Environmental impact

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Greenhouse gas emissions from nitrogen fertilizers

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The increasing production and use of nitrogen fertilizers exert extreme pressure on the environment. There are ways to mitigate its harmful impacts without sacrificing food quality and quantity.

The current food production's contribution to total greenhouse gas (GHG) emissions is about 35% of global total emissions[1]. To this total, the fertilizer emissions due to production, transportation and usage were estimated to be 14–18%[1,2] or 5–6% of global total GHG emissions. In the CO_2 equivalent units, the global nitrogen fertilizer emissions were 245–308 million metric tonnes of CO_2 equivalent per year. Synthetic fertilizers and manure or organic fertilizers contribute to global environmental impact by releasing three major greenhouse gases, CO_2, CH_4 and N_2O, during their production and use (Fig. 1). Synthetic nitrogen fertilizers release GHGs when manufactured, transported to the agriculture field and after farmers apply them to their fields, which is the most important factor contributing to direct N_2O emissions. On the other hand, manure can release CH_4 and N_2O. CH_4 is released from the anaerobic decomposition of organic material, whereas N_2O is released during the storage and processing of manure. CO_2 is released due to fuel and electricity consumption during nitrogen fertilizer production. Accurate estimates of GHG emissions from manure and synthetic nitrogen fertilizer production are essential to developing environmental control strategies.

Now writing in *Nature Food*, Gao and Cabrera Serrenho[3] study this problem by quantifying major GHG emissions from all lifecycle stages of the production and applications of synthetic nitrogen fertilizers and manure. The team subsequently identifies potential mitigation strategies to reduce fertilizer emissions by 2050. This study is different from the previous studies because it consistently accounts for interactive feedback processes between all stages of lifecycle analysis. This is an important step forward to accurately estimate the trade-offs between various viable potential mitigation options for GHG emissions. Some other important aspects the authors applied in the study that enabled them to accurately estimate emissions associated with the production of nitrogen fertilizers include (1) quantification of nitrogen fertilizer mass flows across 9 world regions and 11 types of fertilizer, which usually contain nitrate, ammonia, and ammonium or urea; (2) explicit estimation of the intermediate products used in the production of fertilizers, particularly in the production of ammonium nitrates and urea fertilizers, which are important to estimate the GHG emissions; (3) the use of the regional carbon footprint values[4,5] to estimate regional emission factors of various nitrogen fertilizers; and (4) explicitly accounting for the region-specific domestically supplied and imported nitrogen fertilizer values.

Using their advanced lifecycle analysis method, Gao and Cabrera Serrenho showed that the current global total GHG emissions were 2.6 Gt CO_2 equivalent per year or 4% of global total GHG emissions[6] from global production and use of synthetic nitrogen fertilizers and manure, two-thirds of which were due to their use in croplands. The authors also found that manure's current GHG emissions per unit of nitrogen are

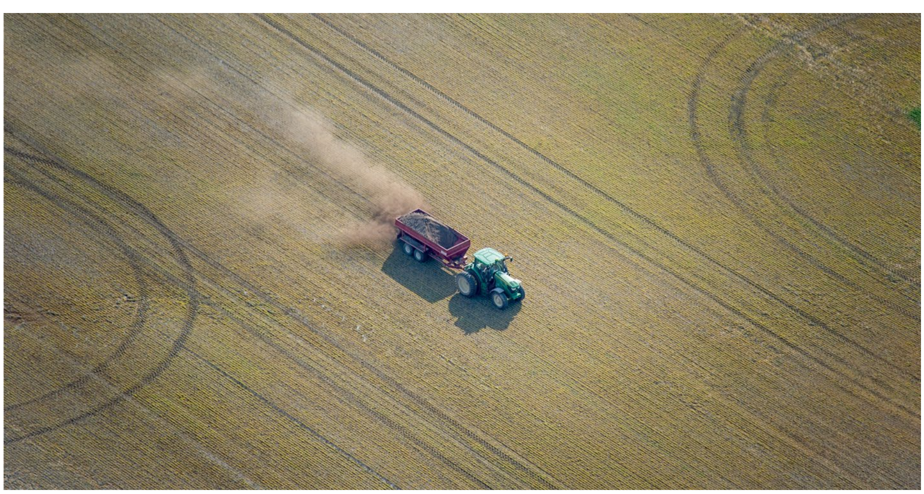

Fig. 1 | Food production heavily relies on nitrogen added to soil to sustain crop growth. The Gao and Cabrera Serrenho method of using all stages of synthetic nitrogen and manure nitrogen fertilizers' lifecycles is a step towards accurately quantifying GHG emissions. The image shows the spreading of chicken manure on a crop field as fertilizer in an eastern shore farm in Maryland, USA.

23 tons CO_2 equivalent per ton of nitrogen, which is about 1.9 times more than an average synthetic fertilizer emission, primarily due to the loss of a large part of manure nitrogen to the environment[7].

After validating their current GHG emission estimates using existing datasets, Gao and Cabrera Serrenho complete the study by applying various maximum mitigation potentials to reduce synthetic fertilizer emissions compared with business-as-usual estimated emissions by 2050. The authors found that by using the currently available technologies, a maximum of 78% (1.30 Gt CO_2 equivalent) of GHG emissions from the use and production of synthetic nitrogen fertilizers could be reduced below the 2050 level (1.66 Gt CO_2 equivalent), with the increase in nitrogen use efficiency found to be the single most important viable option to reduce emissions. However, Gao and Cabrera Serrenho propose that this has to combine with the decarbonization of fertilizer production, deployment of nitrification inhibitors, and a shift in the mix of fertilizers used globally to accomplish the maximum reduction potential. The study reported that manure was currently not a viable substitute for synthetic fertilizers, even though it emitted more GHGs than an average synthetic fertilizer per unit of nitrogen. The current study was more supportive of mitigation options on the production side of synthetic fertilizers because they were easier to control in the industrial environment.

Apart from the emission reduction options explored in Gao and Cabrera Serrenho's study, there are many other mitigation options that need to be explored to achieve the world's aim of net-zero emissions. The options might include, but are not limited to, decarbonizing the whole ammonia and urea value chain of nitrogen fertilizer industries with the possibility of transforming H_2 into ammonia[8]; shifts to healthier diets that require less nitrogen fertilizer to produce food, such as legume crops; agriculture farming with no-till practice[9] and precision farming with control fertilizer application.

Finally, there is no doubt that emissions from nitrogen synthetic fertilizers and manure need to be controlled to accomplish the goal of the United Nations Framework Convention on Climate Change and its Paris agreement. Although Gao and Cabrera Serrenho studied the various mitigation strategies that have the potential to reduce GHG emissions, these options also have the potential to control other environmental impacts, including non-point pollution of water resources, eutrophication and drinking water contamination and industrial and volatilization of nitrogen fertilizers, as well as reducing farm production costs.

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Competing interests

The author declares no competing interests.