



Environmental costs of China's food security



David Norse^{a,*}, Xiaotang Ju^b

^a Environment Institute, University College London, London, UK

^b College of Resources and Environmental Sciences, China Agricultural University, Beijing 100193, China

ARTICLE INFO

Article history:

Received 24 April 2014

Received in revised form 30 January 2015

Accepted 20 February 2015

Available online 27 May 2015

Keywords:

Nr hotspots

Environmental damage

Economic cost

China

ABSTRACT

China's successful achievement of food security in recent decades has resulted in serious damage to the environment upstream of the agricultural sector, on farm and downstream. The environmental costs of this damage are not only agro-ecosystem function and the long-term sustainability of food production, but also bio-physical including human health with impacts at all levels from the local to the global, and with economic loss estimates ranging from 7 to 10% of China's agricultural gross domestic product (GDP).

This paper presents a systematic analysis of the causes and impacts of these environmental costs for China's cropping systems and crop-based livestock systems, and focuses on the nitrogen management. Since the 1980s most of the environmental costs have been related to the intensification of first grain production stimulated by high nitrogen fertilizer and irrigation subsidies, and then vegetable production and fruit trees, with the overuse and misuse of synthetic nitrogen fertilizer and manure being the dominant cause of eutrophication, soil acidification and high greenhouse gas emissions. However, during the last 10 years or so the expansion of intensive livestock production has become a serious cause of direct and indirect air and water pollution and is destined to be the main agricultural threat to China's environment in the long-term unless a holistic strategy for sustainable intensification is adopted for the next and future 5 Year Plans. This strategy should focus on improving nutrient management to limit nitrogen overuse, which is now the main cause of the economic losses from agriculture's damage to the environment.

©2015 Elsevier B.V. All rights reserved.

1. Introduction

China's successful achievement of food security¹ in recent decades has resulted in serious damage to the environment upstream of the agricultural sector, on farm and downstream. The environmental damage is biological, physical and chemical, particularly in terms of changes in soil processes and ecosystem function, with impacts at all levels from the local to the global. It has serious negative impacts on current and the long-term food security, and on the economy with estimated losses of up to 7% (this paper) to 10% (Smil, 1996) of China's agricultural GDP and 2% of gross national income (GNI).

During the period 1960–1975 most of the ecosystem and environmental damage (e.g., soil erosion) was related to

deforestation and cultivation of slope lands for grain production, and then the expansion of intensive grain, vegetable and fruit tree production following the agricultural reforms starting in 1978 (especially after 1980s), and with the overuse and misuse of synthetic nitrogen fertilizer and manure being the dominant causes. However, during the last ten years or so the expansion of intensive livestock production has become a major cause of direct and indirect air and water pollution and is destined to be the main agricultural threat to China's environment in the long-term.

Since about 2005 agriculture has overtaken industry as the dominant source of water pollution, that is, 44% of chemical oxygen demand (COD), 57% of nitrogen (N) and 67% of phosphate (P) (MEP, 2010), and the main driving force for eutrophication and groundwater nitrate accumulation (Gu et al., 2013). Within the agriculture sector livestock has become the main sources of discharges to water, that is, 96% of COD, 38% of N and 56% of P. In addition there is water pollution from pesticide residues and increasingly from veterinary chemicals. The bulk of the non-point pollution is from excessive N fertilizer and manure applied to grains, vegetables, fruit trees and cotton (Zhu et al., 2006) whereas livestock production causes most of the point source pollution (B. Gao et al., 2014; M. Gao et al., 2014).

* Corresponding author at: Environment Institute, University College London, Gower Street, London WC1E 6BT, UK. Tel.: +44 20839841.

E-mail address: d.norse@ucl.ac.uk (D. Norse).

¹ Food security is considered here primarily in terms of food production, because of the Government of China's emphasis on maintaining high food grain self-sufficiency. However, the paper does not neglect access to food, food price and food market issues which have influenced input use.

The situation regarding air pollution and GHG emissions is more complex. Upstream activities associated with the production and transport of fertilizer make a major contribution to system wide agricultural GHG emissions and exceed those from direct N fertilizer use (SAIN, 2011; C. Zhang et al., 2013). Structural change in agriculture, and particularly the rapid increase in livestock production in concentrated animal feeding operations (CAFO's) (SAIN, 2012), in 2007 led to agriculture becoming China's largest source of methane (47%) and of nitrous oxide with estimates ranging from 74–81% (SAIN, 2011; Chen and Zhang, 2010; Gu et al., 2012). Further complexity arises because of the role of N fertilizer use and livestock in the rapid build-up of ammonia emissions in China (Klimont et al., 2009; Gu et al., 2012) and the spread of smog and soil acidification (Guo et al., 2010), which is now a threat to public health and to food production on much of China's cropland.

The complexity of the environmental damage associated with food production is mirrored in the multi-dimensional nature of the economic costs they give rise to. Some of the costs are suffered within the crop season, and are reflected fairly directly in yield losses, and hence can be estimated with some confidence. Other costs may not be suffered for decades after the initial intervention, for example, when leached and runoff nitrogen passes slowly down to an aquifer used for drinking water and needs to be purified to meet health requirements (Chapman, 1996). Agricultural N₂O emissions are an important driver for global warming and ozone depletion (IPCC, 2007). Finally, there are the virtually unquantifiable costs, like the loss of biodiversity or ecosystem function (Sutton et al., 2014). Consequently, there is great uncertainty about the economic costs of the environmental damage, but little doubt that they are substantial. Some of the early estimates were unrealistically high. Smil (1996), for example, suggested that the environmental costs of soil erosion alone were about 2% of China's GDP. Most recent estimates of the cost of environmental depletion and degradation² are in the range 4–9% GNI. The World Bank/DRC estimates (2013) place the total cost at 9% of which soil depletion is about one percentage point and air pollution material damage and water pollution health damage at each about one-half of a percentage point. The World Bank/SEPA study (2007) on the costs of air and water pollution in China estimated them to be 2.8–5.8% GDP depending on how human health damage was calculated. However, none of these recent studies specifically examine the direct and indirect economic costs of the environmental damage stemming from food production, which even in 1995 were over US \$2.0 billion (in year 2010 prices).

The final complication relates to how these environmental and economic impacts affect food security in all its dimensions. Most analyses tend to focus on long-term food supply issues, notably the availability of sufficient land and irrigation water to maintain circa 90% self-sufficiency in food grains and the vulnerability of food production to climate change. However, the environmental impacts also lower current food security, for example, by increasing pest attacks and reducing soil productivity (Gregory et al., 2009). Moreover, the economic impacts include lower access of the poor to food by reducing farm incomes and increasing food prices (SAIN, 2010).

This paper attempts to clarify this complexity by presenting a systematic analysis of the causes and impacts of the nutrient management related (and particularly reactive nitrogen N³)

environmental costs for China's cropping systems and crop-based livestock systems. It focuses on the agricultural sector per se rather than the full food system, and on the national rather than the global context. Section 2 examines the main causes of environmental damage. Section 3 examines the importance of these impacts primarily in terms of the area affected, the reduction in yields and production and their economic costs. Finally, Section 4 concludes by drawing on the foregoing to outline elements of a holistic strategy for sustainable intensification that are substantiated or developed by other papers in this special issue.

2. Main causes of the environmental damage arising from food production that undermine food security

Most of the causes involve resource mismanagement and relate in one way or another to nutrient management. Two of them, namely soil acidification and enhanced greenhouse gas emissions (GHGs) have multiple drivers and complex interactions between crop and livestock production. They are primarily the outcome of nutrient mismanagement and in turn the cause of serious environmental damage that reduces food security.

2.1. Overuse of synthetic N

This is by far the largest and most widespread cause of environmental damage, with economic costs that occur both upstream and downstream of the farm gate (see Section 3). It has been an issue since the 1980s (Zhang et al., 2006) and has grown progressively worse in terms of the area affected and the level of overuse (Fig. 1). In the main cereal growing provinces of the Huang Huai Hai Plain it seems likely that >70% of the cropland suffers from excess synthetic N use (receiving 2–3 times crop needs), and in case of the covered vegetable areas of Shandong and Hubei over 90% of the plots receive very high N rates (up to 1000 kg N per crop) that are greatly in excess of crop needs (Ju et al., 2006). However, the pattern of N use is very heterogeneous, and the spatial distribution of N overuse is not known well enough to correctly determine the ecosystem and economic consequences of this overuse. Huang and Tang (2010) suggest that total overuse is in the range 2.8–6.6 million t and is largely confined to 10 provinces (Fig. 1); other estimates are 7–10 million t N (Kahrl et al., 2010); 9–10 million t (W.F. Zhang et al., 2013).

Average overuse estimates for large areas can be misleading and can mask hotspots of overuse where the environmental impacts are most serious. In Yunnan, for example, average N rates seem to be in balance with crop removals (Fig. 1 and Gu et al., 2012), and N overuse is not a major issue. However, Yunnan is a topographically and climatologically diverse province with very heterogeneous agro-ecosystems. Crop production is concentrated on the flatter lands and better soils where N use rates can be considerably in excess of the provincial average of about 150 kg ha⁻¹ yr⁻¹ creating serious N loss hotspots. Average inputs in these hotspots can reach 400 ± 100 kg ha⁻¹ yr⁻¹ for all crops, and 730 ± 330 for maize (Li et al., 2012). Similar disparities are apparent in Shaanxi for grain crops, fruit trees and vegetables (Tong et al., 2004; Wang, 2006). N rates for maize are commonly >250–350 and >60% of farmers are applying more than the recommended rates of about 100 kg N ha⁻¹ yr⁻¹ estimated from soil tests (Cui et al., 2008). Correct identification of these hotspots is very important for physical, economic and institutional reasons and in particular because some of the environmental costs of N overuse are not linear. Leaching rates, for example, generally increase when average N application rates rise above 150–180 kg ha⁻¹ yr⁻¹ (Goulding, 2000; Cui et al., 2013a; B.Gao et al., 2014) and hence the risk of eutrophication and ground water nitrate accumulation (Ju et al., 2006, 2009; Conley et al., 2009)

² Defined to include soil nutrient, energy and mineral depletion as well as air and water pollution and human health damage.

³ Nitrogen compounds that support growth directly or indirectly including nitrogen oxides (NO_x), ammonia (NH₃), nitrous oxide (N₂O), as well as the anion nitrate (NO₃⁻) and the cation ammonium (NH₄⁺).

Download English Version:

<https://daneshyari.com/en/article/8487682>

Download Persian Version:

<https://daneshyari.com/article/8487682>

[Daneshyari.com](https://daneshyari.com)