Circularity in plant and meat protein in Manitoba – An assessment of circular economy opportunities to support Manitoba Agriculture practices

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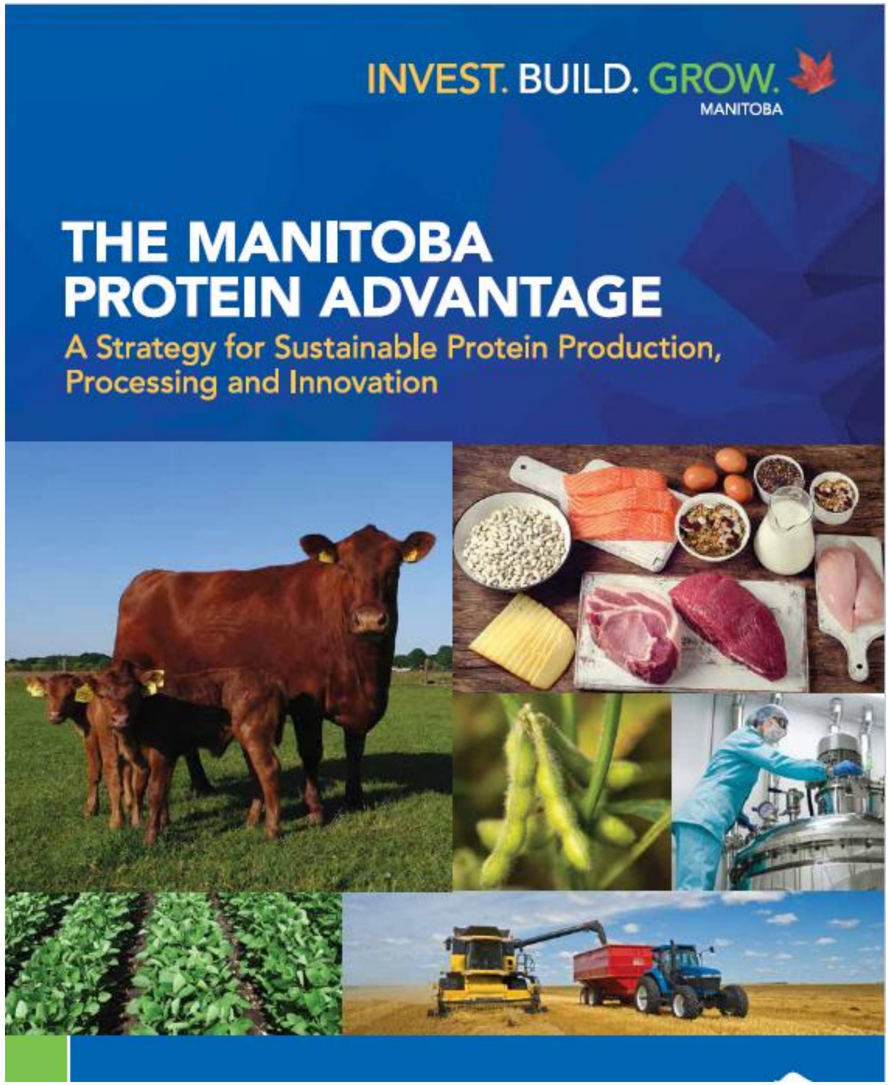
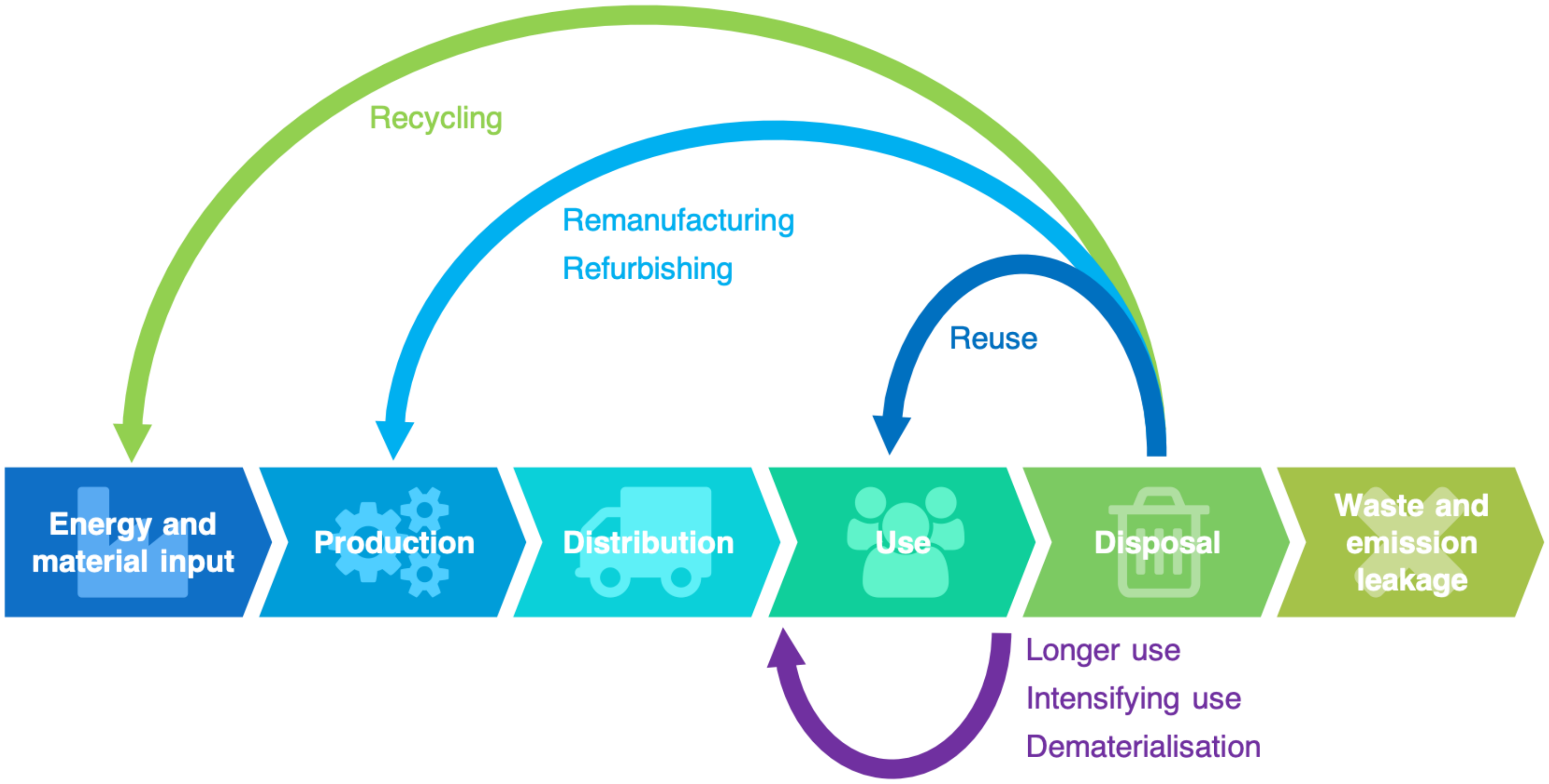
Project Objectives

- Examine the potential for circular economy opportunities in Manitoba in the plant and meat protein subsectors.
- Review international and Canadian best practices and identify relevant circular economy opportunities.
- Assess the applicability of such opportunities in Manitoba, based on technical, cost, policy and other potential barriers to implementation.



What is the Circular Economy

An economic model which does not focus on producing more and more goods, but in which consumption is based on using services – sharing, renting and recycling – instead of owning. Materials are not destroyed in the end but are used to make new products over and over again. (SITRA)



Plant protein subsector

- Plant based proteins are increasingly seen as an attractive market.
- At the global level, the plant protein market is expected to reach USD 14.5 billion by 2025.
- Lower perceived risk from investors with less pressure exerted on natural resources.
- Economic opportunity to unlock value from agricultural waste and create new products and industrial ingredients.

State of play of plant-based protein strategies in Manitoba and internationally

- Major players in Manitoba/internationally include:
  - Merit Functional Foods
  - French based Roquette
  - Paterson Global Foods
  - Maple Leaf Foods
  - Netherlands based DSM

- Other EU countries such as France, Germany, the Netherlands and Finland have also launched their own plant protein strategies.

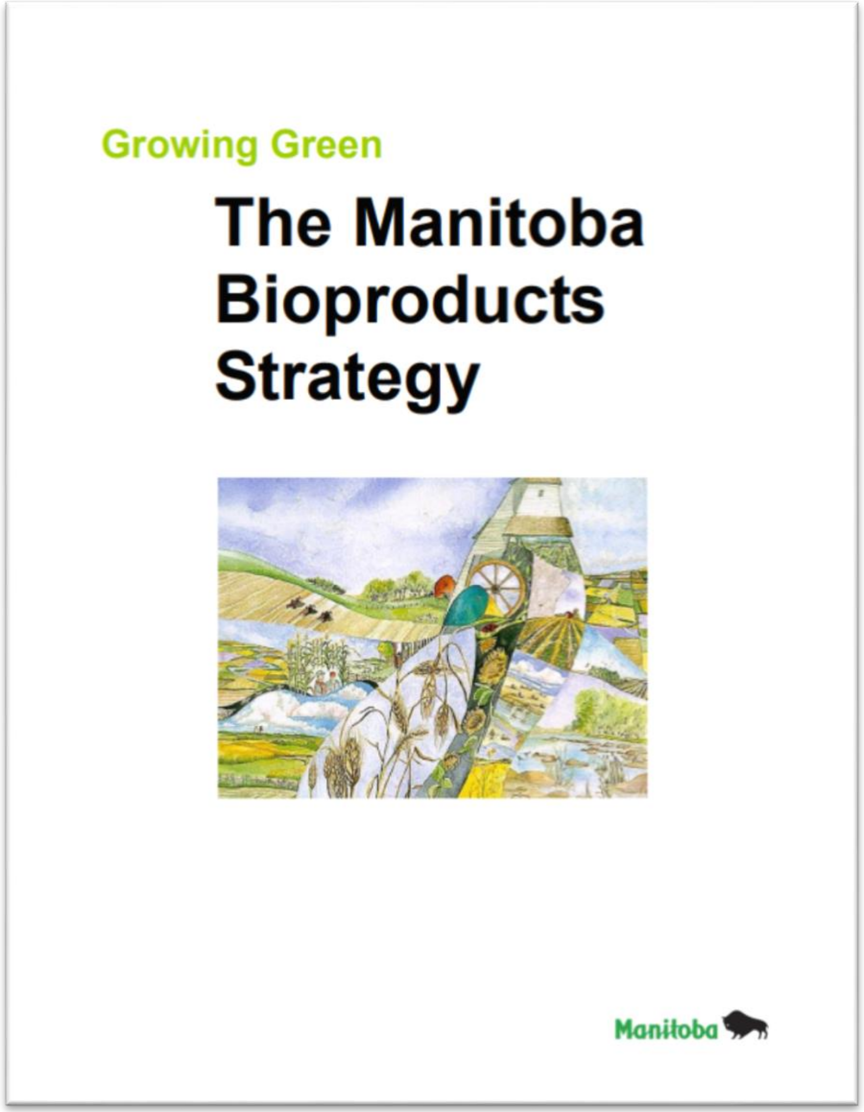
- To increase public-private funding, green impact bonds could be scaled up to incentivize wider circularity.
  - Manitoba's organic green impact bond
  - Canadian Food Innovators (CFI) at the federal level

Aligning a plant-based protein strategy with regenerative agricultural practices

- Manitoba is increasingly applying regenerative agricultural practices, but these could be scaled further including by:
    - Favoring nutrient recycling
    - Encouraging soil-landscape restoration
    - Selecting nitrogen fixing crops
    - Support for sustainable grazing management
    - Additional funding for training and data monitoring for farmer uptake in nutrient 4R management
- International best practices include:
    - The EU's Farm to Fork Strategy
    - France's Low Carbon Strategy
    - R&D funding for regenerative practices in the Netherlands

Increasing circularity as part of Manitoba’s bioproduct strategy

- Manitoba developed in 2011 its 10 year bioproduct strategy with funding of CAD 20 million.
- Important to track bioproduct progress as part of this strategy.
- Multiple opportunities including:
  - Soy based spray foam insulation
  - Bio composite roof panels
  - Hemp ceiling tiles
  - Production of solvents, bioplastics and emulsifiers for food processing



Existing and possible bioproduct developments in Manitoba

Known product development	Sector	Manitoba companies involved
Biodiesel	Transport	In Development
Soy-based spray foam insulation	Construction	In Development
Biocomposite roof panels	Construction	In Development
Hemp ceiling tiles	Construction	In Development
Bioplastics through baler twines and bale wraps	Agriculture	In Development
Biocomposites railway ties	Transport	Maraton Composites
Biofibres from hemp and flax to replace carbon fibres	Multiple	In Development
Use of lignin as feedstock for chemicals and plastics	Industrial	In Development

Existing and possible bioproduct developments in Manitoba

Known product development	Sector	Manitoba companies involved
Use of plant oils in industrial applications for solvents and emulsifiers in food processing	Industrial	In Development
Use of potato starch for bioplastics and prebiotics	Industrial/healthcare	Solanyl Biopolymers , Manitoba Starch Products, MS Prebiotics
Bio fertilizers/pesticides	Agriculture	Ag-Quest
Production of pellets from cattail, oat hull and wood	Energy	Viterra, Central Grain Company, Winnipeg Forest Products, Prairie Pellet Company, Spruce Products Limited
Compost digestion systems, biomass burners, furnaces and grain dryers	Agriculture	Triple Green Products
Bio based erosion control blankets and turf reinforcement mats	Agriculture	ECBVerdyol
Biotic soil amendments	Agriculture	ECBVerdyol
Bio-based resins	Multiple	Ecopoxy
Paper made from wheat straw waste	Industry	Prairie Paper (Step Forward Paper)

Improving compost management and preserving nitrogen

- Compost can increase soil quality for crops that require more organic matter and for land suffering from erosion.

- In 2014 Manitoba developed a compost program to divert organic waste from landfills.

- A mixed method study in Belgium shows several barriers to compost use including:
  - Shortage of available biomass with competing demands for biofuels
  - Complex regulations
  - High initial financial costs for compost equipment

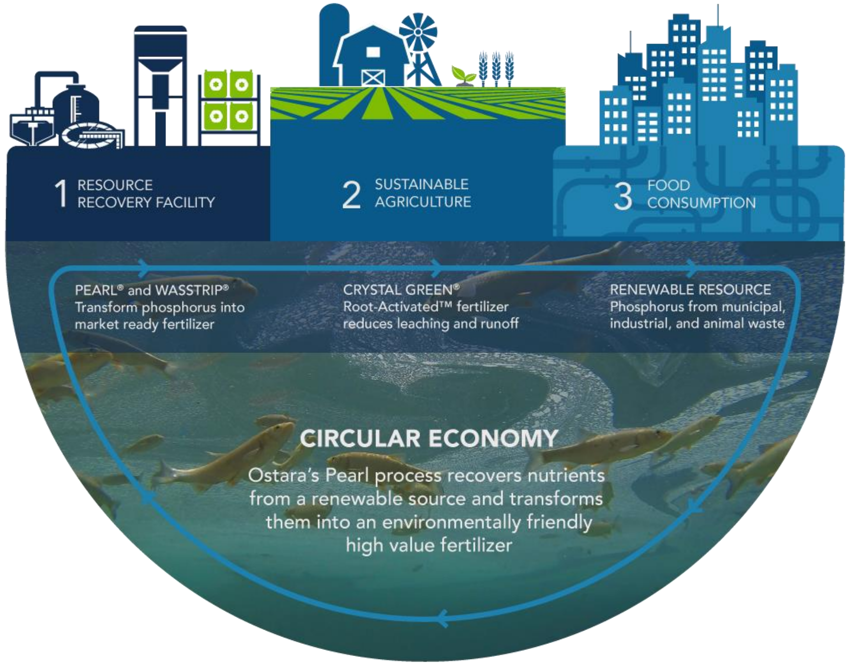
- Improving nitrogen recovery in compost is key and can be achieved by:
  - Adding certain chemical or organic additives
  - Considering carbon to nitrogen and carbon to phosphorus ratios

Reusing nutrients from agricultural wastewater

- The reuse of nutrients from wastewater goes beyond the agricultural sector

- New approaches/technologies could be scaled up with:
    - Biological assimilation through the preservation and construction of wetlands
    - Using innovative nutrient recovery technologies

- International best practices include:
    - Israel's Ostara nutrient recovery facility
    - The EU's International Green Deal of the North Sea Resources Roundabout to export struvite



Meat protein subsector

How to expand the sector to meet growing demand, while minimizing environmental impacts?

GHG emissions

- Methane emissions
- Nitrogen oxide emissions
- Carbon dioxide emissions
- Carbon sequestration

Environmental impacts

Loss of biodiversity

Agricultural runoff

Erosion

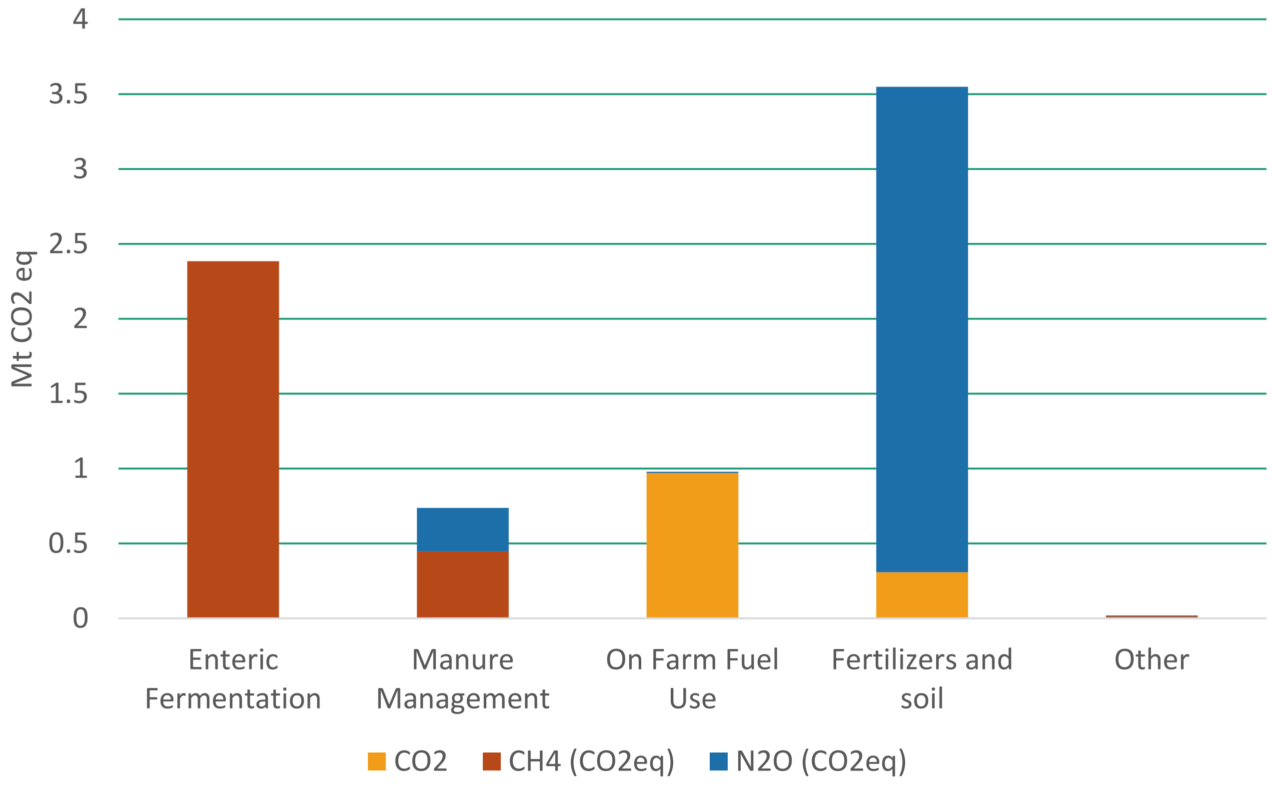
Waste

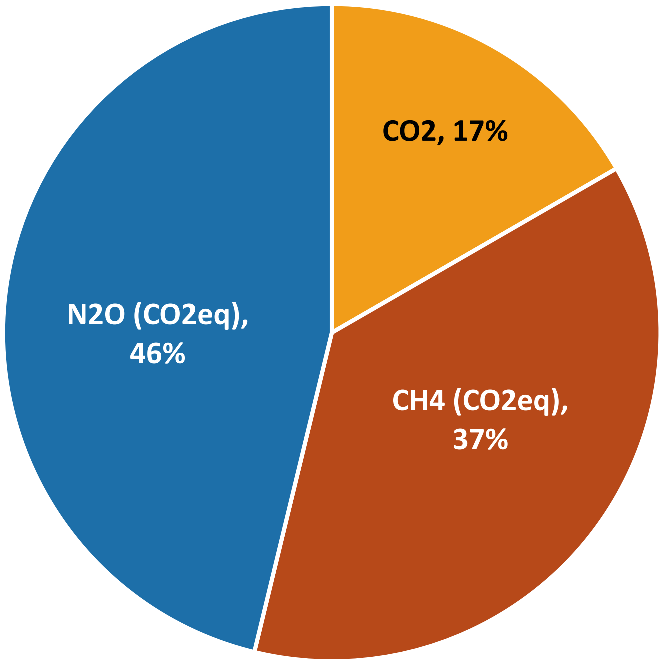
Other important considerations

- Farmer's livelihoods and working conditions
- Animal welfare

GHG emissions profile

Manitoba agricultural GHG emissions, 2018

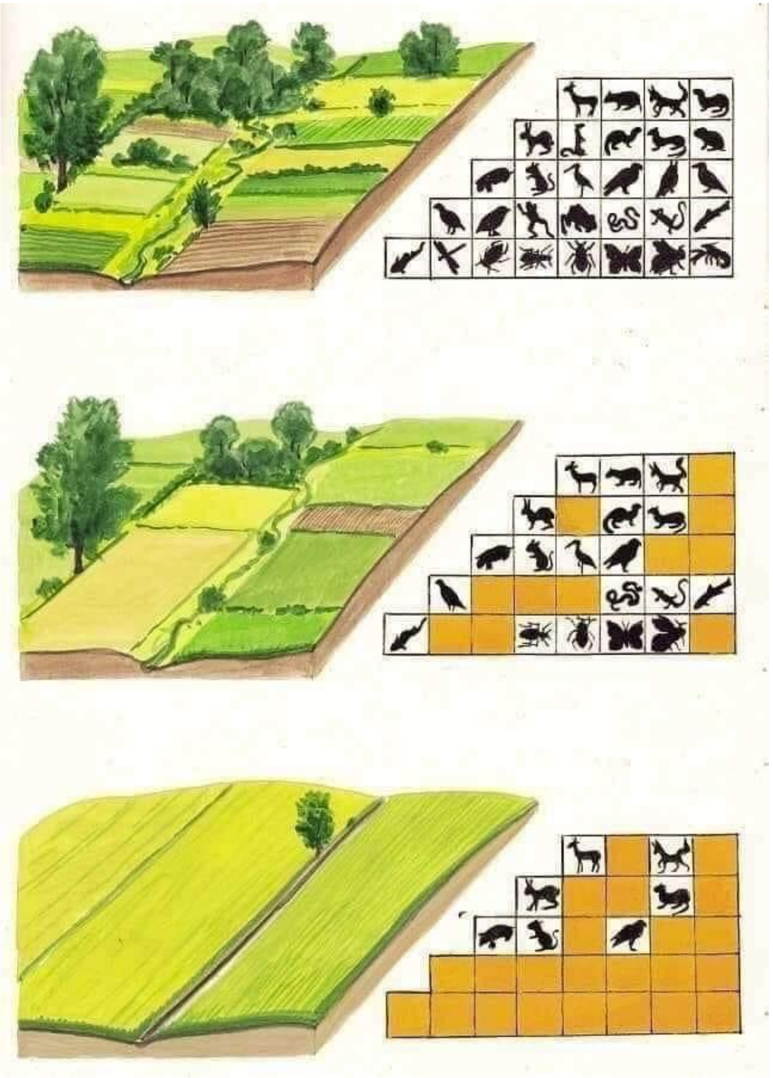




Source: Environment and Climate Change Canada (2020)

Grassland management

- Grazing ruminants can offset 20-60% of enteric methane emissions via increased carbon sequestration (Garnett et al., 2017).
- Agricultural land stewardship programs
- Incentives to:
    - adopt sustainable grazing practices (ex rotational grazing)
    - plant cover crops and other practices that naturally restore soil nitrogen and build soil carbon
    - maintain grass or tree cover on cropland and marginal pasture
- Indicators for sustainable grassland management include:
    - soil organic matter including carbon:nitrogen ratio
    - soil aggregate stability
    - microbial activity
    - soil erosion
    - water quality metrics including nitrogen levels
    - conservation metrics including extent of wetlands and riparian systems



Livestock feeds

Agricultural by-products provide low-opportunity-cost feeds

- By developing supply networks for crop residues, crop farmers growing dual-purpose food-feed crops can both minimize waste and generate additional revenue streams

- **Perennial grains** can be harvested then grazed
- **Food processing by-products** should be recycled back into the food system
- **Food waste** can be converted to high quality protein through insect farming
- Other alternative proteins from CO_2 and CH_4
- Optimal feeds (feed content and quantity) can minimize methane emissions
- Indicators:
  - Food loss and waste
  - GHG intensity of feed production

Manure management

- **Effective manure management** reduces GHGs from manure at livestock production sites and provides a supply of high-quality manure to reduce the use of artificial fertilizers.
    - Increases the circularity of agricultural systems by minimizing external inputs and reducing energy use from manufacturing and transport
    - Achieving the optimal nitrogen:phosphorus ratio in soils using manure presents challenges
        - Solid and liquid separation to remove phosphorus from manure, and for more economical transport
- **Manure storage** to prevent the loss of ammonia and the release of methane and carbon dioxide into the atmosphere
    - More research needed into technologies that function in extreme temperatures
- **Optimal manure application** including proper timing, incorporation and injection, and variable rate (precision) application

Slaughterhouse waste

- Rendering of slaughterhouse by-products
  - The processing of meat by-products by rendering releases one quarter the greenhouse gases and produces five times the value as composting (Gooding & Meeker, 2016).
  - Mature industry, but has traditionally focused on low-value products
- Water2REturn project, Spain
  - Wastewater treatment and reclamation
  - Raw material extraction
  - Manufacturing of agronomic products including organic-source fertilizers and bio stimulants
  - Reduce landfill waste, GHG emissions and pollution from wastewater

On-farm energy

- Use of agricultural waste as energy
  - Combusted as biomass (for example in grain drying and greenhouse heating)
  - Converted into biogas for heating or electricity generation

- Alternative fuels in agricultural machinery (biodiesel, hydrogen)

- Building retrofits to increase heating efficiency

Recommendations

Protein source	Recommendations	Indicator
Meat	Support for sustainable grazing practices	Improved soil health
	Programs to encourage the use of optimal feeds to minimize methane emissions	GHG emissions
Plant	Selecting nitrogen fixing crops	Improved soil health
	Selecting crop varieties that require less inputs	Improved soil health
	Training agronomists in nitrogen 4R management	GHG emissions, energy efficiency
	Using forage/perennial legumes in pastures to reduce and optimize fertilize and manure	GHG emissions, energy efficiency
	Soil-landscape restoration	Improved soil health
	Providing financial support and tax incentives to farmers to shift from fossil fuel to renewable heating for activities such as grain drying	GHG emissions
Meat & Plant	Agricultural land stewardship programs	Protected land area
	Develop/strengthen educational tools for farmers to capitalize on agricultural by-products	Waste reduction

Circular Economy Approach

Through the Protein Advantage Strategy, Manitoba is well positioned to capitalize on the growing meat and plant protein market.

A circular economy approach is:

- Critical to reuse waste, increase energy efficiency, reduce greenhouse gas emissions, improve soil quality and increase farmer incomes;
- A means of building synergies between the plant and meat protein sectors.

Systems modeling for analyzing nutrient balances and assessing Circular Economy potential for Manitoba's agriculture sector

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Quantitative analysis

A quantitative analysis was performed to study nutrient demand for various crop types and availability of nutrients from multiple sources, at the provincial level.

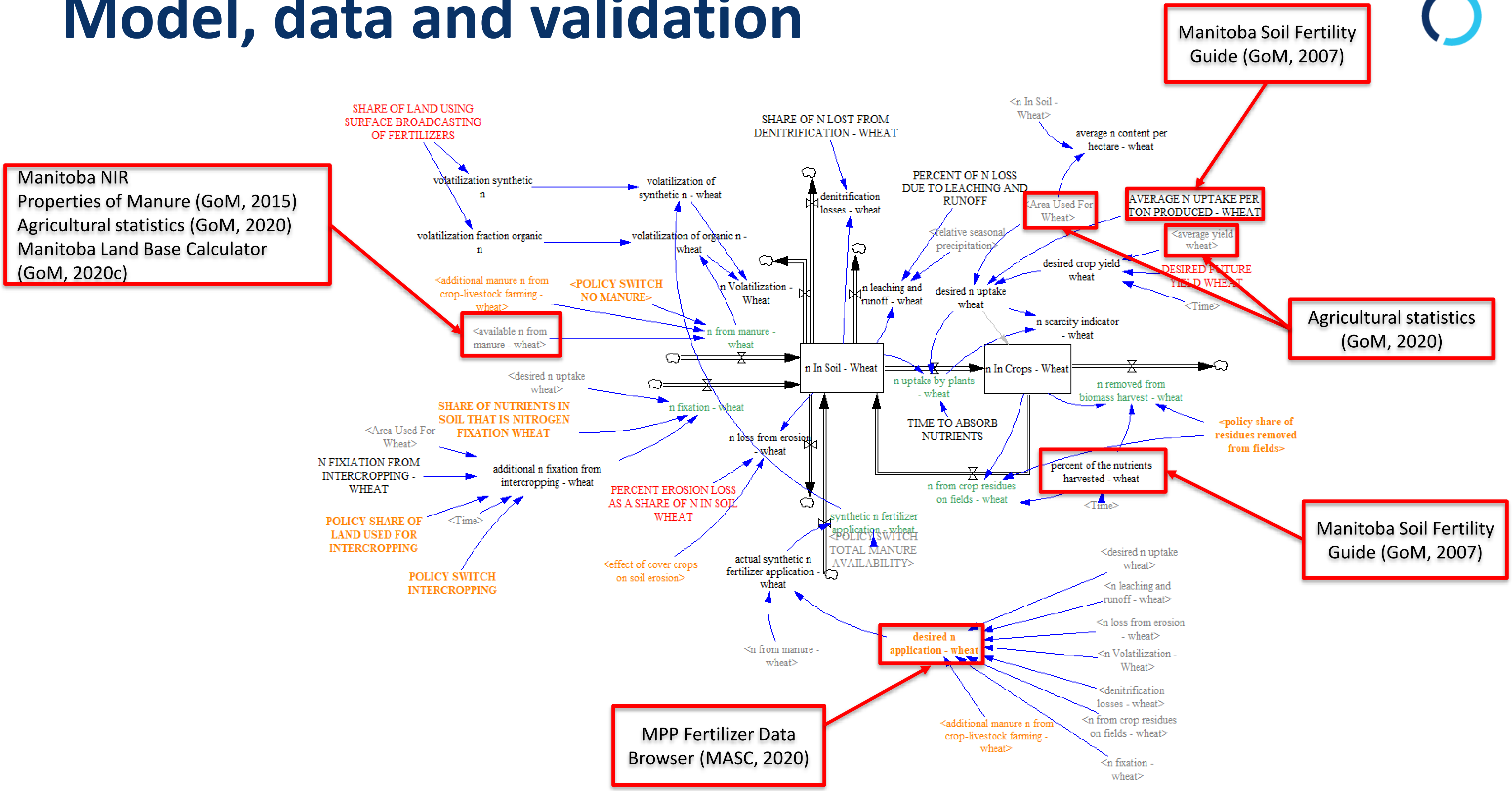
- A quantitative nutrient modeling study for Manitoba's crop production sector was conducted to assess the potential for nutrient recovery (or even recycling).
- Focus of the analysis is the impact of land use and management as well as livestock management practices on future nutrient use.
- The nutrients considered in this study are Nitrogen (N) and Phosphorus (P). Nutrient application distinguishes between synthetic and organic fertilizer (manure).
- A range of future scenarios was simulated to assess the impacts of land management practices and identify potential avenues for the crop production sector to move towards a more circular economy (CE) approach.

Six scenarios

Six different scenarios were simulated for the nutrient balance assessment, a baseline scenario (Business-as-Usual, or BAU) and five policy scenarios.

- The BAU scenario assumes no change in land management or fertilizer application and serves as the baseline against which the other scenarios are compared.
- The following alternative scenarios were simulated
  - Intercropping (additional nitrogen fixation)
  - Improved feeding (N & P reduction in manure, all livestock)
  - Improved feeding (P reduction in manure, nonruminants)
  - Crop-livestock integration (additional manure availability ‘from pasture’)
  - Residue removal (removing crop residues and nutrients contained)

Model, data and validation



Overview of results

Policy impacts on nutrient application vary by type of intervention and the degree to which ambitions are implemented.

An explicit link between the quantitative assessment and the insights gained from the qualitative study would allow to forecast how specific CE practices would affect crop nutrient management in the medium and long run.

- All interventions considered have an impact on the application of nutrients (synthetic, organic, or both).
- While most of the interventions reduce nutrient input requirements, policies concerning nutrient control in animal manure or crop residue removal contribute to an increase.

Scenario	N application		P_2O_5 application	
(named by type of policy simulated)	Avg. annual change (ton N/Year)	Cumulative change 2020-2050 (Ton N)	Avg. annual change (ton P_2O_5/Year)	Cumulative change 2020-2050 (Ton P_2O_5)
Residue removal	31,485	1,007,514	7,612	243,584
Intercropping	-18,525	-592,805	0	0
Improved feeding (N&P reduction)	899	28,761	501	16,047
Improved feeding (P reduction only)	0	0	1,115	35,685
Crop livestock integration	-6,938	-222,007	-568	-18,185
Expansion of hog production	-2,185	-69,927	-1,321	-42,257
Expansion of cattle production	-10,262	-328,397	-922	-29,508

Note:
A range of simplifying assumptions was required to enable the analysis of nutrient application and management on provincial level.

Overview of results

Each intervention options results is the modification of nutrient dynamics. The pros and cons of each option should be analyzed in relation to the goals related to the improvement of circularity.

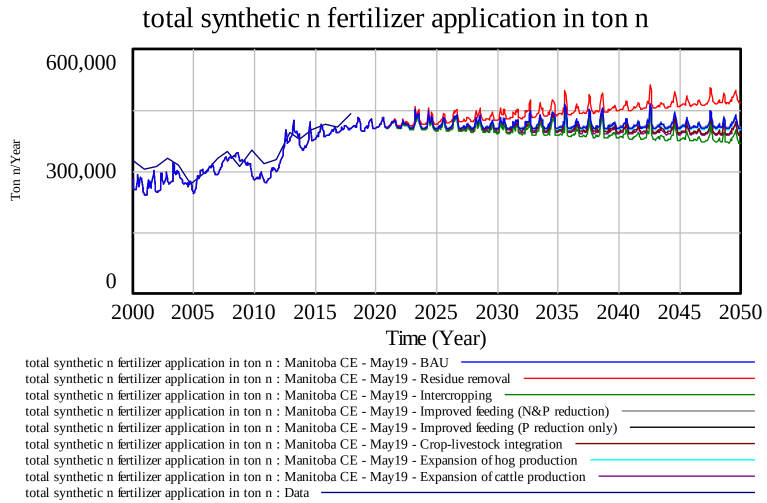
- *Residue removal*: the removal of biomass from soil reduces the amount of N and P available, which need to be replaced with new application.
- *Intercropping*: growing crops and legumes for N fixation leads to the fixation of additional N in the soil, and hence reduces the need for N application.
- *Improved feeding*: improved feeding reduces emissions, as well as N and P content of manure. The reduction of N and P requires new application.
- *Crop – livestock integration*: integrating crop and livestock makes manure directly available for fields, reducing the needs for N and P application.
- *Expansion of hog and cattle*: increasing the number of animals will generate more supply of manure.

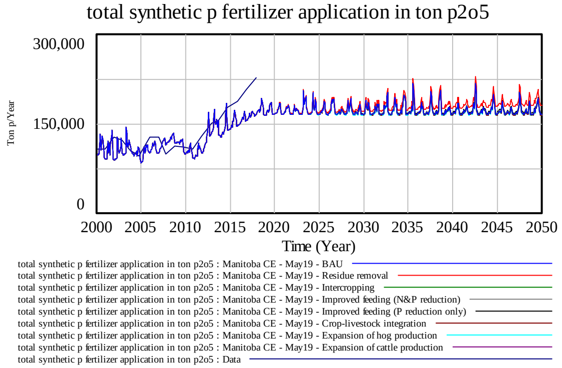
In all cases, when manure is applied, care should be taken to avoid overapplication of P (if manure application is done based on N requirements). A multitude of policy options could trigger the changes that are forecasted.

Results: Fertilizer application

Various pathways affecting nutrient inputs were simulated in isolation. In reality, implementing a combination of interventions would be more likely.

- In most scenarios, nutrient input declines compared to the baseline (dark blue line) as a result of the policies simulated.
- The **strongest reduction** in N inputs is observed in the ‘intercropping’ scenario (dark green line). The additional N fixed by legume crops contributes to significantly reducing required N inputs.
- The **highest increase** in both N and P inputs is forecasted in the ‘residue removal’ scenario (red line). This is because the removal of residues also removes nutrients from the fields that would become available from decomposition.

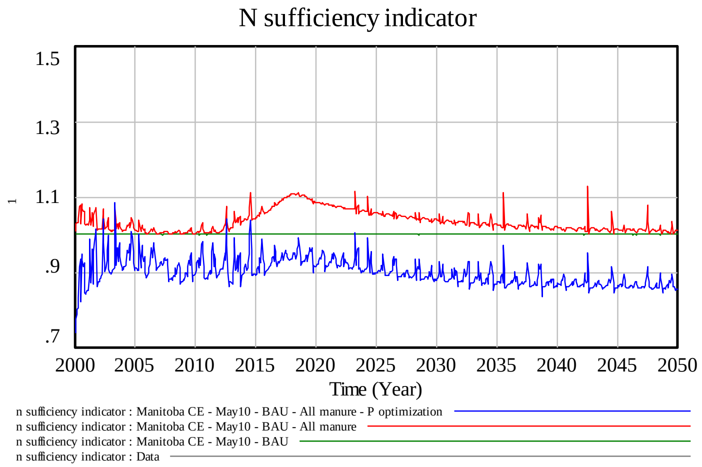


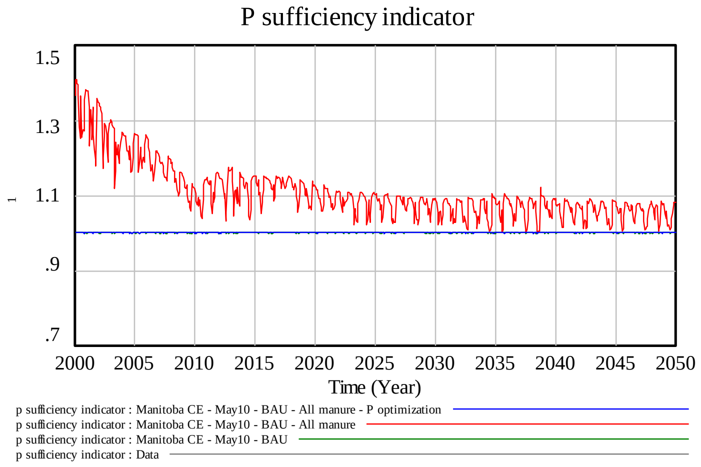


Results: Nutrient sufficiency

A (hypothetical) scenario in which all nutrient demand is assumed to be satisfied by manure application only highlights the importance of soil testing and using plot specific data.

- The nutrient sufficiency indicators compare desired and actual application of N and P_2O_5. This allows for the identification of
    - potential nutrient shortages (indicators value < 1), and
    - excess nutrient application (indicator value > 1)
- If manure application is **optimized to satisfy plant P_2O_5** requirements (dark blue line), the simulation projects a shortage of N.
- If manure application is **optimized to satisfy plant N** requirements (red line), the results suggest an overapplication of P_2O_5 relative to plant requirements.

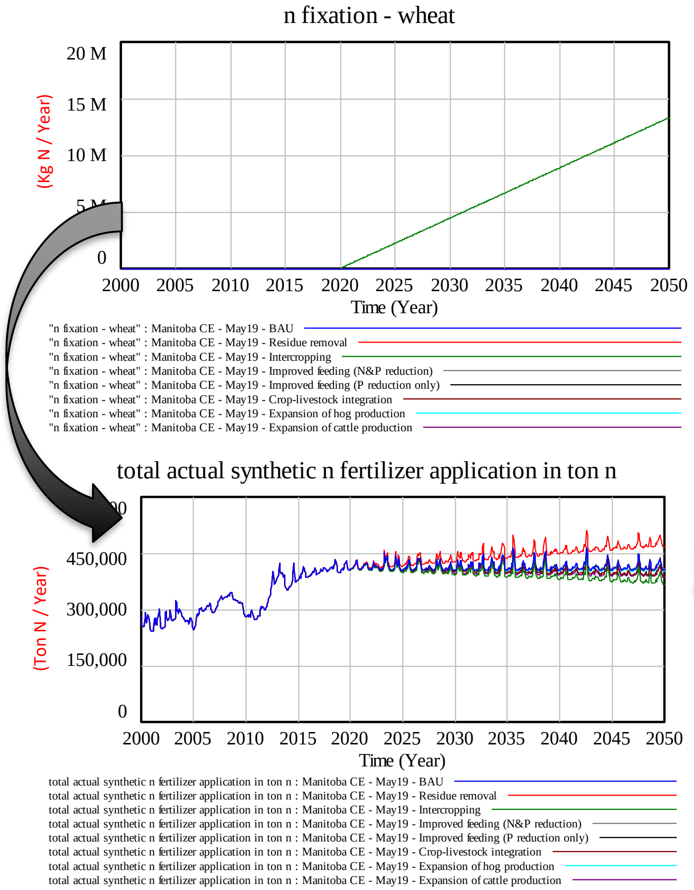




Results: Intercropping

Intercropping refers to growing of non-legume crops with legumes and are assumed, to contribute to the fixation of additional N.

- In the intercropping scenario, the additional fixation of N by legume crops contributes to reducing fertilizer inputs for land under crop rotations.
- Results presented rely on assumptions obtained from international studies at this stage and could vary if Manitoba-specific assumptions are used.
- The extent to which intercropping is feasible depends on a variety of factors, indicating that site specific information should guide the implementation of crop rotations.



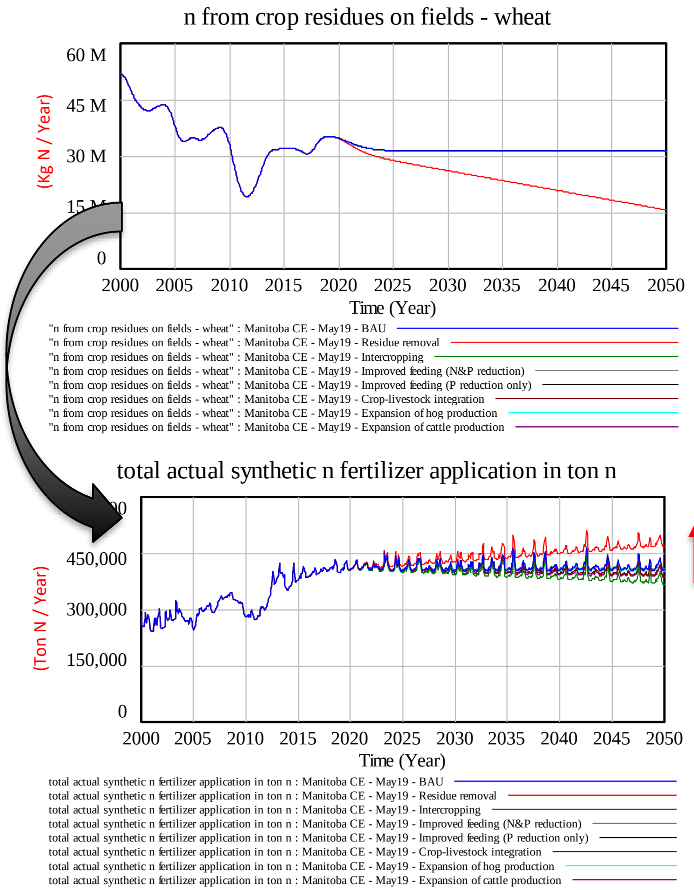
The more nutrients are fixed by legume crops…

…the lower the demand for nutrients from synthetic or organic fertilizers.

Results: Residue removal

Crop residues can be valuable inputs for a range of processes aiming at increasing the circularity of the agriculture sector.

- The removal of residues for other uses reduces the amount of nutrients that become available from decomposition.
- Depending on the amount of residues removed, soils may become more susceptible to soil erosion, which contributes to the loss of topsoil and nutrients and hence increases the need to apply nutrients.
- Further, if removed entirely this can contribute to a loss of soil organic C over time.
    - Studies have found that there is a middle ground between residue removal and soil C management. If residues were to be repurposed on a large scale, capacity building for soil C maintenance would be useful.



The reduction in nutrients from removing residues from the fields…

…increases the amount of synthetic inputs required to satisfy plant demand.

Key Recommendations

Nutrient requirements and application in Manitoba vary widely, and require soil and manure sampling to ensure that the correct amount of nutrients is applied.

- The application of synthetic N yields the benefit of being immediately available to plants, but also bears the **risk** of higher losses due to denitrification, volatilization and others such as leaching and runoff.
- It is more challenging to meet nutrient sufficiency through the application of manure, however manure application can lead to **reducing** nutrient runoff losses and **contributes** to soil organic C development.
- Expansions of hog and cattle can provide additional manure, reducing N and P application. There is an opportunity to create a synergy between economic, environmental and social outcomes.
- Nutrients may become scarce or more expensive in the future, such as in the case of P. Using manure to reduce the dependency on synthetic P can create an important synergy, but care should be taken to avoid the overapplication of P when manure application is optimized to satisfy plant N demand.

Key Recommendations

The recommendations coming forth from the assessment are informed by both modeling outcomes as well as intensive exchanges with local experts.

- The additional provisioning of climate information services to farmers could contribute to reducing N losses. As denitrification especially occurs in waterlogged soils, additional information about soil moisture and expected rainfall could help in improving fertilization schedules to **reduce** fertilizer losses and hence required application.
- The integration of crop production and livestock allows for the recycling of livestock nutrients from soils used for integrated farming approaches, which allows to **reduce** synthetic fertilizer inputs.
- The use of sustainable land management practices, such as intercropping and tillage systems, contributes to the **addition and retention** of nutrients in the system. However, the sequence and timing of rotations is crucial for crop nutrient management

Image sources

https://ec.europa.eu/food/farm2fork_en

https://ostara.com/about/

http://digitalcollection.gov.mb.ca/awweb/pdfopener?smd=1&did=18297&md=1

Fischesser, B., & Dupuis-Tate, M.-F. (1996). Le guide illustré de l'écologie. La Martinière.

Triple Green Products. (n.d.). Grain Drying. https://www.triplegreenproducts.com/grain-drying/

Water2REturn. (2018, February 15). Water2REturn—REcovery & REcycling of nutrients TURNing wasteWATER into added-value products.
https://www.youtube.com/watch?v=7oxln8YhocQ

https://ec.europa.eu/food/farm2fork_en

https://ostara.com/about/

http://digitalcollection.gov.mb.ca/awweb/pdfopener?smd=1&did=18297&md=1

Fischesser, B., & Dupuis-Tate, M.-F. (1996). Le guide illustré de l'écologie. La Martinière.

Triple Green Products. (n.d.). Grain Drying. https://www.triplegreenproducts.com/grain-drying/

Water2REturn. (2018, February 15). Water2REturn—REcovery & REcycling of nutrients TURNing wasteWATER into added-value products.
https://www.youtube.com/watch?v=7oxln8YhocQ

https://bim-bg.com/en/environment-and-circular-economy/