# Targeted Tile Drainage for Agronomic and Environmental Efficiencies

## Year 2 Interim Report

  


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## Executive Summary

Temporary and seasonal wetlands have been shown to provide many ecological benefits in natural landscapes but are less beneficial and can be problematic in land under commercial crop production. Landowners and producers have used tile drainage to manage excess water from temporary and seasonal wetlands, and have demonstrated agronomic, environmental, and economic benefits to this practice. However, there has been little formal research addressing this topic.

The SaskFSA have commissioned a study with the objective to identify and quantify soil and crop production benefits of using tile drainage to manage excess water associated with temporary or seasonal wetlands in a prairie pothole landscape.

Tile drainage was installed on three separate fields in fall 2020. The tile was installed using a targeted design, with the purpose of consolidating of several shallow and seasonal wetlands within each field. A study was designed to monitor changes in the soil and in crop productivity in the landscape in and around the managed wetlands, in the years following the tile installation.

The first two years of data collection have been completed and a final year of data collection is planned for 2023. The trends and results observed after the first two years of the study were generally as hypothesized, considering the conditions experienced over the study to date. A more in-depth interpretation of the results will be possible after the third year of data collection.

## Project Objective

To identify and quantify soil and crop production benefits of using targeted tile drainage to manage excess water associated with temporary or seasonal wetlands in a prairie pothole landscape.

## Project Rationale

Temporary wetlands (Class II) typically have fairly rapid water seepage, but surface water that usually lingers for a few weeks after spring snowmelt and for several days after heavy rainstorms at other times of the year. Seasonal wetlands (Class III) usually dry up by midsummer. These types of wetlands provide many ecological benefits in natural landscapes but can be problematic in land under commercial crop production.

When temporary or seasonal wetlands are located in land under crop production, they can cause production inefficiencies such as delayed field operations due to waterlogged soil, and slowed field operations and overlap of product applications due to equipment having to operate non-linearly over the landscape. Crop productivity is affected by excess water, salinity, and compaction issues in the areas surrounding the wetlands. Wetlands located in agricultural landscapes have also been shown to be prone to the accumulation of nutrients and agricultural contaminants and are often not biologically productive.

Landowners and producers have used both surface and tile drainage to manage excess water from temporary and seasonal wetlands. Tile drainage has become more common in the Prairies in recent years.

Tile drainage is usually preferable to surface drainage in crop production landscapes, for both agronomic and environmental reasons. Tile drainage effectively lowers the water table, so crop productivity is increased in areas that used to be waterlogged. Nutrient uptake may also potentially be increased as crop productivity increases, and also because roots are able to penetrate deeper in the soil. The lower water table also provides temporary storage space for excess water from snowmelt or rain events, resulting in less overland flow of water and nutrients. Unfortunately, tile drainage has also often been associated with negative environmental consequences, most often in relation to the loss of ecological functions that wetlands provide in natural, not managed, landscapes.

There are several designs that are used when installing tile drainage, depending on the objective of drainage and the hydrology of the landscape. Targeted tile drainage design is appropriate in hummocky landscapes, where only a minor proportion of the land is affected by excess water. The majority of the landscape can be left undisturbed, so this design may be less susceptible to environmental issues such as the movement of nutrients. However, there has been little research addressing this topic.

In consideration of the production benefits offered, the SaskFSA would like to demonstrate that tile drainage can be part of good land stewardship and may even provide environmental benefits, such as increased nutrient uptake, decreased overland flow, and more efficient use of inputs.

## Methodology

The study was conducted in the R.M. of Kellross No. 247. Tile drainage was installed by the landowners on three separate fields in fall 2020, prior to the initiation of the study. The tile was installed using a targeted design, with the purpose of consolidating of several wetlands of varying sizes and permanence, mainly shallow and seasonal, within each field.

*Study Design*

The study was designed to monitor changes in the soil and in crop productivity in the landscape in and around the managed wetlands, in the years following the tile installation.

The edges of the managed wetlands, or areas that were previously uncropped, were delineated using geo-rectified aerial photography that was taken in the fall of 2020. Four separate zones were defined in the areas in and around the managed wetlands:

1) Zone 1 is the interior of the managed wetland, or the previously uncropped area.
2) Zone 2 comprises a 60-foot width around the outside edge of the managed wetland, or the first seeding pass using the cooperating operation's 60-foot seeding implement, and represents the marginal cropland.
3) Zone 3 is the second pass of the seeding implement around the wetland, so comprises the area between 60 and 120 ft from the edge of the wetland, and represents the potential overlap and compaction zone.
4) Zone 4 is between 120 and 180 ft from the edge of the wetland, and represents the control or where we would expect normal or average crop productivity.

We expect that different sizes and locations of wetlands might respond differently to tile drainage based on their hydrology, as in where and how much water is moving in the surrounding landscape. Thus, in each of the three fields, four replicate sites were identified that were associated with different managed wetlands of varying sizes, or on different edges of one large managed wetland. Each replicate included sample sites in each of the four zones. Nitrogen fertilizer was applied at a variable rate (VR) in each of the three fields, thus, to control for the effect of applied fertilizer rate, each of the four sample sites within a replicate were located in the same VR management zone, using the prescription map provided by the grower's agronomist.

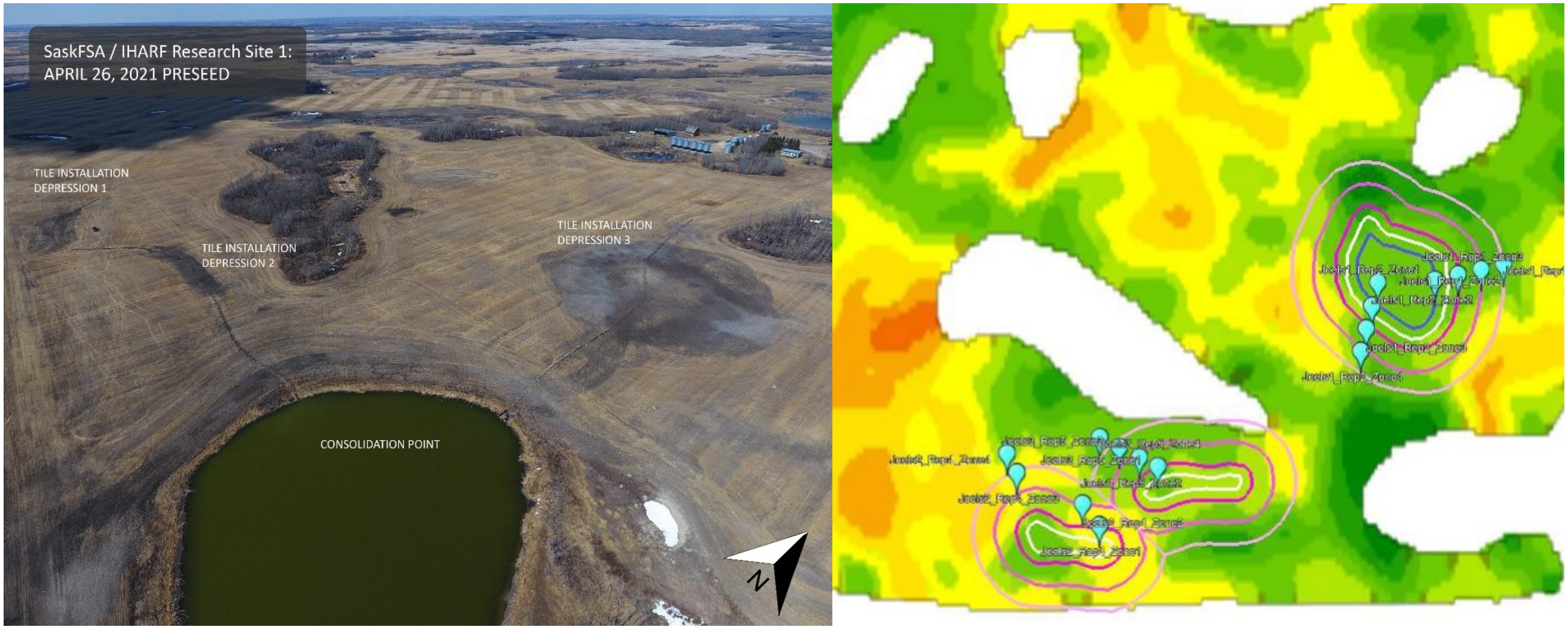


**Figure 1**. Aerial image of Field 1 showing the tile drainage lines shortly after installation (left), and (right) a site map showing the delineation of the managed wetlands and zones (white line is edge of managed wetland and coloured lines run through centre of each zone), and the sample sites grouped by replicate within the same VR management zone (base map shows VR prescription).

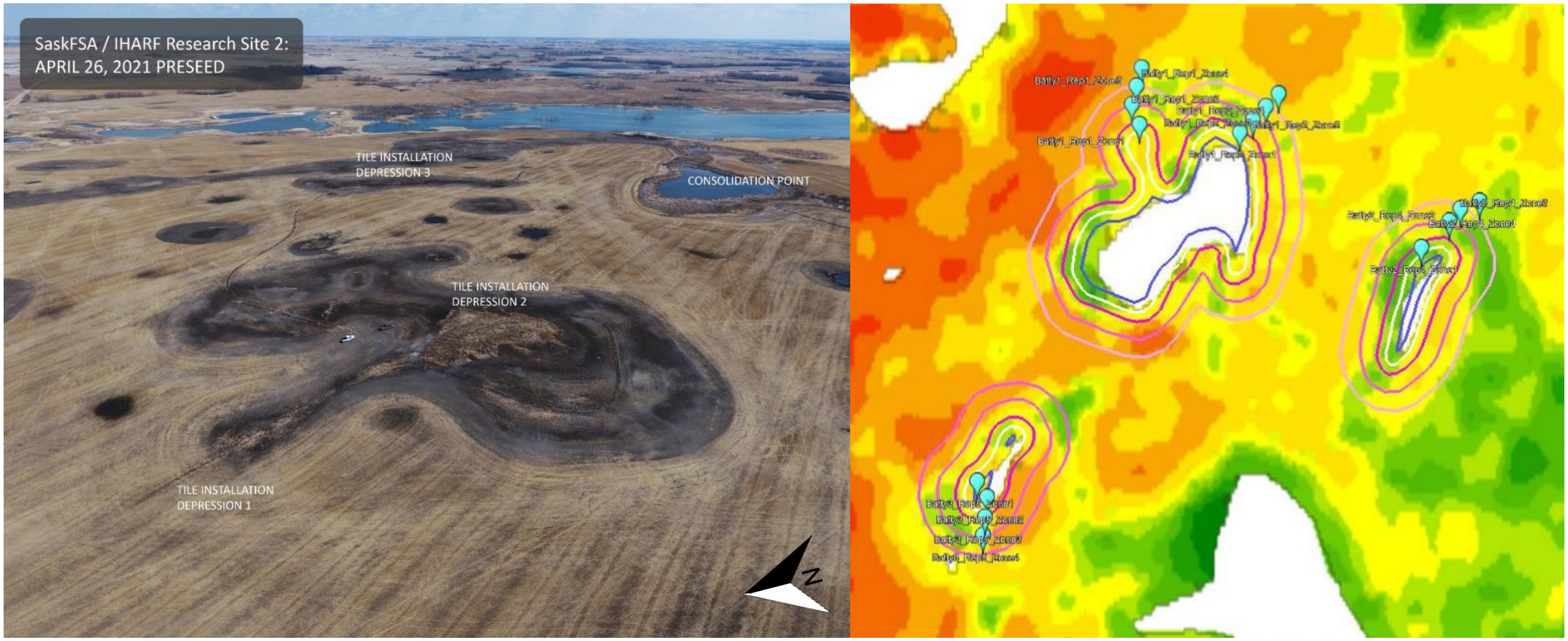


**Figure 2**. Aerial image of Field 2 showing the tile drainage lines shortly after installation (left), and (right) a site map showing the delineation of the managed wetlands and zones (white line is edge of managed wetland and coloured lines run through centre of each zone), and the sample sites grouped by replicate within the same VR management zone (base map shows VR prescription).

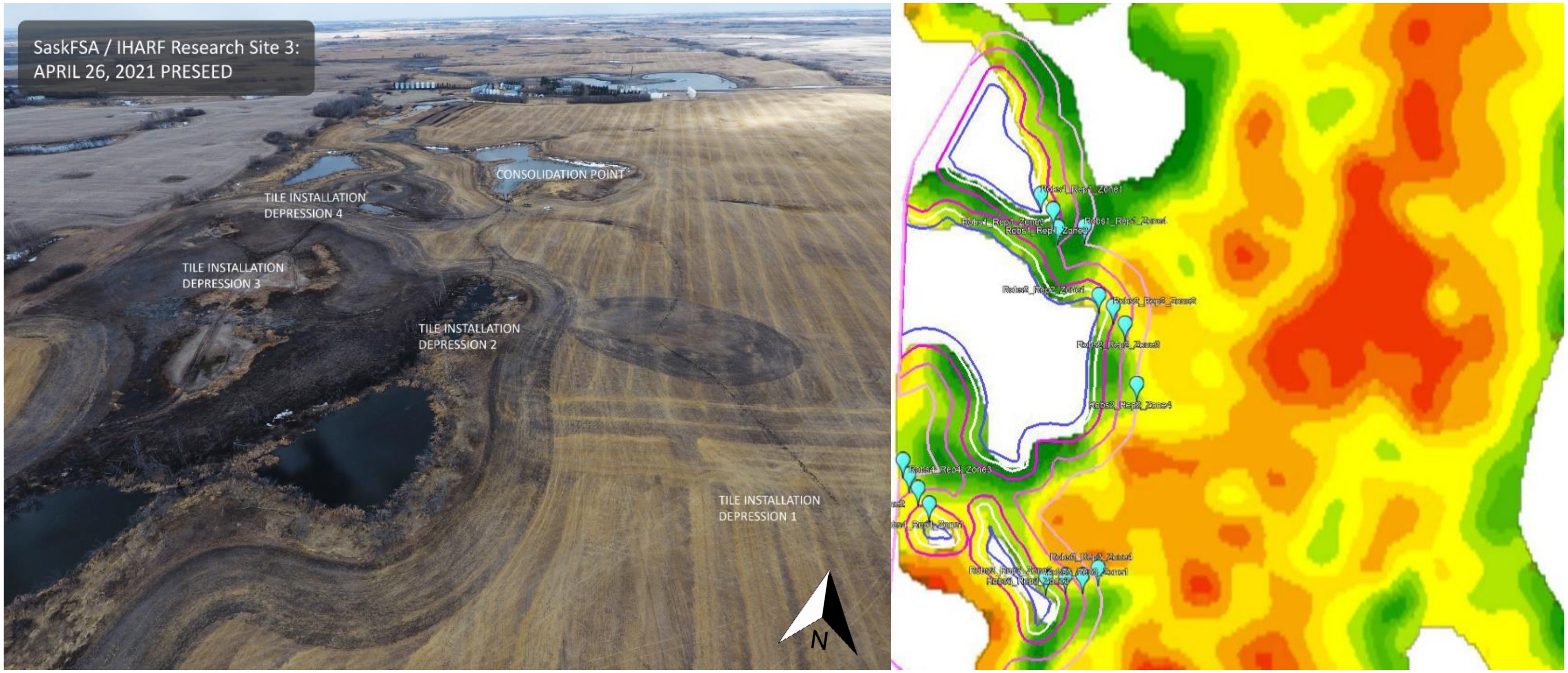


**Figure 3**. Aerial image of Field 3 showing the tile drainage lines shortly after installation (left), and (right) a site map showing the delineation of the managed wetlands and zones (white line is edge of managed wetland and coloured lines run through centre of each zone), and the sample sites grouped by replicate within the same VR management zone (base map shows VR prescription).

*Data collection*

It was hypothesized that each of the four zones in and around the managed wetlands would respond differentially to tile drainage. Thus, changes in the soil and crop productivity in each of the four zones will be monitored for a minimum of three years following tile installation.

Soil samples were collected at each sample site before seeding in the spring of 2021 and 2022. A dutch auger was used to remove 3 soil cores at each sample site, separated by depth from 0 to 6 inches, 6 to 12 inches, and 12 to 24 inches. The 3 cores were combined into a single sample for each depth. The samples were dried, ground, and submitted for a complete analysis of soil properties and nutrients. Non-mobile soil characteristics were only measured for the topsoil depth.

After harvest was completed, yield maps were obtained from the cooperating grower. SMS (Spatial Management System, Ag Leader Technology Inc.) and QGIS ([www.qgis.org](www.qgis.org)) were utilized to extract and clean the raw data, and determine the average yield within a 30-m radius from each sample site.

*Statistical Analysis*

Data were analyzed with the R statistical program (R Core Team 2022), using the *lme4* package for fitting mixed-effects models, the *lmerTest* package for assessing model fit and treatment differences, and the *emmeans* package for means separation. To assess differential changes in soil characteristics and crop productivity in each field in the zones surrounding the managed wetlands, mixed effects models were fitted for organic matter (OM) and P (Olsen) in the topsoil, for nitrate-N and soluble salts at all three soil depths, and for yield. Fixed effects were zone, field, year, and all two- and three-way interactions, and the only random effect was replicate within field within year. For factors measured at different soil depths, fixed effects also included depth and its interactions with all other fixed effects. Estimated marginal means were determined and means were separated using multiple pairwise comparisons with the Tukey method for P-value adjustment and the Satterthwaite method for determining degrees of freedom. Treatments were considered significantly different at $P<0.1$.

## Results

The data presented in this report constitute the first two years of a 3-year (minimum) monitoring study. As such, interpretation of the results will be minimal to avoid prematurely overstating the importance of the measurements completed to date.

For each response variable (OM, nitrate-N, P, salts, and yield), the data will be shown separately by year regardless of whether the results differed significantly, to show the change in measured values year over year. In each figure, “NS” indicates that there was no statistical difference between the zones in that field and year. If there was a significant difference between zones in that field and year, letters will indicate how the zones differed – zones showing the same letter are not significantly different from each other. Error bars in the figures show the standard error, which indicates how variable the values were for that particular factor.

*Soil Organic Matter*

Soil organic matter (OM) is a quality factor that is non-mobile in the soil profile. Soil OM is an indicator of soil carbon storage and is relevant in water management research as wetlands have been shown to be carbon sinks.

It was hypothesized that soil OM would stay fairly stable with the installation of tile drainage. Soil OM matter is affected by the productivity and additions of residue from either the crop or from natural vegetation, and the rate of decomposition and/or mineralization. With the installation of tile drainage, Zone 1 should transition from natural vegetation or no vegetation to an annual crop, so overall productivity and residue is expected to either be maintained or potentially increased. A potential improvement in soil conditions in Zones 2 and 3 may also increase productivity and residue. In contrast, a reduction in waterlogging could increase decomposition and soil mineralization in Zones 1, 2, and 3. Productivity, residue, decomposition and mineralization should not change in Zone 4.

The effect of tile drainage on soil OM differed in each of the fields (Figure 4). In Field 1, OM did not differ between the zones initially (2021), and did not change in any of the zones after one year of water management. In Field 2, OM did not differ between zones in the first year, but differed significantly between zones in 2022. OM was significantly higher in Zone 1 compared to Zone 4, and indicates that OM increased in Zones 1 and 2. In Field 3, OM was significantly higher in Zone 1 compared to Zones 2 and 3 initially, but did not differ between Zones in 2022, indicating that OM appeared to decrease in Zone 1 in this field. Both Fields 2 and 3 were canola stubble in 2022.

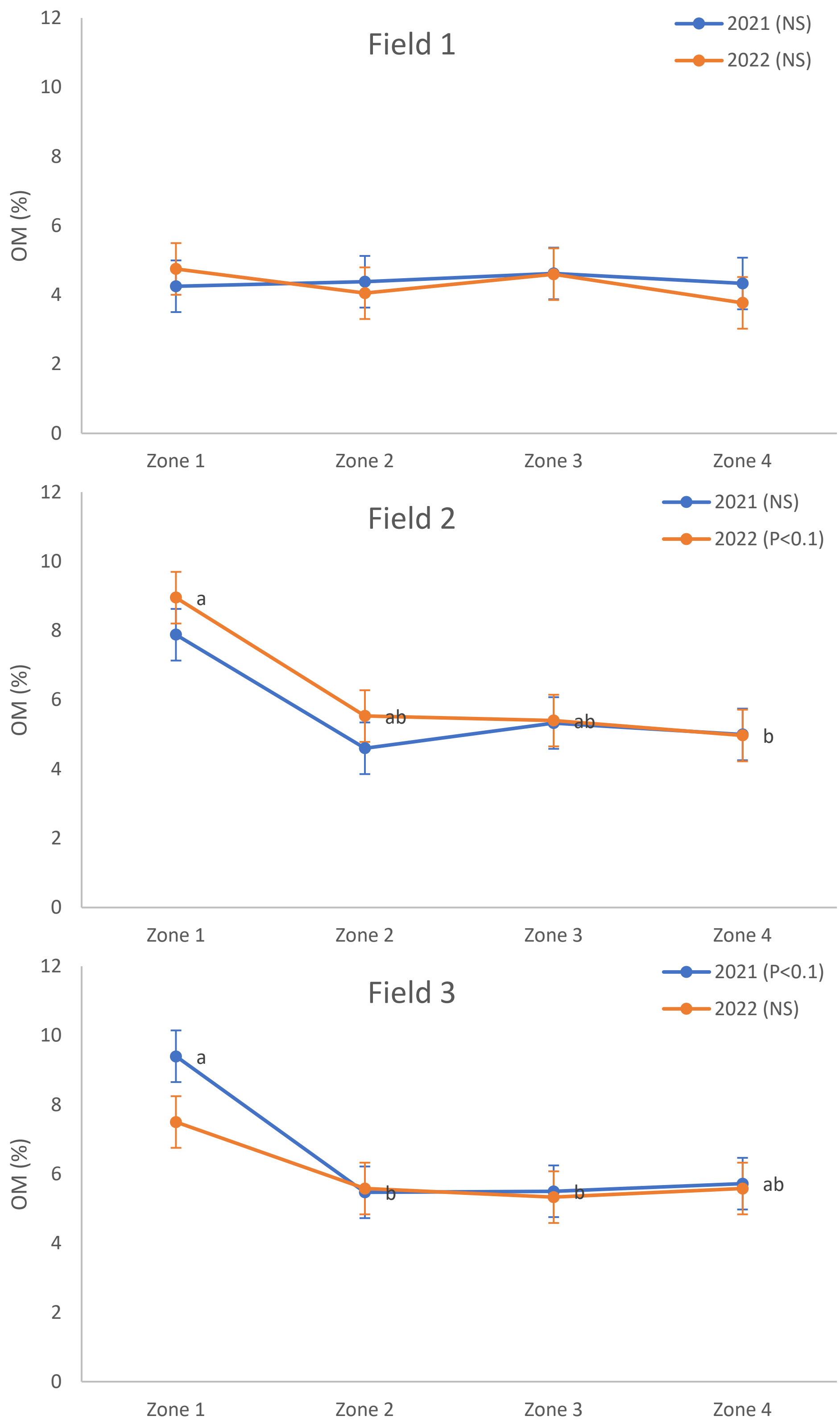


**Figure 4**. The change in soil organic matter (OM) in the zones surrounding the managed wetlands in each of the three fields after one year of tile drainage.

*Residual Phosphorus*

Phosphorus (P) is considered non-mobile in the soil profile but can move overland with the flow of water and soil particles. We expect less overland water movement with the installation of tile drainage.

Thus, it was hypothesized that soil P would potentially have been accumulating in the wetland, or Zone 1, due to overland flow of water, and would initially be high in this zone. It was expected that uptake of the nutrient would increase with crop establishment in Zone 1 and so levels would decrease over time. Soil P would potentially also be accumulating in Zones 2 and 3 due to reduced crop productivity in these zones, and would also be expected to decrease over time as crop productivity increases. Soil P should be not be affected in Zone 4.

There were no significant differences in residual P between zones in any field or year, but variability was high for this measurement as is shown by the error bars in the figures (Figure 5). In fields 1 and 2, residual P was higher in general in 2022, and did not decrease in Zones 1, 2 & 3 as was hypothesized. Uptake of applied P was probably low in 2021 because of dry conditions and low yields. However, the relative levels of residual P among zones within each field was somewhat consistent from year to year, so we can be fairly confident that the trends are real, even if not statistically significant. In Field 1, soil P is relatively high in Zone 1 as was hypothesized, but Zones 2 and 3 were similar to Zone 4. In Field 2, soil P is again relatively higher in Zone 1, but also Zone 3, as was hypothesized. This could potentially be an overlap effect in this field. In Field 3, residual P seems to be relatively higher in Zones 1, 2 and 3 compared to the control, as was hypothesized. In 2022, growing conditions and yields were good and so P uptake is expected to be increased.

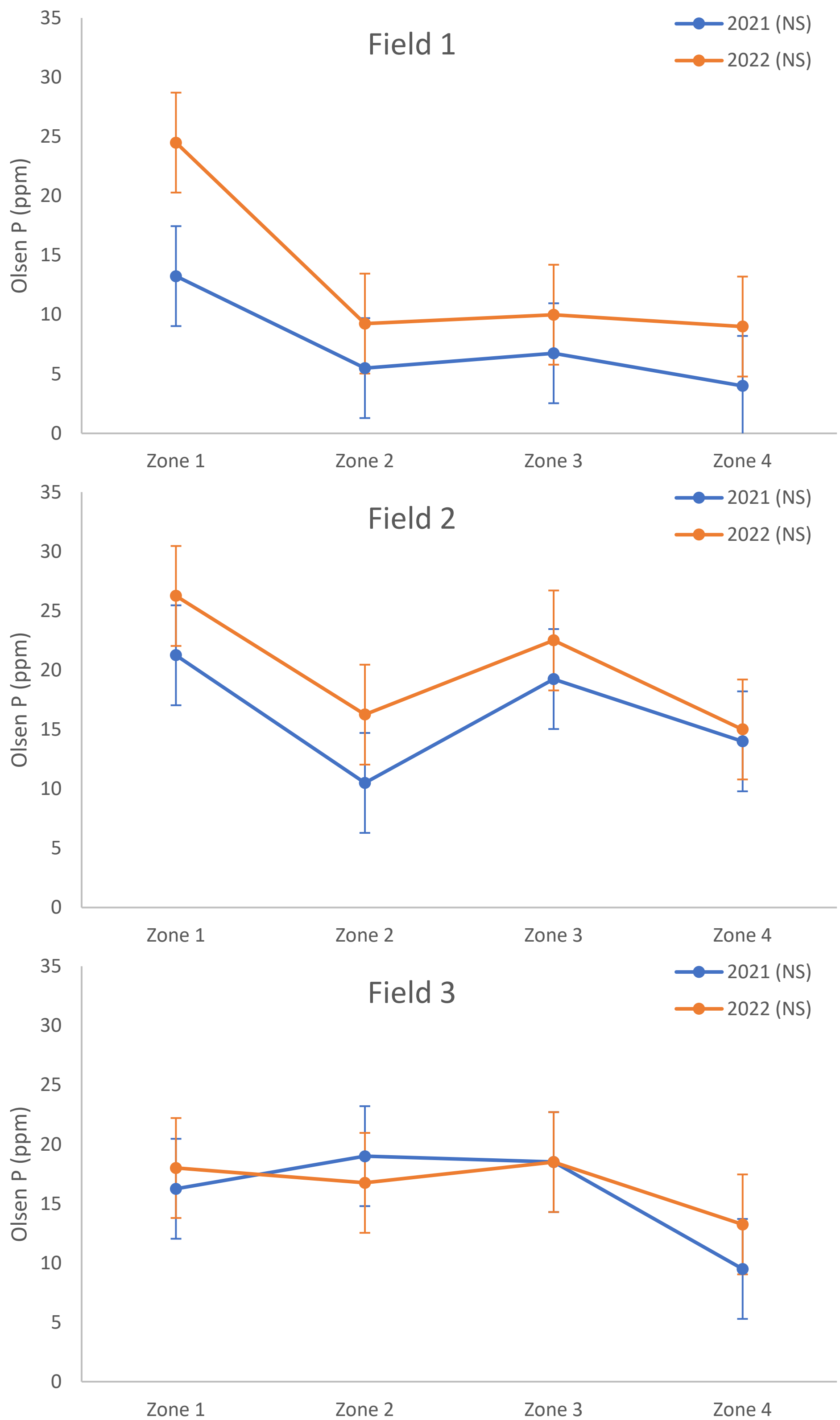


**Figure 5.** The change in soil P (Olsen, ppm) in the zones surrounding the managed wetlands in each of the three fields after one year of tile drainage.

*Residual N*

Nitrate-N is mobile in the soil profile, in that it moves upwards or downwards with water, and so is measured at different depths. Thus, we are examining changes in nitrate-N from year to year in each of the zones as well as in the different depths after installation of tile drainage.

We hypothesized that the relative level of residual nitrates could potentially decrease in Zones 2 and 3 if crop productivity and uptake of applied N improved in those Zones. Residual N in Zone 1 would not be expected to be high initially because there was no previous application of this nutrient in this zone. However, nitrate-N movement and accumulation prior to and after the installation of tile drainage will also be dependent on the hydrology and net water movement into and out of each of the wetlands.

There was no significant change in the distribution of nitrate-N in the soil profile one year after the installation of tile drainage. In Figure 6, the lines show the average nitrate-N among all soil depths, but the values for each soil depth is also indicated by symbols, to show the distribution of nitrate-N through the soil profile. The symbols are not shown in the legend to avoid confusion; circles indicate the 0-6 inch depth, crosses indicate the 6-12 inch depth, and dashes indicate the 12-24 inch depth.

In general, residual N was significantly higher in 2022 compared to 2021, and again this is likely because of dry conditions and poor yields in 2021. Also, anhydrous ammonia was applied to all fields in the fall of 2021. In the first year, there were no differences in residual N between zones in any of the 3 fields, and there were no observable trends in N accumulation among the zones. In 2022, the fields differed in the accumulation of nitrate-N by zone. There was again no significant difference between the zones in Fields 2 and 3. In Field 2, the relative level of nitrate-N among zones was fairly consistent year over year. In Field 3, the relative level of nitrate-N appeared to decrease in Zone 2 compared to the other zones. In Field 1, there was actually significantly higher nitrate-N accumulation in Zone 1 compared to Zones 3 and 4, and the level in Zone 2 also appeared to have increased relative to the other zones. Different responses in each field may be a result of differences in hydrology between the fields, or potentially because of different crop types – Field 1 was flax in 2021 while Fields 2 and 3 were both canola.

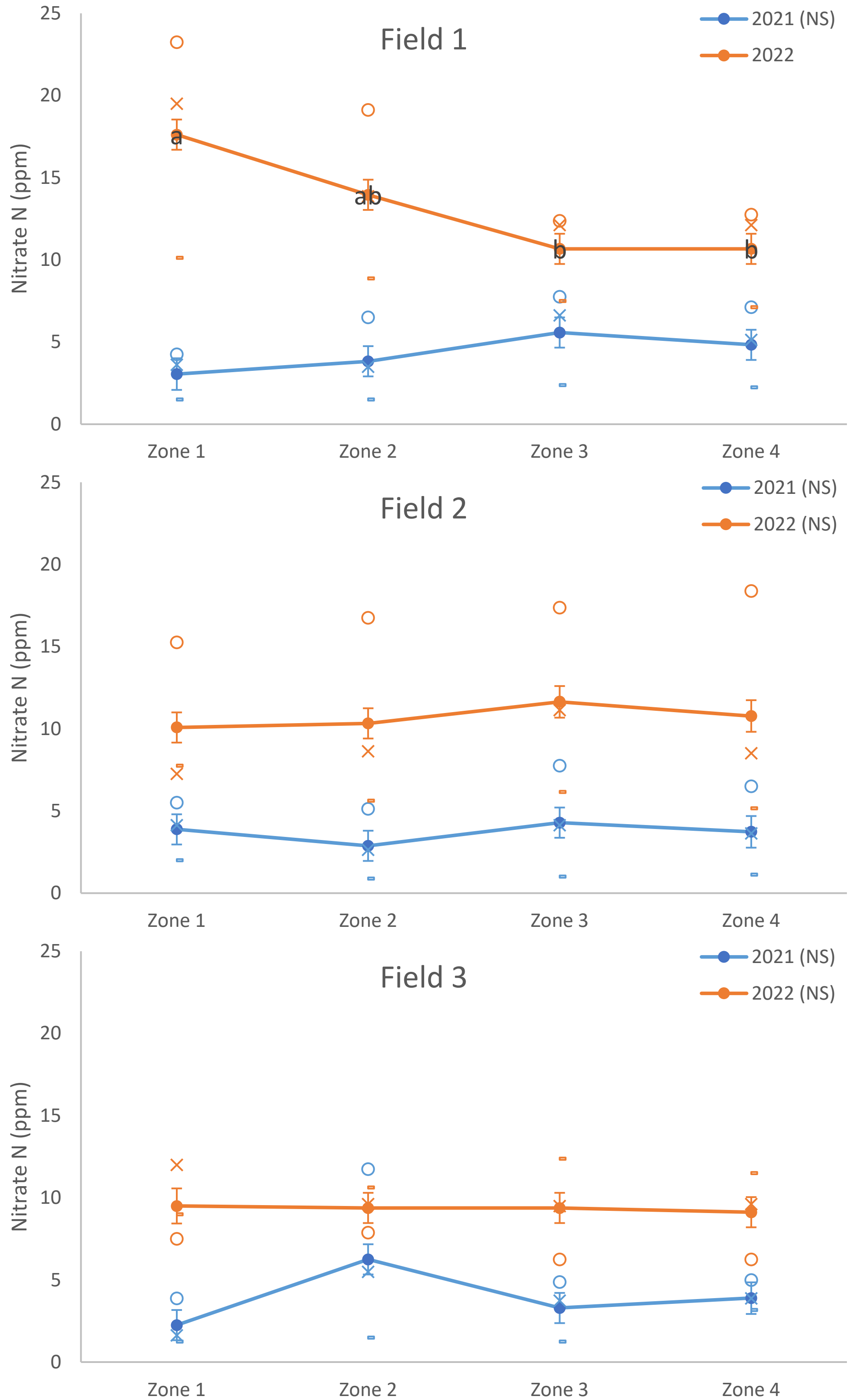


**Figure 6**. The change in nitrate-N (ppm) in the soil profile and zones surrounding the managed wetlands in each of the three fields after one year of tile drainage.

*Soluble Salts*

Soluble salts are a measure of salinity, and are measured as electrical conductivity. Like nitrates, salts move with water in the soil profile so are also measured at different depths. However, unlike nitrate-N, the movement and accumulation of salts is not tied to nutrient application and crop uptake. It was hypothesized that salinity would decrease in Zones 2 and 3 with the installation of tile drainage but would be dependent on the amount of precipitation.

As with nitrate-N, there was no significant change in the distribution of salts in the soil profile one year after the installation of tile drainage. In Figure 7, the lines show the average electrical conductivity among all soil depths, but the values for each soil depth are again identified by symbols to show the distribution of salts through the soil profile (circles indicate 0-6 inch depth, crosses show 6-12 inch depth, and dashes show 12-24 inch depth).

In the first year, there were significant differences in salinity between the zones in Fields 2 and 3. In Field 2, electrical conductivity was significantly higher in Zone 3 compared to other zones, while in Field 2, electrical conductivity was significantly higher in Zone 2. In Field 1, there was no significant difference between zones, but Zone 2 seemed to be slightly elevated compared to the other zones. In 2022, there was a significant change in the relative level of salinity among zones. In Field 2, the difference between zones was no longer significant, and this was because salinity decreased in both Zones 2 and 3. In Field 3, salinity in Zone 2 decreased and was no longer significantly higher than Zones 1 and 4. In Field 1, the difference in salinity between zones was still non-significant but appeared to decrease more in Zone 2 relative to the other zones. The change in salinity was generally as hypothesized, and interesting considering the dry conditions in 2021.

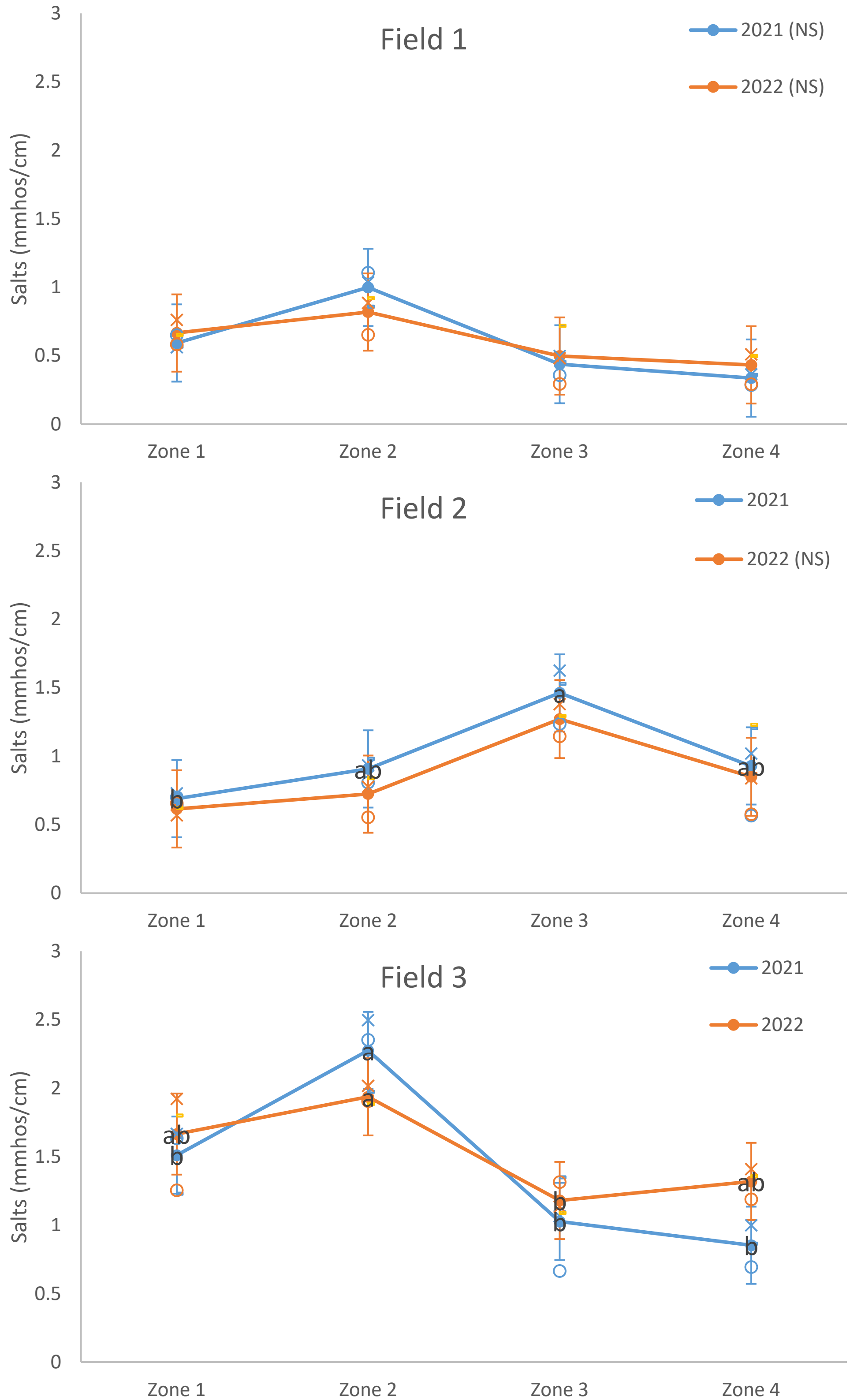


**Figure 7**. The change in soluble salts (electrical conductivity, mmhos/cm) in the soil profile and zones surrounding the managed wetlands in each of the three fields after one year of tile drainage.

*Yield*

Yields are affected by soil OM, nutrients, salinity, and excess or deficit of water. It was hypothesized that there would be an initial yield bump in the zones with nutrient accumulation, and then yields would stabilize across the zones within a field as excess nutrients are taken up by the crop. It was also hypothesized that there may be a gradual yield increase in Zones 2 and 3 as salinity and soil compaction issues are amended.

As was discussed earlier, yields were very low in 2021 due to dry conditions, however, the crops grown in each year also have very different yield potentials (Figure 8). In 2021, Field 1 was flax, while Fields 2 and 3 were canola. All 3 fields were barley in 2022. For further analysis, it may be more insightful to utilize relative crop yields to better compare the different crops between years.

In the first year, yield did not differ significantly between zones in any of the fields. In Fields 1 and 2, there appeared to be a trend of decreasing yield going from Zone 1 to 4. In Field 3 however, the trend showed increasing yield from Zone 1 to 4. In 2022, there was again no significant difference between zones in Fields 1 and 2, but there appeared to be a slight relative increase in yield in Zone 3 in Field 1 and Zones 2 & 3 in Field 2. In Field 3, yield increased significantly from Zone 1 to Zone 4. The lower yield in Zone 1 may be partly explained by some portions of the zone going unseeded in 2022 because of excess water due to the late thaw.

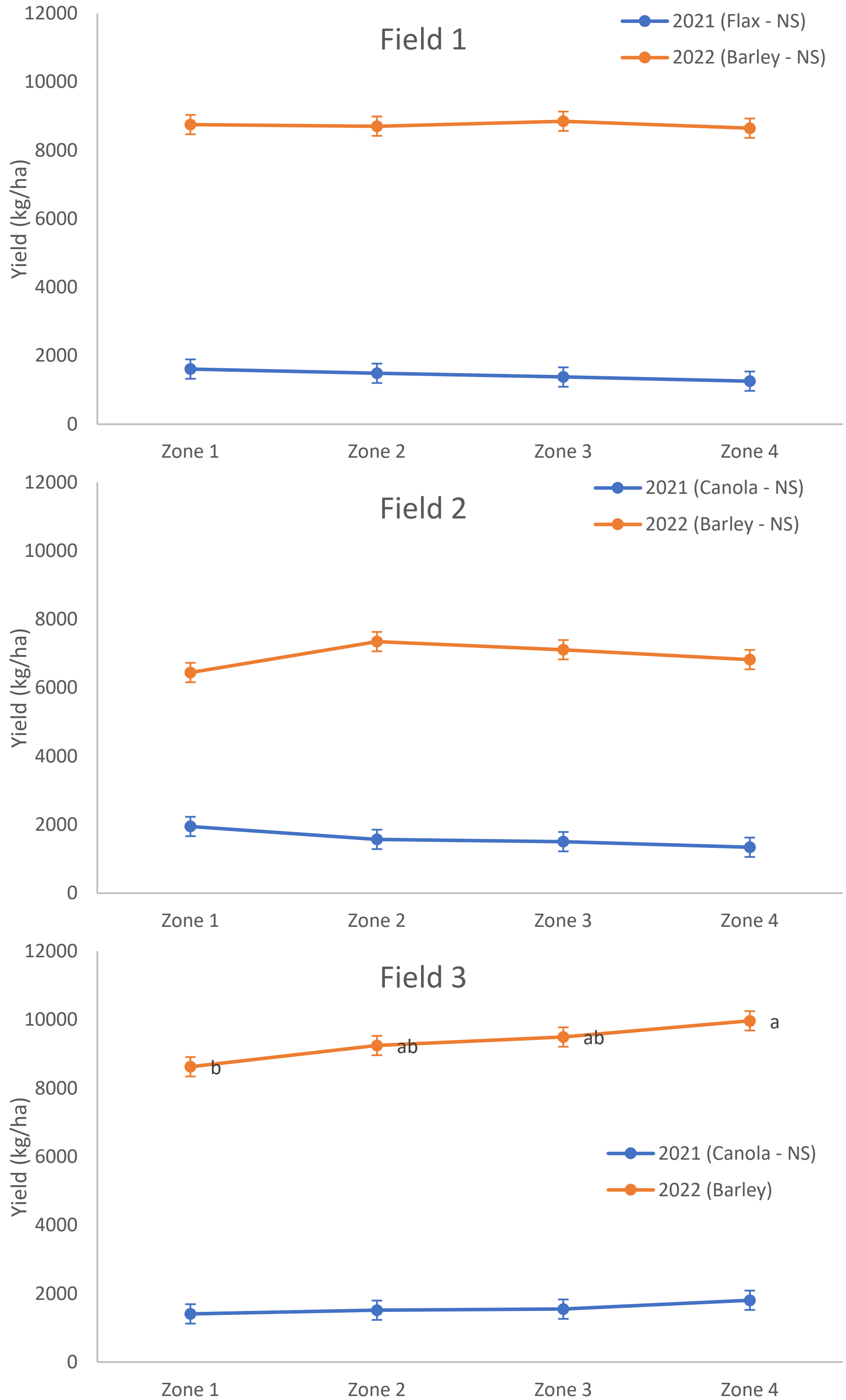


**Figure 8**. The change in yields among zones surrounding the managed wetlands in each of the three fields after one year of tile drainage.

## Conclusions and Recommendations

In field scale research, high variability and limited replication reduce our ability to detect statistically significant differences. As such, results may come up as non-significant even though trends are apparent in the data. While interesting and potentially important trends should not be ignored only because they are not statistically significant, it is important to avoid speculating or drawing premature conclusions from non-significant results.

The trends and results were generally as hypothesized, considering the conditions experienced over the study to date. It will be interesting to see which direction each of the factors will go after the wetter conditions experienced in 2022. A more in-depth interpretation of the results will be possible with the third year of data collection.

Water quality data has been identified as an important component of this study. It was not possible to collect proper spring runoff samples in 2022 due to the late thaw. The collection of water quality samples will hopefully be completed during the 2023 season. Water samples will be collected from managed and unmanaged wetlands at different times during the season, starting at spring runoff. This data will provide insight into nutrient movement in particular.

An additional objective of this study was to calculate the economic benefits resulting from the installation of tile drainage. It may be possible to utilize as-applied seeding data and yield maps prior to the installation of tile to calculate the increase in seeded area, the improvement in yield, and the reduction in overlap, but the quality of and ability to process the available data has not been confirmed.