INTERNATIONAL FERTILIZER ASSOCIATION

Estimating & Reporting Fertilizer-Related Greenhouse Gas Emissions:

linking Fertilizer Best Management Practices with national climate change mitigation targets

A discussion paper for policy-makers[1]

[1] This paper is based on the CGIAR-CCFAS 2018 paper "Estimating and Reporting Fertilizer-Related Greenhouse Gas Emissions".

BACKGROUND

Through the United Nations Framework Convention on Climate Change (UNFCCC) and its Paris Agreement (2015), the international community has agreed to limit global warming to 1.5˚C above pre-industrial levels by the end of this century. To meet this target, significant emission abatement is needed, most particularly from the highest emitting nations and sectors.

Agriculture accounts for an estimated 11-15% of greenhouse gases (GHGs), approximately a third of which comprises nitrous oxide (N_2O) which has a global warming potential 265 times that of carbon dioxide (CO_2) over a 100-year lifespan (IPCC, 2014). The sector's emissions come from agricultural soils (39%), enteric fermentation (38.7%) and rice cultivation (9%)[2].

Fertilizer applications are estimated to represent about 1.5 % of global GHG emissions, which is rather low considering that global agricultural output would be reduced by 50% without the use of mineral fertilizers. However, the fertilizer industry is cognizant of the critical importance to reduce GHG emissions, while increasing agricultural production for a growing world population. This can be accomplished by maximizing the nutrient uptake by plants and minimizing nutrient losses to the environment through the dissemination of Fertilizer Best Management Practices, such as the 4Rs (using the right nutrient source, at the right rate, at the right time, in the right place). – for more information: "The role of Fertilizers in Climate Smart Agriculture".

With the objective to estimate, measure and report fertilizer-related GHG emissions, the fertilizer industry has engaged in partnerships that seek to quantify fertilizer-related emission reductions, resulting from the implementation of Fertilizer Best Management Practices (FBMPs), and as such contribute to national climate change mitigation targets.

4R NUTRIENT STEWARDSHIP

This paper reviews a number of these programs and initiatives and their links to National GHG Inventories.

1 ESTIMATING AND REPORTING EMISSIONS AT NATIONAL LEVEL: NATIONAL GHG INVENTORIES: CURRENT MEANS AND GAPS

National GHG Inventories are required from each country by the UNFCCC. They include activity data, emission factors and methodologies used to estimate GHG emissions from all sectors. Annex I countries (43 countries, either industrialized or with economies in transition) must submit these inventories on an annual basis, Non-Annex I countries (153 mostly developing countries) submit them every four years.

In order to report their emissions as accurately as possible, countries are required to use guidelines from the Intergovernmental Panel on Climate Change (IPCC), which provides internationally agreed methodologies to ensure the inventories

[2] CGIAR, CCFAS "Big Facts on Food Emissions" : https://ccafs.cgiar.org/bigfacts/#theme=food-emissions&subtheme=direct-agriculture

are consistent and produce comparable data. The IPCC Guidelines cover direct and indirect N_2O emissions from soils and CO_2 emissions from urea and liming.

The IPCC offers three tiers (or levels) of reporting emissions: Tier 1, which provides countries with default emission factors (i.e. a representative value that attempts to relate the quantity of a pollutant released to the atmosphere with an activity associated with the release of that pollutant[3]), for all countries to apply to their readily available national or international statistics (aka their activity data); Tier 2, which has a higher level of resolution to include more specific country or regional data and more granular environmental factors; and Tier 3, the most demanding in complexity, whose methodology is left to national experts (with the provision that they follow stringent IPCC rules of transparency on their methods). Tier 3 involves detailed modelling and inventory measurements tailored to address national circumstances.

Of the total 191 countries reporting their emissions from fertilizers in their National GHG Inventories (specifically N_2O emissions), 94.2% are reporting at the Tier 1 level, and 5.2% at Tier 2. Only the United States currently reports at Tier 3 level for N_2O emissions from mineral fertilizers. It should also be noted that 22% of Annex I countries as well as China and India report at Tier 2/3 level, which collectively account for 63% of global fertilizer consumption (IFA, 2018).

Tier 1 reporting certainly continues to dominate National GHG Inventories and emission estimates for fertilizer application, however the default global emission factor of 1% for direct N_2O emissions from N fertilizer application[4] has always been considered a rough average derived from global emissions, and as such is not very precise. Plot/field-level Emission Factors can thus often differ from the IPCC 1% value.

Certain analyses of national reporting of fertilizer application with the Tier 1 emission factor have established a strong relation between an increase of N_2O emissions and the rate of N fertilizer applied. Yet this reporting doesn't provide any room to consider emission mitigating Fertilizer Best Management Practices, summarized as the 4Rs, which call for the right source of nutrients to be applied at the right rate, time and place.

2 "BOTTOM-UP" APPROACHES TO ESTIMATING FERTILIZER-RELATED EMISSIONS:

In recent years, the fertilizer industry has developed strategic partnerships in several regions of the world to facilitate the more precise accounting of GHG emissions from agriculture, which takes into account emissions reduction resulting from site- and crop-specific fertilization.

Fertilizer Best Management Practices (FBMPs) in the 4 areas of nutrient management are being integrated into GHG emission accounting to better reflect the impact of sustainable agricultural practices. So far, mostly developed at the sub-national level, all these efforts involve bottom-up approaches to estimating emissions associated with the adoption of FBMPs.

[3] EPA. https://www.epa.gov/air-emissions-factors-and-quantification/basic-information-air-emissions-factors-and-quantification
[4] This EF is defined as the emissions from fertilized plots minus the emissions from unfertilized control plots expressed as a percentage of the N applied.

UNITED STATES: FIELD-TO- MARKET

Field-to-Market is a multi-stakeholder initiative that includes: growers; agribusinesses; food, beverage, restaurant, and retail companies; conservation groups; universities; and public-sector partners in the United States. Its overall goal is to improve the sustainability of the U.S. agricultural supply chain.

Field-to-Market provides a common framework to measure environmental and socio-economic indicators that can be applied at different scales, from the farm to national level. One of the environmental indicators is GHGs, which include CO_2, methane and nitrous oxide emissions. Field-scale emissions are measured via an online tool that can assess the environmental performance of management practices against local, state and national benchmarks for key sustainability indicators called the Fieldprint Calculator.

Over time, the Fieldprint Calculator has become more precise, for instance in the case of nitrous oxide emissions from fertilizers: until 2011, these emissions were calculated using a default emission factor, which was a simple approach yet with highly uncertain results. However, upon revisal in 2017, Fieldprint Calculator emission factors included measurements from the national N_2O emissions estimating tool, USDA'S DAYCENT, which captures sensitivity of emissions to crop, Land Resource Region, soil texture and farmer-applied N rates.

This system is currently available for corn, soybean and wheat production in different regions of the United States.

Field to Market®

CASE STUDY:

Following Vyn et al.'s 2016 research data analysis, which observed the relationship between partial net N balance[5] and N_2O emissions with different levels of 4R implementation, the Fieldprint Calculator could be even further improved in the future by including all aspects of the 4Rs:

At an intermediate level of 4R implementation, Vyn et al. observed a 7% decrease in N_2O emissions from the basic level (i.e. which follows soil testing and nutrient recommendations); while at Advanced/Emerging level of 4R implementation, N_2O emissions were reduced by 14% compared to the basic level[6] (the three levels of 4R implementation vary in requirements depending on the crop).

[5] The basic model of a partial N balance is: [Farm fertilizer N + Recoverable manure N + Biologically fixed N] – Removal N by crop harvest = Partial N balance. It excludes atmospheric N deposition, N in irrigation water, biosolid N application, soil erosion of N, gaseous N or leaching.
[6] IPNI and TFI. 2017. Page 8

CANADA: THE NITROUS OXIDE EMISSION REDUCTION PROTOCOL

In Canada, the fertilizer industry has recently proposed that federal and provincial governments implement a national 4R Climate-Smart Protocol, also known as the Nitrous Oxide Emission Reduction Protocol.[7]

The Nitrous Oxide Emission Reduction Protocol (NERP) is a Nutrient Stewardship-based approach to mitigate N_2O emissions from fields, that was approved for use in 2010 in the Canadian province of Alberta. NERP allows for farmers to claim carbon credits by adopting 4R nitrogen practices. The 4Rs can be applied at three levels: Basic, Intermediate and Advanced.

NERP takes into account on-farm reductions of GHG emissions from N sources and fuel use associated with the management of fertilizer, manure and crop residues for annual and perennial crops.

NERP calculates N_2O reductions by comparing historic emissions baselines to projected or post 4R implemented emissions. The baseline is generated from 3 years of yield and N use data for each crop, expressed in an average emission in crop events unit (Kg CO_2e/kg crop). The major requirements for quantification and reporting of GHG emissions are N inputs and crop outputs for each crop grown on the farm and for each baseline and project year.

N.E.R.P.

Nitrous Oxide Emission Reduction Protocol

CASE STUDY:

Fertilizer Canada's 2018 4R Climate-Smart Protocol strategy includes a reference to a 2016 study by the University of Saskatchewan[8] that has quantified the impacts of conservation tillage (i.e. soil cultivation that leaves the previous year's crop residue on fields before and after planting the next crop[9]) in Canada from 1985 to 2010, including off-site benefits such as GHG emissions reductions and carbon sequestration. The Report found that "off-site benefits [...] resulted in over $1B (2014 CAD$) worth of value at $5/tonne of emission reductions, of which **$417M was attributed to reductions in N_2O and fossil fuel CO_2 emissions saved**. This example shows the power of value chain partners to scale emission reductions and removals across landscapes in the cropping sector in Canada."[10]

The Report also includes an estimate of NERP's potential contribution to the Canadian economy should it be implemented throughout Canada with proper investments, illustrated on page 6.

[7] (https://fertilizercanada.ca/canadian-fertilizer-industry-poised-to-lead-agriculture-industry-in-reducing-greenhouse-gas/)
[8] https://onlinelibrary.wiley.com/doi/abs/10.1111/cjag.12080
[9] https://stats.oecd.org/glossary/detail.asp?ID=413
[10] Viresco Solutions on behalf of Fertilizers Canada. 2018. Towards a National NERP Carbon Management Strategy. Page 4 https://fertilizercanada.ca/wp-content/uploads/2018/07/National-NERP-Carbon-Strategy-2018_vf-1.pdf

NERP			
Province	**Cumulative Constrained Potential ($MtCO_2e$)***		
	Short Term (2018 - 2022)	**Medium Term (2023 - 2027)**	**Long Term (2028 - 2037)**
Saskatchewan	0.34 - 0.57	1.00 - 1.67	3.51 - 5.85
Alberta	0.38 - 0.63	1.10 - 1.84	3.86 - 6.44
Manitoba	0.24 - 0.40	0.70 - 1.17	2.45 - 4.08
Ontario	0.25 - 0.42	0.73 - 1.21	2.55 - 4.25
Quebec	0.15 - 0.25	0.43 - 0.72	1.52 - 2.53
British Columbia	0.01 - 0.01	0.02 - 0.03	0.07 - 0.12
Total:	**1.37 - 2.28**	**3.98 - 6.64**	**13.96 - 23.27**

* Potential reductions were estimated for years 1 to 5, 6 to 11 and 11 to 20. Source: Fertilizer Canada, 2018

Fertilizer Canada's goal is to achieve 20 million acres under 4R Nutrient Stewardship by 2020, which represents 20 % of Canada's crop land.

EUROPE - THE COOL FARM TOOL

The Cool Farm Tool is a farm-level carbon foot printing tool that is run by the not-for-profit Cool Farm Alliance, which has a wide membership among the food and beverage sector, retailers, fertilizer companies, NGOs, universities, etc.

The Cool Farm Tool is freely available online and includes several modules, including GHG emissions, biodiversity and water use. The Cool Farm Tool can show how the management decisions taken by farmers contribute in sequestering carbon and/or reducing greenhouse gas emissions.

GHG emissions from fields are estimated by including general information about soil and climate, and a set of management options on the farm which includes fertilization, pesticide and herbicide use, residue management, machinery and energy use.

GHG emissions are reported in CO_2 equivalents (CO_2eq) per ha of crops. GHGs from fertilizers also include emissions associated with fertilizer production (for the main regions of the world) and distribution. The CFT allows for farm-level, management and climate-sensitive N_2O emissions from fertilizers to be calculated based on simple data such as fertilizer type, rate, level of inhibitors, crop and yield, soil and climate and study locations.

CFA COOL FARM ALLIANCE

CASE STUDY:

In 2013, WWF India published a Report of a 2010 project entitled "Greenhouse gas emissions from cotton farms in Warangal district of Andrah Pradesh", where the Cool Farm Tool had been used to compare GHG emissions from cotton farm plots that implemented traditional cultivation against plots who implemented Fertilizer Best Management Practices.

Using the Cool Farm Tool (version 373), WWF India analyzed 48 cotton farm sample plots, 27 of which were implementing FBMPs (which the project narrowed down to a balanced fertilization[11]) and 21 using traditional practices. WWF India collected directly from the growers' data such as: crop yields, fertilizer application, organic matter application, pesticide application and volume of irrigation water provided. The Cool Farm Tool then provided a total emission information per production area, unit area and ton of finished product.[12]

The Cool Farm Tool then allowed WWF India to make comparisons between plots, such as the one below:

Table 12: GHG emissions from fertilizer application in BMP and TC plots

Plots	Fertilizer application	Emissions due to fertilizer application		Total net emissions	
	kg/ha	kg CO_2e/ha	kg CO_2e/T	kg CO_2e/ha	kg CO_2e/T
BMP	547	1,642	689	1,032	430
TC	1,127	3,312	1,506	3,236	1,500

Source: WWF India, 2013.[13]

WWF's Report states that the key finding of the project was that: "Emissions from fertilizers are the major determinant in overall GHG emissions in cotton cultivation, and therefore fertilizer management is the most crucial management practice in terms of reducing GHG emissions"[14]. The Cool Farm Tool isn't just a calculator. It stimulates thinking about management, by showing hotspots and helping to develop action plans at farm/field level.

[11] i.e. giving the proper supply of all macronutrients and micronutrients in a balanced ration throughout the growth of crops
[12] Idem, page 10.
[13] Idem, page 32.
[14] WWF. 2013. *Cutting Carbon Emissions. Findings from Warangal, India*. P. 9

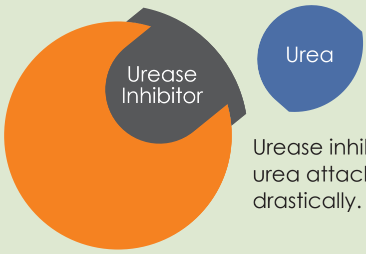
EUROPE - THE SWISS CARBON OFFSET PROGRAM

An important tool in the 4R toolkit are fertilizer products, referred to as slow- and controlled-release and stabilized fertilizers, that seek to match the release of nutrients from mineral fertilizers with crops' requirements. Slow-release fertilizers break down gradually to release plant nutrients; controlled-released fertilizers are encapsulated in a protective coating; and stabilized fertilizers slow the N cycle in the soil.

ABOUT STABILIZED FERTILIZERS:

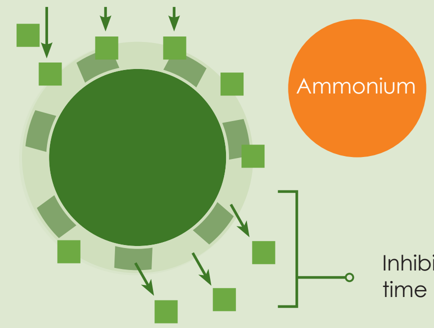
An increasing number of farmers are exploring the use of urease inhibitors (UIs) and nitrification inhibitors (NIs) to improve nitrogen use efficiency. By limiting nitrogen losses, UIs and NIs can be an effective option to improve nitrogen use efficiency.

- UIs work by blocking urease enzymes so that the transformation of urea into ammonia is delayed. A UI blocks the conversion by attaching to the urease enzymes at the same active site where the urea would bind.



Urease inhibitors block the site where urea attaches, reducing ammonia loss drastically.

NITRIFICATION INHIBITOR



ABATED INHIBITION
Nitrification inhibitors delay ammonium conversion by inhibiting the bacterial enzymes, resulting in improved plant nutrition.

Inhibition lasts for only a period of time before nitrification resumes.

- Nitrification inhibitors delay the conversion of ammonium to nitrate, and results in reduced nitrate leaching from applied fertilizers and fewer nitrous oxide emissions due to reduced nitrification rates.

Source: BASF. 2018. *Nitrogen Use Efficiency: Keeping Nitrogen on Target.*

The Swiss Carbon Offset Program uses stabilized fertilizers to develop carbon offsets from reductions of fertilizer-related N_2O emissions, which can then be sold on the open market in Switzerland. The program, launched in 2016 and managed by the company First Climate (which specializes in voluntary and compliance carbon trading), works by using the proceeds from the sale of certified emission reductions to reduce the price of stabilized N fertilizers for farmers.

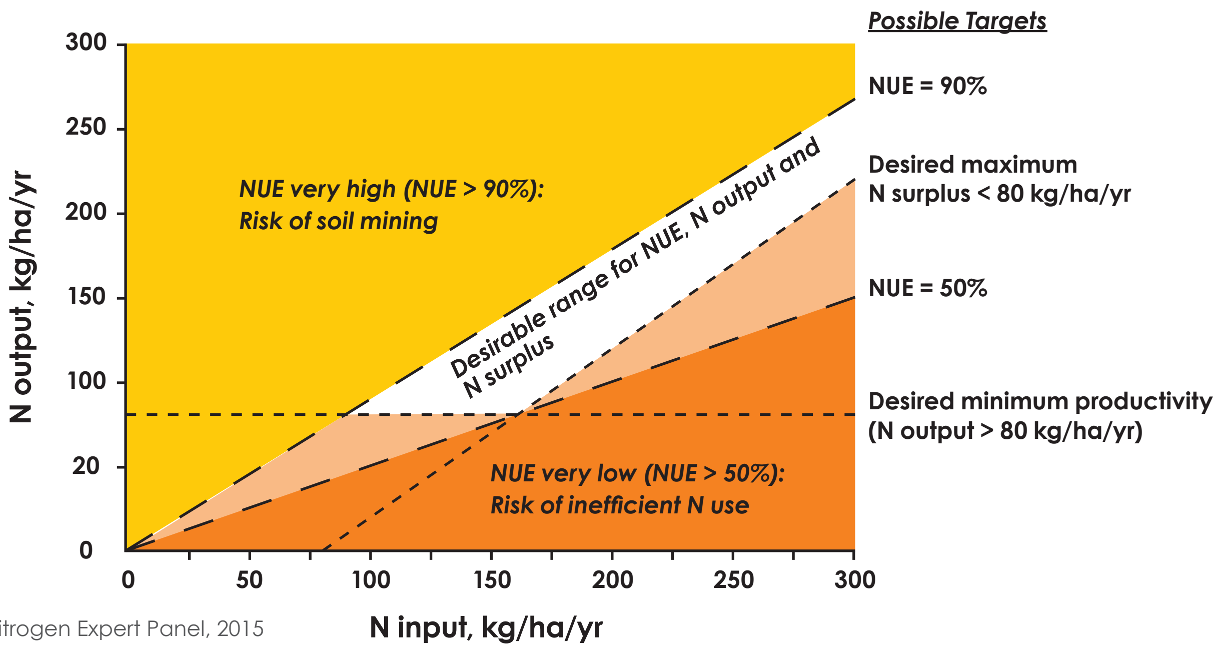
The Swiss Carbon Offset Program calculates emission reductions from the use of stabilized fertilizers using default emission factors defined by Switzerland's National GHG Inventories. Under the Swiss Inventory Report, the default emission factor value for direct N_2O emissions is 0.25% (IPCC EF: 1%) and indirect emissions (N leaching) is 7% (IPCC EF 30%).

The emissions savings resulting from the implementation of the Carbon Offset Program will be taken into account in Switzerland's National GHG Inventory of agricultural emissions as of 2018.

EUROPE - THE EU NUE INDICATOR SYSTEM (EU NITROGEN EXPERT PANEL)

The EU Nitrogen Expert Panel (EUNEP) was established in 2014 with the support of the European fertilizer association, Fertilizers Europe. The EU N Panel's objective is to improve the overall N use efficiency of food systems in Europe by recommending effective solutions and communicating with authority about N issues.

The approach of the EUNEP focuses on developing benchmark metrics for several N indicators, to define sustainable fertilizer N use. Put simply, NUE = N output / N input[15]. The NUE Indicator is simple and flexible and requires N input and N output data. Performance can fall into three different ranges of NUE: too high (> 90%) leading to soil nutrient mining; too low (< 50%) risking inefficient N use and high losses; and a desirable range between the two extremes (90-50%), as illustrated below:



Source: EU Nitrogen Expert Panel, 2015

These desirable ranges have been identified at the beginning of the work stream undertaken by the EUNEP. The Panel and its members are currently assessing multiple case studies at farm/field level, with very different characteristics in order to identify the different desirable ranges for an appropriate NUE, depending on the farming system or the soil conditions. Part of this work, which will be completed by the end of 2018, shows that it is crucial to take into account the crop rotation while calculating the NUE indicator at field/farm level[16].

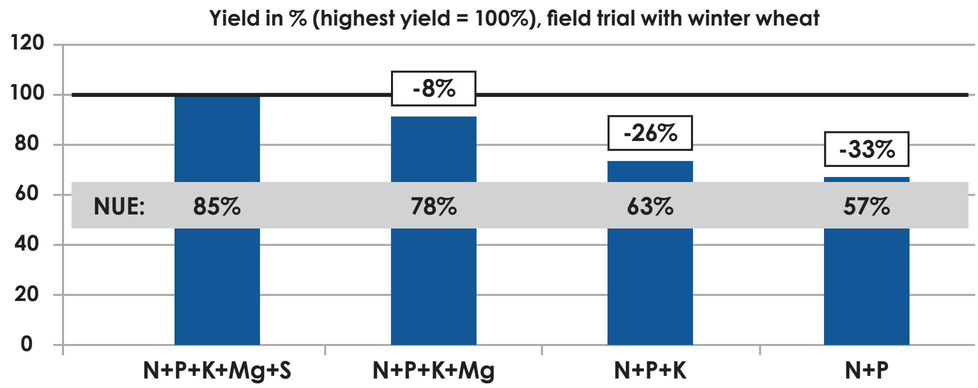
[15] http://www.eunep.com/wp-content/uploads/2017/03/Report-NUE-Indicator-Nitrogen-Expert-Panel-18-12-2015.pdf

[16] NUE should be interpreted in combination with indicators such as soil organic matter, soil nutrient levels and crop yields. It should not be seen as an absolute value; it is more the trend than the calculated value that is of relevance.

CASE STUDY:

Fertilizer producer Yara has found through field trials with winter wheat that balanced crop nutrition (i.e. giving the proper supply of all macronutrients and micronutrients in a balanced ratio throughout the growth of crops) resulted in the highest level of NUE, and in the highest yields, as illustrated below:

BALANCED CROP NUTRITION TO AVOID A LOSS OF CROP YIELD AND IN TURN A LOW NITROGEN USE EFFICIENCY (NUE)



Source: Yara, 2018

By managing nitrogen more efficiently, farmers can better adapt to climate change, sequester more carbon in the soils and reduce the emissions of greenhouse gases such as N_2O emission intensity.

3 LINKING DATA AND AMBITION: FERTILIZER BEST MANAGEMENT PRACTICES (FBMPS) CAN CONTRIBUTE TO NATIONALLY DETERMINED CONTRIBUTIONS (NDCS)

Currently, the projects listed above are not included in National GHG Inventories and operate independently. However, there is tremendous potential for these to complement or even align with National GHG Inventories. It is assumed that countries would move to a higher level of Tier reporting should they have more data: in the case of emissions from fertilizer use, capturing variations of field-level emissions, that can be attributed to mitigation measures (like FBMPs) would enable them to report at the highest level, i.e. Tier 3. Accounting for emissions reductions from FBMPs in national inventories could importantly lead to a recognition of their importance, and provide an incentive for pursuing FBMPs.

The improvement of quality data on FBMPs (for instance their nature and use) would also facilitate these projects' inclusion in national inventories. In the United States for instance, where there is the highest level of reporting N_2O emissions at national level (Tier 3), the 4Rs are partially included in the national modelling system DAYCENT, but certain elements like the "Right Place" still remain outside its scope. The accuracy of the model's result will be improved once all 4Rs are included.

This in turn would give a strong indication to farmers that the efforts they have undertaken and the GHG reductions they have achieved by adopting FBMPs are being recognized at the national level and could motivate them to further engage with climate change mitigation targets.

Last but not least, this would enable policy-makers to link their countries' mitigation targets, expressed in their Nationally Determined Contributions (NDCs), with concrete data on emissions trends and associated mitigation strategies.

NDCs are required of each signatory Party of the Paris Agreement, as are national post-2020 climate action plans that should help limit global warming below 1.5 - 2˚C. NDCs are to be submitted every five years to the UNFCCC Secretariat, and to show an increase in ambition over time. Of the 160 NDCs submitted in the first round (2015-2016), 103 included agricultural mitigation and 17 mentioning fertilizers as a specific mitigation target.

Countries wanting to demonstrate their progress in curbing emissions from fertilizers will be interested to be able to link their NDCs with their National GHG Inventories to demonstrate progress in climate change abatement. Additionally, as NDCs currently do not have uniform requirements for implementation, it is an additional opportunity for countries to support more "bottom-up" approaches that allow for more consistent measuring of fertilizer-related emissions, and link FBMPs with a national climate change mitigation strategy.

Most of the sub-national projects listed in this paper are already well aligned with national GHG emissions reporting methods and are constantly improved to provide quality data on fertilizer-related emissions. There are clear opportunities to better integrate FBMPs in national estimates of fertilizer-related GHG emissions and link them with countries' climate change mitigation targets expressed in NDCs. An important one is the development of nationally consistent and project-specific monitoring, reporting and verifying methods that would accurately capture FBMPs as mitigation measures.