National Agricultural Manure Management Program

Mitigating the Greenhouse Gas Potential of Australian Soils Amended with Livestock Manure

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NAMMP Outcomes to Industry

This project gathered data to understand the emissions resulting from the application of different manures from piggeries, feedlot cattle and poultry compared to the baseline emissions from conventional fertilisers. Practical field strategies were developed to mitigate emissions when applying these manures to different soil types and cropping systems. The major outcomes from this project included:

- Lower application rates of manures have the potential to reduce greenhouse gas (GHG) emissions by up to 60%.
- Dry seeding shows the potential to reduce GHG emissions by 25%.
- Incorporation of manures into soil revealed up to 75% reduction in GHG emissions.
- Composting and pelletising rather than stockpiling livestock manures showed a potential reduction of GHG emissions by up to 70 and 80%, respectively.

The results of comprehensive field trials show that, irrespective of the source of manure, there was a trend towards higher grain and biomass yields in field plots receiving livestock manure. The results from the comprehensive field trial suggested that the addition of low GHG-emitting livestock manures to soil could be a good management practice for increasing organic carbon, nitrogen availability, microbial diversity and resilience in soils as well as improving crop productivity.

Aims and Outcomes

This research project:

- Investigated the greenhouse gas emissions from a wide variety of livestock manures applied to either sandy or clayey soils.
- Examined the method of incorporation of livestock manures into soil, pH modification through liming, timing of application and altering C:N ratios to determine the effects on GHG emissions to develop the most effective mitigation strategies.
- Identified the microbial process responsible for GHG emissions, particularly nitrous oxide emissions, from manure applied to soils, and
- Evaluated the more promising mitigations strategies of managing livestock manures found in the laboratory studies in a cereal cropping field study to determine their effects on crop performance and overall GHG emissions.

NAMMP projects are funded by the Australian Government Department of Agriculture, Australian Pork Limited, Meat and Livestock Australia, Australian Egg Corporation Limited, Rural Industries Research and Development Corporation and Dairy Australia.

Key activities

- Measurement of soil carbon and greenhouse gas emissions from sandy and clay loam soils following applications of different types of manures from the pork, feedlot cattle and poultry industries. These manures include digested pond sludges, raw manures, stockpiled, composted and pelleted manures.
- Laboratory measurements of emissions from different soil/manure mixes to establish baseline emissions profiles.
- In association with the mitigation trials, the microbial processes responsible for causing nitrous oxide emissions were studied to determine key gene and metabolic pathways involved in generating emissions. This information was used to manipulate these microbial communities to further reduce nitrous oxide emissions.
- Abatement methods including timing of applications, incorporation strategies, pH modification and altering carbon to nitrogen (C:N) ratios were tested in the laboratory to determine the most effective mitigation strategies.
- The best mitigation strategies for land application of manures were evaluated in a comprehensive field trial where crop performance, soil carbon and field emissions were measured against normal baseline in a broad acre wheat cropping system.

Key Findings

A laboratory microcosm experiment was conducted to assess the influence of manure derived from different livestock and different storage systems on GHG emissions when applied to either a sandy or clayey soil. The baseline GHG data from soils amended with manures generated from different livestock production systems revealed that:

- Soils receiving beef feedlot manures were the lowest emitters and a major methane sink.
- Poultry manures whose GHG emissions are mostly derived from carbon dioxide were the next lowest emitters.
- The highest emissions occurred in soils amended with piggery manures, especially fresh manure, treated pond effluent and blended composts.
- However, sludges, composts, and stockpiles of pig manure showed highest GHG mitigation potential.

Overall, a similar trend in GHG emissions from manures was observed between the sandy and clayey soils, although higher emissions were seen in the clayey soils, particularly for some manure types. This implies that adopting GHG abatement methods will have the greatest impact on soils with higher clay content.

The results of the first microcosm study indicated that sludge, stockpiled and composted manures were the most promising manure storage systems in terms of reduced GHG potential following application to soils. Consequently, these manure types were selected as the basis for the second series of microcosm experiments which sought to evaluate the effectiveness of a number of potential GHG abatement methods.

1. *Storage methods*

The best storage method for piggery and feedlot manures was composting the manure with the aerated floor system or pelletising, both of which resulted in reducing GHG emissions by up to 80% compared to the standard practice of stockpiling manure during storage. However, for poultry manures composting them prior to land application had little impact on GHG emission.

Composting or pelletising manure is a good mitigation options for larger or mixed enterprises where multiple waste streams are freely available.

2. *Loading rates*

Lower manure loading rates was the most effective strategy for reducing GHG emissions by up to 60%, regardless of soil type and this worked for most manures especially, piggery sludge and stockpiled manures.

Applying lower rates of manure (5t/ha) to land is the best application method for reducing GHG that is simple and not affected by soil or manure type. This mitigation strategy is ideal for farmers who are unable to adopt the more expensive and labour intensive options.

3. *Immediate incorporation*

In sandy soils, directly incorporating manure into the soil led to significant reductions in GHG emissions in many piggery and chicken meat manures that were applied to these soils. However, the benefits of incorporating manures into sandy soils were not observed in beef feedlot and hen layer manure samples. On clayey soils, incorporating manure directly into soil actually increased the GHG emissions compared to the standard practice of surface applying manure to land, for many of the livestock manures.

These results highlight the fact that the same manure source can have a different response under different soil and climatic conditions and as such, findings from one region are not necessarily transferable to another.

4. *Liming to affect soil pH*

There was no significant difference in total GHG emissions between lime and unlimed treatments after the manure was applied to either sandy or clayey soils.

5. *Timing of application*

The release of nitrous oxide emissions from manured applied soils was greatest after a winter rainfall event. Dry seeding resulted in a 25% reduction in GHG emissions from feedlot manures.

Therefore, it is recommended to dry seed and avoid applying manure during or shortly after a rainfall event.

6. *Co-composting green waste (GW) or municipal solid waste (MSW) waste to produce a high C:N compost.*

Blending poultry and piggery manure with a carbon rich waste material such as treated municipal solid waste was not an effective abatement method. It resulted in a 5-7 fold increase in GHG emissions for poultry manure and 4-10 fold increase for piggery manure on sandy and clayey soils, respectively.

This implies that increasing the C:N ratio by incorporating carbon rich material with solid manure during the compost process is not a good GHG abatement method.

The final series of microcosm laboratory studies identified key microorganisms, genes and metabolic pathways involved in GHG emissions in manure applied soils and how they responded to abatement methods. Nitrifying and denitrifying populations were both responsible for nitrous oxide emissions in WA soils and this was largely dependent upon water filled pore space, soil texture and manure type being added. Based upon the results of the microbial processes studies, approaches that could reduce GHG emissions may include:

- decrease nitrified-N emitted as nitrous oxide (increasing pH through liming or adding manures with "liming effect"),
- decrease the availability of mineralised N to nitrifiers (addition of manures with high C:N,), or
- decrease nitrification activity (pelletising manure or immediately incorporating manure below the soil surface).

Furthermore low manure application rates were found to increase the abundance of methane oxidising bacteria in soils. Thus, although microbial communities in manure-amended soils are a potential source of nitrous oxide, they can also be a sink for methane. Applying alkaline manure at a low application rate (5t/ha) may produce a methane sink by increasing the relative abundance of methane oxidising bacteria.

The most promising GHG mitigation methods in the above laboratory experiments were tested in the field study. Stockpiled, composted and pelletised manure from a piggery along with composted and stockpiled feedlot manures were compared to conventional fertiliser application to a wheat crop grown on sandy or clayey soils. The manures were applied at the rate of 4 tonne/ha.

Overall, the total GHG flux was relatively low ranging from 5.6 to 58.5 kg CO_2 equivalent ha^{-1} and 44.3 to 147.2 kg CO_2 equivalent ha^{-1} in the sandy and clayey sand soils, respectively. These levels are similar to those observed in the semi-arid, rain-feed cropping regions of this area. The manure treated sites had higher GHG emissions than the control treatment with no fertiliser in the sandy soils, but in the clayey soils the control treatment had similar GHG emissions to most of the manure treated sites. There was also a trend towards lower GHG flux in the plots receiving composted feedlot manure compared to the stockpiled treatment. This suggests that composting the manure prior to land application is an effective mitigation strategy for lowering GHG emission in clayey soils.

The most dominant GHG was carbon dioxide, which contributed up to 90% of total GHG emissions in some cases. Significant nitrous oxide emissions were mainly associated with rainfall events and the results showed that sandy soils were less responsive to rainfall events, particularly in winter with the nitrous oxide flux being two-folds lower than in the clayey soils. Again, both the soils were a sink for methane emissions.

The grain yield was significantly higher in all fertilised plots, including the synthetic fertiliser treatment and irrespective of the source of livestock manure. There was a trend towards higher yields in the plots receiving manure, particularly the stockpiled manures in the sandy soils and composted manures in the clayey soils. These improvements in grain yield with the livestock manure treatments are likely to increase if manure

application is continued in subsequent years. Long-term field trials have shown it usually takes 3-5 years of repeated manure or compost application before significant gains in crops yields are reported.

The results of the field trial and earlier microcosm studies suggest that GHG abatement methods that either:

- stimulate methane uptake (e.g. low manure application rates)
- decrease nitrification activity (pelletising manure or immediately incorporating manure below the soil surface) or,
- decrease carbon and NO_3 availability (e.g. composting manure) that could lead to significant reductions in GHG emissions.

The field trial revealed that the effectiveness of the mitigation strategy at reducing greenhouse gas emissions is dependent on both the soil texture and manure type used.

Different GHG abatement options need to be matched to specific farming enterprises. A summary of the potential mitigation strategies for reducing GHG emissions is provided in the following Table which is a summary of the possible implementation of the key findings from this project.

Mitigation Strategy	Target Industry	GHG reduction	Implications
Lower application rate	Livestock Mixed enterprises Horticulture Grain	0-60% ↓	Low-cost, simple, easy to adopt May compromise crop yield and quality Increases CH_4 uptake (sink) Reduced cost associated with transport & spreading Improved fertiliser use efficicency Early adopters especially in Feedlot industry
Dry seeding	Livestock Mixed enterprises Grain	0-25% ↓	Low-cost, simple, easy to adopt Dependent upon manure, soil type, crop, geography & climate Improved water use efficiency Beneficial when yield is constrained by drought & frost Combat herbicide resistance Early adopters especially in Feedlot industry
Incorporation	Livestock Mixed enterprises Horticulture Grain	0-75% ↓	Low-cost, simple, easy to adopt Dependent upon manure, soil type, crop, geography & climate Not ideal for no-till farming practices Early adopters especially in Feedlot industry
Composting	Medium-large scale or mixed enterprises	0-70% ↓	Installation & operational costs Good knowledge base Source of GHG emission during production High quality conditioner, increased versatility & off-farm markets Reduced pathogen & pests, improved soil resilience Early adopters especially in Feedlot industry
Pelletising	Medium-large scale or mixed enterprises	0-80% ↓	Installation & operational costs R&D ongoing Good knowledge base Possibly source of GHG emission during production High quality fertiliser, increased versatility & off-farm markets Reduced cost associated with transport & spreading Innovators are providing a small market

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