, and 6 fields had a decrease. For alfalfa/grass, 10 fields had no change in soil nitrate values, 1 decreased, and none had an increase. Of the two fields planted with nursery trees, neither had a change in soil nitrate values. Overall, 3 of the 31 fields that had consistent crops from 2019 to 2020 had an increase in soil nitrate values, 7 fields had a decrease, and 21 fields did not change. For the few fields that saw an increase in soil nitrate, an evaluation of N application practices should be conducted to ensure that an agronomic N rate is being applied and that N is applied efficiently on these fields.

Overall, soil nitrate was similar in 2020 in comparison to soil nitrate values from 2019. From 2019 to 2020, the area-weighted average soil nitrate value for the overall study area decreased by 6 kg NO_3-N ha^{-1} while the median soil nitrate value increased by 3 kg NO_3-N ha^{-1}. Both silage corn and alfalfa/grass had decreases in both measures while nursery trees saw slight increases. Only a few fields saw an increase in soil nitrate values when compared to 2019, while the vast majority of fields either saw a decrease or no change. In the fields that did see an increase, N application practices should be reviewed to determine which practices, such as application rate or timing, may need to be adjusted to ensure optimal N uptake by crops.

4 Conclusions

The 2020 area-weighted average and median soil nitrate values of the study are were similar to 2019 values. As a group, both silage corn and alfalfa/grass fields had lower soil nitrate in 2020 than in 2019. A few fields had an increase in soil nitrate values from 2019 to 2020, but most fields either had a decrease or no change in the amount of soil nitrate. 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 2019 and 2020 post-harvest sampling periods.

	2019				2020			
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	18	302	77	66	21	327	66	63
Silage corn	27	421	88	92	24	396	84	85
Nur. trees	3	68	20	21	3	68	34	28
All crops	48	791	78	70	48	791	72	73

[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 2020.

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	11	22	0-15	16	32	0-15	25	50
15-30	8	16	15-30	2	4	15-30	14	28
30-60	3	14	30-60	2	9	30-60	5	23
60-90	3	14	60-90	6	27	60-90	4	18
0-15	11	22	0-15	20	38	0-15	12	24
15-30	5	10	15-30	7	14	15-30	6	12
30-60	2	9	30-60	2	9	30-60	3	14
60-90	3	14	60-90	5	23	60-90	1	5
0-15	6	12	0-15	18	34	0-15	39	75
15-30	5	10	15-30	9	18	15-30	19	38
30-60	2	9	30-60	6	28	30-60	4	18
60-90	2	9	60-90	5	23	60-90	1	5
0-15	12	24	0-15	20	39	0-15	12	24
15-30	6	12	15-30	8	16	15-30	9	18
30-60	2	9	30-60	3	14	30-60	5	23
60-90	2	9	60-90	4	18	60-90	2	9
0-15	31	61	0-15	11	22	0-15	16	31
15-30	12	24	15-30	6	12	15-30	7	14
30-60	6	28	30-60	3	14	30-60	11	50
60-90	3	14	60-90	2	9	60-90	7	32
0-15	20	40	0-15	5	10	0-15	15	30
15-30	5	10	15-30	4	8	15-30	6	12
30-60	2	9	30-60	19	86	30-60	4	18
60-90	3	14	60-90	11	50	60-90	3	14
0-15	13	26	0-15	12	24	0-15	5	10
15-30	16	32	15-30	10	20	15-30	2	4
30-60	5	23	30-60	5	23	30-60	1	5
60-90	3	14	60-90	9	41	60-90	1	5
0-15	16	30	0-15	4	8	0-15	15	30
15-30	15	30	15-30	1	2	15-30	11	22
30-60	4	18	30-60	16	73	30-60	6	28
60-90	3	14	60-90	3	14	60-90	6	27

Supplemental Table 2. Post-harvest nitrate by soil layer (depth) in sampling areas that were alfalfa/grass or nursery trees in 2020.

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	9	18	0-15	19	38
15-30	5	10	15-30	3	6	15-30	5	10
30-60	1	5	30-60	1	5	30-60	1	5
60-90	1	5	60-90	1	5	60-90	1	5
0-15	6	12	0-15	10	20	0-15	33	64
15-30	4	8	15-30	5	10	15-30	12	24
30-60	1	5	30-60	1	5	30-60	6	27
60-90	1	5	60-90	2	9	60-90	10	46
0-15	14	28	0-15	15	30	0-15	17	34
15-30	6	12	15-30	4	8	15-30	9	18
30-60	3	14	30-60	1	5	30-60	3	14
60-90	2	9	60-90	1	5	60-90	2	9
0-15	14	28	0-15	25	48	0-15	23	44
15-30	5	10	15-30	9	18	15-30	10	20
30-60	5	23	30-60	3	14	30-60	4	18
60-90	2	9	60-90	2	9	60-90	2	9
0-15	13	26	0-15	17	34	0-15	17	34
15-30	4	8	15-30	10	20	15-30	19	38
30-60	3	14	30-60	5	23	30-60	9	41
60-90	3	14	60-90	3	14	60-90	5	23
0-15	15	30	0-15	6	12	0-15	8	16
15-30	5	10	15-30	3	6	15-30	3	6
30-60	2	9	30-60	1	5	30-60	3	14
60-90	2	9	60-90	1	5	60-90	9	41
0-15	7	14	0-15	12	24	0-15	10	20
15-30	2	4	15-30	6	12	15-30	5	10
30-60	2	9	30-60	2	9	30-60	4	18
60-90	1	5	60-90	2	9	60-90	6	27
0-15	15	30	0-15	3	6	0-15	14	28
15-30	3	6	15-30	2	4	15-30	5	10
30-60	1	5	30-60	2	9	30-60	3	14
60-90	2	9	60-90	2	9	60-90	3	14