

Policy Brief No 1

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Improved Nutrient Management in Agriculture

– A Neglected Opportunity for China's Low Carbon Growth Path¹

The opportunity

China and the UK are committed to achieving a low carbon economy and slowing down climate change. Low carbon agriculture can make a significant contribution to these objectives at less cost and more quickly than other sectors of the economy yet this opportunity has not been included in recent proposals for achieving low carbon growth. One of the most critical actions is to improve nitrogen management, and particularly to stop the current widespread overuse of synthetic nitrogen fertilizers, which is the main reason why China is probably responsible for >30 % of global emissions of nitrous oxide – the most powerful of the agricultural greenhouse gases causing climate change. The manufacture and use of synthetic nitrogen fertilizer is estimated to have accounted in 2007 for about 10% of fossil energy use by the industrial sector. It is now the source of about 8% of China's total greenhouse gas (GHG) emissions as well as contributing to acid rain, water pollution, and the increasing frequency of red tides. A large proportion of these negative impacts can be reduced because there is indisputable evidence from some of China's leading scientists that there is widespread 30-60% overuse of nitrogen fertilizer on crops. This overuse accounts for about 10-15% of total GHG emissions from agriculture. Tests on thousands of farmers fields across China show that fertilizer application rates could be cut in many situations by at least 30%, with no loss of crop production or risk to national food security. Such a decrease in overuse could reduce China's total GHG emissions by >2% and nitrous oxide emissions by 30% or more within about 10 years – with the potential for even larger savings in the longer term. Improved N management is a clear win-win action with economic and environmental benefits at all scales from the local (e.g. higher net farm incomes) to the regional and global (e.g. reduced pollution of the

¹ This briefing note was prepared primarily by David Norse, UCL based on the findings of the China-UK Project "Improved Nutrient Management in Agriculture-a Key Contribution to the Low Carbon Economy". The project is funded by the UK's Foreign and Commonwealth Office and by China's Ministry of Agriculture. It is led by Prof Zhang Fusuo, China Agricultural University, Beijing and Prof David Powlson, Rothamsted Research, UK. The project forms part of the China-UK Sustainable Agriculture Network – SAIN (see www.sainonline.org).



China Sea and lower GHG emissions). The required policy actions are multi-sectoral, and could begin immediately. Although implementation of these policy actions could take several years much could be achieved by 2020. It is feasible to reduce the carbon intensity of grain and vegetable production in China by >2% per year from 2010 up to 2020 and beyond thereby making a significant contribution to the plans for an overall reduction in carbon intensity by 2020 recently announced by the State Council. It is therefore important that high priority is given to formulating China's programme for low carbon agriculture since the State Council's plans do not currently include the major reduction in carbon intensity that agriculture could provide.

The wider case for action

The substantial growth in the use of synthetic nitrogen fertilizer in China since the 1970s has provided major economic and social benefits in terms of higher farm incomes, improved food consumption and the maintenance of national food security. Consequently China is now the largest producer and user of nitrogen fertilizer in the world. In 2007, agriculture and the agro-chemical industries accounted for over 10% of China's total fossil energy use and 19-22% of total GHG emissions (Table 1). The largest fossil energy input to China's agriculture is that used to manufacture nitrogen fertilizer (about 70%). It is mainly coal (and some natural gas) burnt in factories that do not use the best available technologies so energy efficiency tends to be low and carbon dioxide and other GHG emissions are high. Moreover, most of this fertilizer is used inefficiently with average grain yields per unit of fertilizer being considerably less than those obtained in the UK and other developed countries. The main cause of the low fertiliser use efficiency is the widespread overuse of nitrogen (from manufactured fertilisers and livestock manures) on grain and vegetable crops with farmers commonly applying 30-60% more nitrogen fertilizer than required to obtain optimum yields.

Table 1 Agriculture's contribution to China's energy use & GHG emissions in 2007 (Mt CO₂eq)

Source	Fossil energy (Mt sce*)	CO ₂	Methane	Nitrous oxide	Total
N fertilizer production & transport (43 Mt)	117	235	26	13	274
P&K fertilizer production & transport		18			18
N fertilizer use for crops (32 Mt)		57	(170 rice**)	176***	233(403)
Other agricultural uses (3-5Mt)		15-25		15-25	30-50
Livestock – enteric & manure			295-443	172-258	467-701
Direct fossil energy inputs to agriculture	82	190			190
Total agricultural emissions		515-25	491-639	376-472	1382-1636
Total economy emissions	2656	6,000			7,230
Agricultural emissions as % of total national emissions					19-22

*sce= standard coal equivalent; ** not closely N related ***Conservative estimate for indirect N₂O emissions

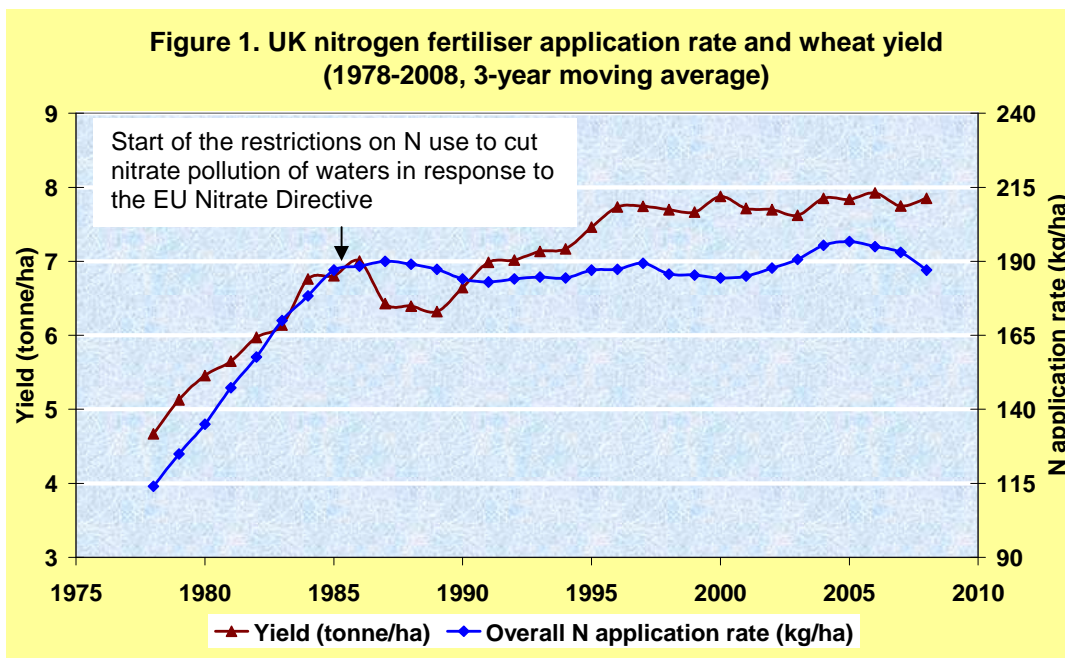
Overuse stems largely from inadequacies in the mechanisms to supply farmers with correct information on improved nutrient management, although there are other constraints such as poor fertilizer quality, lack of soil testing facilities and limited progress in developing modern fertilizer technologies. The overuse has a number of serious environmental and economic impacts.

The most serious environmental impact concerns greenhouse gas (GHG) emissions. Much of the excess nitrogen is lost to the environment as gases or in water draining from the soil. The most serious gas is nitrous oxide which is 298 times more powerful than carbon dioxide in terms of global warming. But large amounts of ammonia gas are also lost from fertilizer and manure. Much of this is re-deposited onto land, contributing to acidification of soil and waters and becomes an important source of indirect nitrous oxide emissions from lakes and rivers. The nitrogen lost from soil as nitrate is one of the major causes of nitrate contamination of drinking water supplies and of eutrophication, algal blooms and red tides in lakes and coastal waters. Losses of nitrate also represent significant indirect losses of nitrous oxide.

The negative socio-economic impacts include those on human health, on the profitability of fish farms damaged by eutrophication, and most directly on the net incomes of farmers. Synthetic nitrogen fertilizers account for about 25% of farmers total grain production costs and up to 40% or more of their non-labour costs, therefore 30-60% overuse of nitrogen fertilizer represents a significant reduction in their net incomes.

It follows, therefore, that one of the key actions to achieve low carbon agriculture in China is to reduce inefficiencies in the production and use of nitrogen fertilizer. Fortunately, field trials in China over many years, crops and provinces show that the overuse of N fertilizer and other causes of low fertilizer use efficiency can be reduced substantially through improved nutrient management techniques that allow farmers to apply less nitrogen fertilizer without lowering yields and therefore without endangering national food security. Further evidence that N use can be lowered without risk to farm incomes or food output comes from a network of long-term fertilizer experiments in some of China's main grain producing provinces. They show that N application rates can be lowered by 20-30% below those commonly used by farmers for over 15 years with no decline in yields. The UK's experience is very relevant in this respect. The overuse of synthetic nitrogen fertilizers was common in the UK in the 1970s and early 1980s with serious environmental consequences. Since then policy and regulatory changes have brought about improvements in nutrient management and agricultural technology which have allowed application rates of synthetic nitrogen fertilizer to stop increasing or decline slightly (depending on the crop) whilst wheat yields have risen from 6 to >8tons/ha (Figure 1).

Agriculture's environmental problems are not restricted to crop production. The rapidly expanding livestock sector is also a major source of GHGs (largely methane and nitrous oxide) and of ammonia, and is a serious cause of water pollution. However, there are a number of opportunities for improved manure management, particularly those relating to biogas production, which can make a major contribution to low carbon growth, GHG emission reduction and water pollution control as well as supporting improved fertilizer nutrient management by increasing the availability of organic fertilizers.



The magnitude of benefits

Agriculture's contribution to low carbon growth could take five main forms:

- 1) reduction of nitrogen fertilizer overuse per se;
- 2) improvements in fertilizer management regarding the timing and placement;
- 3) reduction of emissions by the greater use of slow-release fertilizers and N inhibitors;
- 4) improved management of manures and replacement of some synthetic fertilizers with organic fertilizers;
- 5) increased biogas production.

The changes in fertilizer management could bring benefits immediately. Improvements in the efficiency of manufacturing N fertilizer and the use of less polluting fertilizers could begin to deliver benefits within only a few years. Improvements in efficiency of N utilisation by crops, through breeding and selection, could be significant but will require longer periods (perhaps 10 years at least) to deliver benefits.

These contributions could be quite large. In 2007 synthetic N fertilizer production and transport in China needed about 117 Mt coal equivalent and N fertilizer use accounted for > 70% of fossil energy inputs into crop production. Consequently actions to limit the current 30-60% overuse of fertilizer N would make a major contribution to the achievement of a low carbon economy and GHG reduction. For example, even a 30% reduction in N fertilizer use if translated into an equal reduction in the production and transport of fertilizer would reduce energy use by some 34 Mt coal equivalent and lower emissions of CO₂, nitrous oxide and other GHGs by over 150 Mt CO₂ eq. as well as reducing acid rain, water pollution, red tides and boosting farm incomes. Moreover, because the reduction in fertilizer use will be achieved largely through improved nutrient management it will not interfere with any climate change mitigation through increased carbon sequestration in China's cropland. This carbon sequestration could be some 20-30 Mt C (70-110 Mt CO₂ equivalent) per year although this rate of gain will slow down in the longer-term as soils

reach a new equilibrium value. The benefits of improved synthetic fertilizer N management will be expanded as a result of the Chinese government's support for (a) increased use of organic fertilizers which could lower synthetic nitrogen fertilizer needs by about 30% by 2020 and (b) greater biogas generation from livestock manures which could provide renewable energy equivalent to about 50 Mt of coal and reduce GHG emissions from livestock wastes by around 50% by 2020 if correctly managed. In addition, biogas residues can be used as a source of nutrients for crops, replacing some demand for fertilizers – though careful management of nutrients from these residues is required to maximise efficiency of use and minimise loss.

The economic benefits are equally significant. At the farm level they include a 5-10% increase in net incomes because of the reduction in costs of production. At the national level they provide one of the lowest cost routes to a low carbon economy. In many sectors of the economy the abatement costs are up to 600 Yuan (55-60 GBP) per tonne of carbon eliminated, whereas most of those described above for agriculture have negative abatement costs because of the high economic as well as the environmental benefits they provide.

The global benefits would be equally significant. China accounts for about 33% of world N fertilizer production and 32% of global N fertilizer use. Using IPCC values for direct and indirect nitrous oxide emissions from fertilizer use suggests that in 2007 China was responsible for >30% of global nitrous oxide emissions from fertilizer. However, given (a) the high applications and low use efficiency of N fertilizer in China, (b) the evidence that although some emission coefficients in China are probably lower than the IPCC values others may be significantly higher, and (c) China's large and rapidly growing livestock is also a major source of GHGs, then China could be responsible for 30-40% of global nitrous oxide emissions from agriculture. Thus, even a 30% reduction in the production and overuse of N fertilizer in China and the consequent decline in GHG emissions would be an important contribution to global climate change mitigation. Furthermore, additional reductions in GHG emissions can be achieved through the diverse opportunities for raising the technological efficiency of N fertilizers by both chemical (for example, slow release formulations) and physical means (for example, drip irrigation), and through changes in timing of applications and improved utilization of N in manures.

The way forward

Chinese scientists have made considerable progress in devising improved N management practices to limit N overuse, but uptake by farmers has been limited by technical, institutional and socio-economic factors. Some of these factors are now being addressed and there are other technical and policy opportunities that could be developed. Restructuring and technological upgrading of the N fertilizer industry is another option but it will face a number of economic constraints that may not be easy to overcome.

The UK used to suffer from serious nitrogen mismanagement but national and EU environmental legislation has forced farmers to be more efficient, and British natural and social scientists have extensive experience of technological and policy research to overcome these problems. They are now sharing this experience with their Chinese colleagues and helping them to adapt successful technological and policy measures from the UK to China's unique situation through a three year joint project launched in April 2009. This project is part of the wider programme of China-UK collaboration on sustainable agriculture organised through the China-UK Sustainable Agriculture Innovation Network (SAIN) and the China-UK Sustainable Development Dialogue. The main objectives are to (a) produce more comprehensive information on the carbon intensity of agricultural production, and (b) help China's national and provincial policy makers to formulate and implement measures to improve nutrient management, lower direct and

indirect GHG emissions and slow climate change. The focus is on synthetic nitrogen fertiliser use for crops, but the project is also considering the links between crop and livestock production and the potential for improved manure use and organic fertiliser production. Specific aims are given in Box 1.

Box 1 Specific aims of the project include:

- Application of life cycle assessment to the manufacture and use of N fertilizer in China to identify the best opportunities for improving nitrogen productivity and lowering the carbon intensity of food production.
- Review of current and emerging techniques for increased efficiency of N fertilizer use, building on results from the Ministry of Agriculture project "Fertilizer recommendations and soil testing".
- Review of current and emerging techniques for increased efficiency of use of manure and manufactured organic fertilizers and their role as substitutes for synthetic N fertilizers
- Assessment of improved ways of communicating to farmers, extensions workers and policy officials the multiple benefits of improved nutrient management, taking account of farmers' economic and social situations.

Preliminary recommendations

The project has already made significant progress because it has been able to build on the results of past national research and China-UK collaboration. The structure and carbon intensity of synthetic N fertilizer use and its contribution to China's GHG emissions are now well quantified. The scientific evidence on overuse has been complemented by work on farmer's fields to prove that fertilizer use can be reduced by 30-60% without reducing yields or endangering national food security. Thus it is now possible to start examining how this information may contribute to the formulation of a national strategy for low carbon agriculture, and how this project may contribute to or complement related ongoing or planned activities by other research groups to identify technological opportunities for mitigating China's agricultural GHG emissions

Conversion factors and data sources for Table 1

The table uses a conversion factor of 2.3 tCO₂/t standard coal equivalent and converts CH₄ & N₂O emissions to CO₂ equivalents using the latest IPCC GWP factors of 25 & 298

Rows 1-4 Estimates made using IPCC Tier 1 and Tier 2 approaches with two main data sources :Fusuo Zhang, Weifeng Zhang, Wenqi Ma, *et al*, .2009 "The Chemical Fertilizer Industry in China: A Review and its Outlook" International Fertilizer Association, Paris; and Pan He, Zhang, W., Ju, X., Zhang, F., Powlson, D., Norse, D., Lu, Y., and Chadwick, D. et al 2010, Carbon accounting of N fertilizer in China: From production to consumption (forthcoming).

Row 5 based on Chinese statistics and studies

Row 6 Estimates of Yan, X., Akiyama, H., Yagi, K., and Akimoto, H. 2009, Global estimations of the inventory and mitigation potential of methane emissions from rice cultivation conducted using the 2006 Intergovernmental Panel on Climate Change Guidelines, Global Biogeochemical Cycles, Vol. 23, with production data revised from 2000 to 2007.

Rows 7&8 FAO estimates for 2004 given in "Livestock's long shadow", FAO, 2008 updated to 2007 using NBS or FAO statistics for livestock numbers and milk output

Row 9 FDI, 2008 published by the Ministry of Commerce

Row 11 FDI, 2008 for energy use & assuming non-CO₂ emissions are 17 % of CO₂ emissions as in NDRC 2007/08.