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REVIEW PAPER

Agricultural Non-Point Source Pollution in China: Causes and Mitigation Measures

Bo Sun, Linxiu Zhang, Linzhang Yang, Fusuo Zhang, David Norse, Zhaoliang Zhu

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Abstract Non-point source (NPS) pollution has been increasingly serious in China since the 1990s. The increases of agricultural NPS pollution in China is evaluated for the period 2000−2008 by surveying the literature on water and soil pollution from fertilizers and pesticides, and assessing the surplus nitrogen balance within provinces. The main causes for NPS pollution were excessive inputs of nitrogen fertilizer and pesticides, which were partly the result of the inadequate agricultural extension services and the rapid expansion of intensive livestock production with little of waste management. The annual application of synthetic nitrogen fertilizers and pesticides in China increased by 50.7 and 119.7%, respectively, during 1991−2008. The mitigation measures to reduce NPS pollution include: correct distortion in fertilizer prices; improve incentives for the recycling of organic manure; provide farmers with better information on the sound use of agro-chemicals; and tighten the regulations and national standards on organic waste disposal and pesticides use.

Keywords Non-point source pollution · Synthetic nitrogen fertilizers · Organic manure · Agricultural policy · Mitigation strategy

INTRODUCTION

China is facing the challenge of feeding her large and increasing population with a limited and decreasing cultivated land while achieving a clean and safe environment (Fu 2008). After the onset of the green revolution in the 1950s, increasing inputs of inorganic fertilisers, organic manures and pesticides became the principal means globally and in China of attaining high-crop yields and, indirectly, greater livestock production (FAO 2008). Consequently, China is now the largest user of synthetic nitrogen fertilisers in the world. However, this agro-chemical-based intensive agriculture has contributed substantially to the emission of the very powerful greenhouse gases CH_4 and N_2O, and the entry of pollutants (excessive nitrogen and phosphorus, pesticide and heavy metals) into water bodies and soils (Smil 1997). These pollutants have adverse effects on environmental quality and public health, for example, eutrophication of lakes and streams, soil contamination by heavy metals and the accumulation of pesticide residues in food.

The response to these problems since the 1960s has been to shift agricultural policies and R&D programmes towards a more sustainable growth path. This has led to the development of many new techniques and integrated resource management practices that can mitigate the adverse effects of intensive farming on the environment (Conway 1994, 1997). However, controlling NPS pollution at the regional, national and local scale is a complex and difficult problem which can take decades to overcome, for example, reduction of nitrate pollution in the EU. This study analyses the reasons for increasing NPS pollution in China, then put forwards mitigation measures for NPS pollution control that are primarily for crop production and need to be complemented by other measures to control NPS pollution from the livestock sector.

STATUS OF NON-POINT SOURCE POLLUTION FROM CROP PRODUCTION IN CHINA

Water Pollution from Crop Fertilization

Water bodies in China have become seriously polluted since the 1990s and there have been no marked improvements in recent years. China has 4880 lakes, covering a

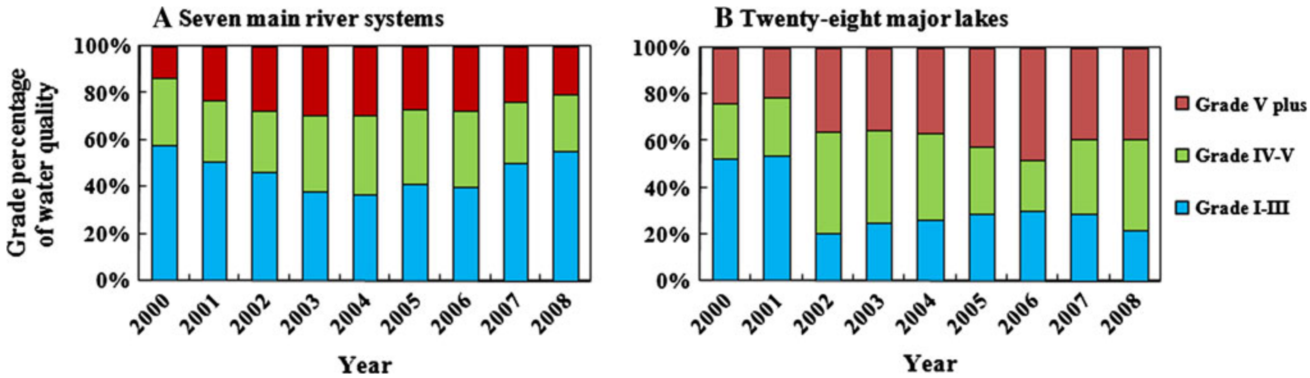

Fig. 1 Water quality in (**a**) seven main river basins and (**b**) 28 major lakes (% in different grades)

total area of 83 400 km^2 and accounting for 0.8% of the country. According to an evaluation of eutrophication in 131 major lakes in 2000, about 50% of them were eutrophic (Yuan 2000), and for 75% of these lakes the eutrophication is getting worse. Over half of the rivers and about two-thirds of the lakes in the seven river systems and 28 major lakes were assessed to be of poor quality (Grade IV and above[1]) during 2000−2008 (Fig. 1) (SEPA 2000−2008). Lake eutrophication has been showing a rapidly increasing trend since 2000, with serious algal bloom crisis in Dianchi Lake in 2001 and in Taihu Lake in 2007 (Qin et al. 2007; Gao and Zhang 2010). Nitrogen concentrations in large rivers, especially the Yangtze and Yellow river, have been increasing in recent years (Li et al. 2007; Yu et al. 2010). The estuaries and coastal water near cities are seriously polluted, and the annual frequency of red tides has increased from 28 in 2000 to 68 in 2008 with a cumulative area of 13,738 km^2 (SEPA 2000−2008).

The NPS problem is not restricted to surface water bodies. The shallow groundwater in intensive vegetable growing areas generally suffers from very serious nitrate pollution. A survey of 16 counties in the Yangtse Delta region (i.e. Jiangsu Province, Zhejiang Province and Shanghai City) found 38% of the drinking water wells had a nitrate–N content > 20 mg L^{-1} (Zhang 1999). Another survey of 14 counties in three cities in North China (i.e. Beijing, Tianjin and Tangshan) found that 50% of the sampling sites had nitrate–N levels > 11.3 mg L^{-1} (the Europe Union limit for drinking water) in nitrate–N content—the highest reached 68 mg L^{-1} (Zhang et al. 1996). The national groundwater resources assessment in 2000−2002 showed less than 5% of the total resources of 350 thousand million m^3 per year suffered from serious pollution, so most of it could be used in agriculture and industry after the conventional treatment.[2] The shallow groundwater resources polluted by nitrate are mainly in the North China Plan, the Northeast Plain, the Jianghan Plain (in the middle reach of Yangtze River) and the Yangtze Delta region (Zhang and Li 2004).

Projections suggest that the future nitrogen surplus from crop production will increase from about 154 kg ha^{-1} in 2004 to 179 kg ha^{-1} in 2015, and hence the risk of non-point source pollution will increase (Shen et al. 2005). During 2005−2008, the high-risk area for fertilizer application included five coastal provinces and three municipalities in the east region and four provinces in middle region. There will be three more provinces (Hainan, Anhui and Hebei) and one municipality (Chongqing) facing high risks in 2020 if current policies and trends continue (Fig. 2).

Pollution from Pesticides

Long-term intensive application of pesticide has caused contamination of soil, surface water, groundwater and farm products. In the period 1950−1983, soil pollution was mainly caused by organochlorine pesticides (OCPs), with a total consumption of 4.46 Mt of Lindane (HCH) and 0.435 Mt of dichlorodiphenyltrichloroethane (DDT) in 33 years

[1] There are five grades in the national environmental quality standards for surface water (MEP 2002). There are 24 items to evaluate the water quality, such as pH, COD, BOD, N, P, heavy metal, petroleum, Faecal Coliform Bacteria, etc. From Grades I to IV, the threshold value for total N is 0.2, 0.5, 1.0, 1.5 and 2.0 mg L^{-1}, respectively. The standards also set limits for the content of different pesticide in surface water with the highest value of 0.08 mg L^{-1} for dimethoate.

[2] Conventional treatment for water includes physical and biological treatments. The solid pollutants are removed first by sand sedimentation; then the colloidal and dissolved organic pollutants (BOD, COD) are removed by biological treatment including the biological filter biofilm, biological dial, bio-contact oxidation and fluidized bed. Advanced treatment is to remove the refractory organic matter, nitrogen and phosphorus by biological nutrient removal, coagulation precipitation, sand filtration, activated carbon adsorption, ion exchange and electrodialysis method.

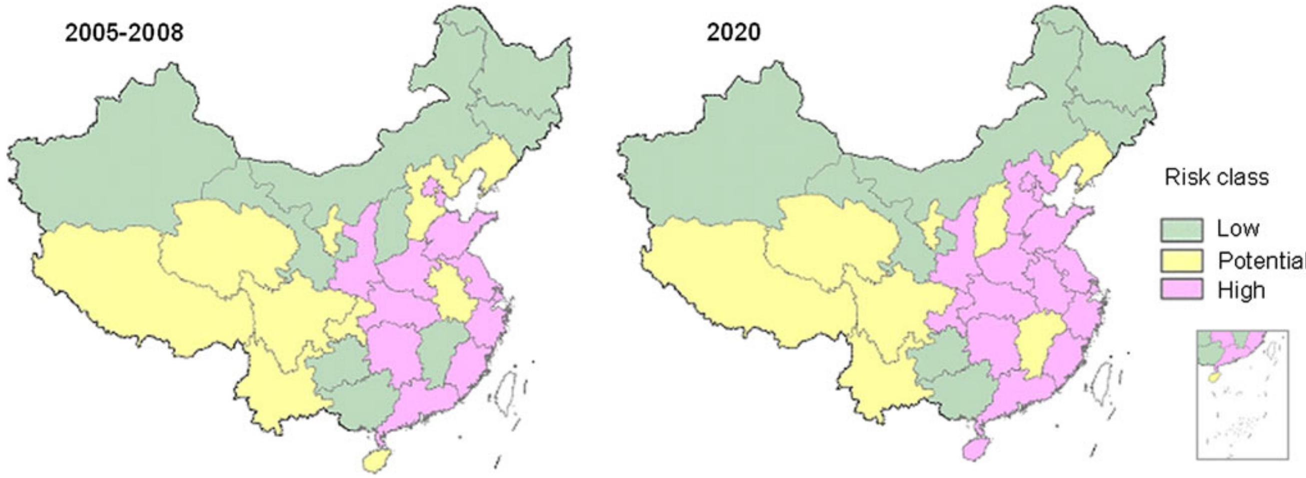

Fig. 2 Evaluation of the risk of NPS pollution within province from excess nitrogen application during 2005–2008 and in 2020. The risk of NPS pollution is evaluated by annual surface nitrogen balances which is the difference between N inputs and outputs for the agro-ecosystems within the province. The N inputs include synthetic single and compound N fertilizers, crop straw returned to the field, human and livestock manure, and biological N fixation by legumes. The N output is the crop N export by harvest. The potential and high-risk regions in China were identified as those with more than 100 and 180 kg ha^{-1} of surface N balance surplus, respectively. The N surplus is projected by non-seasonal Box−Jenkins model

before they were banned in 1983. About 14 million ha of farmland suffered from OCPs pollution in 1985, with a residual amount of 0.181−0.254 and 0.222−0.273 mg kg^{-1} for HCHs and DDTs in the surface soil, respectively (first grade limitation is <0.05 mg kg^{-1} in National Soil Environmental Quality Standards, GB15618-1995) (Lin et al. 2000). NPS pollution from pesticides is still serious in many regions although residue levels have declined since 1983. The average concentrations of DDTs and HCHs were 60 μg kg^{-1} (ND[3] ~2910 μg kg^{-1}) and 8.7 μg kg^{-1} (ND ~131 μg kg^{-1}) in 2000s, respectively. The regional differences were very large. The average concentration of DDTs in the soils of East China was 14- and 5-fold of that of South and Southwest China, while the ones of HCHs in South and Southwest China were 4- and 2-fold of those in North China (Cai et al. 2008).

A survey during 2003–2004 of 217 reservoirs and 406 rivers and lakes in seven major river basins revealed that surface waters in China also suffered from moderate pollution by OCPs (Gao et al. 2008). Lindane (γ-HCH) and *p,p*′-DDT were detected in 84 and 63% of sites, with a mean concentration of 0.0313 μg L^{-1} (ND ~0.860 μg L^{-1}) and 14.6 μg L^{-1} (ND ~0.368 μg L^{-1}), respectively. The concentrations of HCH in the rivers of northern China were usually higher than those of southern China. The surface water with the highest concentrations of HCH and *p,p*′-DDT occurred mainly in the Yellow River and Huaihe River basins.

[3] ND = Not detected at or above the method detection limit.

REASONS FOR NON-POINT SOURCE POLLUTION FROM CROP PRODUCTION IN CHINA

Huge Losses of Inorganic N Fertilizers from Cropland to Surface Waters

China's consumption of synthetic fertilizers has been increasing year by year since the early 1960s to feed her huge population from a limited area of cropland (Fig. 3); however, the growth of crop yields has slowdown since 1990 (EOCSSB 2009). China is now the largest producer and consumer of synthetic N fertilizer in the world. Total fertilizer consumption reached 52 million tonnes in 2008, that is, over one-third of world consumption. The national average annual application rate is about 230 kg N ha^{-1} cropland, which is the third highest in the world after Korea and Japan. In some provinces, the average is greater than 400 kg N ha^{-1} and in some counties over 1000 kg N ha^{-1} for the vegetable lands.

Fertilizer use efficiency of inorganic N fertilizer has been decreasing in China since the 1980s. The recovery ratio of N in the harvest crop decreased from 57% in 1979 to 43% in 1998, and the total loss of N increased by about two times (Wu 2005). This decline in nitrogen use efficiency has continued since 1998 and now is an issue for almost all cereal and vegetable crops and some tree crops. The national survey of pollution sources in 2007 showed that the total nitrogen loss from cropland was about 1 600 000 tonnes, in which some 320 000 tonnes was from surface runoff and >200 000 tonnes from underground

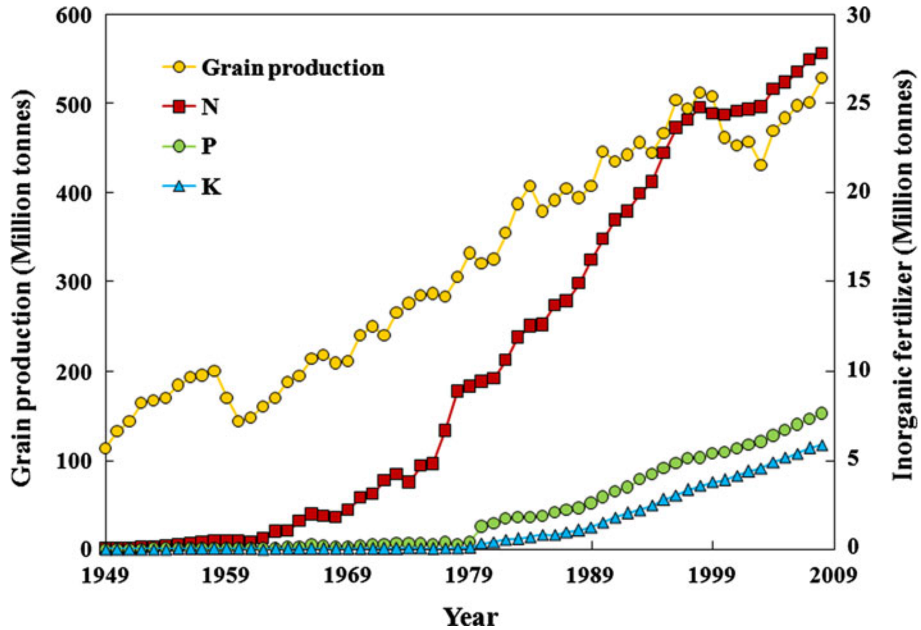

Fig. 3 Grain production and synthetic fertilizer consumption in China from 1949 to 2008

Table 1 Estimated N output from synthetic fertilizer N in three main river valleys in China in 1995

River name	Major regime			Nitrogen loss in river valley (million tonnes)			
	Length (km)	Drainage area (km^2)	Annual flow (10^8 m^3)	Denitrification in agricultural soils	N transported into water bodies	NH_3 volatilization	Total loss
Yangtze River	6300	1 808 500	9513	1.77–2.61	2.87	1.32	5.96–6.80
Yellow River	5464	752 443	661	0.24–0.53	0.65	0.17	1.06–1.35
Pearl River	2214	453 690	3338	0.39–0.49	0.62	0.29	1.30–1.40

leaching. The total phosphorus loss was much less at about 108 000 tonnes (MEP et al. 2010). Estimates based on field observations on the use of the main nitrogen fertilizers (urea, ammonium bicarbonate and ammonium sulphate) for the main cereal crops (rice, wheat and maize) and the key food production provinces of China (Zhu et al. 1997; Zhu and Chen 2002) indicated that in the 1990s the total loss of nitrogen fertilizer from crops to the environment was about 19.1%, of which 5% entered the surface water by runoff, 2% passed down to the groundwater by leaching, 1.1% entered the atmosphere through denitrification process (largely in the form of N_2O) and 11% through ammonia (NH_3) volatilization process. These national averages hide considerable regional and cropping system variation in N losses to the environment (Table 1) (Xing and Zhu 2002). For example, leaching losses can be far greater in the high-rainfall areas of southern China, and from irrigated intensive vegetable production, and are still increasing. A review of research on urea utilization efficiency showed that the average N leaching rate in North China was 2.1 and 2.7% of the total urea-N applied for upland and paddy field, respectively, while in South China it was 8.2 and 6.1% (Yang and Sun 2008).

Rapid Development of Intensive Livestock Production with Limited Treatment of Organic Wastes

Intensive livestock production has developed rapidly in China during the last two decades (Fig. 4) (EOCSSB 2009), leading to the generation of large amounts of organic wastes but the use of these wastes for the production of organic fertilizer has received little attention. In 2007, livestock and poultry farms produced 243 million tonnes of organic waste and 163 million tonnes of urine[4]; the total N and P discharge from animal excretion reached 1 024 800 and 160 400 tonnes, respectively (MEP et al. 2010). The N and P discharge in 2007 coming from human excreta of residents and livestock was larger than that from inorganic fertilizers application and has become the main cause of NPS in China. This happened because the lack of national waste discharge standards has led to no or inadequate waste disposal or treatment facilities in 90%

[4] The census includes 1 963 624 discharge sources from medium to large intensive units and do not include discharges from small producers.

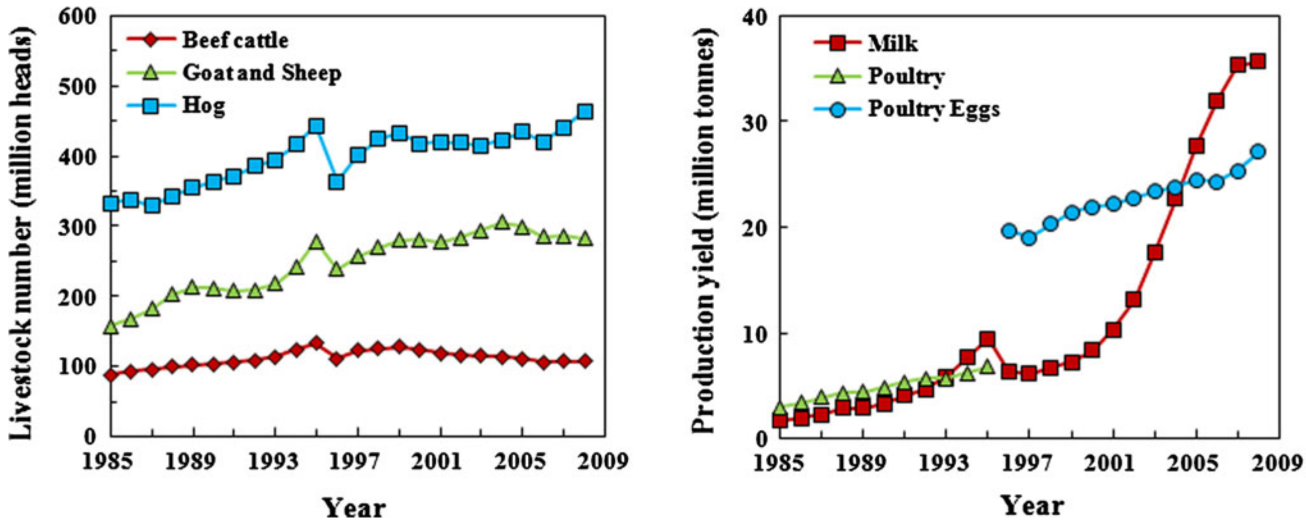

Fig. 4 Livestock number and milk and poultry production in China from 1996 to 2008

of the animal farms of China. At the national level, the proportion of animal wastes directly exported to water was 2–8% for solid wastes and about 50% for liquid wastes in 2002 (ECCEY 2003). The national average load of poultry manure in 2002 was 4.19 t ha^{-1} (based on the total cropland area), with the highest environmental risk of NPS pollution arising from this manure occurring in Shanghai, Henan, Tianjin and Shandong where the load >18 t ha^{-1} the medium level NPS risk was in Beijing, Jiangsu, Hebei, Anhui and Hunan where the average loads were between 5 and 18 t ha^{-1} (Wu 2005).

Increasing Use of Pesticides

China has been the world largest consumer of pesticides for more than 10 years (EOCASY 2002–2009) with an annual application amount of 1.67 million tonnes (active ingredient) in 2008 (Fig. 5). The average application rate of pesticide[5] in the east, middle and west part of China is 12.91, 7.26 and 3.43 kg ha^{-1} (active ingredient) in 2001, respectively, with a mean value of 8.19 kg ha^{-1} (ECCPDR 2005).

In 2000, insecticides, fungicides, herbicides and plant growth regulators accounted for 54.7, 25.3, 19.3 and 0.7%, respectively, of the total consumption (Lin et al. 2000). The organo-chlorine and organo-phosphorus pesticides accounted for over 39.4 and 37.0%, respectively, of total pesticide use. The highly poisonous organic phosphorus and aminoformin pesticides accounted for 67.0% of the total insecticides. Most of them were applied to vegetables, fruit trees and cereals (rice and wheat) (ECCPDR 2005). A large amount of pesticide enters directly into or is deposited on soil or is moved by wind drift to surface waters. The average pesticide-use efficiency was only about 30% of the total pesticide applied, which was caused by the over application, inadequate spray technology and poor mixing methods (Shao and Zhao 2004). The recovery of pesticide on the target plant was only 9–16% of the total sprayed to the wide-row crops, such as cotton and oil seed rape (Tu et al. 2003).

REASONS FOR UNSUITABLE APPLICATION OF FERTILIZER AND PESTICIDE

The Pressure for High Levels of Food Self-Sufficiency

China is a major agricultural country with 22% of the world's population (1.3 thousand million) but only 7% of the cultivated land of the world. Food production has increased substantially during the past 50 years, and this is largely because of progress in science and technology and institutional reform. Much of the increase in grain production was the result of greater use of synthetic N fertilizers, and there is a significant correlation between the annual fertilizer application and the grain production. The collectives on behalf of central government used to put pressures on farmers to increase production to meet local and national food self-sufficiency targets, and most of them responded by increasing fertilizer use. Since 1978, however, when China started to open up its economy, farmers have become more involved in off-farm activities and

[5] Insecticides mainly include parathion, parathion_methyl, trichlorfon, dichlorvos, dimethoate, omethoate, ethamidophos, isocarbophos, carbamate, pyrethroid, disosultap and chlordimeform. Fungicides mainly include copper sulphate, carbendazim, benodanil, kitazin (EBP), iprobenfos (Kitazin P), zineb, tricyclazole and jiangangmycin. Herbicides mainly include nitrofen, butachlor, 2,4-D butylate, chlortoluron, MCPA, glyphosate, atrazine, prometryn and trifluralin.

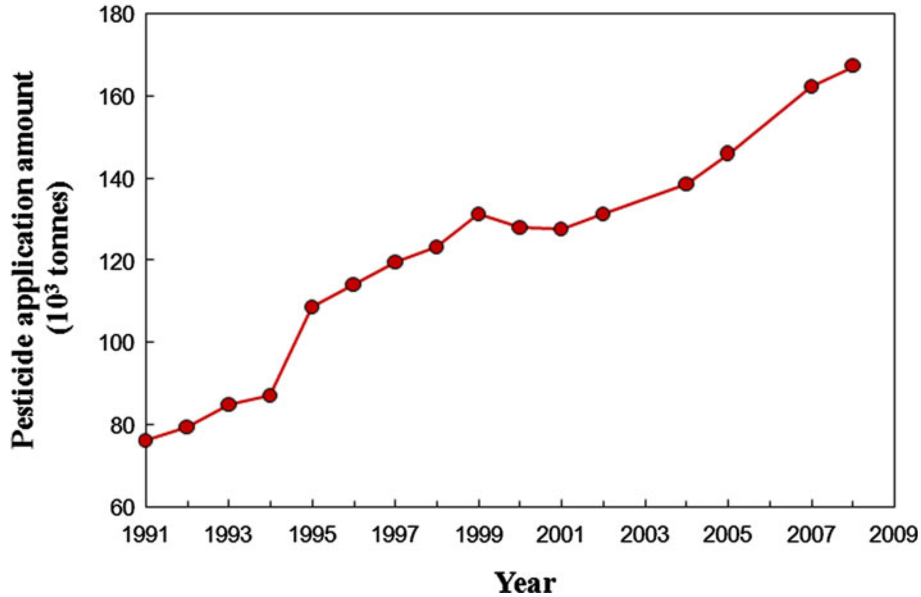

Fig. 5 Total pesticide (formulation) application rate in China from 1991 to 2008

responded to the rising opportunity cost of their labour. They applied fertilizer in a single application rather than using split applications which give higher nitrogen use efficiency but need more labour.

Farmers generally fail to take into account of the differences between the agronomic, economic and environmental optimum application rate. Fertilizer trials in China over many years for different crops, soil types and agroclimates have provided good estimates of the agronomic optimum application rate (Yang and Sun 2008). The average agronomic efficiency of fertilizer N in the 1990s when applied to cereals at a rate of 120−150 kg N ha^{-1} was 8.1−11.8 kg yield per kg of N in over 2700 field experiments (Zhu et al. 1997). Farmers, however, generally need to apply higher rates of fertilizer to reach the optimum agronomic efficiency, because of crop varieties developed in recent years commonly require more nutrients and higher management levels. The economic optimum N input (the balance between the income from increased yield and the cost of increased fertilizer used to achieve it) will be less than the agronomic optimum. Finally, the environmental optimum N input will generally be comparable or less than the economic optimum because the latter fail to take account of the costs to the public at large of the environmental damage caused by NPS pollution. These costs (depending primarily on the extent of overuse) are difficult to estimate and are not known with precision but in the case of rice in the mid-1990s were estimated to be in the range of 2.0−7.4 thousand million USD per year for whole China (Norse et al. 2001).

The fast development of vegetable production has added considerably to the overuse of fertilizer and pesticide. The total area planted with vegetables in China increased from 3.3 million ha in 1980 to about 28 million ha in 2008. An investigation in the late 1990s of 18 provinces (city) showed that in all of them except Inner Mongolia, the average synthetic N fertilizer application rate commonly exceeded 200 kg N ha^{-1}, with the highest rate of 740 kg ha^{-1} occurring in Shandong province (Fig. 6) (Ma et al. 2000). In addition, they commonly applied high rates of nitrogen as manure (Li et al. 2006). Excessive N inputs are often one of the main reasons for the high incidence of pests and diseases in vegetable production, and in turn, this commonly leads to farms using even more pesticide, resulting in high-pesticide residues on vegetables and in the environment. Insecticide application rate are often 2–3 times the recommended dosage (Ma et al. 2000; Li et al. 2006).

The excessive and unbalanced inputs of inorganic fertilizers can cause the damage to soil structure and soil quality. Although the ratio of N:P:K increased from 1:0.20:0.11 in 1991 to 1:0.28:0.21 in 2008, the proportion of potassium fertilizer commonly needs to be increased. Nitrogen ratios have been too high in most of regions in China since the 1970s, especially in eastern areas. Phosphorus ratios have changed from a deficit to small surplus (with a large surplus in some vegetable areas), but potassium is generally still in deficit (Shen et al. 2005). Unbalanced nutrient ratios in mixed synthetic fertilizers can cause both biological and physicochemical damage to soils, leading to acidification, secondary salinization and reduction of microbial activity (Cao et al. 2004; Ge et al. 2009; Guo et al. 2010). This damage lowers crop yields and may lead to farmers applying even more fertilizers to try to compensate for the reduced soil productivity and thereby intensify NPS pollution and the cycle of environmental degradation.

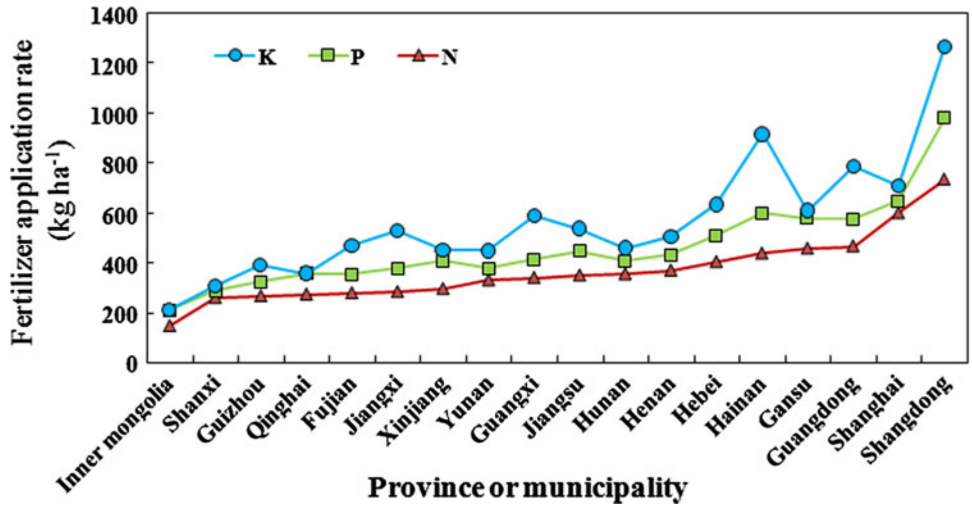

Fig. 6 Synthetic fertilizer application rates on vegetables in 18 provinces (municipalities) in China

Inadequate Agricultural Extension Services

The ratio of agricultural extension investment as a percentage of total agricultural GDP in China was only 0.49% in 1999, and 80% of the funds allocated to extension services were used to pay staff salaries. Local government reforms in the 1980s required local extension agencies to allocate staff to other duties unrelated to extension, and to engage in commercial activities in order to generate revenue to maintain or supplement salaries and compensate for the reduced public funding for extension. However, because one of the main commercial activities of the extension workers was (and may continue to be) the selling of pesticides and inorganic fertilizers, this hampered their enthusiasm to give any technological or nutrient management advice that would reduce the overuse of fertilizers and pesticides. Surveys in many parts of China have highlighted the poor support that farmers receive from extension services. For example, an investigation in Hubei and Fujian provinces in the 1990s showed that only 15% of families received the training in fertilizer management, 34% of famers received instruction from technicians on pesticide application and 84% of farmers applied the pesticide over the recommended dose (Huang et al. 2001).

POLICY SUGGESTIONS AND MITIGATION MEASURES TO REDUCE NON-POINT SOURCE POLLUTION FROM AGRICULTURE

Correct Distortion in Fertilizer Prices

One of the dominant strategies that China has used for many years to boost grain production is to keep chemical fertilizer price low. Subsidies are provided to fertilizer manufactures in various ways but particularly through low-energy prices >RMB 6.3 thousand million every year since 2003 (Chanda et al. 2009) and tax rebates, to keep production costs and retail prices low so that farmers can afford to buy and use more fertilizers on their crops. While in the past such approaches helped to increase grain production, it has also encouraged the overuse of N fertilizer (Zhang et al. 2006; Ju et al. 2009) and serious environmental damage. Therefore, the Chinese government needs to remove such price distortion and place more emphasis on providing farmers with better advice on plant nutrient management, and support to research and development on breeding higher yielding varieties and small scale equipment for the precision placement of fertilizers. In addition, more investment is needed to improve the basic production infrastructure, such as high-efficiency irrigation.

Provide Greater Incentives for Recycling Organic Manure

The addition of straw to soil is a means to immobilize N as organic N in microorganisms and their remains, which is a favourable option in terms of soil carbon sequestration and nutrient returning (Lu et al. 2009). Rural environmental protection strategies should require the development of comprehensive straw utilization plans that maximize the return of straw and forbide the straw burning in the fields. The recycling of organic manure needs to be promoted by introducing new incentive measures such as investment for the development of better techniques to produce commercial organic fertilizers with high-quality standards. At the same time, the state should consider expanding the subsidy programme for the enhancement of soil organic matter by the application of rice straw decomposition agents and commercial organic fertilizers, and possibly expand the scope of programme and increase the scale of subsidies[6] where this is the most cost-effective way of mitigating GHGs and other forms of NPS pollution. Furthermore, there needs to be clear labelling requirements for green and organic foods so that consumers can understand and accept the need for price premiums for such products.[7]

Giving Farmers Access to Better Knowledge on the Sound Application of Agro-Chemicals Through Promotion of Farmers Associations

Lack of awareness by farmers and the general public of the negative consequences of overuse of fertilizer and pesticides is a major challenge to appropriate use of these essential agricultural inputs. This includes the widespread lack of knowledge of the correct applications rates. Furthermore, the rural household contract responsibility system allows farmers to decide which crops they will grow depending on market demand themselves (as opposed to the earlier State system of set crop production targets). This has led to more diversified needs for fertilizer and pesticides and posed challenges to the extension services. The latter are being reformed to meet these challenges but in addition farmers need to better organized through the formation of farmer technical associations that promote information exchange. In recent years, laws and regulations have been introduced to promote farmers associations and help farmers to have better access to technical assistance and market information.

Other Measures to Provide Better Agricultural Extension Services

Reforms to the agricultural extension system in the last decade have helped to correct conflict of interest issues in the roles of some public extension services workers. Earlier reforms in 1980s created a situation in which extension workers were not only responsible for teaching farmers how to adopt agricultural new technologies, including appropriate use of agricultural chemicals, but they also had the tasks of selling these chemicals in order to generate revenue or income. This created a major incentive for them to emphasize the expansion of sales of fertilizers and pesticides rather than advising farmers on appropriate application rates. The recent reforms efforts have focused on how to separate these two functions. Furthermore, new extension service models have been examined to find more effective ways of meeting farmers' needs for sound information on the control of NPS pollution. It is important to emphasize that no matter which communication model is used the guidance they provide must include measures to promote the sound management of agro-chemicals, manure and crop residues in ways that are both economically viable and environmental sustainable. These measures will include the promotion and adoption of high-efficiency fertilizer technology.

Improving the Implementation of National Standards and Legislations on Organic Waste Discharges and Pesticide Use

Tighter controls should be imposed on the discharge of organic waste from livestock and poultry farms. Legally enforceable environmental protection regulations for livestock production should be established based on the consideration of the potential to increase waste treatment and utilization of livestock's excrements, the livestock carrying capacity of the land, the waste storage and disposal requirements, and the need for ecological buffer zones. Especially in the provinces and regions that are most at high-risk from NPS, the protected area should be established to control random discharges of manure.[8]

The registration and application of pesticides needs to be managed more rigorously, together with measures to eliminate highly toxic and stable pesticides, and to develop new pesticides which are environmentally safe. The central strategy for pesticide use should be based on the precautionary principle and on integrated control systems, which requires (a) the establishment of a plant disease and insect pest forecasting system, (b) the adoption of integrated pest techniques that use biological agents and biological pesticides together with knowledge of population dynamics, (c) expansion of basic research on pest control and applied research on methods of application. Finally, farmers need

[6] The Ministry of Agriculture implemented the subsidy programme to enhance soil organic matter in 287 counties of 21 provinces (municipalities) in 2009, covering an area of 1.03 million ha. The state give 300 CNY (Chinese Yuan) ha^{-1} (1 USD is equal to about 6.4 CNY) subsidy to the farmers for application of 30 kg ha^{-1} rice straw decomposition agent in the South region and for application of 1500 kg ha^{-1} commercial organic fertilizer in the northern region.

[7] In China, there was 23.27 million ha of farmland certified to produce innoxious food (green food) with the rational use of synthetic fertilizers and organic manure in 2006, accounting for 19.1% of the total arable land (121.7 million ha). There was only 3.3 million ha of farmland certified to produce organic food without synthetic fertilizers and pesticides.

[8] Taihu Lake Water Pollution Prevention Regulations of Jiangsu Province was implemented in 2008. The most closely protected areas include the body of Taihu Lake; a 5-km wide band of land around the lake; and 1 km of land bordering the river for 10 km upstream of the lake. In this area, the construction of new centralized livestock and poultry farms is prohibited.

more training and supervision on the safe use of pesticides.[9]

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AUTHOR BIOGRAPHIES

Bo Sun is a research professor at State Key Laboratory of Soil and Sustainable Agriculture, Institute of Soil Science, Chinese Academy of Sciences. His research interests include the management of nutrient cycling in agroecosystem and soil quality conservation.
Address: State Key Laboratory of Soil and Sustainable Agriculture, Institute of Soil Science, Chinese Academy of Sciences, No. 71 East Beijing Road, Nanjing 210008, People's Republic of China.
e-mail: bsun@issas.ac.cn

Linxiu Zhang is a research professor at Center for Chinese Agricultural Policy, Institute of Geographical Sciences and Natural Resources Research. Her research is mainly concerned with the policy for sustainable agricultural development.
Address: Center for Chinese Agricultural Policy, Institute of Geographical Sciences and Natural Resources Research, Chinese Academy of Sciences, Beijing 100101, People's Republic of China.
e-mail: lxzhang.ccap@igsnrr.ac.cn

Linzhang Yang is a research professor at State Key Laboratory of Soil and Sustainable Agriculture, Institute of Soil Science, Chinese Academy of Sciences. His research is mainly focused on agriculture ecological management and water quality restoration.
Address: State Key Laboratory of Soil and Sustainable Agriculture, Institute of Soil Science, Chinese Academy of Sciences, No. 71 East Beijing Road, Nanjing 210008, People's Republic of China.
e-mail: lzyang@issas.ac.cn

Fusuo Zhang is a professor at College of Resources and Environmental Sciences, China Agricultural University. His research is mainly concerned with plant nutrition and soil resource management.
Address: College of Resources and Environmental Sciences, China Agricultural University, Beijing 100094, People's Republic of China.
e-mail: zhangfs@cau.edu.cn

David Norse is a professor at Department of Geography, University College London. His research interests include policy making for sustainable agriculture and environment protection.
Address: Department of Geography, University College London, 4 Taviton Street, London WC1H 0BT, UK.
e-mail: jarvisnors@aol.com

Zhaoliang Zhu (✉) is a research professor at State Key Laboratory of Soil and Sustainable Agriculture, Institute of Soil Science, Chinese Academy of Sciences. His research is mainly focused on nitrogen cycling in agroecosystem and its management.
Address: State Key Laboratory of Soil and Sustainable Agriculture, Institute of Soil Science, Chinese Academy of Sciences, No. 71 East Beijing Road, Nanjing 210008, People's Republic of China.
e-mail: zlzhu@issas.ac.cn