Filling the Research Gap Program

National Agricultural Manure Management Program

Advancing Livestock Waste as Low Emission – High Efficiency Fertilisers

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NAMMP Outcomes to Industry

This Project has identified the potential of sorbers, when incorporated into livestock manures that have been applied to soils, to reduce net greenhouse gas (GHG) emissions. Vermiculite tended to be the most efficient sorber that was studied in a series of experiments.

- Sorbers can substantially decrease GHG (notably, nitrous oxide and ammonia) emissions by up to 60% and potentially reduce the need for conventional fertiliser.
- Sorbers can potentially improve plant growth (20%) and boost carbon retention in the soil by about 50%.

The overall outcome from this major component of the project was that the sorber-based approach has strong potential to be developed into a technology to mitigate manure GHG emissions. In addition, there is potential for significant productivity gains and a reduction in the use of conventional fertilisers when sorbers are incorporated into livestock manures as they are being applied to soils, because significant amounts of the nitrogen derived from nitrous oxide is retained and used for plant growth.

Environmental factors such as temperature, soil moisture, the carbon to nitrogen (C:N) ratio, soil permeability and soil pH often have a much greater effect on GHG emission rates from livestock manure applied to soils than the type of manure or amount applied.

Aims and Outcomes

This research project:

- Developed techniques to mitigate GHG emissions from land-applied livestock manures;
- Gained an understanding of factors affecting GHG emissions from land-applied manures and their effects on plant growth;
- Developed innovative fertilisers and manure management techniques that efficiently nourish crops and have low environmental and carbon footprint compared with traditional fertilisers; and
- Quantified soil/manure emissions for use in National Carbon Accounting and potential development of new Emission Reduction Fund (ERF) Methods.

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There were two mitigation approaches:

- Firstly, a technical approach involving the addition of specialised materials (in this case, sorbers) to soil and livestock manure systems under laboratory, microcosms, glasshouse and experimental plot conditions.

- Secondly, a management-based approach using process-understanding of manure GHG production to avoid emission triggers.

Key activities

- Assessed mineralisation of nutrients (carbon, nitrogen, phosphorus) and greenhouse gas emission potentials (methane, ammonia and nitrous oxide) of 20 types of manures from the beef, chicken, egg, and pig industries.
- Assessed chemical and microbial characteristics of 10 formulations of livestock manures combined with 3 soil types and a range of smart sorber mineral recipes and their greenhouse gas emissions.
- Measured plant responses to 10 manure/soil/amendment combinations as a fertiliser compared with commercial inorganic fertilizers and determine the 3 best bet technologies to control greenhouse gas emissions, as well retain carbon in the soil mixtures.
- Field trialed the most successful formulations and management strategies to determine fertiliser use efficiency, plant production and greenhouse gas emissions.
- Conducted Life Cycle Assessments comparing emissions of commercial fertilisers in plant production with the successful manure/soil amendment technologies.
- Identified barriers to adoption of the developed technology with livestock and plant industry stakeholders.

Key Findings

This project has delivered novel scientific findings that could underpin the formulation of an ERF method for Australian farmers

The major component of the project was to examine the ability of sorber technology to reduce greenhouse gas emissions. Experiments were conducted on a laboratory scale, in microcosms, in greenhouse pots and finally in field plots. In these intensive experiments, several sorbers, including vermiculite and bentonite were examined for their ability to reduce GHG emissions and improve plant yield with different animal manures applied to a range of different soil types.

The key findings from the laboratory studies were that both vermiculite and bentonite were very effective in decreasing nitrous oxide and ammonia emissions from manures applied to sodosol soils by up to 80%. Reductions in the nitrous oxide emissions from manure applied to vertosol soils approached 60%. The results of these preliminary laboratory studies indicated the efficacy of sorbers to mitigate agricultural GHG emissions were very promising and justified subsequent studies at a larger scale.

Further experiments were conducted to investigate the effectiveness of sorbers at decreasing nitrous oxide and ammonia emissions from manure-amended soils in small pots at the glasshouse scale. The main findings from these studies were that vermiculite significantly reduced nitrous oxide emissions by an average of 40% across all manures and soils. Furthermore vermiculite was associated

with a minor, yet insignificant, increase in dry matter plant yields in the sodosol soil. The vermiculite had no effect on dry matter production in the manure-amended ferrosol soil. From a GHG perspective, these results confirm the above laboratory results and thus a field plot study was conducted to further explore these findings in a practical situation. Again, the vermiculite and bentonite treatments resulted in up to 60% reduction in nitrous oxide emissions. Dry matter yields were also improved by up to 20% which may be attributed to the sorbers preventing nitrogen from escaping as N gaseous losses, and being trapped for plant uptake.

The results from laboratory, glasshouse and plot trials suggested that the sorber-based approach has strong potential to be developed into a technology to mitigate manure GHG emissions. However, when considering technology development at full-scale it is important to factor in the complete technology emission footprint. Consequently a life cycle analysis (LCA) was conducted to determine GHG emissions associated with the use of different types and levels of sorbers to mitigate total GHG emissions from land applied livestock manures.

While the highest level of bentonite inclusion delivered the largest mitigation of direct emissions, this resulted in a two-fold increase in net emissions from the whole system because of the cumulative effect of mining, transport and land application of the large mass of sorber. This demonstrates the potential for adverse outcomes if external leakage factors are not considered. However, with lower levels of sorber incorporation, substantial reductions in manure N_2O could be achieved, with a net reduction in overall emissions, with manufacture and transport of the sorber taken into account.

Finally in the examination of sorber technology to reduce GHG emissions, a diversity of key stakeholders comprising intensive animal industries, end-users, consultants, agronomists, researchers and industry service organisations were engaged to identify opportunities and barriers to adoption sorber technology transfer. These discussions together with case studies identified a diversity of knowledge gaps and understanding of the use of livestock manures in Australia and the response to sorber technology. Barriers to adoption that were identified included cost of product, cost effective transportation, variability of product (both physical and nutrient status), pathogens, application technologies and research to substantiate benefits to soil and plant health.

The overall outcome from this major component of the project was that the sorber-based approach has strong potential to be developed into a technology to mitigate manure GHG emissions. In addition, there is potential for significant productivity gains and a reduction in the use of conventional fertilisers when sorbers are incorporated into livestock manures as they are being applied to soils.

Other aspects of the project included:

- a review of GHG emissions from livestock manures in Australia and New Zealand,
- the GHG emitting potential of a diverse range of livestock manures,
- the effect of manure fertilisers on the plant root development,
- the effect of livestock manure land-application on soil carbon retention,
- the effects on soil chemistry and biology on N_2O emissions, and finally,
- a series of process trials in the laboratory to examine the influence of key control factors on N_2O emissions from livestock manure applied to ferrosol soils.

The review highlighted that many of the manure-based emission estimates are poorly substantiated by field measurements and that the estimates in the Australian GHG Inventory may be quite inaccurate. The experiments to examine the GHG emitting potential of livestock manures revealed that the ultimate methane emitting potential of some of the livestock manures was substantially less than similar values reported by the Intergovernmental Panel on Climate Change (IPCC). Nonetheless, the gas emission potential experiment showed that stored or older manures may still possess a reasonably high latent GHG emitting potential; certainly much higher than current IPCC estimates. Research at field scale is needed to demonstrate if these potentials are realised. It is critical to firm-up emission estimates before embarking on developing large scale mitigation technologies that may be based upon unreliable data.

Finally the laboratory based process trials identified the significant effect that some of the environmental factors could have on GHG emissions. Temperature and moisture have significant impact on GHG emissions with peak emissions occurring at $30^{\circ}C$ and 70% water filled pore space. Increasing C:N ratios and soil permeability was accompanied with a general increase in GHG emissions. These process-based findings have important implications from a policy perspective because they reveal that environmental factors, rather than manure or bulk N application rates, may primarily control emissions. This suggests that GHG inventories may need to have a more responsive environmental-based approach.

Furthermore, a much greater understanding of these process factors could be used to develop management based GHG mitigation strategies at farm scale. For example, applying livestock manures at cooler periods when soil moisture levels are well below field capacity could help in substantial emission reductions. The results from the soil permeability process trial also suggest that aerating, or fluffing soils can lead to increased nitrous oxide emissions.