Reducing emissions from fertilizer application via site-specific nutrient management (SSNM)

THE CHALLENGE

Agrifood systems account for roughly one-third of all greenhouse gas (GHG) emissions globally, when food production, transport, processing, and retailing are considered (Crippa et al. 2021; IPCC 2022; Costa Jr et al. 2022). The production and use of nitrogen fertilizers account for approximately 5% of global GHG emissions (Gao and Serrenho 2023). Fertilizer application leads to the release of carbon dioxide (CO_2), nitrous oxide (N_2O), and methane (CH_4), which are among the most important global GHGs. Most notably, N_2O is directly generated as a by-product of nitrification and denitrification processes of soil bacteria. Additionally, N_2O is indirectly released from leached nitrates and volatilized ammonia, which are partially converted to N_2O later by bacteria in the soil. Carbon dioxide is also produced during the decomposition of urea and ammonium bicarbonate in the cropland and as a result of the use of limestone to neutralize the soil acidification caused by nitrogen fertilizers (Gao and Serrenho 2023).

While fertilizers have allowed us to keep up with the growing demand for agricultural products, their historical overuse has introduced an environmental crisis in many parts of the world, with a detrimental effect on terrestrial, marine, and freshwater ecosystems, in addition to increased GHG emissions (Walling and Vaneeckhaute 2020). In other parts of the world, including much of Africa, not enough fertilizer is applied. Across Africa, there is a need to boost food production and improve the quality of agricultural soils, which are in decline amid overuse and the effects of climate change.

HOW DOES SITE-SPECIFIC NUTRIENT MANAGEMENT HELP US REDUCE EMISSIONS FROM FERTILIZER APPLICATION?

Site-specific nutrient management (SSNM) is an approach to achieve increased nitrogen use efficiency (NUE) through the precise application of balanced fertilizer inputs, leading to higher crop productivity and other environmental benefits (Dobermann and White 1998; Dobermann et al. 2002). SSNM is an important axis of integrated soil fertility management (ISFM). ISFM is a set of soil fertility management practices, adapted to local conditions, that aim to maximize the agronomic use efficiency of the applied nutrients and improve crop productivity (Vanlauwe et al. 2010). In a meta-analysis covering 11 countries in Africa and Asia, Chivenge et al. (2021) demonstrated that SSNM increased yields by 12% for maize, rice, and wheat and led to a reduction in nitrogen application by 10% and an increase in profitability of 15% at farm level.

Supported by advances in big data science, crop modeling, and geospatial analytics, and with the increasing availability of remote sensing products, SSNM is guided by an array of decision support tools that provides guidance on the right source at the correct rate, the right time, and in the right place, i.e., the 4Rs (Johnston and Bruulsema 2014). Efficiently used fertilizer will ensure that available nitrogen in the soil is minimal, thus reducing the potential for nitrous oxide emissions (Tian et al. 2020). Many studies have demonstrated GHG emission reductions with SSNM: Gupta et al., 2022; Pampolino et al. 2007; Sapkota et al. 2014; Zhang et al. 2018; Huang et al. 2021; Sapkota et al. 2021. However, when SSNM tools recommend increased fertilizer input due to low baseline conditions (as in much of Africa), an increase in GHG emissions will ensue. That said, the land-sparing effect of closing yield gaps can counteract the effect of the increased emissions from agricultural inputs; Africa is the region that witnessed the largest cropland expansion between 2003 and 2019 (Potapov et al. 2022) and is also projected to have the largest agricultural expansion to 2050 (Searchinger et al. 2019).

BARRIERS TO THE UPTAKE OF SITE-SPECIFIC NUTRIENT MANAGEMENT

SSNM decision support tools are heavily dependent on data availability. The lack of standardized and open data hinders the application of big data science to decision support tools with sufficient accuracy/ resolution. There is minimal data on robust GHG measurements at present. The accuracy of these tools needs to be further improved to minimize the risk of under- or non-performance, as the performance of these tools is strongly related to data quality and availability.

There is limited bundling of decision support tools with other agro-inputs (e.g., seeds, mechanization), limiting the achievement of agronomic gains in terms of yields and other key performance indicators, which in turn makes it harder for farmers, often with limited digital skills, to adopt these tools.

The lack of sustainable business models, including revenue generation options, limits the sustainable deployment of decision support tools at scale. There are limited financing models to fund the hosting of data and tools. Notably, in low- and middle-income countries, the cost and accessibility of fertilizer are major issues, and strong input markets are a prerequisite for SSNM, along with the availability of local nutrient sources such as manure and compost.

There are inadequate policies and incentives to encourage and facilitate the development of digital tools to support SSNM. Government support and subsidies can play a crucial role in promoting these practices.

The initial investment in SSNM decision tools such as GPS-guided machinery, plus fluctuating crop and fertilizer market prices, reduces the cost-effectiveness and incentives for adoption.

CALL TO ACTION

A1. Increased international climate finance should be directed toward unlocking the potential of agricultural technologies and approaches with proven effectiveness

- Include tools to strengthen site-specific nutrient management and enhanced efficiency fertilizers in Climate Bonds Initiative (CBI) Agriculture Criteria – under efforts to reduce GHG emissions, where the science has been proven – so that they are eligible for green finance. This in turn should be used to include tools to strengthen site-specific nutrient management and enhanced efficiency fertilizers in country- and regional-level taxonomies, e.g., the EU taxonomy of permissible activities for green finance.
- Encourage multilateral development banks (MDBs) and donor countries to provide concessional loans and grants for adoption of SSNM, where there are large opportunities for productivity improvement as well as reducing emissions, but upfront costs are a barrier to action.
- Seek and obtain international consensus on "repurposing" the more than US$600 billion spent annually by governments on agricultural support. One of the most promising shifts in such investments would be an increase in funding for R&D dedicated to productivity-enhancing and emissions-reducing technologies.
- The Breakthrough Agenda should make stronger linkages to G7 and G20 agendas where parallel decisions are taking place to direct investment for broader development and environment objectives in agrifood system.

A2. Promote international sharing of knowledge on policy and implementation to facilitate faster uptake of proven technologies

- Encourage governments to sign NUE Pledges in lines of the methane pledge. Such a NUE pledge will help reduce nitrous oxide emissions, as nitrogenous fertilizer is the top source of nitrous oxide emissions. A pledge to reach a global NUE of 70% by 2030 is ambitious but feasible with appropriate policies and financial support.
- Countries should take advantage of existing platforms such as the World Bank and the UK Foreign, Commonwealth and Development Office (FCDO) facilitated Global Agriculture Policy Dialogues to engage in intensive exchanges of knowledge on questions such as which policies are most effective for encouraging and supporting farmers' adoption of SSNM.

A3. Develop common metrics and indicators to track the adoption of sustainable agricultural solutions

- Fertilizer companies must be encouraged to expand their GHG accounting to include the GHG emitted as a result of fertilizer application in the field (so-called Scope 3 emissions). Greater scrutiny of Scope 3 emissions can incentivize greater efforts to reduce nitrous oxide emissions from fertilizer application and enhance NUE.
- Countries should come together and develop "Codex Planetarius" on the lines of Codex Alimentarius which develops internationally agreed food safety standards. 'Codex Planetarius' can set forth criteria for crops and animal-derived products (that is, end products for consumption) to be certified as compatible with international climate targets, which will then incentivise all actors in the value chain, such as fertilizer and livestock producers, to adopt low emissions and climate compatible technologies.

A4. Increase support for food system research, development, and demonstration to support the uptake and scaling of promising technologies and approaches

- Strengthen global knowledge exchange by expanding and strengthening the Nutrient Management Network of the Global Research Alliance on Agricultural Greenhouse Gases. This would involve assembling scientific expertise in novel science areas; supporting the development of evidence-based decision support tools (e.g., artificial intelligence) and their translation into forms that diverse stakeholders can interact with; organizing science communication around best practices for nitrogen fertilizer recommendations; and facilitating multistakeholder interactions (to exchange data, information, and lessons learned and use such coordination functions to provide technical support to fertilizer-related investment programs). Such decision support tools should account for local soil and weather conditions when determining the right application rates.

A5. International efforts should work toward enabling the private sector to scale up solutions through global markets

- Revive moribund World Trade Organization (WTO) Agreement on Environmental Goods and Services. Plurilateral negotiations for an Environmental Goods Agreement were started in 2014 to promote trade in essential environmental products, i.e., solar panels and wind turbines. In future negotiations, the list of green goods and services should include low-carbon fertilizers like green ammonia and products to enhance SSNM, feed additives, and low methane forages, among other emissions-reducing technologies. This would involve advocating for harmonized standards, certifications, and accounting methodologies with multilateral organizations such as WTO and various UN agencies.

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For more information see:

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