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Agricultural greenhouse gas (GHG) emissions from the raising of livestock and growth of crops for human consumption represent 14% of global GHG emissions. Methane (CH_4) is a central GHG generated during agricultural production (via microbial methanogenesis, a process which occurs under anaerobic conditions such as those of the rumen of some livestock, flooded rice fields, and certain kinds of manure storage systems). Because methane has 28 times the global warming potential of carbon dioxide and a shorter atmospheric life of only 12 years, immediate action to reduce methane emissions—including from agriculture—is critical to slow our warming climate, especially in light of expanding global populations and food demand.

Doing so will require the development and application of proven, sustainable, and affordable interventions to inhibit methane emissions from livestock, considering both enteric (i.e., animal gas) and manure sources, and crop sources such as rice. A number of such interventions exist or are in development, from anaerobic digesters to cattle diet alterations. The most compelling interventions are those which not only inhibit methane emissions but also conserve expensive or ecologically vital resources; remain effective in the long term; can achieve economic scale; improve animal or crop productivity and nutritional value; and lack harmful health or environmental side effects. Because methods for reducing methane emissions can concomitantly increase nitrous oxide emissions under some circumstances, the effects of such methods on both gasses must often be considered to ensure an overall reduction in GHG emissions.

To rapidly reduce methane emissions, governments (at the local, state, and national level) will need to develop legal, regulatory, and incentive policies that require implementation of available cost-effective methods and support development of new strategies. This post provides an overview of the science behind agricultural methane emissions reduction strategies for livestock and rice emissions. (It does not cover strategies related to supply and demand management, which could be key components of future emissions management policies.) In a follow-up post I will review mechanisms for inventorying emissions, monitoring verification and compliance of facilities, and the regulatory, incentive, and cap and trade structures which currently exist to enforce or facilitate a methane emissions reduction program.

Enteric Emissions

The scientific literature suggests many potential avenues for combatting enteric methane emissions in ruminants, including vaccination against methanogens, alterations to diet composition, addition of compounds such as 3–NOP, essential oils, or red seaweed to the diet, and breeding more efficient cattle. While methods vary in consistency and magnitude of effect across the literature, preliminary results suggest the inclusion of species of red seaweed, for example *A. taxiformis*, as a food additive is especially promising. Methane reductions of up to an astounding 98% have been reported alongside positive side effects such as, in one study, enhanced steer average daily weight gain and, as in another, improved feed efficiency which would reduce costs per unit production. However, the literature supporting productivity effects is not entirely consistent and more research in this area will be required. Meat quality seems to be generally unaffected, and preliminary evidence suggests low risk of toxicity, though more work must be done to ensure the safety of seaweed additives with respect to humans, animals, and the environment.

Other possible interventions, for example vaccines (up to 7.7% methane reduction), feeding high-tannin forages (up to 55% methane reduction), supplementation with essential oils like horseradish oil (up to 19% methane reduction, though with a 10% decrease in dry matter consumed), supplementation with fatty acid (up to 36% methane emissions reduction), and inclusion of 3-NOP as an additive (up to 30% methane emissions reduction) may each have a role to play in achieving agricultural methane emissions goals. However, as for red seaweed, potential trade-offs and uncertainties surrounding each method must be considered. For example, rumen microbial populations may adapt to the presence of essential oil compounds, nullifying their effects and the effects of fatty acid supplementation on milk composition and, ultimately, consumer health must continue to be investigated. It is likely that the most effective, sustainable, healthy, and affordable approaches will include a combination or rotation of strategies.

Manure Emissions

Livestock GHG emissions are driven not only by enteric sources, but also by the microbial decomposition of stored manure. Manure can be stored in either wet (i.e., as slurry) or dry states, with different consequences for GHG emissions. For example, wet manure storage tends to produce more methane via anaerobic decomposition, while dry manure storage tends to aerobically decompose

generating minimal methane, but still generally producing nitrous oxide. Ultimately, in developing a comprehensive methane emissions reduction strategy, both nitrous oxide and methane emissions ought to be considered to reduce total GHG impact. Interventions to combat emissions seem to predominantly take three forms: modifications to the manure storage environment, slurry additives, and anaerobic digestion.

Modifications to the manure storage environment like cooler temperatures can inhibit the chemical process of methanogenesis, with recorded methane emissions reductions up to 46% in the literature. A straw cover over solid manure can reduce both methane and nitrous oxide emissions. Slurry additives, like NX_{23} or sulphuric acid can modulate manure slurry chemistry to influence emissions. Methane emissions reductions can be drastic, up to 99% in one study.

Anaerobic digesters, which physically capture methane in a bubble or dome atop the storage facility, can use the gas to generate energy (for use on site or for sale), providing additional financial incentive for methane reduction. Methane emissions reductions up to 68% have been recorded as a result of anaerobic digestion, although increases in nitrous oxide emissions of up to 49% are possible. (While burning methane to generate energy releases carbon dioxide into the atmosphere, the overall climate impact is reduced and the gas could potentially replace fossil fuel sources.) However, leaks which allow gasses to escape can mitigate reductions or result in overall increases in emissions relative to alternate storage methods, and generating energy via anaerobic digesters can emit pollutants like nitrogen oxide and carbon monoxide, among others. Unlike most of the strategies discussed in this post, digesters are already widely deployed but will still need significant investment and policy support to achieve scale.

Rice Emissions

Just as for manure management, mitigating GHG emissions from rice agriculture, which are generated by the activities of soil microbes, requires considering both nitrous oxide and methane emissions. The primary interventions seem to consist of controlled water use, breeding for efficient rice (thereby reducing the ratio of emissions to food), and fertilizer management.

Flooded paddies are a largely anaerobic environment which facilitate microbial methane production, so drawing down water when feasible is a natural methane reducing solution. Just a single, midseason water drawdown, which could plausibly

be deployed even in agricultural contexts where precise control over water is difficult, is expected to reduce methane emissions by 40%. Where more precise control is possible, the practice of alternate wetting and drying (AWD), which requires more regular drawdowns, has demonstrated reductions in methane up to 93%. A mixed literature suggests a properly implemented AWD regime could produce yield increases up to 10%, no change, or decreases of up to 16%.

Dry seeding of fields, an alternative to either the transplanting of rice seedlings into wet fields or wet-seeding, has demonstrated the potential to reduce methane emissions by 47% when compared directly to wet seeding. Dry seeding, or direct seeding in general, costs less in labor to implement than transplanting. Any such method which saves water — AWD may reduce water usage by up to 44%, for example — not only conserves an essential resource but also can provide a financial incentive for implementation where water or the pumping of water is not heavily subsidized.

However, because water drawdowns can generate increased nitrous oxide, this tradeoff must be considered and managed, especially in light of evidence suggesting that we may currently be underestimating the nitrous oxide production of rice cultivation by a factor of three. Despite this tradeoff, generally, AWD appears to successfully decrease total global warming potential. Additionally, management of fertilizer presents an opportunity to mitigate both nitrous oxide release and methane emissions. For example, use of the nitrification inhibitor dicyandiamide has demonstrated methane emissions reductions of up to 18% and nitrous oxide emissions reductions of up to 29%. Alternatively, breeding and genetic manipulation may produce rice which is more efficient, and so requires less flooded land, or which is specifically less methane producing.

Conclusion

The literature reviewed demonstrates that substantial methane emissions reductions are possible in the agricultural sphere; however, much additional research and development is required to validate and scale promising methods. Innovative regulation and incentive programs can facilitate the development and implementation of many of these methods, and these will be explored in a future blog post.

References (may be paywall-restricted)

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