Optimising organic resources

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Traditionally, organic resources such as animal manures were returned to agricultural land to provide nutrients for crop growth. However, the increase in agricultural productivity since the Second World War has resulted in the replacement of this recycling philosophy by one that, in extreme circumstances, resembles a waste disposal attitude. In consequence, nutrient surpluses are commonplace. In addition to the c. 90 million tonnes (on a fresh weight (fwt) basis) of farm manures applied to UK agricultural land each year, there are also three to four million tonnes (fwt) of biosolids targeted at agricultural land because dumping at sea is now prohibited. Approximately four million tonnes (fwt) of industrial ‘wastes’ are also applied to land. The pressure on land to receive organic resources will increase over the next decade when there is likely to be a significant increase in the production of composts from green waste and other organic materials that are diverted away from landfill in order to meet the UK recycling targets.

There are clear concerns over the spreading of organic resources to land. These include: oversupply of nutrients such as nitrogen (N) and phosphorus (P) (in excess of crop requirements) resulting in an increased risk of transfer to water; emissions of environmentally-damaging gases such as ammonia (NH_3) and nitrous oxide (N_2O); the quantity of heavy metals applied to soils in biosolids, farm manures and other organic materials that can affect long-term soil fertility; and the risks of pathogen transfer to food crops, bathing and shellfish waters. Public perception and acceptability is crucial in ultimately determining the way in which organic resources will be managed in the future. The challenge for society is, ‘How do we manage these organic resources sustainably within the landscape?’

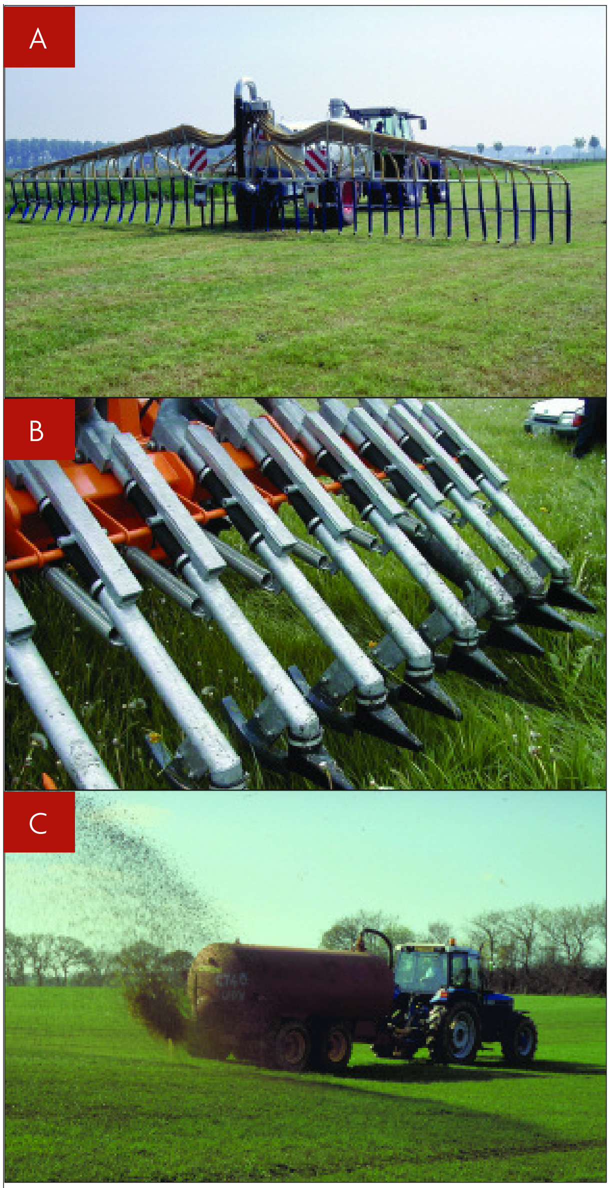


Figure 5.1 Various means of applying slurry to grassland. A. Trailing hose; B: trailing shoe; C: surface broadcast spreaders

The key to minimising nutrient and pathogen transfers is to match nutrient inputs (via all sources) to crop requirements by applying them to appropriate soils and topography at suitable times of the year. However, these simplistic guidelines assume that there is: (1) robust knowledge of the nutrient, metal and microbial content and availability of organic resources; (2) known impact on soil function; up-to-date information on soil nutrient reserves; (3) adequate storage facilities to facilitate spreading at the most suitable time of year; accurate and appropriate spreading machinery; and (4) that this information is available to land users in an easily assimilated format. Without this knowledge and the appropriate strategies for management of organic resources, there is little chance of complying with the various EU Directives (Water Framework, Nitrates, Habitats, Bathing Waters, Freshwater Fish, Shellfish, National Emissions Ceiling).

Recent research

Taking the National Emissions Ceiling Directive as an example of a policy instrument driving research, the MFR team has been at the forefront in increasing our knowledge of the processes responsible for gaseous emissions, e.g., of NH_3, N_2O and methane (CH_4). Through a greater understanding of the factors that control these processes, we have developed and tested management practices to reduce such emissions. For example, we have demonstrated that by increasing straw use within cattle buildings by 25%, we can potentially reduce emission of NH_3 from the building by 55%. However, increasing straw use impacts on farm costs and feeding practicalities as the bedding height increases more rapidly (Figure 5.2).

Figure 5.2 IGER facility for quantifying gaseous emissions from housed cattle

(Figure 5.3) Compaction and covering solid manure heaps as a potential measure to reduce gaseous emissions

Recently, we have demonstrated the potential to reduce NH_3 and N_2O emissions from farmyard manure (FYM) stores by compacting them and covering with plastic (Figure 5.3). We hypothesise that these techniques reduce airflow, maintain anaerobic conditions and reduce temperature. The net result is reduced NH_3 volatilisation and nitrification of ammonium to nitrate, and reduced N_2O emissions. As a result, we were able to reduce emissions of NH_3 from 4.5% to 0.3%, and N_2O emissions from 2.3% to 0.7% of total N content.

Current research is testing the efficacy of different incorporation techniques to reduce NH_3 emissions following solid manure spreading to tillage land. Although ploughing is the most effective at reducing NH_3 at the emissions plot-scale, when operating at a field scale, a shallower incorporation technique such as spring tines or disc may be more effective at reducing NH_3 emissions from the whole field because of the higher work rates compared with ploughing (Figure 5.4).

The MFR team is responsible for collating new NH_3 emission data as well as animal and fertiliser census statistics to update the UK NH_3 emissions inventory on an annual basis. The current emissions ceiling for NH_3 is 297 kt / year, which may be achievable with the current trend in reductions of animal numbers. However, the emissions ceiling is being renegotiated, so it may become necessary to implement some of the mitigation measures that we have tested and developed in order to meet a reduced annual target.

Figure 5.4 Use of shallow incorporation to reduce ammonia emissions

The UK is committed to reducing its emissions of greenhouse gases, with all industries, including agriculture, expected to contribute to this effort. Much focus has been on quantifying the sources of emissions of N_2O and CH_4, e.g., from manure and fertiliser management, and ruminant livestock sources, respectively. However, until recently, little account has been taken of the source strength of N_2O and CH_4 emissions from 'unmanaged' components of the landscape of intensively-managed livestock production (viz. seepage areas of effluent from manure; poached and camping areas within grazed pasture, feeding/water trough areas, gateways/tracks and ditches (Figure 5.5). Preliminary data suggest that these areas could be significant sources of emissions because of large interactions between the physical, chemical, climatic and soil factors. There is potential to reduce emissions from these sites.

Figure 5.5A and B Potential sources of N_2O and CH_4 emissions on farms, poached areas and around gateways and seepage areas around silage clamps

Understanding decay processes of organic materials is key to developing sustainable strategies for their use. Such processes begin as soon as organic resources are generated. For example, decay of specific proteins results in emissions of characteristic and specific non-methyl volatile

Figure 5.6 Odour sampling at a mushroom composting site

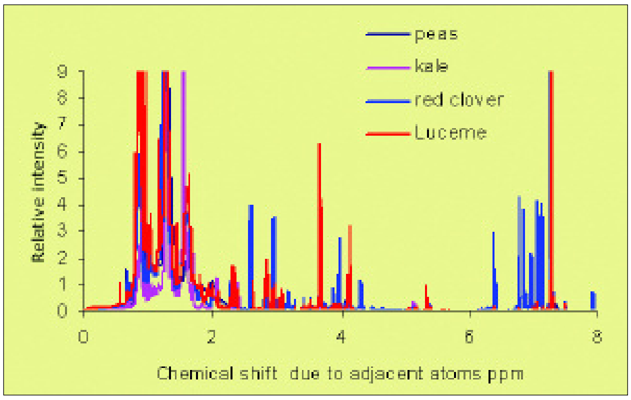


Figure 5.7 Differences in the NMR spectra of faeces from sheep fed different forage silages

organic compounds (NMVOCs) which can be used as indicators of decay rates and thus surrogates of the decomposition environment. We have used NMVOC emissions as indicators to optimise management of mushroom composts and reduce the odorous nuisance (Figure 5.6).

In a different context, we are using a variety of advanced analytical techniques to build a comprehensive database on faecal biochemistry from which we are establishing relationships with, for example, animal diet. This faecal-omics approach has been employed initially on faecal samples from a feeding trial with sheep on five contrasting diets (kale, red clover, lucerne, peas and ryegrass – Figure 5.7). Initial results demonstrate that the faecal chemo-metrics can be used to separate out the faeces from contrasting sheep diets. The methodology is being refined for use with faeces and urine from dairy cattle fed a range of reduced crude protein diets, and we intend to develop the approach to quantify feed intake of different plant species as well as to indicate animal health status.

Organic resources and grazing livestock are also important sources of faecal indicator organisms (FIOs – Figure 5.8). We co-ordinate a project collaborating with social scientists at the University of Exeter and hydrologists and experts in contaminant transfer at the University of Lancaster, which forms part of the Rural Economy and Land Use Programme. This project aims to evaluate the impact of management practices to control the risk of FIO transfers from grazing livestock, manures and other waste streams on economics and practicalities at the farm level and the 'knock-on' effects of such decisions on local communities and industries reliant on clean water supplies.

Where next?

Finally, the economic reality of managing organic resources cannot be ignored. Farmers are being asked to deliver good quality, safe and affordable food produced with a high degree of animal welfare. The by-products of this food production are large volumes of various organic resources and our challenge is to exploit these organic resources using appropriate technology. Other waste streams from non-food processing (e.g., paper production) are also contributing to the loadings of organic matter, nutrients, etc. to land. The costs of this increased level of management will need to be borne by somebody, which inevitably means the consumer. Hence the onus is on researchers to develop, test, validate and demonstrate low-cost solutions where possible.

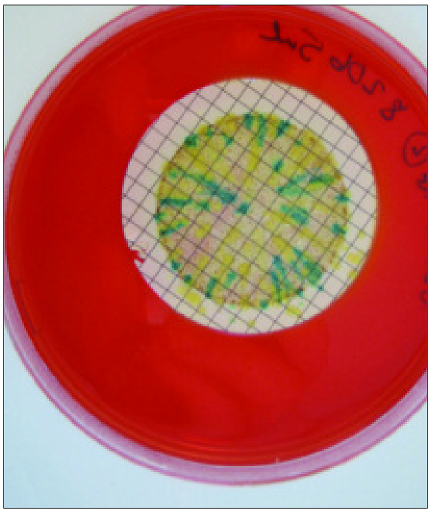


Figure 5.8 Agar plate with faecal indicator organism colonies

Future research efforts will focus on the following:

- Better characterisation of organic resources for nutrients, heavy metals, pathogens and veterinary/medical compounds.
- Greater understanding of nutrient release from organic resources will allow land users to take into account to a larger extent the nutrient supply in their fertiliser strategies.
- Dealing with nutrient surpluses: restricted spreading, export to more suitable land, or treatment to remove nutrients, e.g., aeration to denitrify N, or P concentration and removal by microbial uptake/release followed by crystallisation.
- Co-composting high C:N organic resources with low C:N organic resources (e.g., paper waste with poultry manure).
- Optimising biogas generation from a range of organic resources for heat and power production (Figure 5.9). Research is required to optimise the substrate / microorganism interaction to increase biogas generation and reactor performance through an increased understanding of organic resource characterisation and hence stream mixing, as well as better process control through new sensor technology linked to predictive software.

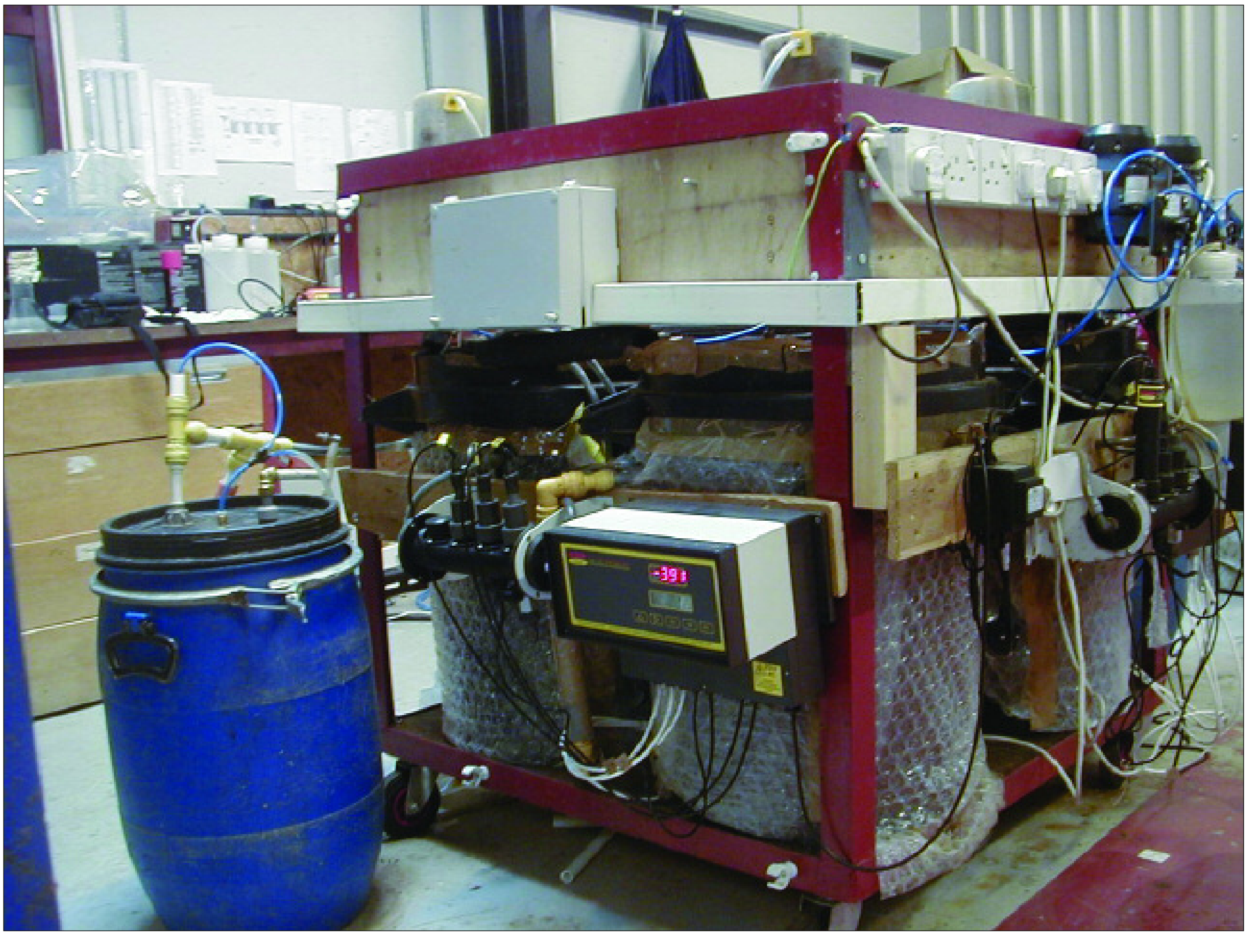
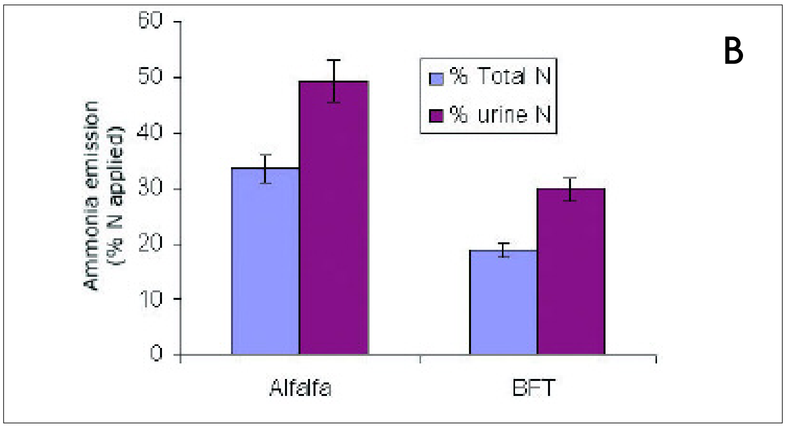


Figure 5.9 Experimental biogas generation

Figure 5.10 A: Equipment for quantifying NH_3 emissions from excreta
B: Reduced NH_3 emissions from excreta of animals fed bird's foot trefoil (BFT) compared with alfalfa. Condensed tannins (present in BFT but not alfalfa) protect plant protein from rapid rumen digestion resulting in enhanced protein utilisation and reduced N excretion



- Optimising feeding and foraging strategies to reduce nutrient content of manures and subsequent gaseous emissions from the resulting manure (e.g., NH_3 – Figure 5.10) or from the rumen (CH_4).
- Optimising the rates and timing of manure applications to maximise crop N offtake and minimise N losses, with attention given to potential 'pollution swapping'.
- Continued research to minimise nutrient and FIO mobilisation and loss to the environment.
- Improving our understanding of pathogen survival in manure stores and following manure application to land or excretal returns from grazing livestock, resulting in the development of mitigation practices.
- Developing guidelines for managing and prioritising organic resource applications based on appropriate field- and catchment-based risk assessments to avoid applications to vulnerable soils at the wrong time of year. Vulnerability in this respect can refer to both those land areas with high connectivity to watercourses and soils which have been perturbed to such an extent (e.g., through heavy metal accumulation) that their function has been damaged.

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