4R Nutrient Management for Emission Reductions and Increased Productivity

Submission to the UNFCCC Subsidiary Body for Scientific and Technological Advice from the International Fertilizer Industry Association on behalf of Fertilizer Canada

Fertilizer Canada, a member of the International Fertilizer Industry Association (IFA), wishes to respond to the call for submissions on "**Identification and assessment of agricultural practices and technologies to enhance productivity in a sustainable manner, food security and resilience, considering the differences in agro-ecological zones and farming systems, such as different grassland and cropland practices and systems**".

Fertilizer Canada is supportive of the outcomes of the Climate Change Conference held in Paris. Achieving these goals will require all to contribute towards both mitigation and adoption of new practices. Sustainable agriculture underpins development, health, and growth across economies. Agriculture needs to be included in efforts to limit and reduce the negative impacts of climate change. Innovations in practices and technologies can help achieve those objectives without compromising productivity and food security, making agriculture more sustainable, more productive, and more resilient.

Introduction

Feeding the world with climate-smart agriculture, as defined by the FAO, is a priority for Fertilizer Canada. Global crop production must increase by 70 per cent to feed nine billion people by 2050. This must be accomplished in the context of a shrinking availability of arable land. As noted by the FAO, the average amount of cropland and pasture per capita has decreased from 0.4 and 0.8 hectares respectively in the 1970s to 0.2 and 0.5 hectares by the 2000s. (FAOSTAT, 2013)
Climate change makes this challenge all the more significant, as it threatens productivity and livelihoods and forces quicker adaptation in farming systems. Meeting the demand for nutritious food will require the efficient use of valuable resources. While increasing crop production by 70 per cent to feed the growing population remains a priority, the fertilizer industry has also prioritized climate-smart agriculture as a way to minimize the impact on the environment.

Agriculture represents on average 30 per cent of the total greenhouse emissions[1] and is the largest contributor of non-CO2 greenhouse gas emissions[2]. Without the reduction in emission intensity, increases in productivity cannot be sustainable over the long term. It is thus important to consider which technologies and practices can be applied that meet not only adaptation needs, but also mitigation needs.

It has been estimated that one billion hectares of natural land has been preserved from crop production between 1961 and 2005 because of increases in yield and productivity. This has also led to carbon emissions savings of 317 to 590 Gt CO2-eq from conserving that land area as forest, wetland, and other habitat.

Agriculture is the cornerstone of food and nutrition security. Reductions in emissions cannot come at the cost of reduced output of food. Reconciling the dual objectives of increased food production and reduced emissions requires increasing the efficiency of agricultural practices so farmers are able to get more out of all the inputs and resources they use – therefore reducing the relative footprint of agricultural production and maximizing the soil carbon sequestration potential of agriculture.

Reducing Emissions

Globally, two-thirds of nitrous oxide emissions are from natural sources and the remaining third as a result of human activity. This last third – the anthropogenic element – represents about eight per cent of global anthropogenic greenhouse gas emissions. At eight per cent, nitrous oxide emissions are not the main source of global emissions, however, nitrous oxide is a potent greenhouse gas with a global warming potential 300 times greater than carbon dioxide and an atmospheric lifetime of 120 years.

Furthermore, most of the anthropogenic nitrous oxide emissions are related, directly or indirectly, to agriculture production. Nitrous oxide is the second main source of emissions in agriculture (36 per cent), behind methane (53 per cent) but well ahead of carbon dioxide (11 per cent). Most of the nitrous oxide emissions in agriculture occur as a result of fertilizer application and through leaching.

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[1] CCAFS (2015) Info Note: Agriculture's contribution to national emissions https://cgspace.cgiar.org/rest/bitstreams/61660/retrieve
[2] CCAFS Big Facts: https://ccafs.cgiar.org/bigfacts/#theme=food-emissions

Identifying technologies and practices that can make fertilizer use more efficient can help significantly reduce emissions of nitrous oxide in agriculture. It can also help farmers grow more food by improving applications so crops benefit most from the fertilizer, while improving farmers' income through more effective spending on inputs and reducing waste. Responsible use of fertilizer plays a significant role in sustainable agricultural intensification.

Fertilizer Canada, in collaboration with the International Plant Nutrition Institute (IPNI), The Fertilizer Institute, International Fertilizer Industry Association (IFA), and other partners, developed a framework that enables better use of fertilizer: **4R Nutrient Stewardship (Right Source, Right Rate, Right Time, Right Place ®)**. Farmers in Canada are using the 4R framework to increase sustainable production of grains and oilseeds, while reducing emissions of nitrogen and phosphorus to the air and water. In particular, 4R Nutrient Stewardship can be used to dramatically reduce nitrous oxide emissions while significantly improving productivity through adaptable and incremental implementation of best management practices in fertilizer management. 4R Nutrient Stewardship allows producers to grow abundant food using existing farmland and ensuring the protection of the environment.

What is 4R Nutrient Stewardship?

4R Nutrient Stewardship is a science-based framework that promotes economic, social, and environmental sustainability on the farm by considering collectively the source, rate, time, and place practices for fertilizer and other crop nutrients.

4R Nutrient Stewardship is based on four key principles:

- Use the **Right Source** of fertilizers that are in – or are easily converted to – compounds best used by the target crop.
- Apply the **Right Rate** of fertilizer to match nutrient supply with crop requirements.
- Apply fertilizer at the **Right Time** so nutrients will be available when crop demand is high.
- Apply or maintain fertilizer in the **Right Place** where the crop can access the nutrients most effectively.

Figure 1

4R Nutrient Stewardship requires the implementation of site-specific Best Management Practices (BMPs) that optimize the efficiency of fertilizer use. The goal of fertilizer BMPs is to match nutrient supply with crop requirements and to minimize nutrient losses from fields. Selection of BMPs varies by location, depending on local soil and climatic conditions, crop, management conditions, and other site-specific factors. The image below provides examples of BMPs which may be used as a part of a 4R Nutrient Stewardship consistent plan:

RIGHT	CURRENT PRACTICE SUB-OPTIMAL CROPPING SYSTEM PERFORMANCE	EVIDENCE FOR IMPROVED PRACTICE	BPM IMPROVES CROPPING SYSTEM PERFORMANCE
SOURCE	UREA IN ALL FIELDS	→	CONTROLLED RELEASE IN HIGHER RISK FIELDS
RATE	SAME RATE ALL WHEAT FIELDS	→	FIELD SPECIFIC RATE FOR EACH WHEAT FIELD
TIME	EARLY FALL	→	LATE FALL AFTER SOIL COOLED BELOW 10ºC
PLACE	BROADCAST	→	NARROW BAND

Figure 2

Other agronomic and conservation practices, such as no-till farming and the use of cover crops, play a valuable role in supporting 4R Nutrient Stewardship. As a result, fertilizer BMPs are most effective when applied with other agronomic and conservation practices.

Farmers implementing the 4R Nutrient Stewardship outline specific goals and performance indicators (as seen in Figure 3) to measure progress. This allows for ongoing monitoring of the farms' performance and enables reporting if necessary. The goals and indicators can be changed to respond to specific objectives and concerns and to adapt to local situations. As demonstrated by the table below, the performance indicators allow for measuring a variety of outcomes hence balancing emission reduction objectives with productivity and economic efficiency.

PERFORMANCE INDICATORS

YIELD	AMOUNT OF CROP HARVESTED PER UNIT OF CROPLAND PER UNIT OF TIME
QUALITY	SUGAR, PROTEIN, MINERALS, VITAMINS OR OTHER VALUE ADDING ATTRIBUTES
NUTRIENT USE EFFICIENCY	YIELD PRODUCED OR NUTRIENT REMOVED PER UNIT OF NUTRIENT APPLIED
CARBON CREDITS	NITROUS OXIDE EMISSION ESTIMATES, CARBON SEQUESTRATION ESTIMATES
SOIL EROSION	DEGREE OF SOIL COVERAGE BY ACTIVELY GROWING CROPS AND CROP RESIDUES
OFF-FIELD NUTRIENT LOSSES	LOSSES FROM EDGE OF FIELD, BOTTOM OF ROOT ZONE, AND TOP OF CROP CANOPY
NUTRIENT BUDGET	A TOTAL ACCOUNT OF NUTRIENT INPUTS AND OUTPUTS PER FIELD
FACTOR COST	DOLLARS OF CROP PRODUCED PER DOLLAR OF NUTRIENT INPUT
SOIL PRODUCTIVITY	SOIL ORGANIC MATTER, AND OTHER SOIL QUALITY INDICATORS
BIODIVERSITY	DIFFICULT TO QUANTIFY – CAN BE DESCRIPTIVE
WATER USE EFFICIENCY	YIELD PRODUCED PER UNIT OF AVAILABLE WATER

Figure 3

Canadian farms which are currently implementing 4R Nutrient Stewardship demonstrate improved fertilizer efficiency while increasing the quantity produced per acre for each unit of nutrient applied, without sacrificing yield potential. Using 4R Nutrient Stewardship can substantially reduce the nitrous oxide emissions per unit of crop produced, in some cases by up to half. Canadian 4R Research Network suggests there is the capacity to reduce greenhouse gas emissions from nitrogen fertilizer use by 15 to 25 per cent. Equally important, the practices that reduce nitrous oxide emissions also tend to increase nitrogen use efficiency and the economic return on fertilizer dollars.

How can 4R Nutrient Stewardship be used to measure and reduce emissions while increasing productivity?

The implementation of 4R Nutrient Stewardship can help farmers reduce greenhouse gas emissions and increase productivity by improving practices. For those who wish to go further, the Nitrous Oxide Emission Reduction Protocol (NERP) was developed to allow for specific measuring and reporting of emission reductions.

Improved nitrogen management within NERP is delivered through the implementation of a 4R Nutrient Stewardship Plan at the farm level. Producers wanting to participate in a NERP project develop a 4R Nutrient Stewardship consistent plan with an accredited professional advisor (APA). The APA helps the producer develop a set of sustainability goals that incorporate greenhouse gas reduction measures, as well as other issues that are specific to the farm, into their nutrient management. Reducing greenhouse gas per unit of crop produced, generating carbon offsets to help society adapt to climate change, and improving the return on dollars spent on fertilizer are examples of environmental, social, and economic goals that might be included in a 4R Nutrient Stewardship consistent plan under a NERP project.

The APA also helps the farmer develop a suite of practices that integrate the right source at the right rate, time, and place (see Figure 4 below). These BMPs must meet certain thresholds to be NERP eligible at basic, intermediate, or advanced levels. Requirements include site-specific nitrogen management with the field as the management unit at the basic level and subfield or zone management within fields at the intermediate and advanced levels. Practices (particularly right rate) are adjusted to meet the unique conditions of each field.

Figure 4

Performance Level	Right Source	Right Rate	Right Time	Right Place
Basic	• Ammonium-based formulation	• Apply N according to recommendation of 4R Plan using annual soil testing and/or N balance to determine application rate	• Apply fertilizer in spring; or • Split apply; or • Apply after soil cools in fall	Apply in bands / Injection
Intermediate	• Ammonium-based formulation; and • Use slow / controlled release fertilizers; or • Inhibitors; or • Stabilized N	• Apply N according to qualitative estimates of field variability (landscape position, soil variability)	• Apply fertilizer in spring; or • Split apply; or • Apply after soil cools in fall if using slow / controlled release fertilizer or inhibitors / stabilized N	Apply in bands / Injection
Advanced	• Ammonium-based formulation; and • Use slow / controlled release fertilizers; or • Inhibitors; or • Stabilized N	• Apply N according to quantified field variability (e.g. digitized soil maps, grid sampling, satellite imagery, real time crop sensors) and complemented by in season crop monitoring	• Apply fertilizer in spring; or • Split apply; or • Apply after soil cools in fall if using slow / controlled release fertilizer or inhibitors / stabilized N	Apply in bands / Injection

Nitrous oxide emissions are notoriously difficult and costly to measure directly. In place of direct measurement, NERP uses a series of emission factors to estimate the nitrous oxide emissions associated with nitrogen additions to the cropping system. The emission factors were developed by Agriculture and Agri-Food Canada to operate at the eco district level. This ensures that emission estimates are based on local climate, soil types, and baseline management practices.

Major quantitative data requirements are nitrogen inputs and crop outputs for each crop grown on the farm in each baseline and project year. Qualitative requirements include, for example location of fields enrolled in the project, 4R Nutrient Stewardship practices used on each field, and configuration of banding equipment

NERP estimates take into account all sources of added nitrogen including fertilizer and manure; alternative sources like compost or other by-products; as well as the nitrogen recycled from crop residues. NERP's accounting of greenhouse gas emission is comprehensive. Both direct emissions from the cropping system and indirect losses from nitrogen that has been lost from the cropping system through ammonia volatilization or leaching are included in the estimate.

While NERP does not account for the complete lifecycle of fertilizer, it does account for things like increased (or decreased) fuel use on the farm that may be a result of practice change.

Are 4R Nutrient Stewardship and NERP applicable outside North America?

The principles that underpin 4R Nutrient Stewardship can be applied in any geography and farming system. Cost-effective and environmentally responsible soil management and enhancement is key to increased food production and sustainability for small-holder farmers as well as larger farms. In each setting, the 'right' actions might differ but the flexibility of the 4R Nutrient Stewardship system allows adaptation to local needs and conditions. While 4R Nutrient Stewardship can be optimized through the use of more complex measurements, essential information on soil and crops is either already in existence or can be found.

For example, the 4R Solution project, a partnership between Fertilizer Canada and the Canadian Cooperative Association, aims to improve agricultural productivity and sustainability for smallholder on three continents over the next five years.

The collaboration focuses on knowledge sharing and training in best practices in fertilizer management using 4R Nutrient Stewardship principles for smallholder farmers. The training is delivered through the Canadian Cooperative Associations extension services network and in each country will also involve governments, agricultural input companies, research institutions, and small farmers organized in cooperatives. The objective is to enable smallholder farmers, working through their own co-operatives, to grow more nutritious, and marketable crops, benefiting from better agricultural practices.

Regarding NERP, the protocol was developed initially for Canada. It uses a modification of Canada's internationally accepted and peer reviewed Tier II inventory method to estimate nitrous oxide emissions at the farm level. NERP can also easily be adapted to temperate region cropping systems outside Canada (for example the United States, Europe, and the Russian Federation) using Tier I or localized Tier II emission factors. In other regions, the protocol could be adapted to match the reporting systems and the crop systems of different countries.

Additional Resources:

- **4R Nutrient Stewardship and Greenhouse Gas Reduction**
  http://fertilizercanada.ca/wp-content/uploads/2015/07/4R-Nutrient-Stewardship-Greenhouse-Gas-Reduction-Report-English.pdf
- **4R Nutrient Stewardship in Alberta**
  http://fertilizercanada.ca/wp-content/uploads/2015/07/4r-farming-report_Updated_Feb8_spages.pdf
- **4R Nutrient Stewardship Research Report (20110 – 2013)**
  http://fertilizercanada.ca/wpcontent/uploads/2015/07/science_cluster_summary_report_v2.pdf
- **Video: Roots for Growth – Feeding the World**
  https://www.youtube.com/watch?v=x3Wx0-dRAYk
- **Video: 4R Nutrient Stewardship and Reducing Greenhouse Gas with NERP**
  https://www.youtube.com/watch?v=dJMIf0NBbU8&feature=youtu.be

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