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IMPROVING MANURE NUTRIENT MANAGEMENT TOWARDS SUSTAINABLE INTENSIFICATION IN CHINA[1]

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Key Messages

- 3060 million tonnes (fresh weight) of livestock manure was generated in China in 2010. The N, P_2O_5 and K_2O content of these manures is estimated to represent *ca*. 14 million, 10.2 million and 12.0 million tonnes respectively, which worth *ca*. 201,300M RMB;
- Manure is commonly over-applied to horticultural crops, particularly greenhouse vegetables and fruit, which causes negative environmental impacts;
- The barriers for effective management of manure, compost and digestate include lack of labour to transport and apply to the field; lack of knowledge of the nutrient content and availability; and inadequate labelling of e.g. composted manure products;
- The pathways for improved manure nutrient management include:
  - Retaining nutrients through the manure management continuum
  - Using an integrated nutrient recommendation system
  - Generating knowledge of the nutrient content and nutrient availability of manure, compost and digestate
  - Ensuring CAFOs have manure nutrient management plans for utilisation in the local area (planning regulations)
  - Encouraging and incentivising improvements in other infrastructure, e.g. to facilitate mechanised transportation and spreading of manures

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INTRODUCTION

Traditionally farmers in China have relied on organic manures to build the organic matter content in soil and to fertilise crops for both human and livestock consumption. For example, in the 1950's nutrients from organic manures supplied over 90% of the total nutrients applied to farmland. However, with requirements to increase food production, policies to increase fertiliser production and promote their use have resulted in manure nutrients no longer being used to their potential.

There is already clear evidence of overuse of nutrients, via fertiliser and manure inputs, in some parts of China and this is causing undesirable impacts on the environment. With the increasing demand for livestock products, an integrated approach to nutrient management (i.e. use of soil, crop residue, manure and fertiliser supplies) is essential, to safeguard the environment, reduce the requirement for inorganic fertiliser production and use, and improve farmer incomes.

The SAIN project, *A review of manure use in China,* collated national data on livestock numbers and current manure management practices, as well as generated regional information on contrasting manure management from three different provinces. The project also estimated the effects of future demand for livestock products on manure generation and identified barriers to current efficient manure nutrient utilisation in China. Knowledge and communication gaps were also identified. In this policy brief we use the outcomes of this SAIN funded project to assess the challenge of improving manure nutrient management, in a country with an increasing demand for livestock products, at a time when sustainable agricultural intensification is required.

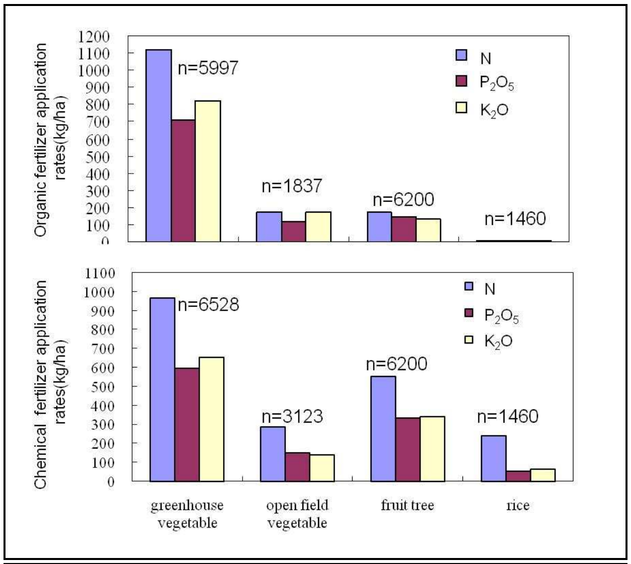
THE CURRENT SITUATION

Livestock numbers have increased dramatically in recent years in China, and so has the quantity of manure that they produce. It is estimated that ca. 3060 million tonnes (fresh weight) of livestock manure was generated in 2010 by Chinese livestock and was available for spreading to land. A recent survey (2007 data) has suggested that almost 20% of manure is 'wasted' and not applied to land, with implications for water quality. Of the remaining 80%, ca. 26% was composted and 8% used for biogas generation prior to spreading. The remainder (66%) was spread direct to land. A range of subsidies have meant that much more livestock manure is managed via the digestion and composting route, and will continue to do so. The composting of faecal solids, followed by pelletizing and placing into labelled bags for selling to farms some distance from the point of manure generation is a model that is currently being adopted, especially if linked with large concentrated animal feeding operations (CAFO's), which have become decoupled from agricultural land. Biogas generation with livestock manures is also becoming a dominant treatment in CAFO's.

The total nitrogen content contained in these livestock manures each year is in excess of ca. 14 million tonnes, compared to the 32 million tonnes of manufactured N fertiliser. The P_2O_5 and K_2O content of these manures is estimated to represent ca. 10.2 million tonnes and 12.0 million tonnes per year, compared to the 11.5 million tonnes and 7.5 million tonnes of inorganic fertiliser, respectively. At 2012 prices for N, P_2O_5 and K_2O, the total nutrient value of this manure resource is worth ca. 201,300M RMB per year (based on 5.4, 5.5, 5.8 RMB per kg N, P_2O_5 and K_2O, respectively). Although not all of these nutrients are wholly available to crops in the following growing season, livestock manures represent a huge potential source of nutrients, which farmers have already paid for in terms of the costs of livestock feeds, and the labour involved in rearing the livestock. It therefore makes sense that this source of nutrients is used effectively for crop growth.

There are numerous examples of over-application of manure nutrients, especially to soils where high value products are grown, e.g. in vegetable greenhouses. Figure 1 illustrates rates of nutrient inputs via chemical and organic fertilisers into different cropping systems. These data come from Yan (unpublished), Lu (2009) and Li (2009). It is clear that rice receives much lower nutrient application rates, and nearly all of these nutrients are supplied by inorganic fertilizers. Whereas for greenhouse vegetables >50% of the nutrients supplied come from the manures. For open field vegetables and fruit, manure applications supply ca. 40-50% and 20-30% of the total nutrients, respectively.

Figure 1. Nutrient applications to different cropping systems via manures and inorganic fertilisers. (source: Yan (unpublished), Lu (2009) and Li (2009))



There are implications of the overuse of manure nutrients on the environment. For example, the large losses of ammonia followed by deposition can result in soil acidification, eutrophication of lakes and terrestrial systems, and re-emission of nitrous oxide (indirect losses). Ammonia emissions are also associated with particulate formation in the atmosphere with implications for human health.

Injudicious use of manures can also result in nutrient accumulation in soil (especially nitrogen and phosphorus), which increases the risks of nitrate leaching and transfers of nitrogen and phosphorus to water where eutrophication can result in algal blooms, such as those seen in Lake Tai Hu, and asphyxiation of aquatic life. Any loss of nitrate from soil also represents an indirect loss of nitrous oxide. There may also be increased risk of pathogen transfers from manures to watercourses.

An improvement in manure nutrient management would reduce the risk of these environmental impacts. Also an increase in manure nutrient use efficiency would reduce the reliance on chemical fertilisers, both reducing the greenhouse gas emissions associated with the production and utilisation of those fertilisers, and improving farmer incomes.

CURRENT BARRIERS

Provincial survey data show that one of the main barriers to effective utilisation of manure nutrients is the shortage of effective labour. Transporting manure from the point of generation to the field is one issue, whilst the application of manure to the field is another. The increasing number of farmers working off-farm (e.g. in cities), has exacerbated this labour issue, since it also influences the timing of applications to suit the time when the farmer is back in the household, and not the agronomic demand for nutrients.

Another factor influencing the effective use of manures is the lack of knowledge of the nutrient content and availability of nutrients. For example, the database of manure nutrient content currently used in China is out-dated. Although it is published annually, data date back to 1994. Livestock diets, especially in CAFOs have changed over the past decade, and hence the manure nutrient contents will also have changed. Also, labelling of composted (and often pelletised) livestock manure is inadequate, with the total manure nutrient content often stated, i.e. the total of $N+P_2O_5+K_2O$. This is not helpful for an advisor or farmer wishing to match the manure nutrient supply to crop requirement for the separate macro-nutrients.

FUTURE CHALLENGES FOR MANURE NUTRIENT MANAGEMENT IN CHINA

Increasing demand for livestock products fuelled by a change in dietary preference and a growing human population is anticipated to generate an additional ca. 1,000 million tonnes livestock manure per year by 2030, resulting in even greater quantities of manure nutrients to be managed. With the increasing proportion of livestock already being reared in confined animal feeding operations (CAFO's), most of these additional manure nutrients are likely to be generated in CAFO's in peri-urban areas. The challenges facing China include how to manage this growing quantity of organic resource in a sustainable way, and how regulation and planning could be used to ensure that new and expanding CAFOs collect all the effluent produced and that their geographical position is optimised and coupled with a sufficiently developed infrastructure to ensure effective utilisation of the manure nutrients generated, i.e. ensure that there is sufficient 'land-bank' for the sustainable use of the manure nutrients.

China is providing subsidies to stimulate the growth of both biogas generation from livestock manures, and composting of faecal solids. Whilst these treatment technologies appear to be a responsible approach to utilising both the energy potential and nutrients of livestock manures, there remains some doubt to the current level of attention paid to the environmental losses that arise from large composting factories and CAFOs, and the fate of the liquid effluent, as well as the ultimate best practices for the use of digestate (the slurry left after the anaerobic digestion process).

GAPS IN KNOWLEDGE AND COMMUNICATION AND IMPACTS ON POLICY AND RESEARCH

- From a policy and planning perspective, it makes senses that some form of responsibility should lie with the CAFO, composting factory and anaerobic digestion plant to demonstrate that a) all effluent is collected and stored, and b) that the manure nutrients generated can be utilised efficiently on the land area and farms that are targeted to receive those manures. To make this simpler for the planning authorities, a tool is required to determine the potential crop nutrient requirement and hence suitability of land in the region around the CAFO to receive and utilise the manures safely, based on land use, soil type, existing manure nutrient inputs and transport distances. Such a tool could also be used to assist in the strategic planning for the siting of centralised anaerobic digestion plants. From a research context, there is little known about the nutrient budgets of CAFOs and large composting factories, so a programme of research to better understand the fate of nutrients, identify loss pathways and develop management practices to reduce them, is much needed.

- National data on manure nutrient content are outdated, dating back to 1994. Feed management and manure management (solids separation, anaerobic digestion, storage conditions) has changed considerably over the last 15 years, especially in CAFO's, hence manure nutrient composition could be very different now. A strategic campaign of manure nutrient analysis, perhaps coupled with some of the existing programmes on soil and fertiliser testing, would provide much required new data. This should be reviewed every 3-4 years, as the data-base expands.
- At land spreading, what seems to be lacking is an integrated recommendation system for manure and fertiliser nutrients for the range of key crops grown throughout China. The UK has a relatively mature and sophisticated nutrient recommendation system (now in its eight edition), which has benefited from decades of research. Advice in the UK is based on the nutrient requirements of crops. Thus an emphasis is put on all key sources of nutrients, such as the soil, crop residues, manures and fertilisers, to satisfy the crop demand. It is not clear that this is the case in China. We would recommend that an integrated programme of research is put into place to collate existing information and conduct new studies to fill gaps in knowledge, to enable an integrated nutrient recommendation system to be developed for key crops, to take account of the nutrient supply from different sources, as effected by the range of climate, soil types, application timing and sue of irrigation.
- It is clear that despite farmers being aware of the value of manures as sources of nutrients, over-supply still occurs. This is particularly so for fruit and vegetable producers, where the high cash value of their crops means they will not risk the potential loss in yield through under-supply of nutrients. In such cases, total loading rates of N can exceed 1,000kg/ha (through manures plus fertilisers). Further research is required to better understand how nutrient balances can be restored in such systems, and how manure nutrients can be utilised efficiently alongside requirements for irrigation water.
- Provincial survey data show that one of the main barriers to effective utilisation of manure nutrients is the lack of labour. Transporting manure from the point of generation to the field is one issue, whilst the application of manure to the field is another. Perhaps through incentives for 'land-linking', areas of land will increase to the extent that mechanised manure spreading would become financially feasible, and indeed offer the opportunity for the generation of some small specialist service providers for manure spreading (similar to the maize planting and harvesting). The small unit of land area for most Chinese farms means that the purchase of spreading equipment is not cost-effective. Availability and cost of livestock manure is also a limiting factor in its use in some regions.
- A project is required to develop and test different spreading equipment e.g. for solid and liquid manures, basal applications (incorporation) and potentially some limited applications to growing crops via top dressing, and determine how they can be used to increase manure nutrient use efficiency for the main crop types in China. Once successfully developed, the equipment would need to be demonstrated.

Perhaps this proposal could be linked to the potential Low Carbon Zones project in China (if it is to include agriculture). This proposal could also be linked to a similar proposal on spreading machinery for fertiliser products.

- Many farming households now earn much of the family income from off-farm sources, meaning that the application timing of manure and fertilisers has to fit around the times when farmers have returned to the farm. This is not conducive to effective management of nutrients (manures and fertilisers) on their farm. This is a difficult socio-economic challenge to address, but incentives to retain an able and informed farming population on farms has to be a key objective.
- China has the huge challenge of disseminating advice and guidance on manure nutrient management to several hundred million farming households. The question is, how can this be best achieved? It would appear that the Extension Service has lost it's focus in recent decades. There is still a role for a modernised Extension Service where officers are trained and updated with new research messages. But other knowledge exchange approaches should be investigated, e.g. use of farmer field schools to demonstrate best manure management practice. However, with the increase in the number of CAFOs being planned throughout China, there could be a real benefit from industry involvement in both the development of integrated nutrient guidelines and their promotion to farmers.