**Prince Edward Island Soil Quality Monitoring Project:**
**Observed soil nutrient trends on PEI over 20 years (1998-2018)**

**Report updated: June 2020**

## INTRODUCTION

To examine the impact of changing crop rotations and management practices on soil characteristics within the PEI agriculture industry, the PEI Department of Agriculture and Land began a long term soil quality monitoring project in 1998 to routinely assess and monitor fluctuations in soil quality and soil nutrient levels within agricultural land on PEI. This project was initially reported on in an intensive 2012 report (PEI Department of Agriculture and Forestry, 2012) and data specifically discussing soil organic matter results were further reported on in 2017 (PEI Department of Agriculture and Land, 2017). This report is to serve as an updated version of the 2012 report and includes results up to 2018.

## METHODS AND DATA ANALYSIS

The PEI Soil Quality Monitoring Project began in 1998 by using a 4 $km^2$ grid system derived from the National Forestry Index grid program, but adapted for use on agricultural land (Douglas et al. 2000). Gridlines that intersected on actively farmed agricultural land in 1998 were selected for sampling. All points were referenced using the Global Positioning System (GPS), for an initial total of 796 sampling points from approximately 232 sites (Figure 1). The first third of the samples were taken in the spring of 1998, the second in the spring of 1999 and the last third during the spring of 2000. Therefore, each site that is part of this monitoring project is sampled every three years (having begun in 1998, 1999 or 2000), and, each site has been sampled approximately seven times throughout 1998-2018.The whole dataset is shown in complete ‘cycles’. Cycle 1 includes all samples collected from 1998-2000, cycle 2 from years 2001-2003,…up to cycle 7 (2016-2018). Since the data obtained from this project is reported in 3-year cycles, the 2019-2021 data (cycle 8) is not yet complete and is not reported within this update.

Throughout the length of the project, some sites were lost due to a variety of factors (land use or landowner changes, residential development, etc.), with the total sampling points decreasing to

611 points by the end of 2018. Beginning in 2019, new sampling points have since been added to maintain the database, and additional site results from 2019 onwards will be reflected in future report maps.

All samples were taken in the spring following spring thaw, and before any type of cropping practice occurred that year - such as spring tillage, crop seeding, and application of synthetic or organic fertilizers and/or lime. At each site, crop history has been monitored yearly for all sites during the summer months (from 1998 to 2018). Cropping information was used to assess general crop frequency at each site (for example: forage or pasture, grain or oilseed, and/or potato). Other cropping management characteristics have not been recorded and management can vary greatly among sites.

All maps were generated by Agriculture and Agri-Food Canada using the regression kriging method. Data was first used to develop models to interpret total land area, followed by development of individual spatial variation maps demonstrating a range of soil characteristics with their estimated distribution across PEI.

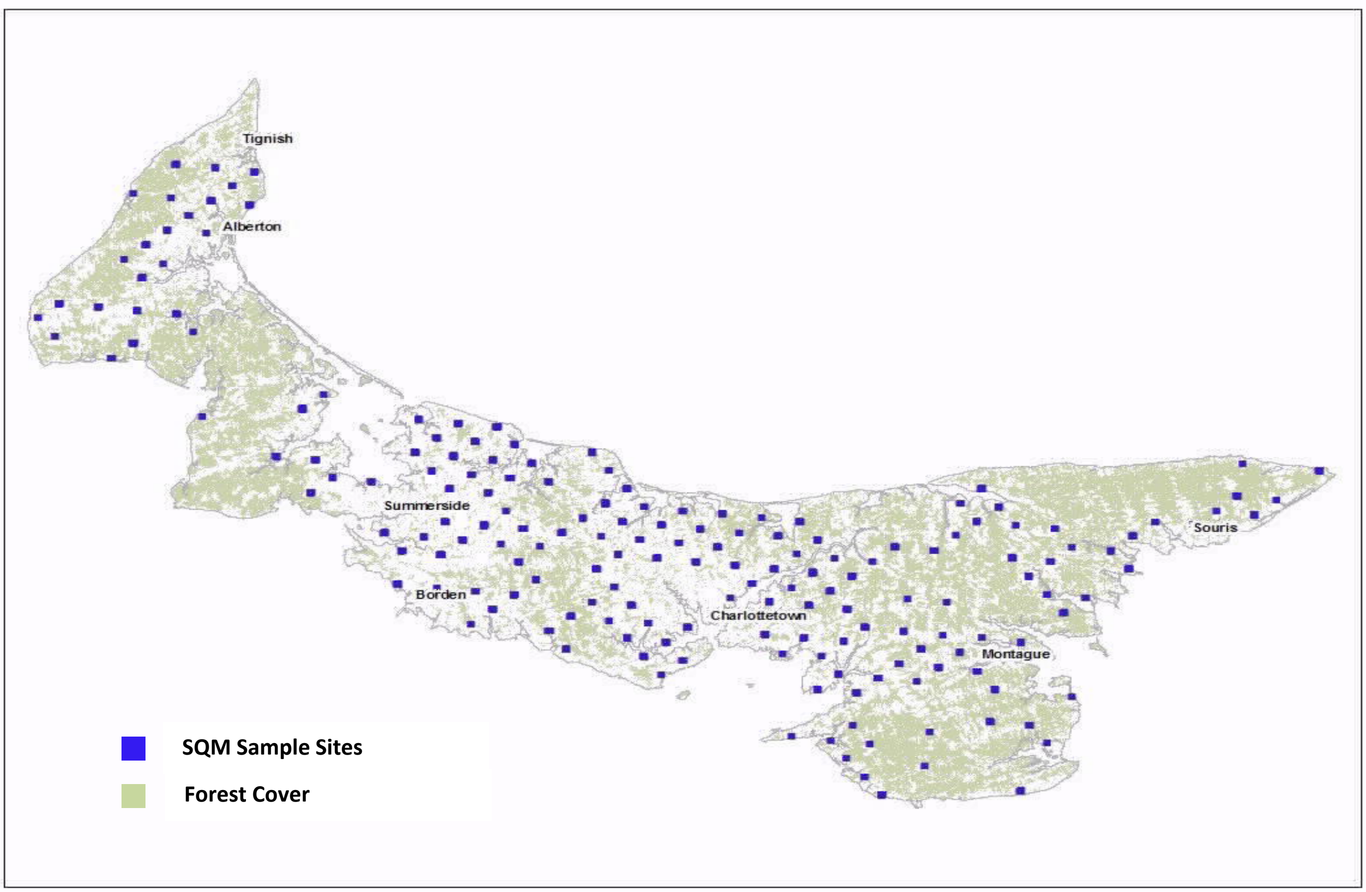


**Figure 1.** Geo-referenced sample sites from the PEI Soil Quality Monitoring Program (1998).

## RESULTS AND DISCUSSION

Land area maps were generated for soil organic matter, pH, phosphorus (represented as phosphate, $P_2O_5$), phosphorus saturation index (PSI), potassium (represented as potash, $K_2O$), calcium, magnesium and sulfur (Figures 2-9 below). Individual maps were divided into classes by colour either for visual demonstrative purposes, or based on known nutrient thresholds from the PEI Analytical Laboratories soil nutrient rating system. More discussion is provided in previous publications on the trends in soil organic matter (Nyiraneza et al. 2017), PSI (Benjannett et al. 2018) and sulfur and magnesium (Nyiraneza et al. 2019).

Soil organic matter levels have shown a general decline from the beginning of the program throughout the cycles, but have since remained relatively unchanged throughout cycles 6 and 7 (Figure 2). The majority of agricultural land modeled for PEI is depicted within the 2-3% range, with the second highest land area predicted to be within the 3-4% range. SOM fluctuations have been largely discussed within the Nyiraneza et al. (2017) report, but are believed to be influenced by a variety of confounding factors. These factors include but are not limited to: coarse, sandy soil texture inherent to the PEI land base; humid climactic conditions paired with undulating topography leading soils prone to erosion throughout shoulder and winter months (and in some circumstances soil erosion can occur early in growing season prior to crop canopy cover and soil consolidation), a reduction in manure inputs available for land use applications, as well as influence of many agronomic factors that have a cumulative effect over time on soil quality (i.e. influence of cropping system, tillage effects, and presence/absence of cover cropping, etc.).

Beneficial management practices (BMPs) that will stabilize or increase SOM levels over time have been heavily promoted and adopted by the agricultural industry within recent years. The influence of continued adoption of these practices is the desired effect to maintain and build SOM on PEI to ensure that soils will remain productive and resilient to changing climate pressures. Although individual BMPs, such as winter cover cropping, applying manures and soil amendments to cropland, reduction in tillage events, increase in green manure and forage crops within the rotation, and implementation of erosion control structures, may take years to demonstrate the desired change to SOM levels, the cumulative effect of many BMPs occurring at once will amass greater and more efficient changes to SOM levels over time.

Based on the maps, soil pH levels are primarily estimated to be within the 5.5 to 6 range across PEI, however areas $< 5.5$ and $> 6$ are found in a variety of regions (Figure 3). It is assumed that these fluctuations are largely due to pH preferences based on crop. For instance, pH values $< 6$

are preferred for potato production due to its observed influence on scab disease. Ideal nutrient availability for many other perennial crops generally remains within a pH range of 6 to 7, and can greatly influence plant nutrient availability, and inevitably, nutrient uptake. Soils on PEI are prone to acidic conditions, and can be influenced over time with increased use of ammonium-based fertilizers. Frequent addition of lime (or once during the rotation) is a general recommended practice to ensure soils maintain a pH within the level of most efficient nutrient availability, while also ensuring pH is at an ideal level for individual crops grown in the rotation.

Total phosphate ($P_2O_5$) levels have generally remained within low to medium levels within many regions of PEI; however, there remains a general increase in higher $P_2O_5$ levels primarily within West Prince County throughout all cycles (Figure 4). A Phosphorus-Saturation Index (PSI) was adapted for use on PEI by Dr. Judith Nyiraneza (AAFC Charlottetown) to estimate phosphorus (P) availability under the influence of pH. Under low pH values, P can be prone to becoming unavailable for crop uptake as it binds chemically with soil aluminum and iron.

Soil P environmental indicator thresholds for PEI (PEI Department of Agriculture and Land, 2017), and $P_2O_5$ fertility recommendations (specifically for potatoes) have been developed based on the estimated PSI thresholds (PEI Department of Agriculture and Land, 2018). For areas where the soil pH > 5.5, high PSI environmental risk thresholds were observed. At PSI levels > 14%, there is a higher risk for loss of P that can lead to subsequent environmental considerations (Figure 5). Large areas of the PEI agricultural land base are predicted to be within moderate ranges for PSI levels, however, there are some areas that demonstrate high risks > 14%, with observed pockets within both the very high to extremely high risk regions. These areas should be carefully managed over time to ensure PSI levels are maintained at current levels or decreased, to limit environmental risks associated with soil erosion and proximity to watercourses and wetlands. Areas demonstrating low PSI levels do not pose a high environmental risk, and may benefit from increased $P_2O_5$ fertilizer sources to achieve optimal crop yields.

Soil potash levels ($K_2O$) have consistently remained within low to medium levels as estimated through most cycles (Figure 6). There are demonstrated pockets of high levels across PEI for potassium (K), however K is not deemed to pose as great of an environmental risk in comparison to some other soil nutrients, as previously discussed. Ensuring adequate amounts of soil $K_2O$ are available to crops for uptake is necessary for overall sufficient crop growth and development. Potassium has a significant impact on maintaining water and nutrient movement within the plant and in plant photosynthesis, and can lead to plant stunting or reduced crop yields if deficient.

Soil calcium (Ca) levels are estimated to remain consistent throughout all cycle years sampled, and were rarely found to be within the high range (Figure 7). Soils on PEI are naturally deficient in Ca, and are influenced primarily through lime, gypsum and other soil amendments. Fluctuations in Ca levels were primarily seen within Prince County throughout all cycles, and an increase in soil Ca levels was seen within regions of Kings County in cycle 7. Similar to soil Ca, magnesium (Mg) levels are greatly influenced by addition of lime, and a decline in cycles 3 to 6 in soil Mg (Figure 8), can be similarly observed with declining soil pH levels within the same cycles. An increase in soil Mg levels was observed within some regions throughout cycle 7, to medium and medium plus levels.

Soil sulfur (S) levels declined greatly from cycles 1 to 2, up until cycle 6 (Figure 9). It is believed that the large decline in S levels was a result of decreased atmospheric deposition of S when acid rain pollution was remediated over time. Due to this decline in soil S levels, additional S fertility was implemented for many crops across PEI, and levels in the majority of land base shown have since resurged to medium plus to high levels by cycle 7.

General annual crop frequency has been observed for all sample sites, and has been grouped together into the following categories: potato, grain, and forages. Individual rotations can vary greatly, and can include a variety of differing seeding and termination techniques, tillage practices, winter cover cropping options and additional amendments. Without these specific details, crop rotations were separated into the three main crop categories, as these were the most consistently grown cropping types observed across PEI throughout the majority of the study. The crop categories were generated using the following method for each cycle: if potatoes were grown in any of the 3 years of the cycle, it was considered “potato”; if there were 3 years of consecutive forage within the cycle it was considered “forage”, and if within the 3 year cycle there was no potato found in the rotation, but a grain or oilseed crop (i.e. cereals, pulses, oilseeds, etc.) was present at least once, it was considered “grain/oilseed” regardless of what was seeded the other two years.

Crop rotation at each sampled site can affect soil characteristics greatly; however, it is only one of many factors that can influence soil characteristics. Crop management considerations, such as the tillage regime and timing of tillage, addition of manures, soil amendments and green manures, crop residue management, and other beneficial management practices such as winter cover cropping, may significantly impact different parameters. Without additional agronomic information associated with each sample site being available, only the influence of crop type alone can be discussed. The influence of many other management practices, such as those previously mentioned, is beyond the scope of this project, and is being extensively researched by other federal and academic agricultural research institutions.

It is important to note that the figures represented on crop estimates the average soil characteristics for that crop type, and may not be the representative trend of all fields within that crop category. For instance, it was demonstrated in the previous 2012 report that phosphate levels were increasing with time under land frequently cropped to potatoes and grains while it was declining under land cropped to forage. Therefore, the results presented here are average values and soil test analyses at any specific farm may also fall in low or high range of the values presented.

Soil organic matter levels were generally highest among the crop category forage, followed by grain/oilseed and potato (Figure 10). Consistent with what is observed in the regression-kriging maps, SOM levels appear to remain relatively consistent within the last four cycles for all crop type categories, with some showing slight increasing trends within the last cycle. Soil P levels are greatest within the potato category, followed by grain and forage. All cropping categories have shown a steady increase throughout all cycles; however PSI values are trending lower within the last two cycles for all crop types. As soil pH drops, increased solubility of soil aluminum may occur, which could cause the PSI value to decrease as more P is available within the soil solution to chemically bond with available soil P.

Soil pH values are consistently highest among the grain/oilseed category. All crop types showed a decline throughout the length of the study, with a recent trend toward soil pH levels consistent with levels at beginning of cycle 1 (Figure 10).

Both S and Mg levels have shown a declining trend throughout the length of the study for all crops, except for the potato category within the last two cycles, where an increase in both Mg and S was observed (Figures 10 and 11). The forage category showed the highest Mg and Ca levels consistently throughout the length of the study, which may be due to the influence of manure amendments, or lime applications to achieve higher pH values for forage crops such as alfalfa or red clover . Whereas Ca levels varied for both the potato and grain categories throughout all cycle years. Soil K varied among crop type - with a slight decrease for the forage category, a slight increase in grain/oilseed category, and a consistent and steady increase among the potato category (Figure 10). The greatest soil K levels were found within the potato category.

## NEXT STEPS

Maintaining a long-term approach to monitoring soil quality is necessary to encourage the productivity and integrity of soil across PEI, and continued assessment over time will help gauge soil changes due to market adaptations by the agricultural industry and varying crop management practices that accompany this. Changes in factors such as crop rotations and soil management practices must be factored in to assess the impact of these practices on soil quality. The importance of continued widespread adoption of BMP's on agricultural land over time will positively impact many of these soil quality characteristics, however can take many years to confidently conclude that the effect is taking place. This influence of soil quality on crop productivity may only increase in importance over time as agriculture must adjust to changing climate pressures and conditions, and should be monitored accordingly.

## ACKNOWLEDGEMENTS

This report was developed in partnership with Dr. Judith Nyiraneza (Agriculture and Agri-Food Canada Charlottetown Crop and Development Centre). Special acknowledgements to Juanxia He and Xiayuan Geng (Agriculture and Agri-Food Canada) for statistical analysis and map figures, as well as to Sherry Fillmore (Agriculture and Agri-Food Canada) for crop frequency statistical analysis for this project for many years. Thank you also to all landowners who have permitted the PEIDAL to take these soil samples throughout the length of the project, and continue to do so.

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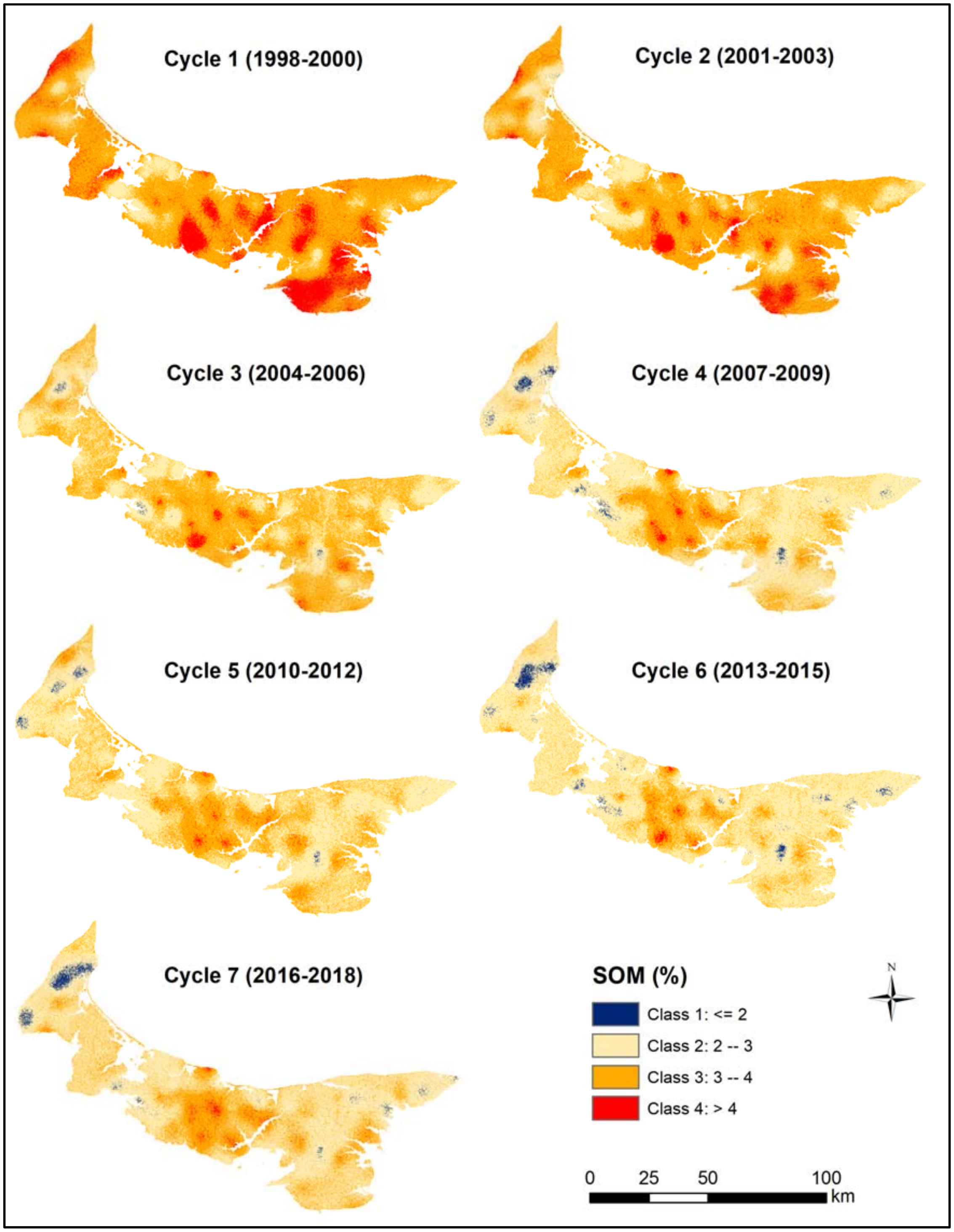


**Figure 2.** Soil organic matter (SOM) levels spatially distributed using a regression-kriging model from data acquired through the PEI Soil Quality Monitoring Project, up to and including until end of cycle 7 (Nyiraneza et al. 2017).

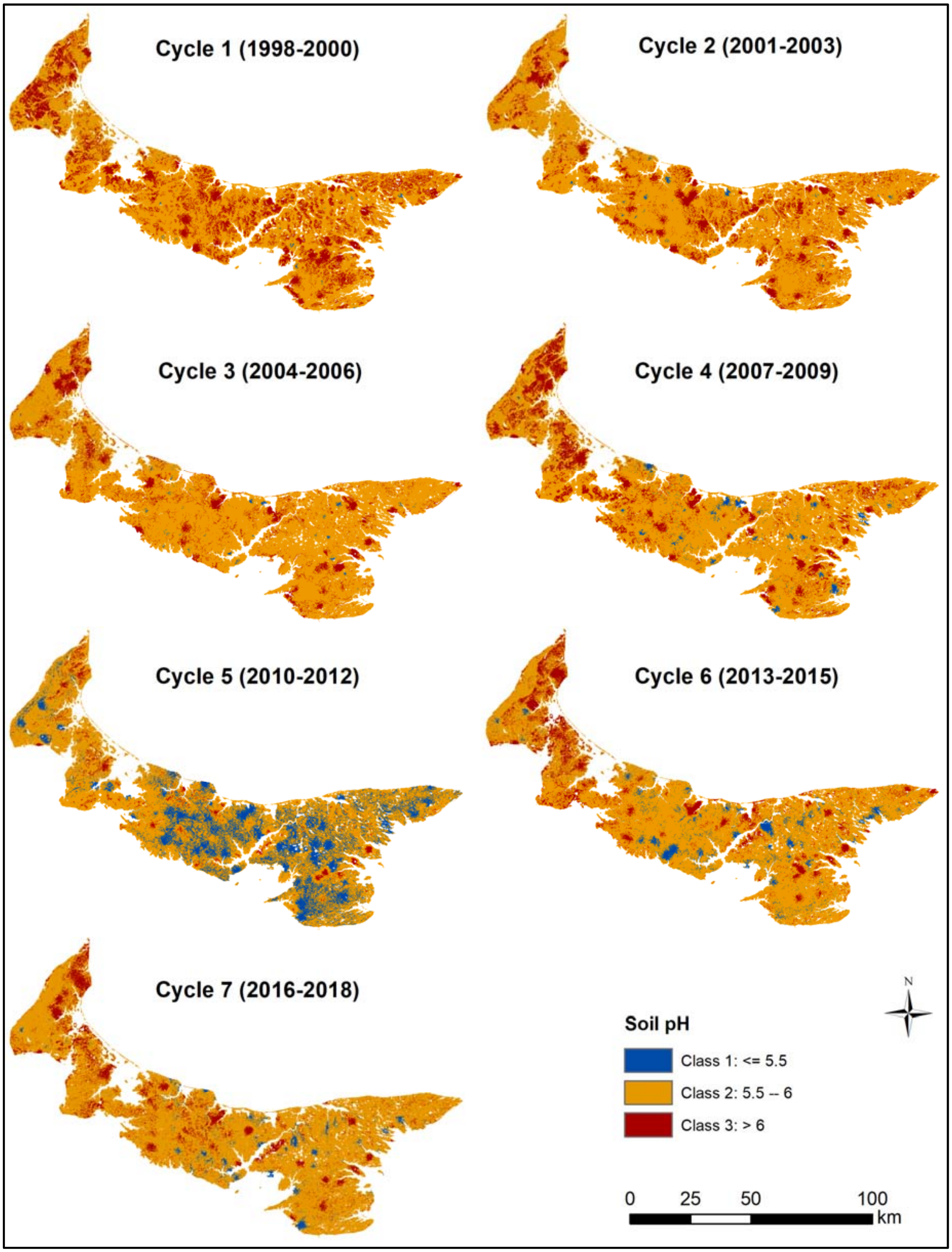


**Figure 3.** Soil pH levels spatially distributed using a regression-kriging model from data acquired through the PEI Soil Quality Monitoring Project, up to and including until end of cycle 7.

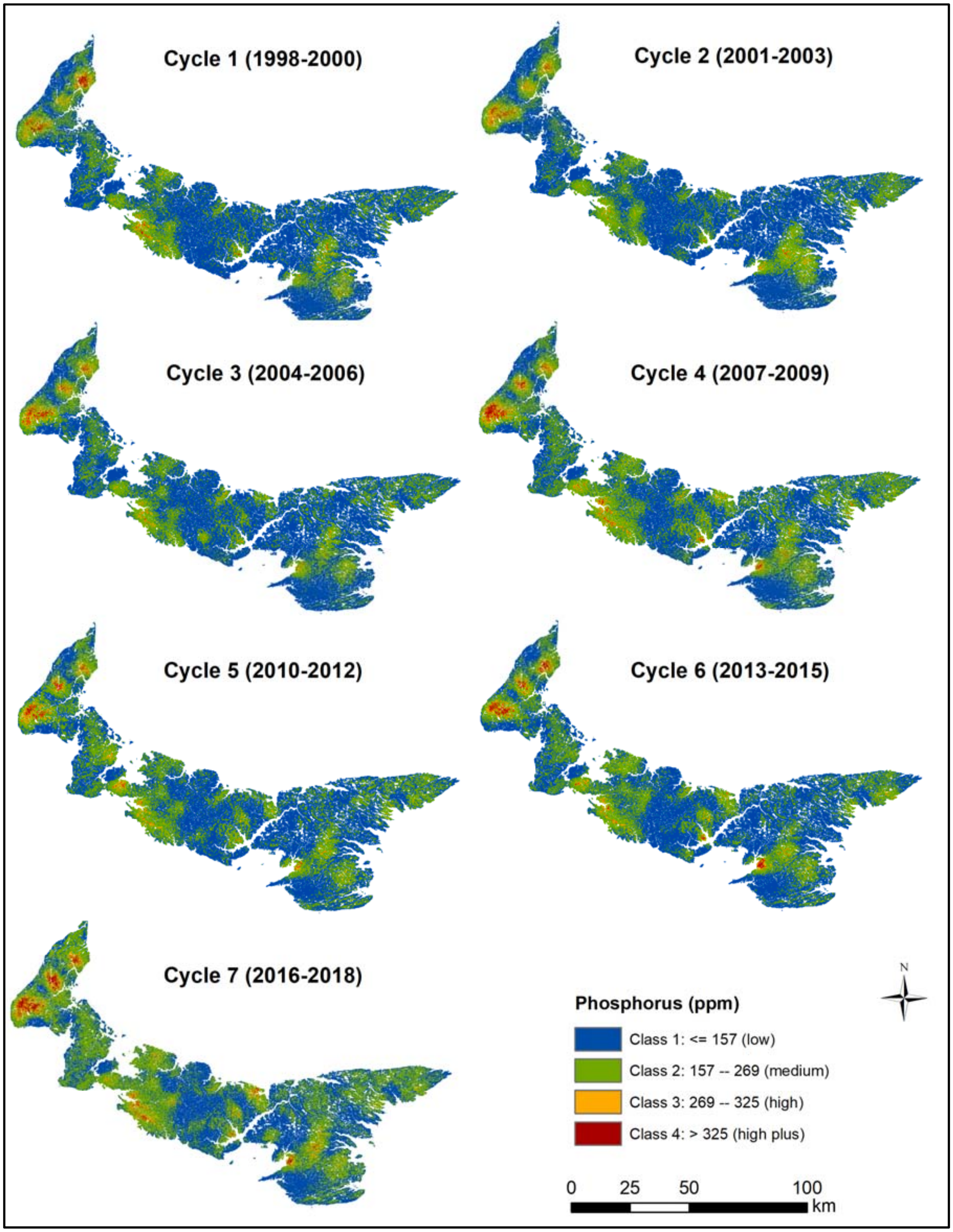


**Figure 4.** Soil phosphate ($P_2O_5$) levels spatially distributed using a regression-kriging model from data acquired through the PEI Soil Quality Monitoring Project, up to and including until end of cycle 7.

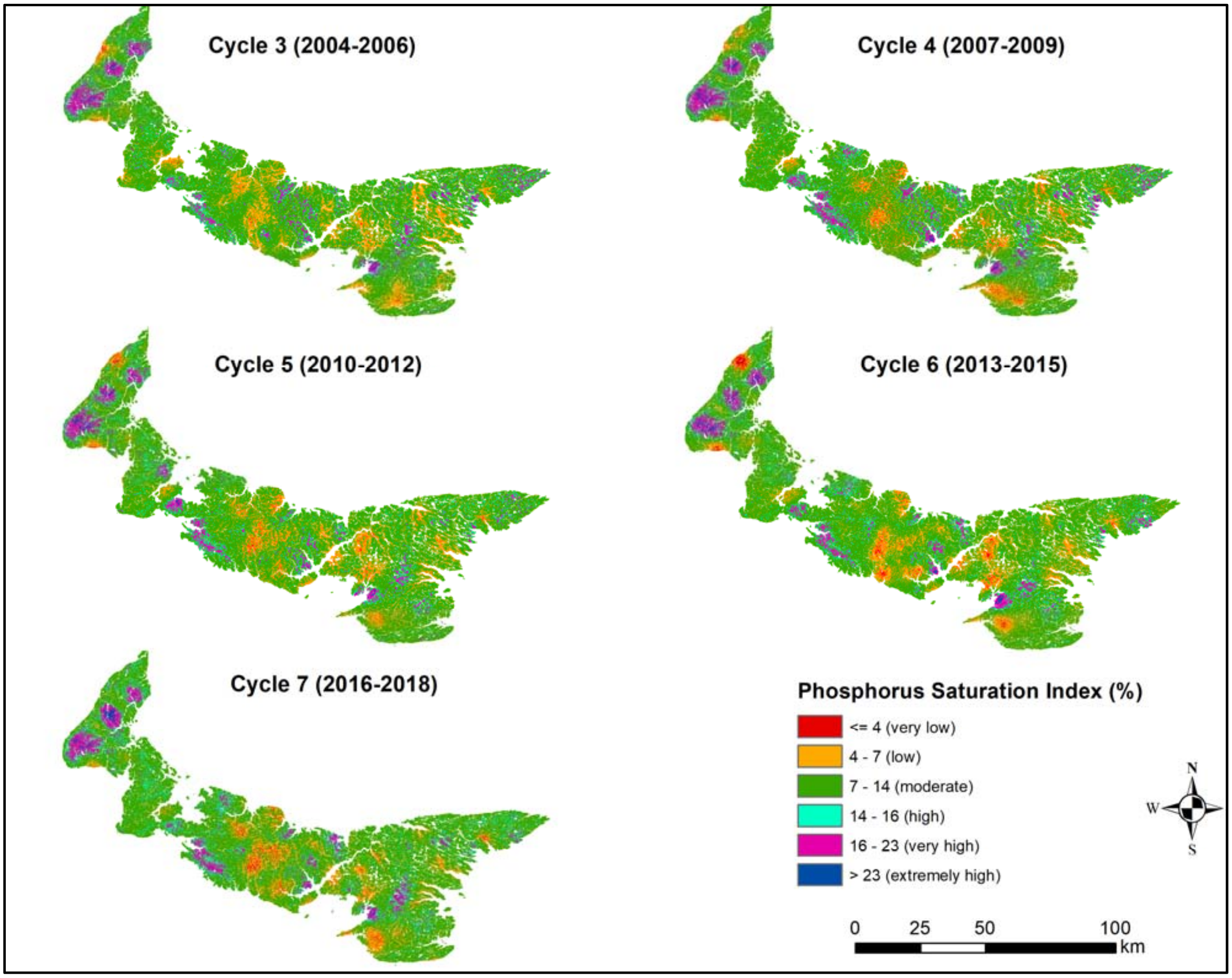


**Figure 5.** Phosphorus Saturation Index (PSI) levels spatially distributed using a regression-kriging model from data acquired through the PEI Soil Quality Monitoring Project, from cycles 3 until end of cycle 7. Cycles 1 and 2 are unavailable due to aluminum level analysis beginning in 2004 at PEI Analytical Laboratories (Benjannett et al. 2018).

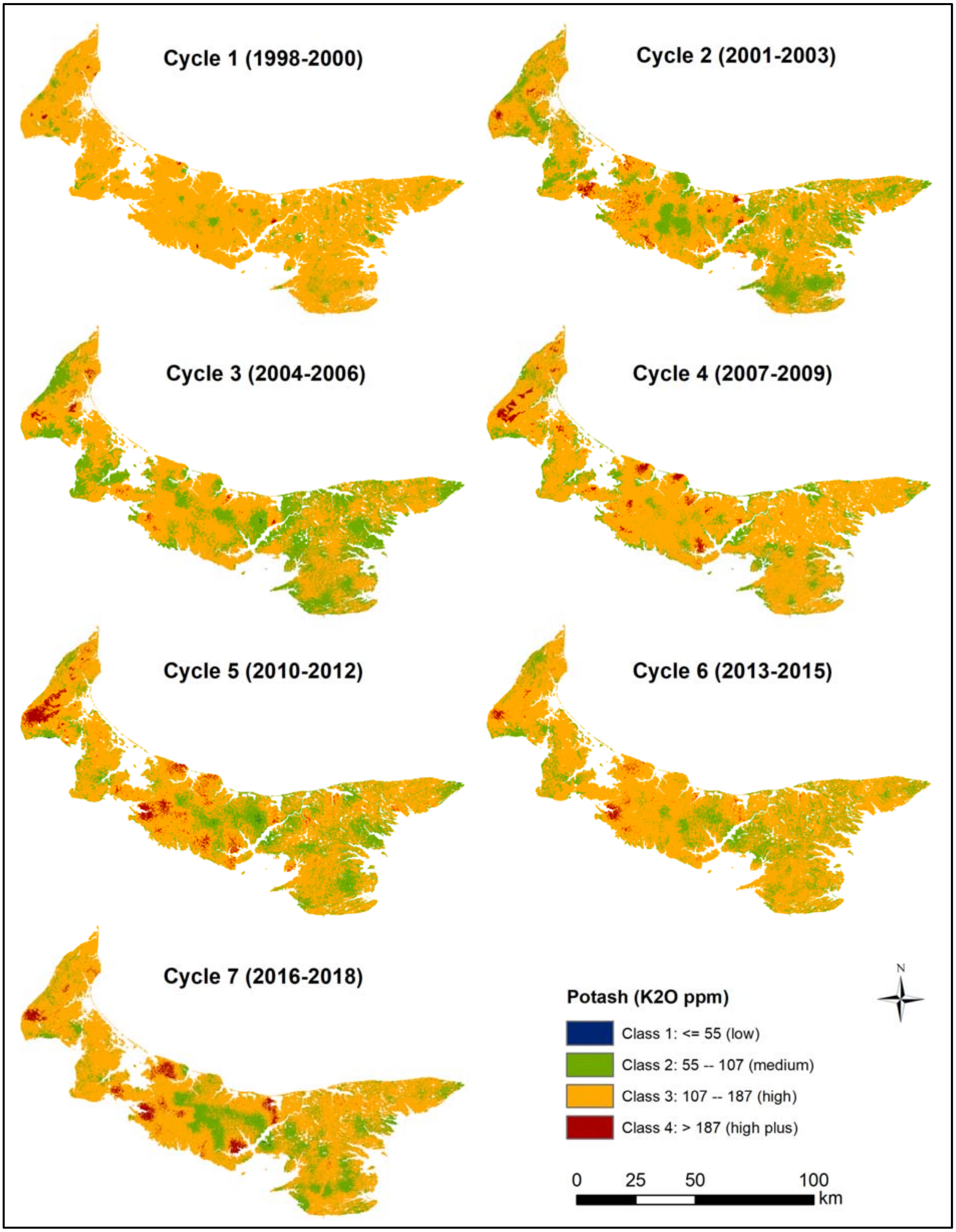


**Figure 6.** Soil potash ($K_2O$) levels spatially distributed using a regression-kriging model from data acquired through the PEI Soil Quality Monitoring Project, up to and including until end of cycle 7.

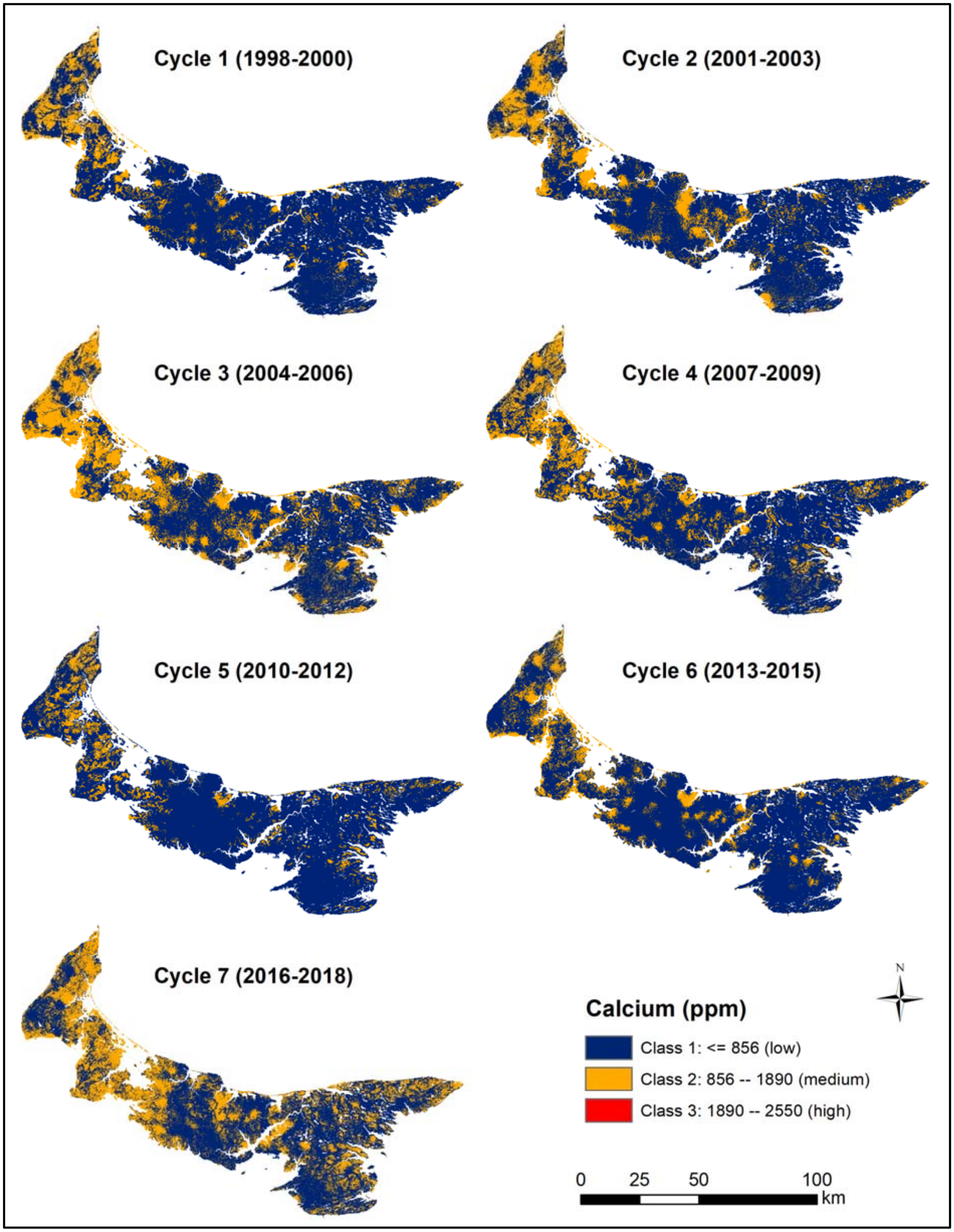


**Figure 7.** Soil calcium (Ca) levels spatially distributed using a regression-kriging model from data acquired through the PEI Soil Quality Monitoring Project, up to and including until end of cycle 7.

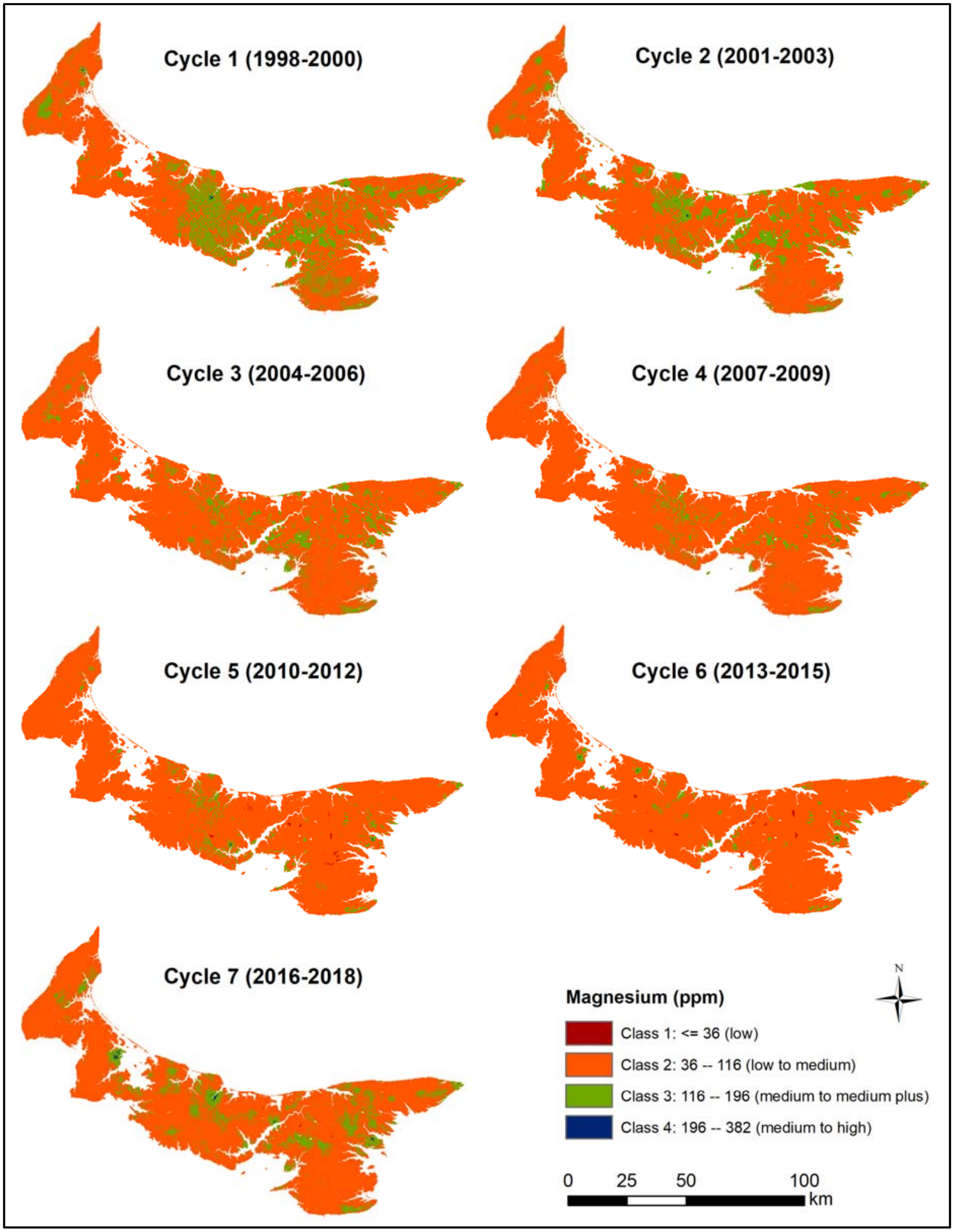


**Figure 8.** Soil magnesium (Mg) levels spatially distributed using a regression-kriging model from data acquired through the PEI Soil Quality Monitoring Project, up to and including until end of cycle 7 (Nyiraneza et al. 2019).

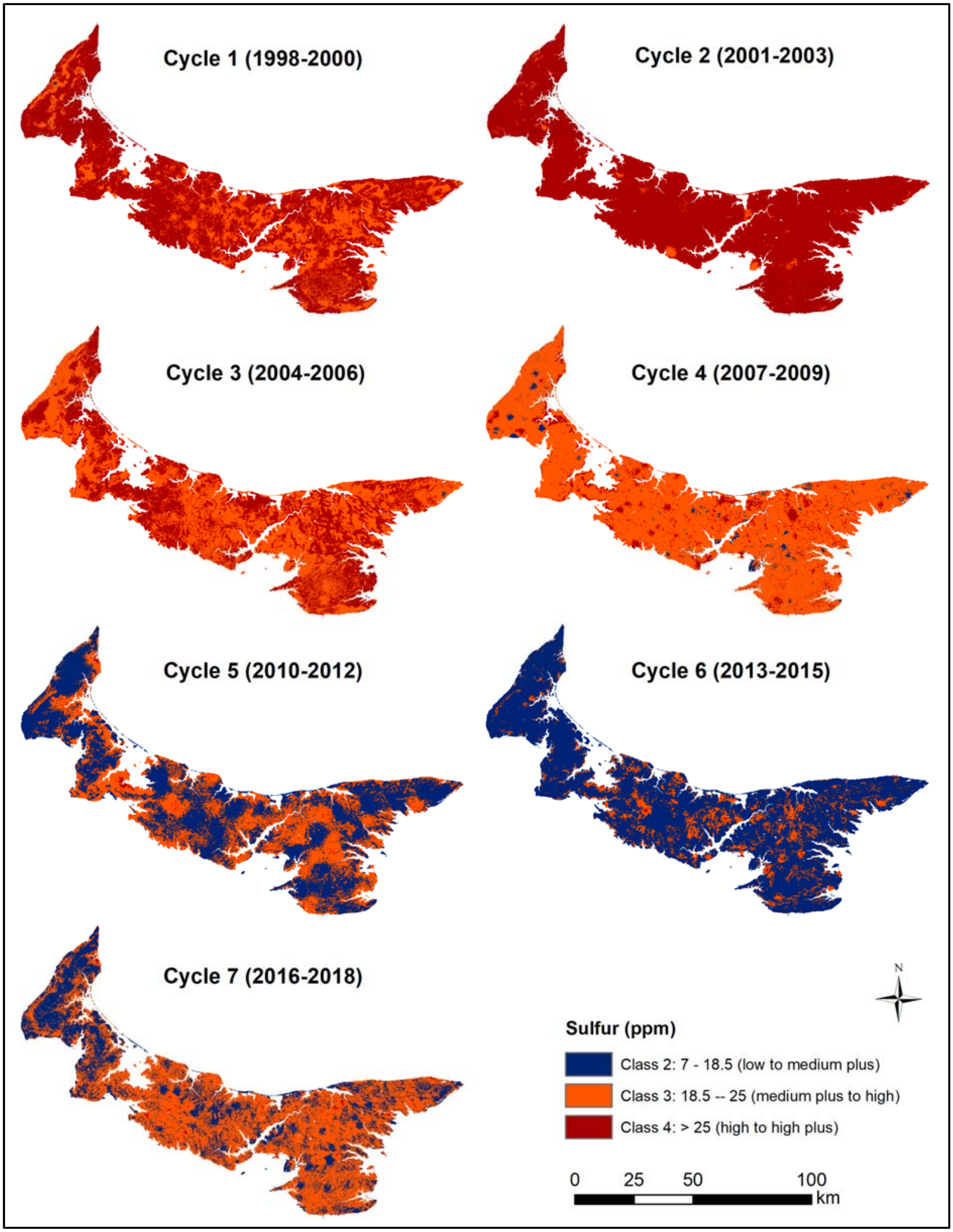


**Figure 9.** Soil sulfur (S) levels spatially distributed using a regression-kriging model from data acquired through the PEI Soil Quality Monitoring Project, up to and including until end of cycle 7 (Nyiraneza et al. 2019).

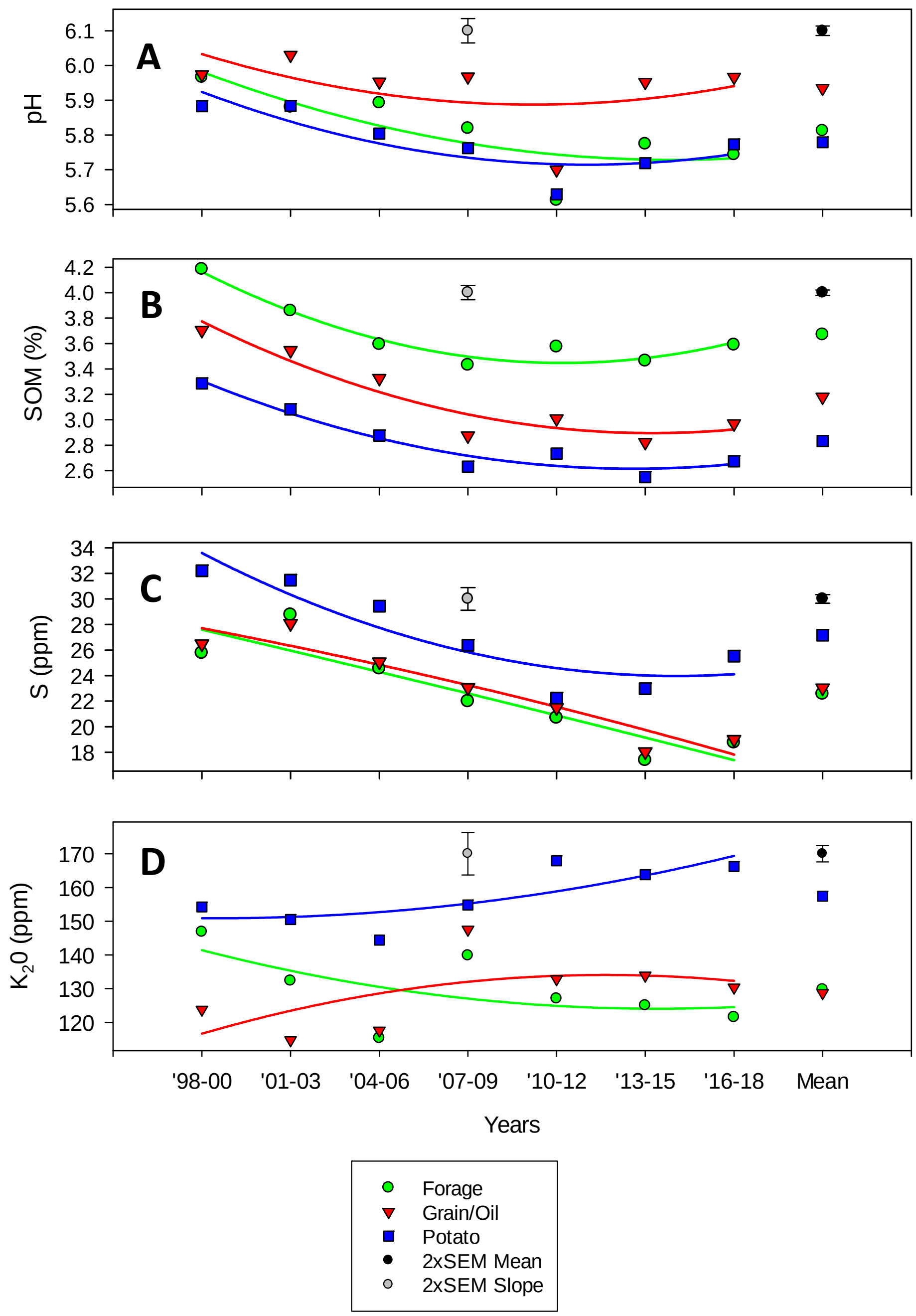


**Figure 10.** Crop frequency associated with soil pH (chart A), soil organic matter (SOM; chart B), sulfur (S, chart C), and potash ($K_2O$; chart D) levels using data acquired through the PEI Soil Quality Monitoring Project, up to and including until end of cycle 7.

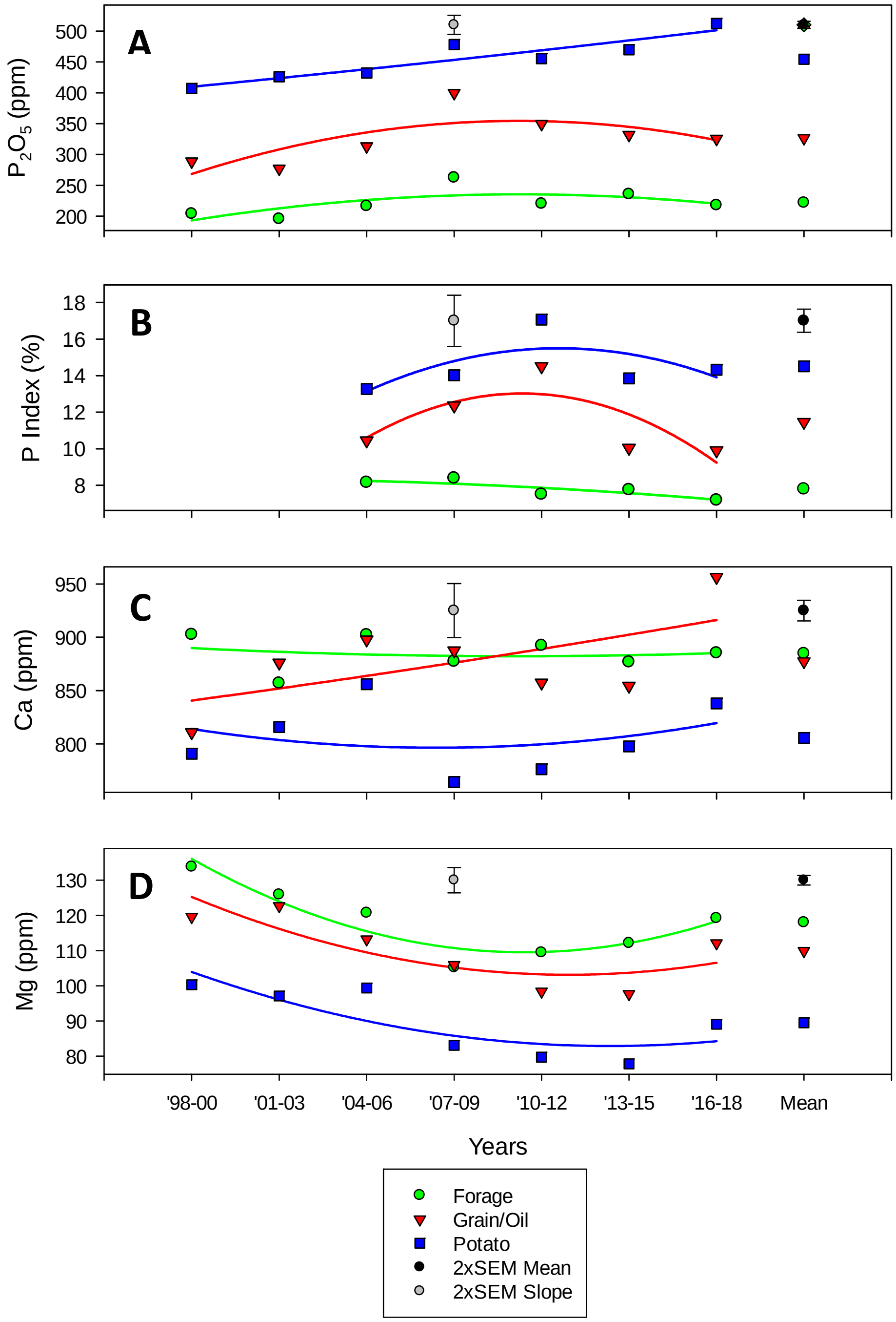


**Figure 11.** Crop frequency associated with phosphate ($P_2O_5$; chart A), Phosphorus Saturation Index (P Index; chart B), calcium (Ca, chart C), magnesium levels (Mg, chart D) using data acquired through the PEI Soil Quality Monitoring Project, up to and including until end of cycle 7.

**REFERENCES:**

Benjannett, R., L. Khiari, J. Nyiraneza, B. Thompson, J. He, X. Geng, K. Stiles, Y. Jiang and S. Fillmore. 2018. Can. J. soil Sci. 98: 317-329.

Douglas, B.W., J. A. MacLeod, T.M. Mellish, W.M. Glen, B.L., Thompson, K. R. DeHaan, A.V. Sturz, M.R. Carter, and M.B. Brincombe. 2000. A method for measuring Prince Edward Island soil quality. Commun. Soil Sci. Plant Anal. 31 (11- 14): 1837-1845.

Nyiraneza, J.,B. Thompson, X. Geng, J. He, Y. Jiang, S. Fillmore and K. Stiles. 2017. Changes in soil organic matter over 18 years in Prince Edward Island, Canada. Can.J. Soil Sci. 97: 745-756.

Nyianeza, J., B. Thompson, J. He, K. Stiles, X. Geng, Y. Jiang and S. Fillmore. 2019. Long-term changes in Mehlich-3 extractable sulfur and magnesium under intensive agriculture in Eastern Canada. Comm. Soil Sci. Plant anal. 50:2505-2520.

PEI Department of Agriculture and Forestry. 2012. “Prince Edward Island Soil Quality Monitoring-2012, Soil nutrient status over the last 15 years in Prince Edward Island.” Available at: https://www.princeedwardisland.ca/sites/default/files/publications/pei_soils_quality_monitoring_report_2012.pdf .

PEI Department of Agriculture and Land. 2017. “Soil organic matter status on PEI”. Available at: https://www.princeedwardisland.ca/en/information/agriculture-and-land/soil-organic-matter-status-pei.

PEI Department of Agriculture and Land. 2017. “Understanding the factors controlling phosphorus availability for crop production on PEI”. Available at: https://www.princeedwardisland.ca/en/information/agriculture-and-land/understanding-factors-controlling-phosphorus-availability-crop.

PEI Department of Agriculture and Land. 2018. “Determining phosphorus fertilization requirements for potatoes based on Phosphorus Saturation Index for PEI”. Available at: https://www.princeedwardisland.ca/sites/default/files/publications/af_nmp_p_fertilization_recommendation.pdf.