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CANOLA WEEK
50th Anniversary
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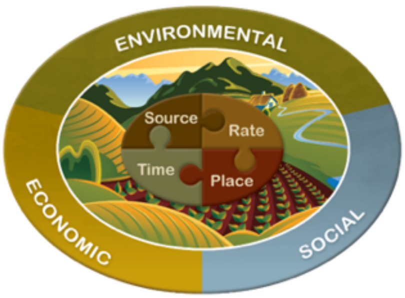
Fertility nationally and internationally

Overview of global novel fertility research

Tom Bruulsema, Plant Nutrition Canada

Greetings from Plant Nutrition Canada! My name is Tom Bruulsema. I thank Warren Ward and the organizers of Canola Week for the opportunity to join you. I have been providing science support for the nutrient stewardship programs of the fertilizer industry for the past 26 years. My goal is to provide an overview of global research relevant to your efforts in nutrient stewardship.

Outcome Metrics of 4R Nutrient Stewardship



nutrient stewardship

1. Farmland productivity
2. Soil health
3. Nutrient use efficiency

(items 1–3: On-farm)

4. Water quality
5. Air quality
6. Greenhouse gases
7. Biodiversity
8. Macroeconomic value
9. Food security

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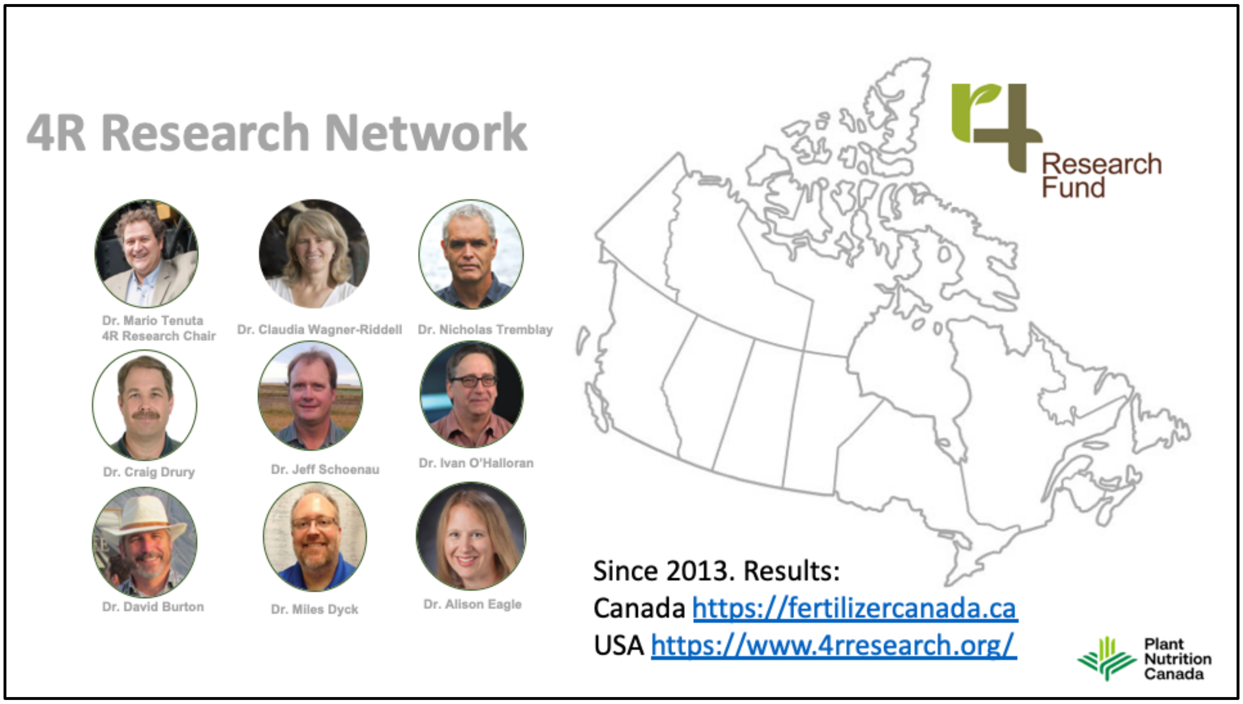
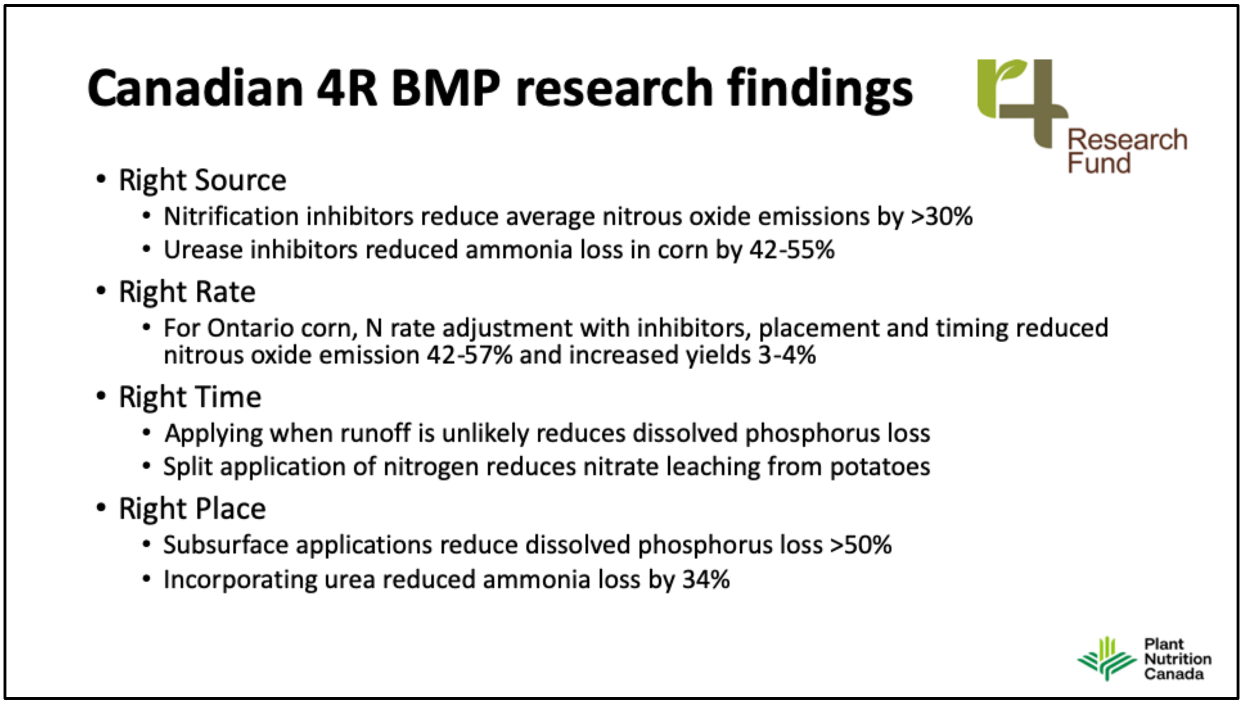
This framework of outcome metrics identifies the major impacts of nutrient stewardship. The first three are most relevant on-farm. They can be and should be part of the record-keeping and decision cycle of any well-managed farm.
Productivity is mostly yield, but can include quality and value as well.
Soil health includes soil fertility.
Nutrient use efficiency is often shown as the ratio of outputs to inputs, but can also include more descriptive nutrient balances.
These three complement each other. It's good to keep an eye on all three, because you can do really well on any one or two at the expense of one or two of the others. For example, high yields with high nutrient use efficiency can deplete soil fertility in the long run. You want optimum levels for all three for profitable production. Attention to the 4Rs can get you there. And when you are at that optimum level, you have gone a long way to minimizing losses of nitrogen and phosphorus that pose risks to water quality, to air quality, and in terms of greenhouse gases.
Those three environmental metrics – 4 through 6 – are difficult to measure at the farm scale, but the research we support can link 4R practices and the first three metrics to make site-specific estimates through models. Several 4R practices have additional effects beyond their improvement of efficiency in reducing losses of nitrous oxide or dissolved phosphorus.

Metrics 7 through 9 are more global in scope. At the international level, industry supports a Scientific Panel on Responsible Plant Nutrition, which is developing new information on these topics, particularly biodiversity and food security.



The North American fertilizer industry continues to support a 4R Research Fund. In Canada, a network of at least nine researchers has had support over the past seven years. Reports on projects in Canada and the USA can be found at the websites of Fertilizer Canada and 4RResearch.

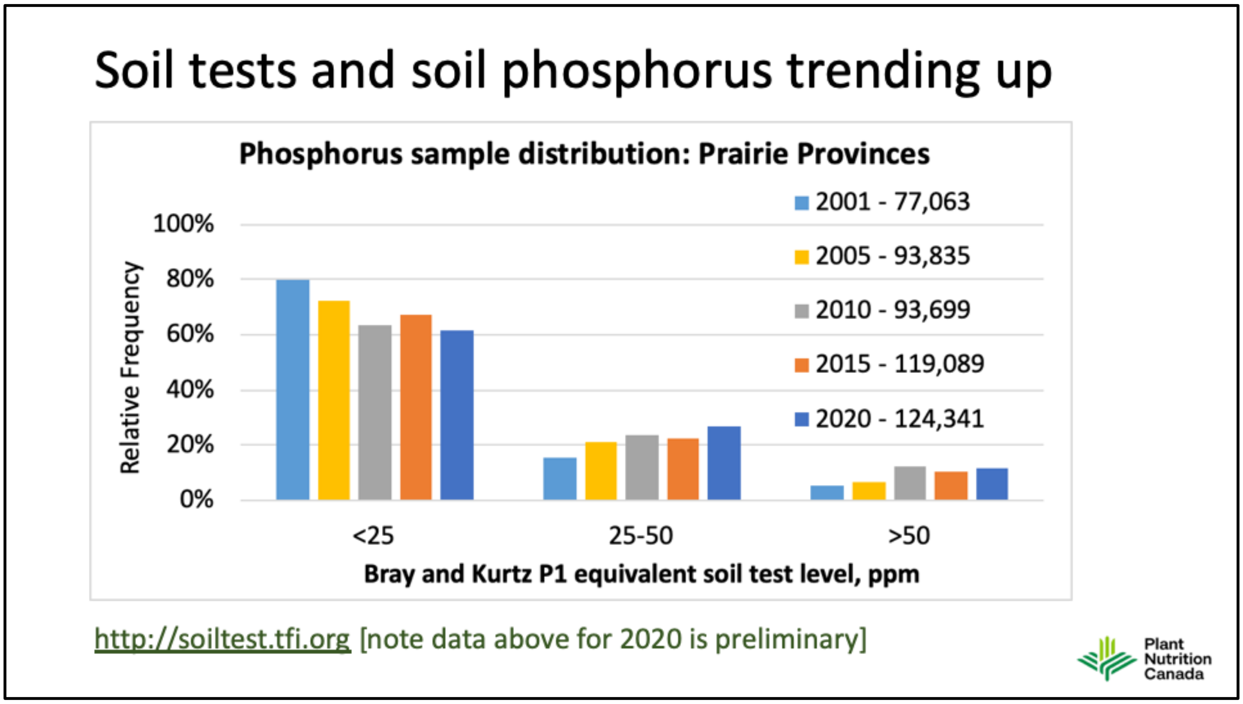


Research supported by the 4R research fund emphasizes quantification, measuring the size of the effects of better combinations of source, rate, time and place. That provides a basis on which to communicate the benefit delivered by practice adoption.

- On right source, inhibitors are remarkable for their efficacy: nitrification inhibitors reduce nitrous oxide more than 30 percent, and urease inhibitors reduced ammonia loss by 42 to 55 percent.
- Combining rate adjustments with inhibitors, on Ontario corn, placement and timing reduced nitrous oxide by 42 to 57 percent, with a small increase in yields.
- 4R timing research finds reduced loss of phosphorus when it's applied at times of the season with low runoff risk. Splitting nitrogen applications on potatoes reduces nitrate leaching risks.
- Right place applications of phosphorus, either fertilizer or manure, can reduce losses of the dissolved form by more than 50 percent.
- Working urea into the soil reduced ammonia loss by 34 percent.
- Some of these findings apply broadly, others are more site-specific. Our knowledge is not complete, but research continues.
- I'd like to look next a some of the trends in outcomes we are currently able to monitor for soil fertility and nutrient use efficiency.

Woodley, A. L. *et al.* Ammonia volatilization, nitrous oxide emissions, and corn yields as influenced by nitrogen placement and enhanced efficiency fertilizers. *Soil Sci. Soc. Am. J.* **n/a**, (2020).

Banger, K. *et al.* Modifying fertilizer rate and application method reduces environmental nitrogen losses and increases corn yield in Ontario. *Sci. Total Environ.* **722**, 137851 (2020).



The North American industry continues to support a survey of soil testing labs, that was run by the International Plant Nutrition Institute.

The 2020 survey is nearly complete.

Here I show the distribution of soil test phosphorus levels across the Prairie Provinces. The soils are divided into three categories.

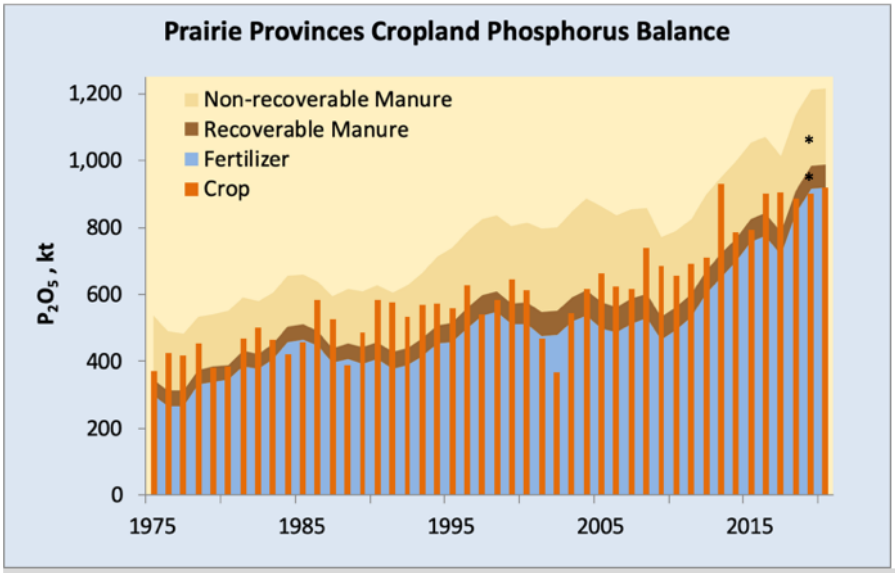
The actual samples are largely analyzed using locally appropriate Kelowna or Olsen extracts, but we convert to the Bray and Kurtz for a standard comparison.

Two things are trending up: the number of soil samples, and the soil test levels.

Since 2001, the number of samples included in the survey has grown from 77 thousand to over 124 thousand.

The frequency of soils testing in the low category has decreased from 80% to 60% - still a large fraction of the soils.

Generally we can say that 4R practices are avoiding depletion of soil fertility, and slowly building up soil fertility, mostly where it’s needed.



Crop removal of phosphorus often exceeds inputs

Calculated from CANSIM data for crops, livestock, and fertilizer using methods of IPNI NuGIS.
** assumes no change in manure P since 2013.*

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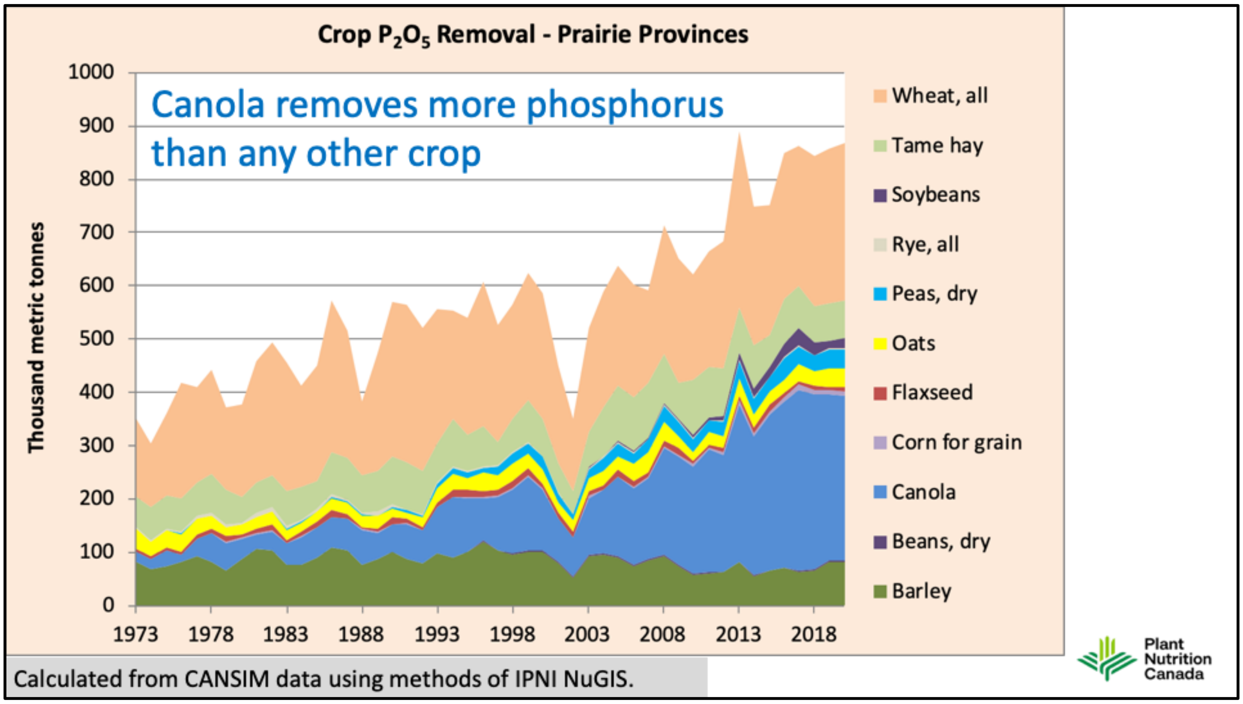
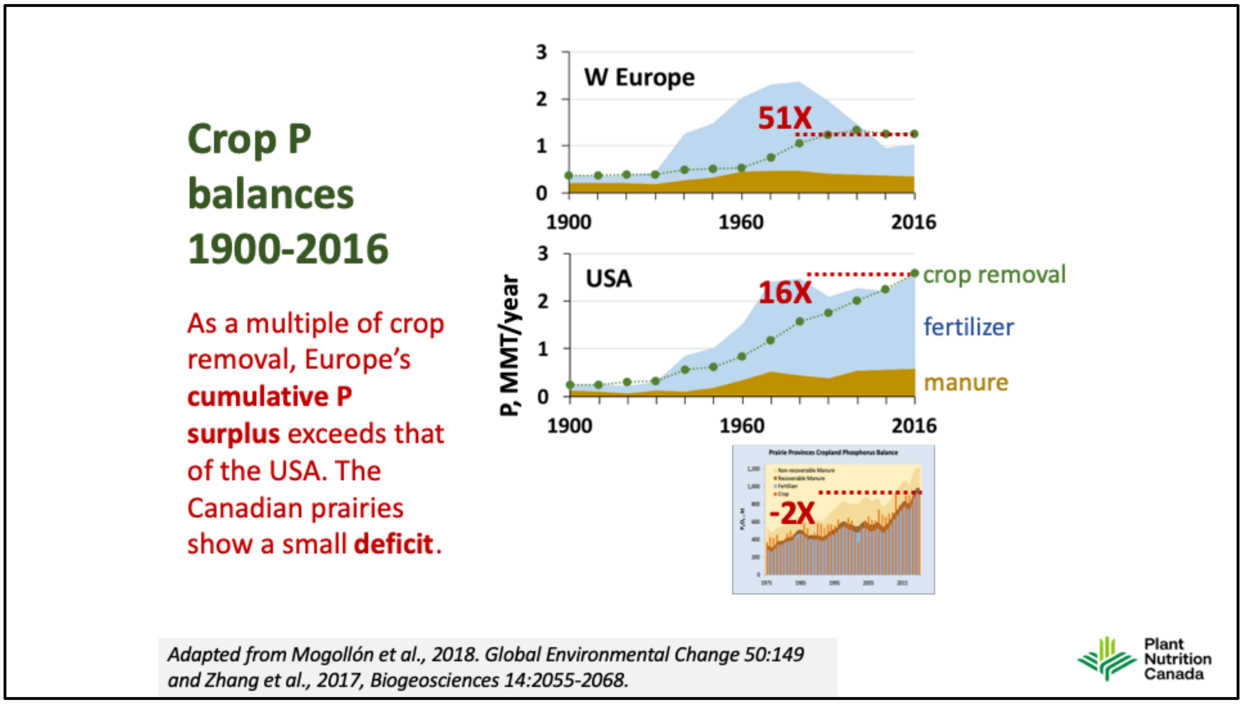
- The phosphorus balance is interesting to compare to the trends in soil test.
- The aggregated crop removals are shown as the orange bars.
- The background shaded areas represent inputs of fertilizer and manure.
- The recoverable manure is that applied to land. Non-recoverable is manure excreted but not applied.
- In several recent years (2013, 2016, 2017), phosphorus removal in harvested crops exceeded inputs applied as fertilizer and manure,
- Over the whole period, outputs exceed inputs by 7%. Crop removal is not being fully replenished.
- The slight surplus in the last three years is not likely enough to explain the increase in soil test phosphorus seen in the 2020 survey.
- As always, a balance over a broad area lumps together areas of surplus and deficit, and those surpluses and deficits could be large.



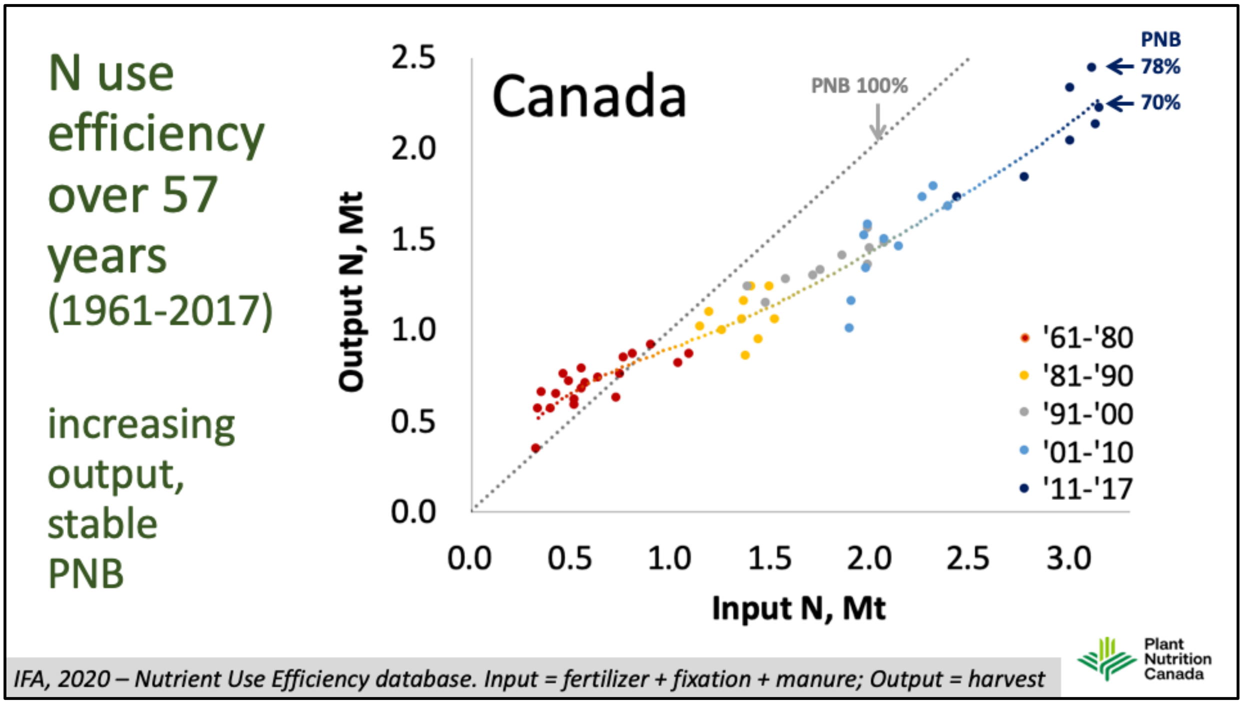
This figure shows the outputs, the phosphorus removed by each of the major crops of the prairies.

For the past ten years, canola harvest removes more phosphorus than any other crop.

Total removal has increased to almost 900 thousand metric tonnes of P2O5, as crop yields and production have increased.



- Moving to the global scale, similar phosphorus balances compare western Europe and the USA.
- Fertilizer use is plotted as the blue area, stacked over the estimated input of phosphorus in applied manure.
- Superimposed in front of the input is the output in the form of crop removal, shown in ten year intervals as green dots.
- In both Europe and the States, surplus began in 1930 and continued to the year 2000.
- Over more recent decades, fertilizer inputs declined, more in Europe than in the USA.
- Crop removal plateaued there but continues to increase in the USA. Has the higher level of regulation in Europe perhaps limited productivity growth?
- For Europe, the cumulative surplus amounts to 51 times crop removal.
- For USA, 16. The same figure for the prairies: negative 2.
- This is something unique to Canadian prairie cropland: no history of cumulative phosphorus surplus!



- Turning now to nitrogen.
- This chart plots output, the total removed by crop harvest, against inputs in the form of fertilizer, manure and symbiotic fixation.
- The color of the dots changes over time from red in the sixties and seventies to blue more recently.
- As production has increased over time, nitrogen use efficiency has decreased, going from surplus to deficit.
- Expressed as PNB – partial nutrient balance – it reached 78% for the 2017 crop, though the trendline is at 70%.
- Output is still increasing, N use efficiency is staying about the same for the past twenty years.
- The high efficiency further back represents nutrient mining: summer fallow mineralizing the nitrogen that was stored in soil organic matter.
- 70 percent is higher than the world average, and is close to the “safe space” of 70 to 90 percent defined by the European Expert Panel on Nitrogen.
- Here, two, however, the average obscures. The high efficiency of legumes like soybeans and alfalfa hides the fact that other crops are less efficient.

Nutrient Use Efficiency of Prairie Canola is Improving

Years	Average yield, bu/A	Nutrient use efficiency, removal as % of fertilizer	
		Nitrogen	Phosphorus
2011-2013	34	52	82
2018-2020	41	59	93

Calculated from CANSIM yields, IFA fertilizer use by crop, and IPNI crop removal coefficients

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Looking specifically at canola, industry data show improvement in both yields and nutrient use efficiencies. But there is room to improve the nitrogen use efficiency figure – it suggest that currently, harvested nitrogen amounts to 59 percent of the fertilizer nitrogen applied to canola.

Strategies to improve sustainability

- Blue and green ammonia
- New inhibitors of urease and nitrification
- Smart fertilizers - aptamers, nanotechnology
- Microbes, biofertilizers and biostimulants
- Precision agriculture – managing variability among and within fields, among and within years
- Fertilizers from recycled sources – e.g., struvite
- Integration with cover crops and conservation

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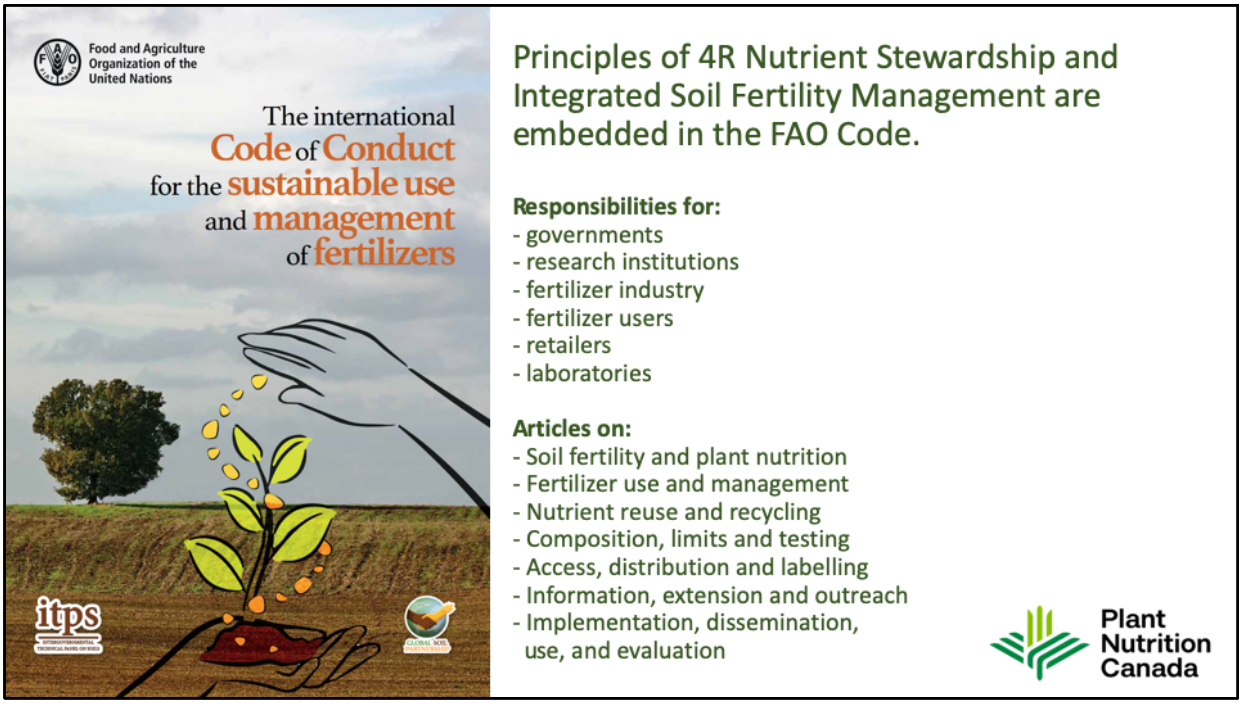
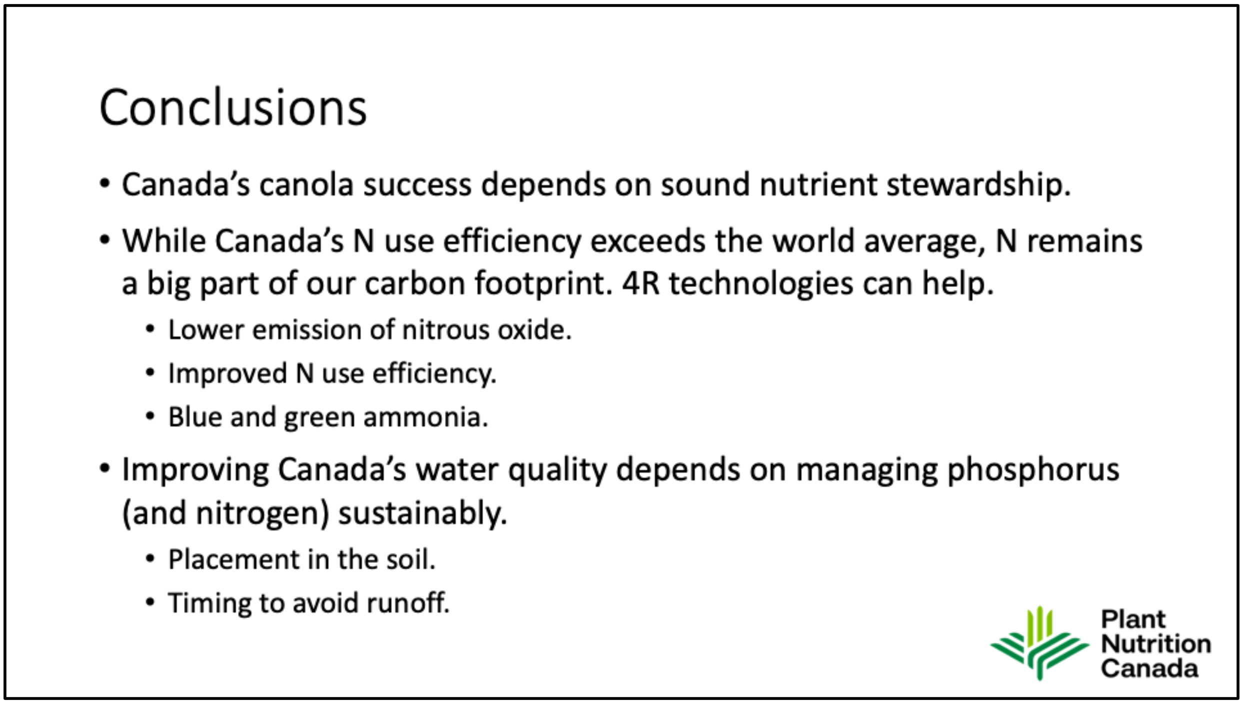
- Many strategies are being investigated through research as means to improve nutrient use efficiency and sustainability.
- Nitrogen producers are investing in blue and green ammonia, produced with low or no carbon emission.
- New inhibitors of urease and nitrification are coming on the market. Expanding use of those currently available could reduce nitrous oxide emissions.
- Smart fertilizers, using aptamers or nanoparticulate forms that hold the nutrient until the growing root of the target crop species reaches them, have been reported. Their efficacy across a range of crop and soil conditions is yet to be determined.
- The same is true for many microbes, biofertilizers, and biostimulants.
- Precision agriculture often involves a lot of technology. Managing variability in both space and time has huge potential to improve efficiencies.
- We are seeing new fertilizers made from recycled sources come on to the market.
- And finally, integration of 4R with cover crops and conservation is essential if we are to reliably sequester carbon in soils.



- In order to drive the adoption of such 4R strategies, 4R needs more widespread recognition.
- The principles of 4R Nutrient Stewardship are embedded in the FAO Code of Conduct for the sustainable use and management of fertilizers.
- The Responsible Grain Code of Practice, discussed by Ted Menzies, also builds on 4R principles and training.
- Continued programs in Canada, the States, and internationally are aimed at raising the awareness of the value of 4R as an industry-driven approach to a more sustainable future.



In conclusion….

These are the aims of 4R Nutrient Stewardship. A lot can be achieved by integrating the 4Rs for nutrients with sound practices for crop management and soil conservation.

Thank you kindly for your attention. I look forward to your questions. On behalf of Plant Nutrition Canada, enjoy the rest of Canola Week!