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ALBERTA INSTITUTE OF AGROLOGISTS

WEBINAR - 19 November 2020

Nutrient stewardship strategy for western Canadian agriculture

Tom Bruulsema, Plant Nutrition Canada

Professionals in agriculture, thanks for this invitation to talk to you about nutrient stewardship strategy. Plant Nutrition Canada is a new organization, providing science support for sustainable management of plant nutrition. I work closely with Fertilizer Canada, and other fertilizer industry associations in the United States and internationally.

My background in western Canada began in Grassy Lake Alberta, where I had a summer job on a farm and feedlot. I was interested to hear about the new Federated Co-op fertilizer terminal that recently opened there.

Brief Abstract: In the last decade, awareness and use of the concept of 4R Nutrient Stewardship has grown widely. Nutrient stewardship influences a wide range of areas including farmland productivity, soil health, nutrient use efficiency, water quality, air quality, greenhouse gas emissions, food and nutrition security, biodiversity, and economic value. This presentation will discuss the principles and the implementation of 4R practices in Western Canadian industry initiatives, assess trends in soil nutrient status and crop nutrient balances, and demonstrate how 4R fits into sustainability strategy for agriculture.

Outline – Nutrient stewardship strategy

- 4R Nutrient Stewardship
  - Principles
  - Performance metrics
  - Implementation of 4R practices
- Trends in soil fertility and nutrient balances
- 4R in sustainability initiatives
  - Canadian Roundtable for Sustainable Crops
  - IFA – Scientific Panel on Responsible Plant Nutrition
  - UN-FAO

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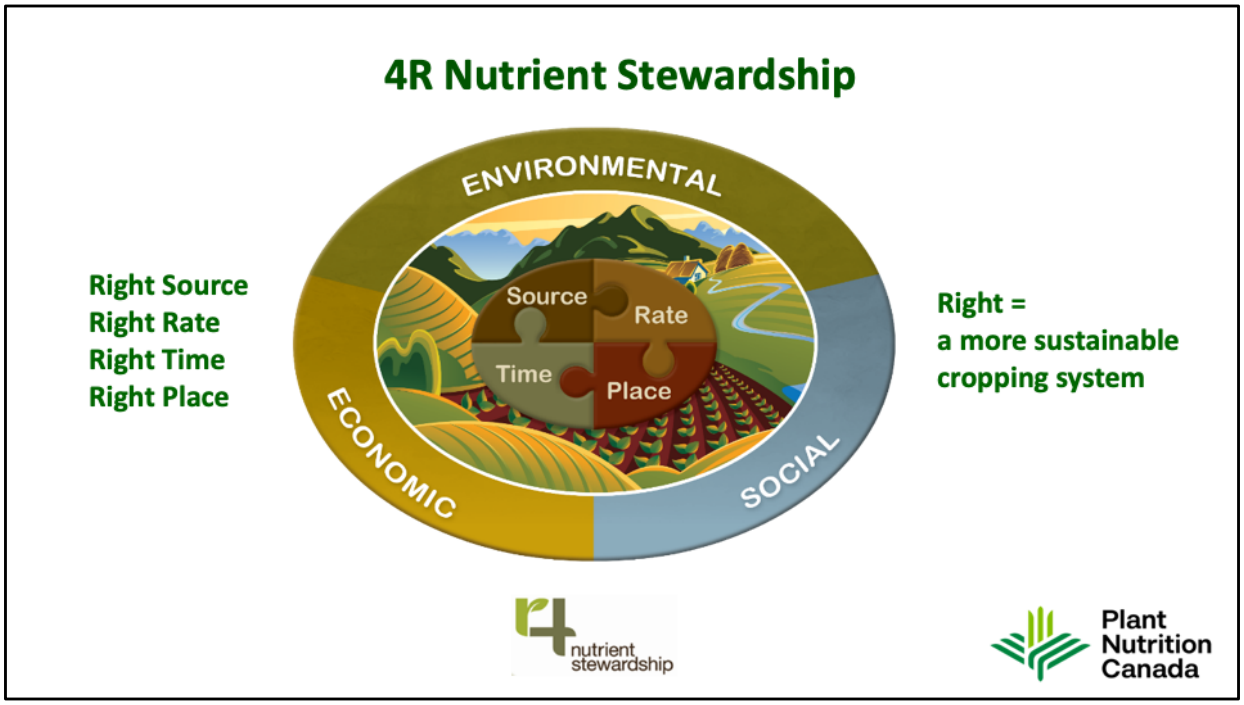
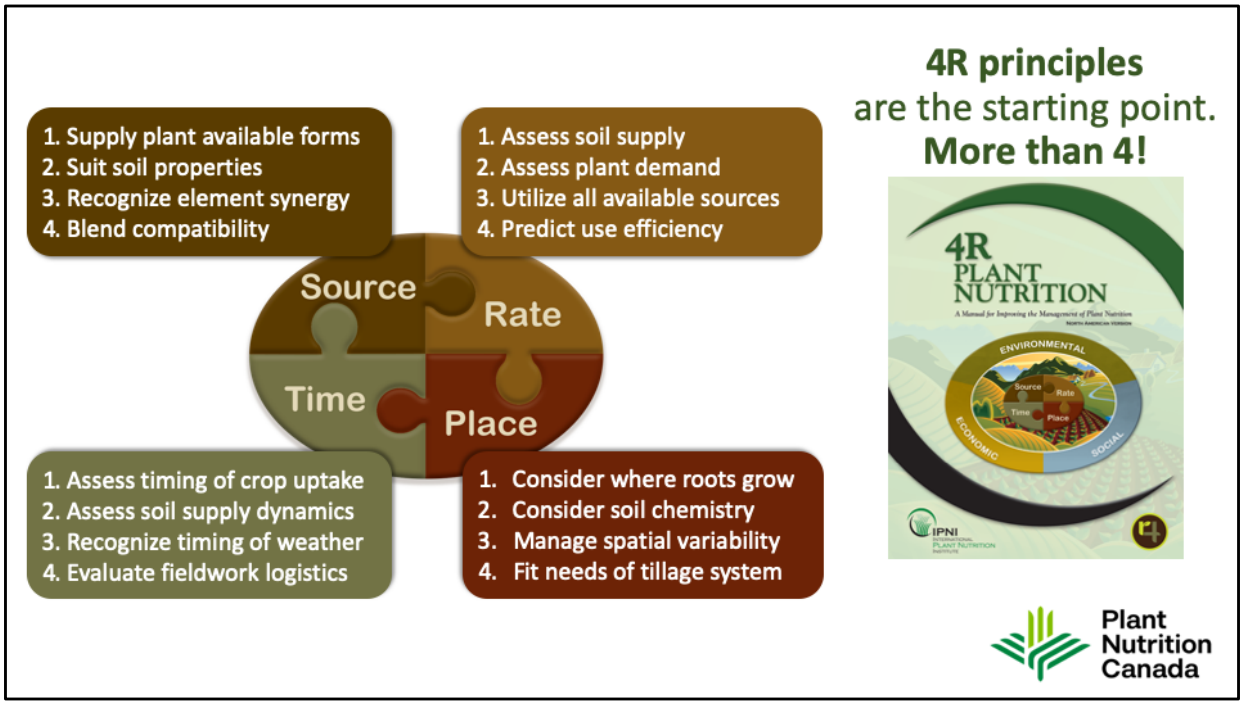
- Today's presentation has three parts.
- First I'll talk about the 4R principles, performance metrics, and the programs through which 4R practices are being implemented in Canada.
- Second, I'll show some recent trends in soil fertility and nutrient balances in Alberta, the prairie provinces, the nation and the world.
- Finally, I will discuss how 4R is integrating with the wider world of sustainability initiatives, with the Canadian Roundtable for Sustainable Crops, the International Fertilizer Association's Scientific Panel, and the Food and Agriculture Organization of the United Nations



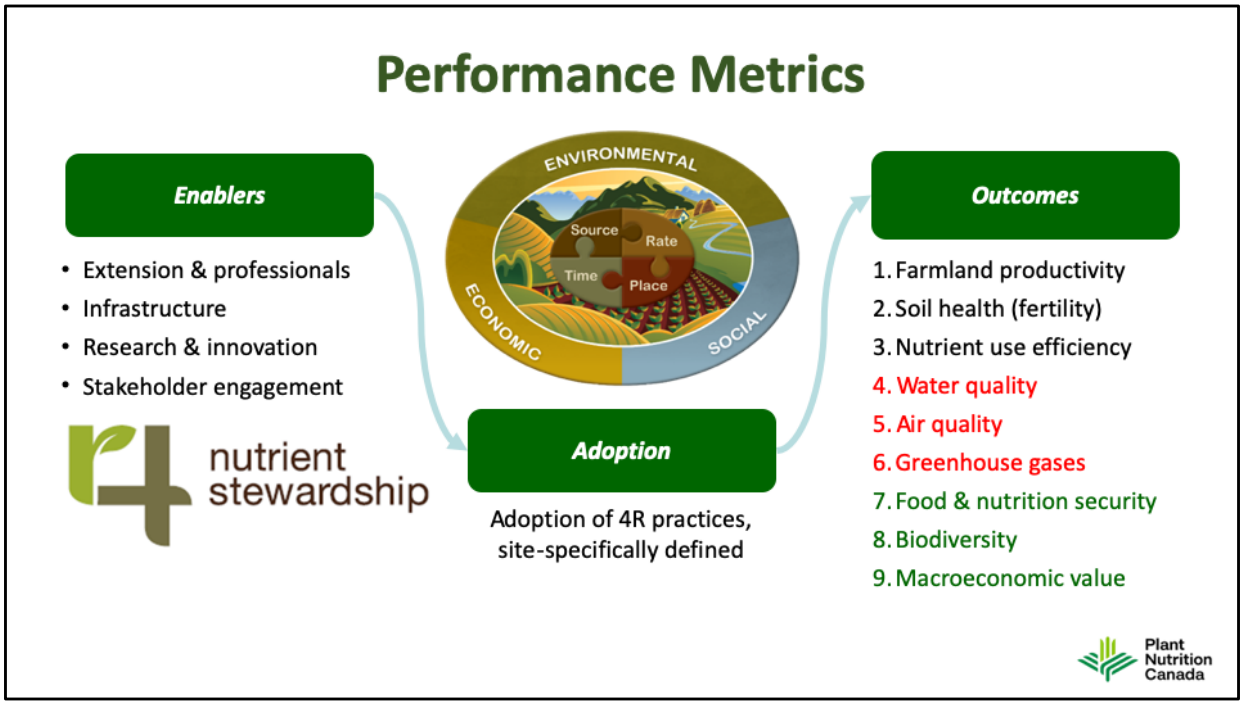
4R Nutrient Stewardship is central to the crop nutrition industry's strategy. The focus is on what the industry can control: the source, rate, time and place of nutrient application. It can be called right if it contributes to making the cropping system more sustainable, recognizing stakeholder priorities for environmental, economic and social performance. Sustainability of the cropping system depends on many more aspects of management beyond nutrient application, of course, but the industry focuses on what it can control. It is an important control, because the application of fertilizer is a large entry point for nutrients to the agricultural system, and to the environment.

- [Embodied in that idyllic landscape, management of nutrients must be accompanied by management of soils, water, crops, and pests.]



The principles are more than four. Each component has a set, described in detail in the 4R Plant Nutrition Manual – a 130-page textbook of 4R. The principles shown here, attached to source, rate, time and place, just address the biophysical processes affecting the fate of the applied nutrients.

- But a stewardship strategy goes further.
- For sustainability, or for good stewardship, there are also many principles regarding the choice of goals and balancing outcomes to reflect the needs and aspirations of stakeholders.
- Sustainability principles are discussed in the 4R manual
- They include accountability to stakeholders impacted by 4r decisions.



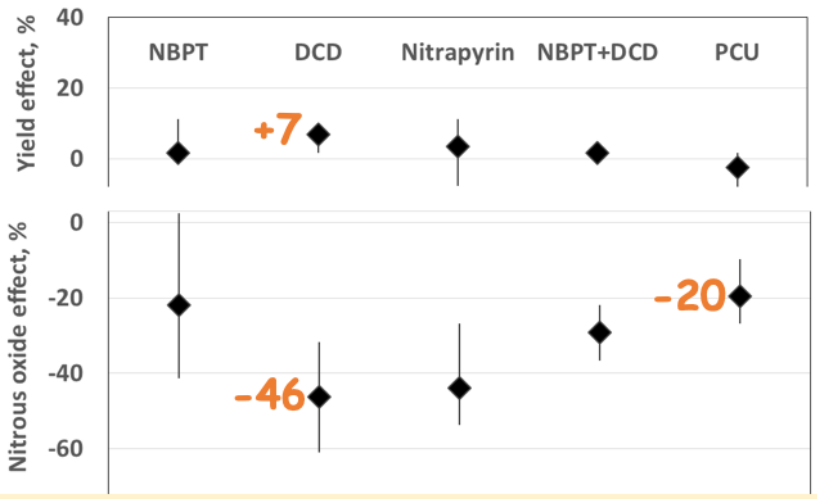
This slide represents an accountability framework that is part of implementing the 4Rs. This set of performance metrics forms the industry stewardship strategy, and also an outline for the rest of this presentation.

- Industry has supported enablers a long time. You can find information on that at any association website.
- The ultimate goal is measuring outcomes, but many outcomes are hard to measure, and require models, that need data on an intermediate metric, adoption
- An adoption metric would seek to count acres under 4R. It requires site-specific, crop-specific definition.
- I'll present some numbers and show what's behind them.
- Outcomes – three groups. First three can be measured on farm. But not all farmers do, and fewer report.
- Next three are environmental impacts. Much more difficult to measure on farm. Generally benefit when we optimize the first three, but specific 4R practices can have greater direct impact in reducing risks.
- 4R does more than improve NUE.
- Final three are being addressed at the international level by IFA's scientific panel on responsible plant nutrition.
- Even simple outcomes, however, are hard to measure. A single farm can be tracked

with soil tests, but it is rare to find systematic tracking of trends over large areas.

- Syngenta reported an effort to increase soil fertility on 10m ha in Brazil. No data, only program statistics. [IFA high level Forum on Sustainable Plant Nutrition, yesterday 18 Nov 2020]

Inhibitors impact nitrogen loss more than yield



Thapa et al. (2016) Effect of enhanced efficiency fertilizers on nitrous oxide emissions and crop yields: a meta-analysis. Soil Science Society of America Journal 80:1121–1134

Mean effect size (%) and 95% confidence interval for technologies applied to urea

- The use of inhibitor with the N source is a 4R practice that can increase yield and nitrogen use efficiency.
- But it has a much bigger impact in reducing loss of the GHG nitrous oxide.
- Same is true for phosphorus placement – banding affects loss risk more than yield.
- Predicting the effect of 4R on such impacts depends on knowing the practices in place – past, present and potential.
- This is why industry strategy includes metrics for adoption, and science for quantifying contributions to outcomes

Why a Retail Designation Program?

- Increasing pressure to demonstrate on farm stewardship.
- Canada's Fertilizer Retailers are well positioned to assist farmers.
- The 4R Designation provides recognition for sustainability improvement efforts:
  - Retailers recommending 4R practices.
  - Farmers who complete and apply 4R-consistent plans.

fertilizercanada.ca/nutrient-stewardship/ @FertilizerCA linkedin.com/company/fertilizercanada

nutrient stewardship FERTILIZER CANADA

The industry believes more can be achieved with 4R than with a focus on NUE improvement alone.

- 3 programs in Canada
- Designation
- Certification of ag retailers
- Certification of crop advisers with 4R specialty

CCA – over 1100 in Prairies, over 600 in Ontario
Government of SK target is 25% of cropland (~9.1M acres) by 2025
Canadian Canola Growers Association (CCGA) set a sustainability target of having 90% of their acres implementing 4R practices by 2025 (measured through the Fertilizer Use Survey)
Fertilizer Canada goals – by 2025, 15M acres validated, support grower associations and provincial governments to get 30M acres by survey

The fertilizer industry supports a 4R Research Fund, operational since 2013. In Canada, at least nine researchers have had projects supported over the past seven years.

Research Network Resources

Research Fund

Key Findings of the
Canadian 4R Research Network

Increasing Profitability and Improving Environmental Sustainability

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» https://fertilizercanada.ca

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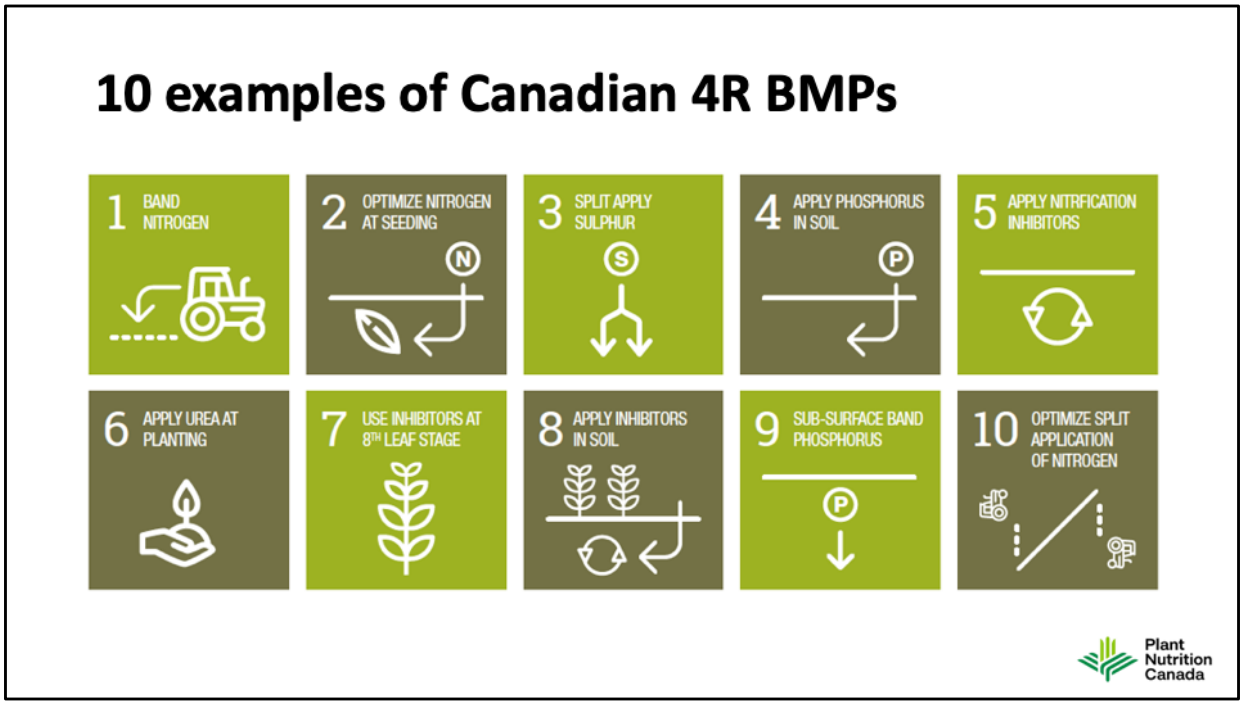
Details on these projects can be found in online resources at the Fertilizer Canada website.



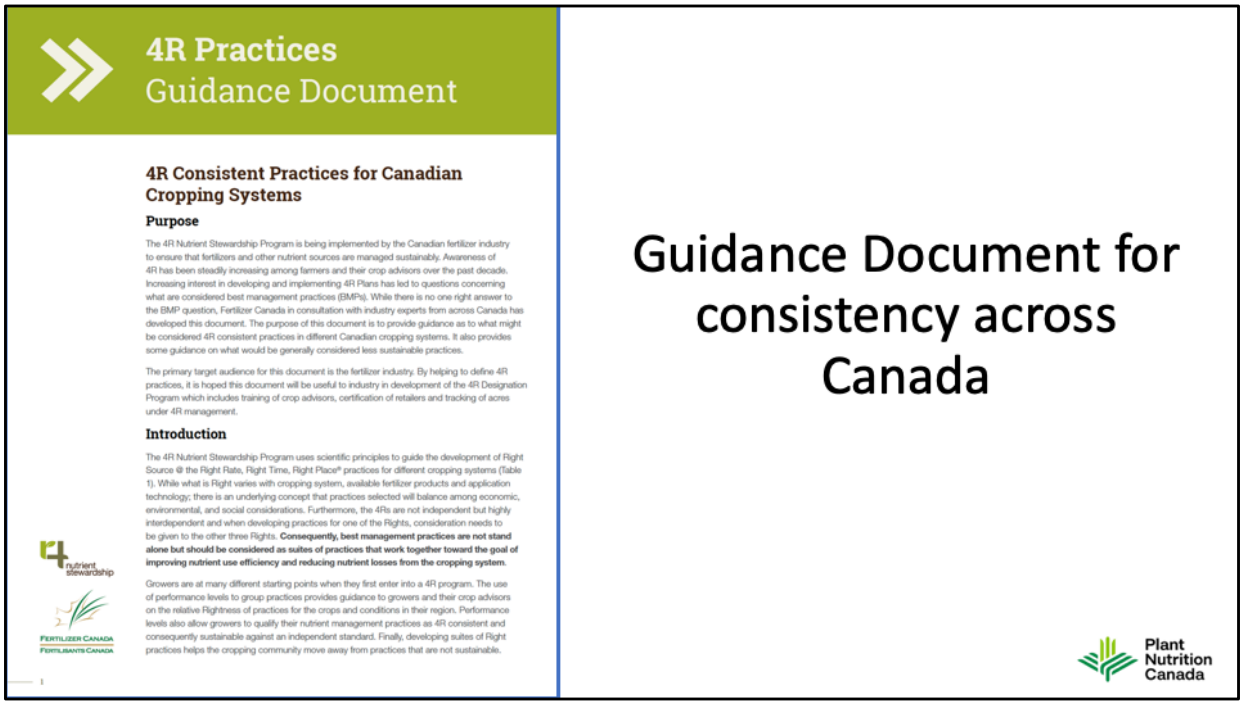
- When we get specific about practices, not every practice suits every farm. These ten have been shown through research to be effective in different situations across Canada.

1. Banding nitrogen close to the seed row is useful for wheat and canola in Alberta, increasing uptake efficiency and reducing nitrous oxide emission.
2. Ditto, but get the rate right as well.
3. Split application of sulfur to wheat was shown to increase nitrogen use efficiency and thus lower nitrous oxide emission in Alberta.
4. Getting phosphorus into the soil was shown in both Saskatchewan and Ontario to reduce runoff loss. It is an important challenge for no-till farming.
5. Nitrification inhibitors help cut N loss and nitrous oxide loss almost anywhere, from ammonium-supplying fertilizers, but not from calcium nitrate.
6. Urea applied at planting can be done in small amounts but be careful about injury to seedlings. For wheat in Manitoba, it reduced greenhouse gas emission relative to fall applied.
7. Nitrification #7 and #8: Using urease and nitrification inhibitors at the 8th leaf stage of corn reduced losses of both ammonia and nitrous oxide from applications of urea and UAN.
8. *[It actually refers to inhibitors applied to urea or UAN, and was shown in research*

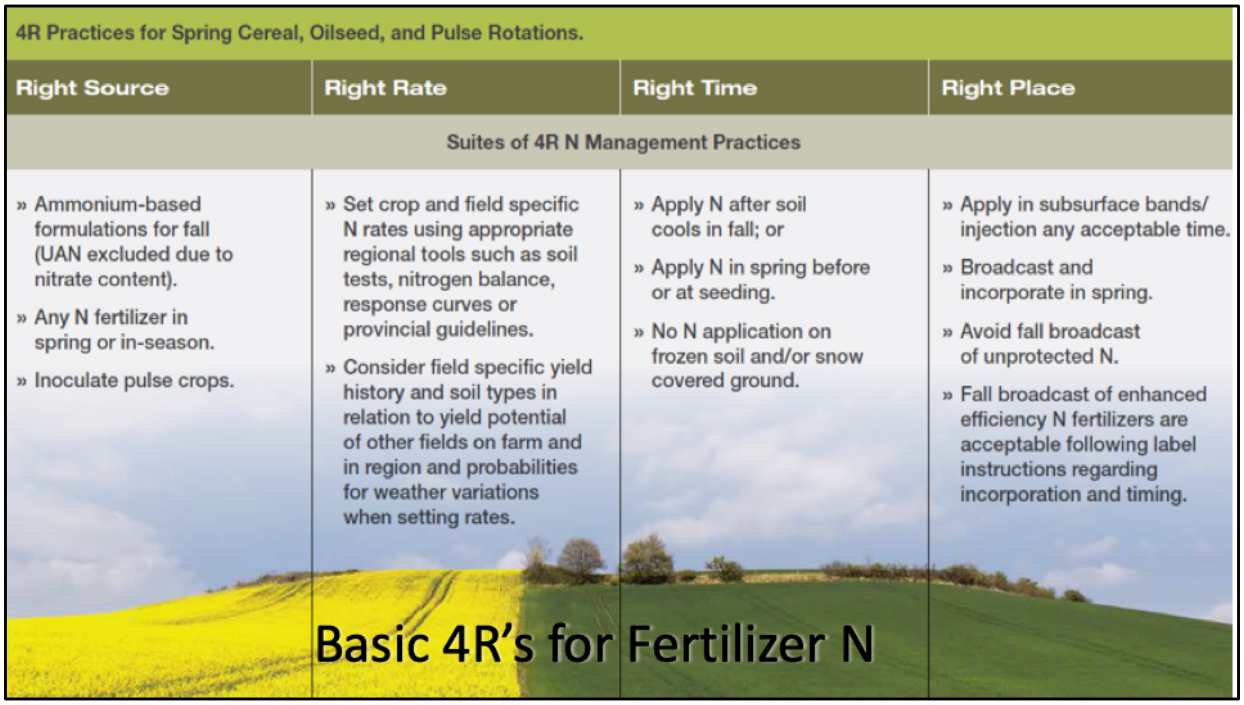
by Claudia Wagner-Riddle and Craig Drury to reduce losses of ammonia and nitrous oxide in some situations.]

9. A subsurface band is a great way to apply phosphorus for corn in Ontario. Can make a big cut to loss of dissolved phosphate.
10. Split application can be more easily optimized on sandy soil than on soils of finer texture. Was shown to reduce nitrate leaching in PEI potatoes.

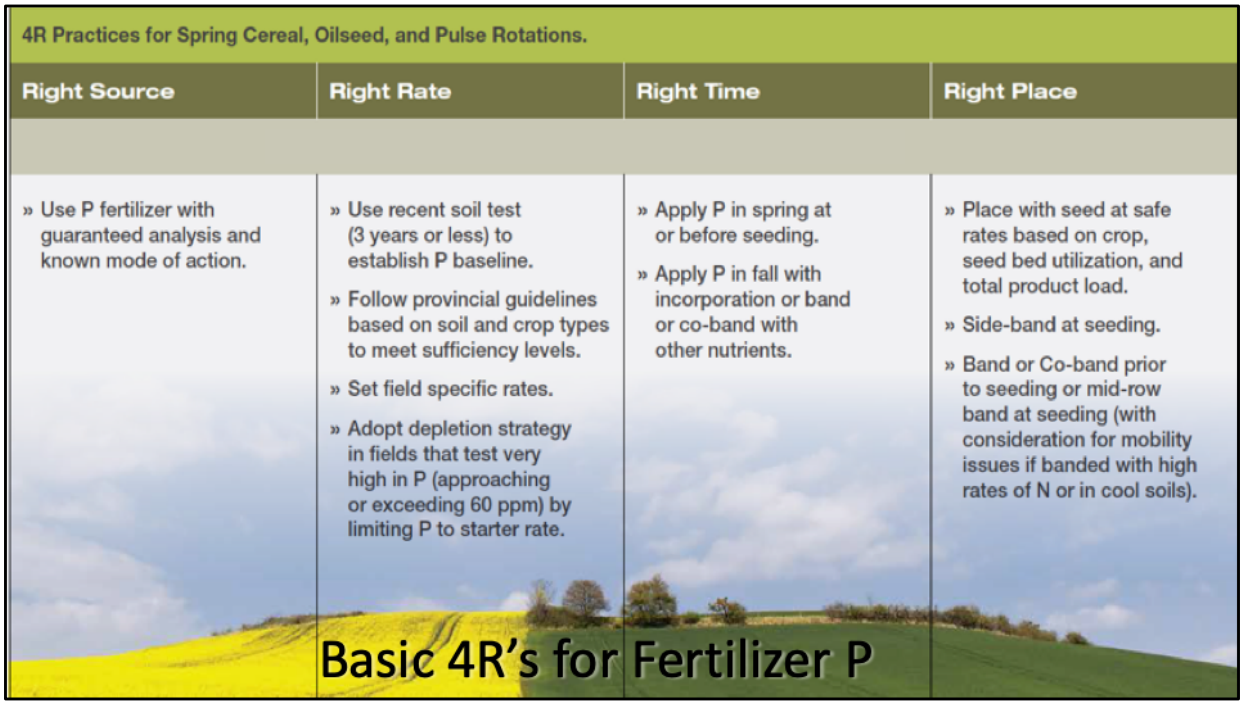
- Any of these 10 practices can be right or wrong for any specific crop. Making the choices can be hard. A good reason to get advice from certified professionals.



- So a big question arises: how do we know what's right, when what's right is site-specific? Is 4R an anything-goes philosophy?
- Not at all. Guidance documents have been developed, with input from scientists.
- They recognize need for definition and description of what constitutes a 4R practice for a given crop in a given region
- Consistency across Canada is the goal but practices are spelled out separately for Western and Eastern parts of the country, for each major nutrient, and for specific major crops within each.
- Consistent with, but not quite as prescriptive, as the standards for the Ontario 4R Certification program.



Example of the description of 4R practices at the basic level for **nitrogen**, for prairie crop rotations including spring cereals, oilseeds and pulses.



Example of the description of 4R practices at the basic level for **phosphorus**, for prairie crop rotations including spring cereals, oilseeds and pulses.

- So, what are farmers actually doing?
- Sustainability requires accountability, and the fertilizer industry has been surveying farmers to monitor 4R adoption and its results.
- The example on the next slide is from a recent survey conducted by Stratus Ag, which is ongoing for 2020 as well.

Wheat and Canola SRTP trends

Canola (2019)

- More than 95% of N and P applied subsurface
- Rates of N and P trending up, 130 lb N/A and 37 lb P_2O_5/A
- Sulphur: average rate 23 lb S/A, 89% applying
- Potash: average rate 10 lb K_2O/A, 45% applying

Wheat (2016)

- Average N rate 87 lb/A – 71% at planting
- 92% of P applied at planting
- Average S and K_2O rates 7 and 8 lb/A

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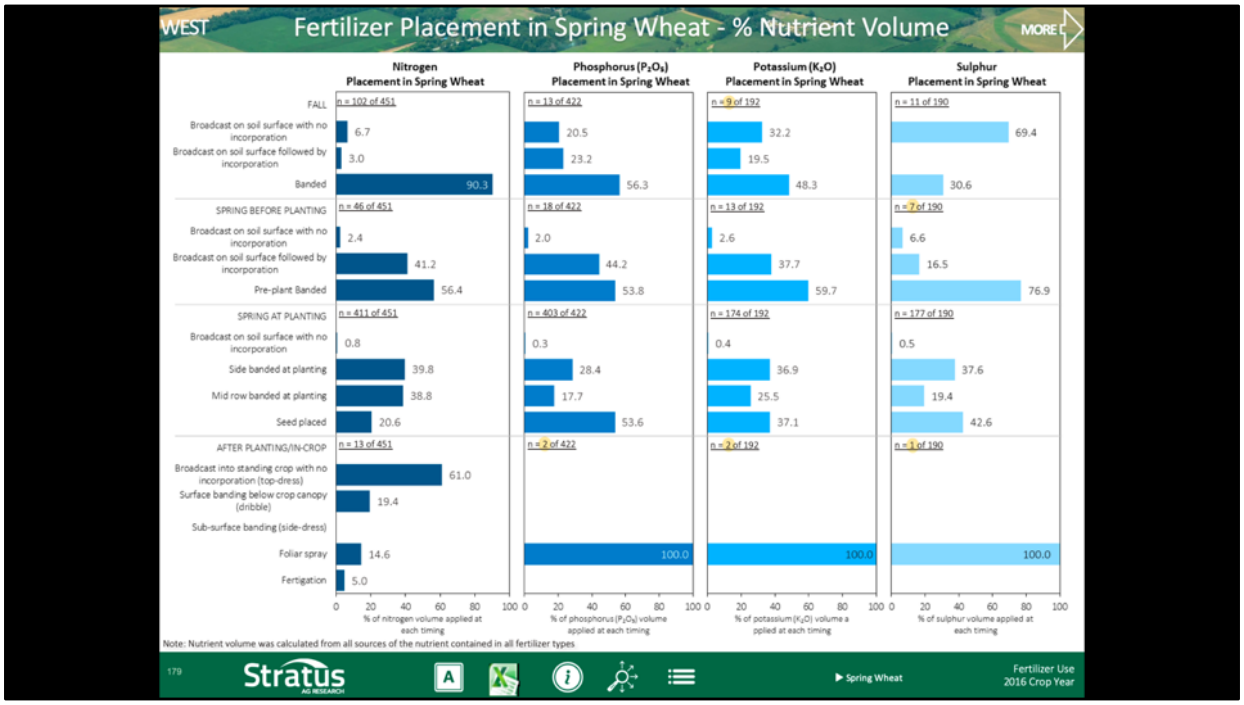
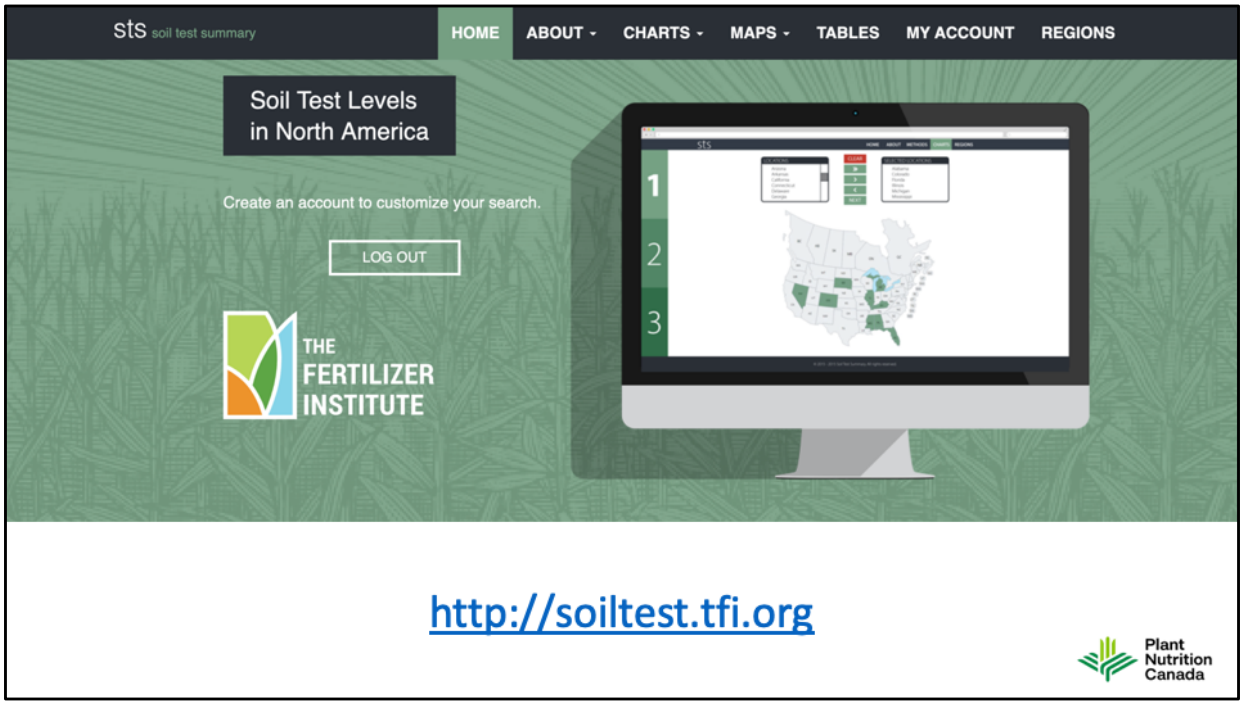
Source, rate time placement trends.



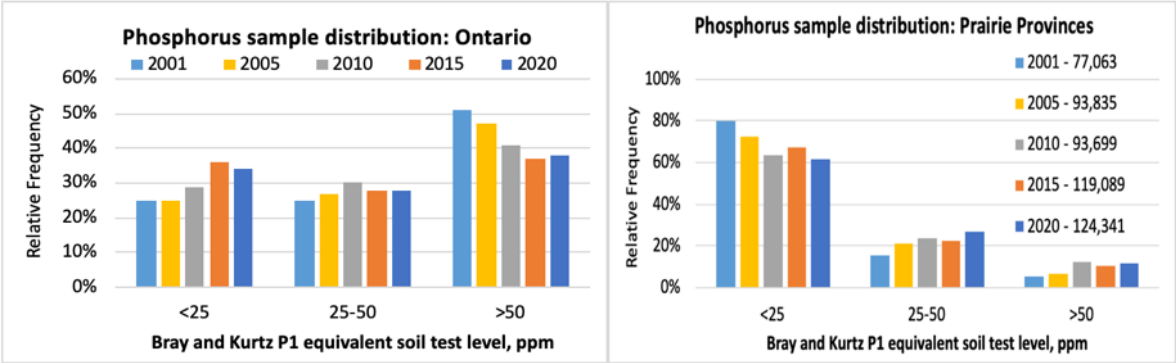
- The survey provides detailed data on source, timing and placement as well as rate.
- It's very complex. The survey slideset has over a hundred pages of such data.
- Such information is crucial to estimating impact of fertilizer use on losses of ammonia to the air – need to know very specifically – how much of the N was in the form of urea, left on the soil surface and at what time of year, if we are to estimate impact of ammonia loss on air quality
- Or, what fraction of phosphorus was left on the surface at times of runoff risk



The industry also supports surveys of soil fertility.
Look for new information coming soon to this site. Currently it includes the survey data from 2001 through 2015, but by the end of this year we are hopeful that full information on 2020 will be available. We thank the Fertilizer Institute for the financial support for this effort.
Thank you for your attention. Please direct any comments or questions on this talk to me at Plant Nutrition Canada.

- Measured change in soil fertility.
- Syngenta claims to have increased soil fertility on 10m ha in Brazil. No data, only program statistics. [IFA high level Forum on Sustainable Plant Nutrition, yesterday 18 Nov 2020]

Findings from 2020 soil test survey (preliminary)



Ontario: high soil test P, declining
Prairies: low soil test P, increasing

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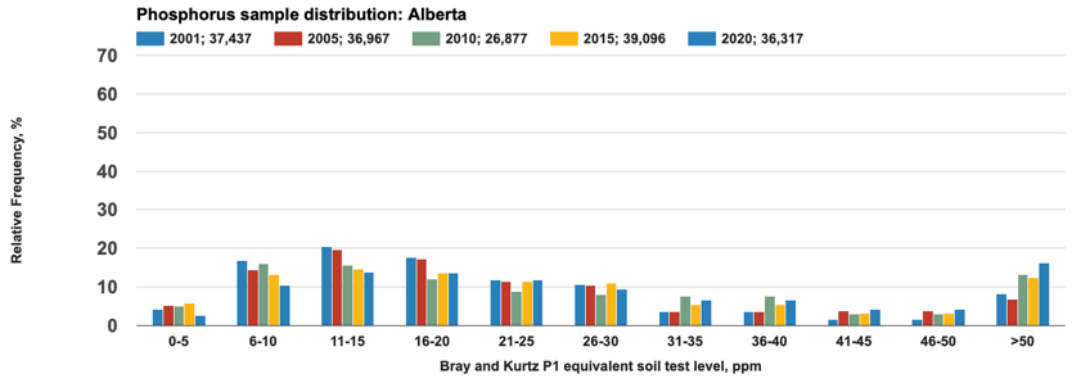
- 2020 survey not yet complete, but fortunately most data for Canada are in
- These figures group soil test levels into three categories – below a Bray & Kurtz P1 value of 25 (about the same as an Olsen of 20 ppm), up to twice that level, and above.
- Ontario differs from Prairies! Long history of growing grain without livestock, versus growing livestock without grain!
- Trend over time shows soils low in P fertility now comprise only 60% rather than 80% in the prairies.
- Number of samples trending upward - very positive. We don't capture all the labs – so more samples are actually taken.

Findings from 2020 soil test survey (preliminary)



Alberta soil test P: greatest change on low and high ends

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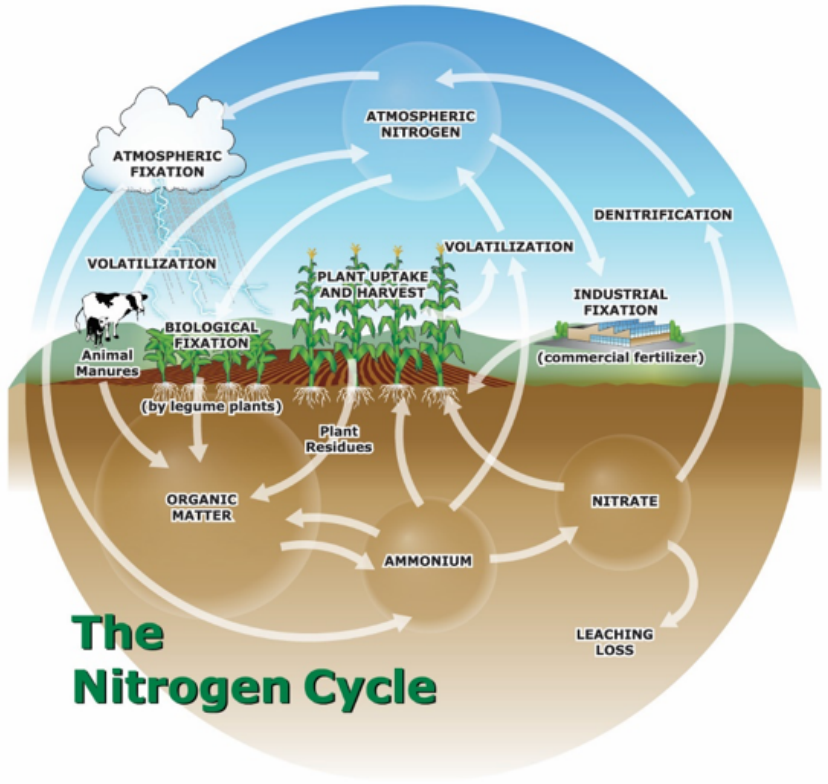
- Zeroing in on the province of Alberta, The lowest categories are declining the most in soil test P. Positive trend.
- But, troubling trend in the soils above 50 ppm
- Similar data to be available soon on K, Mg, S, Zn and pH
- Much more detail at the soiltest website



Nutrient Use Efficiency

Many forms of nitrogen can be lost to air or water.

Many processes are involved in nitrogen use efficiency.

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- A metric that complements soil fertility well is nutrient use efficiency or nutrient balance
- Nutrient cycles are complex, and many different efficiencies can be calculated.
- The nitrogen in a harvested wheat crop, often amounts to at least 75% of the amount applied in fertilizer
- At the same time, “full chain” nitrogen use efficiency, accounting for losses all the way to the dinner plate, is estimated at 10 to 20 percent.
- So we need to be clear, in discussing nutrient use efficiency, what part of the cycle we are talking about, which inputs, which outputs.

Nutrient use efficiency can be defined and calculated in many ways

NUE term		Calculated from	Typical levels for N (maize or wheat)
Partial factor productivity	**PFP**	**Y/F**	40-90
Agronomic efficiency	**AE**	**$(Y-Y_0)/F$**	15-30
Partial nutrient balance	**PNB**	**R/F**	>90% = deficiency <70% = surplus
Recovery efficiency	**RE**	**$(U-U_0)/F$**	40-65% (whole-plant) 33% (grain only)
Internal efficiency	**IE**	**Y/U**	30-90
Physiological efficiency	**PE**	**$(Y-Y_0)/(U-U_0)$**	40-60

Y = yield, F = fertilizer, R = removal, U = uptake

After Dobermann, 2007; Fixen et al., 2014

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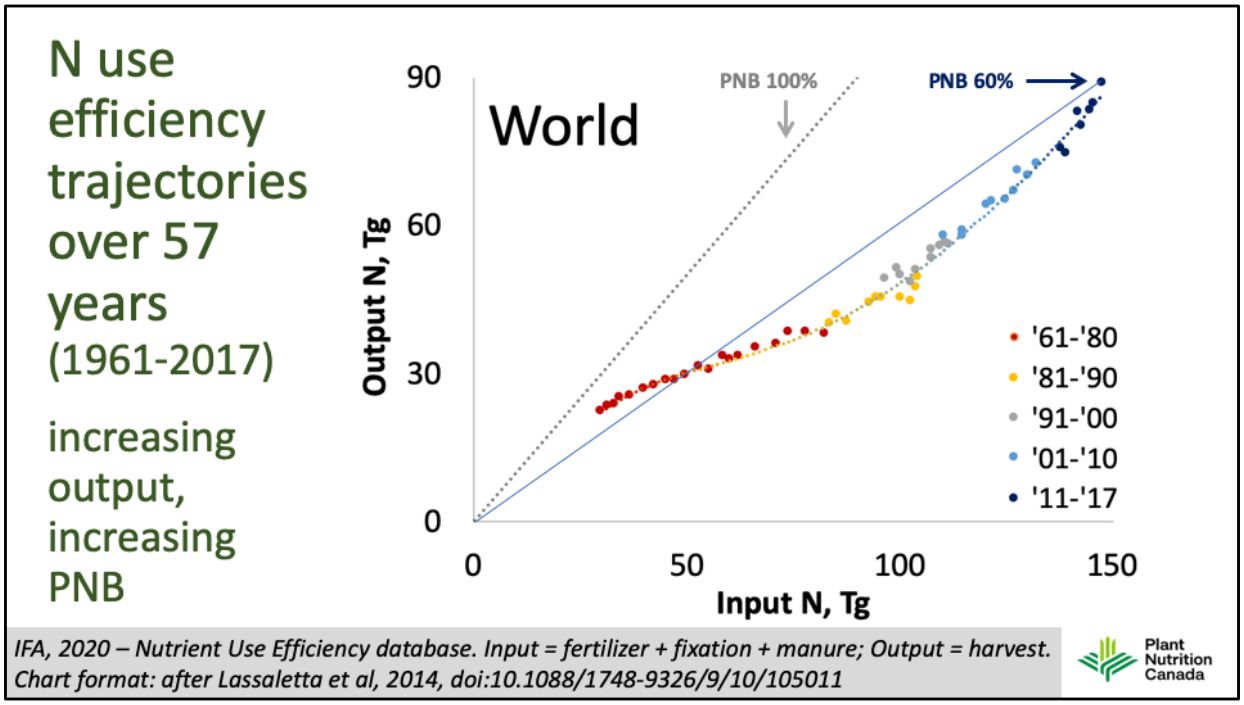
Even when we look only at the crop and soil, many methods are used to calculate different forms of use efficiency.

- From yield, fertilizer, uptake into the whole plant, and removal from the field with harvested product
- Range of values for each
- As a performance metric of a crop production system, the simple terms are best –
- partial factor productivity for a single crop,
- partial nutrient balance integrating across crops.



Nutrient use efficiency relates to yield. Both relate to output, one per unit of nutrient input, one per unit of land area. In this format, we get an indication of both. Output N – Nitrogen in harvested crops is very proportional to yield, and input N include fertilizer and manure applied as well as biological fixation.

Tg = teragram = million metric tons

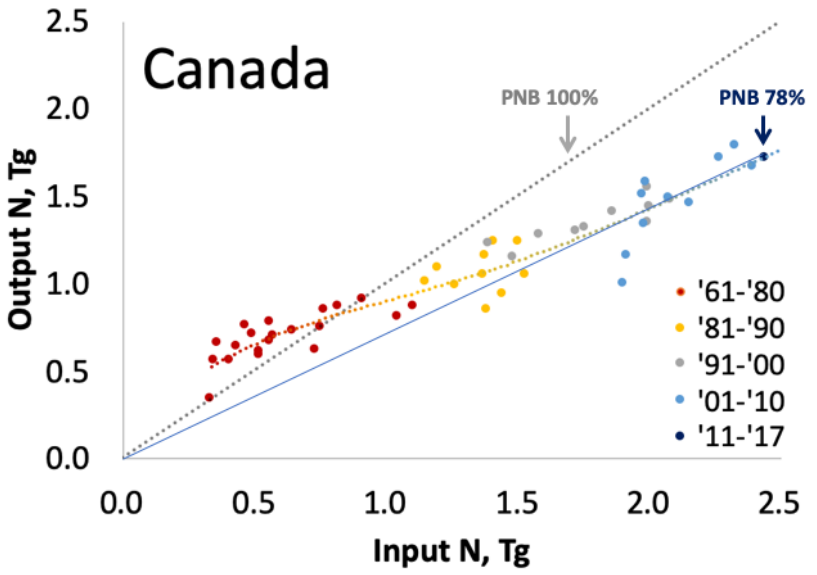
The International Fertilizer Association, IFA, has recently created simpler but more up to date nutrient use efficiency comparisons at the national level. They do not include deposition from the atmosphere. Here I have plotted their data in a manner similar to Lassaletta, but using total production rather than per hectare yields and application rates. This figure, updated to 2017, shows considerable improvement in world nitrogen use efficiency since 2009, along with substantial increase in production.

Luis Lassaletta1, Gilles Billen1,2, Bruna Grizzetti3, Juliette Anglade1 and Josette Garnier1,2
Environ. Res. Lett. 9 (2014) 105011 (9pp) doi:10.1088/1748-9326/9/10/105011
50 year trends in nitrogen use efficiency of world cropping systems: the relationship between yield and nitrogen input to cropland

1 Université Pierre et Marie Curie (UPMC), UMR 7619 Metis, 4 place Jussieu, F-75005 Paris, France
2 Centre National de la Recherche Scientifique (CNRS), UMR 7619 Metis, 4 place Jussieu, F-75005 Paris,France
3 European Commission, Joint Research Centre (JRC), via E. Fermi 2749, I-21027 Ispra (VA), Italy
E-mail: lassalet@bio.ucm.es

N use efficiency trajectories over 57 years (1961-2017)

increasing output, stable PNB



IFA, 2020 – Nutrient Use Efficiency database. Input = fertilizer + fixation + manure; Output = harvest.
Chart format: after Lassaletta et al, 2014, doi:10.1088/1748-9326/9/10/105011

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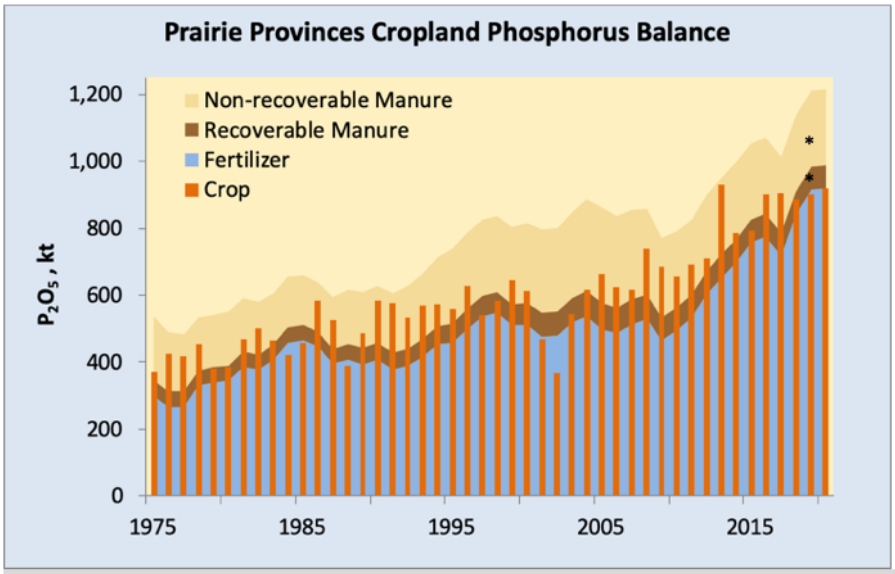

Crop removal of phosphorus often exceeds inputs

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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- In several recent years (2013, 2016, 2017), phosphorus removal in harvested crops exceeded inputs applied as fertilizer and manure
- 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.
- The light-colored non-recoverable manure is manure excreted but not collected to spread on cropland. It's large. Likely goes to pasture. A lot more N and P could be recovered.

Soil tests, nutrient balances & 4R

- Increasing trend in soil sampling is consistent with the 4R rate principle "use adequate methods to assess soil nutrient supply."
- Soil test P: fewer too low in Western Canada, fewer too high in Ontario.
- Canada's nitrogen use efficiency of 78% good but can be improved.
- Prairie provinces phosphorus balance often in deficit, but:
  - A balance can average large deficits and surpluses
  - A lot more manure P (and N) could go back to the land

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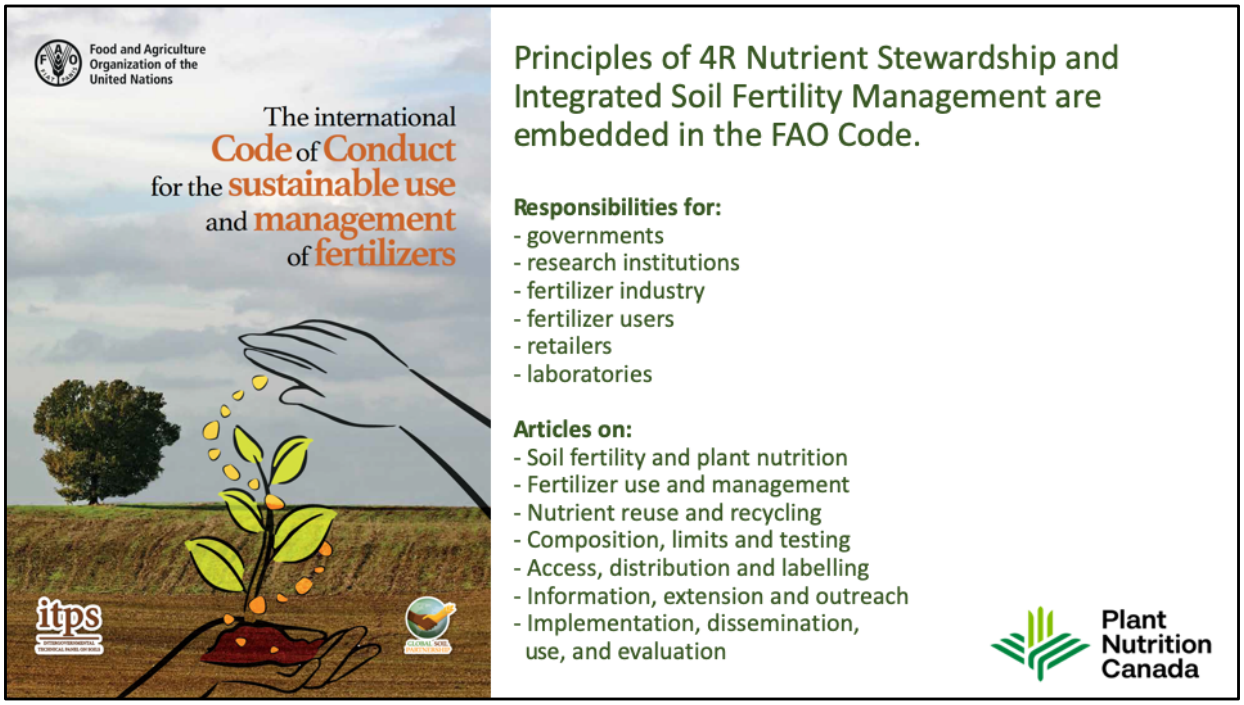
- Changing the fraction of manure nutrients recovered demands collaboration with the livestock industry

- Nutrient Management is one of seven in the CRSC Sustainability Reports
- Report provides data on familiarity with 4R, applying nutrients based on soil test, and time time application, from the 4R fertilizer use survey
- Its report on GHG Emissions & Air Quality also cross-references to 4R in the Nutrient Management report
- The three industry initiatives listed all reference and include 4R.
- The code of practice, to be released soon, refers to 4R practices and training.
- Fertilizer industry also engages with many other farm and environmental organizations, including Field to Market, the Environmental Services Marketing Consortium, and the Nature Conservancy.

- IFA initiative
- Launched last fall – meeting in Versailles - came up with a definition
- 11 members - scientists from a range of disciplinary expertise and geographies, spanning time zones from Australia to Mexico.
- New paradigm for responsible plant nutrition – issue brief coming soon
- Issue briefs on biodiversity, 4R nutrient stewardship in the works



- Impressive effort of FAO.
- Outlines responsibilities for many sectors, recognizing their importance in the global improvement of nutrient use efficiency and effectiveness. They include…
- Many areas to consider, including….

Conclusions: Nutrient Stewardship Strategy

- Through programs at provincial, national and global levels, industry seeks to enable the adoption of 4R nutrient stewardship to achieve measurable outcomes.
- Measuring outcomes depends on:
  - support for science
  - collaboration with sectors influencing the same outcomes
  - Engagement with stakeholders through the value chain

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