Nitrogen Budget on Township Scale in North China Plain

Xinsheng NIU[a] Baojing GU[b] Xiaotang JU[c1]

[a] Qu Zhou Experimental Station, China Agricultural University, Quzhou 057250, PR China.

[b] Department of Land Management, Zhejiang University, Hangzhou 310058, PR China.

[c] College of Resources and Environmental Sciences, China Agricultural University, Beijing 100193, PR China.

Abstract

To find out the critical problems of reactive nitrogen (Nr) on township scale and ascertain Nr flows in basic agricultural farming unit, we carried out a research of Nr budget on the township scale in North China Plain (NCP). Results showed that chemical N fertilizer dominates the Nr imported into a township. Low Nr use efficiency in cropland subsystem was found in agro-pasturing interlocked area. Environmental Nr loads mainly derived from cropland subsystem due to excessive and irrational applying of N fertilizer in NCP. Therefore, application rates of N fertilizer synchronized to demand of crop and alternatives of scientific and advanced application measurements were all necessary. Huge losses of Nr from storage of both human feces and animal manure were caused by lack of treatment facilities and local habitants' ignoring the rational management on wastes. The extension of new extensive technologies of livestock husbandry for achieving higher converting ratio of feed and provided with facilities of treating manure with great efforts are necessity, especially in agro-pasturing interlocked area.

Keywords

Nr flow, Nr transfer, Township scale, NCP

1. Introduction

Many studies on Nr flows and transfers on national scale (Cui *et al.*, 2013; Gu *et al.*, 2015) or on province-scale (Ma *et al.*, 2014) have been documented recently. They revealed Nr transfers and fluxes to provide administrators with good information for better managing Nr from a larger scale in order to increase nitrogen utilization efficiency and decrease impacts on environment. However, we think that research into Nr flows at a fine scale, such as in representative typical townships in rural areas may be better suited to understanding Nr flows where management decisions are made.

2. Method

We carried out this research from 2014 to 2015 on rural township scale, a basic administrative unit in China. We used the method of daily recording on agricultural practices and food consumption in typical and representative households. We randomly selected 40 households in Disituan township (DST) (36°20′N, 114°00′E, 37 m of altitude), a cropland-dominated region with nearly 40,000 rural population and 5.142×10^3 ha of cropland accounting for 74% of administrative land in Quzhou county, Hebei province in NCP. In addition, 30 households were chosen in Gaoshanbu township (GSB) (41°46′N, 115°41′E, 1380 m of altitude) located in agro-pasturing interlocked area with 177 km^2 of administrative land and approximately 10,000 population and land use was as follows: cropland is 2.584×10^3 ha accounting for 15% administrative land, grazing land 2.225×10^3 ha, and forest land 2.199×10^3 ha. Therefore GSB is relatively a scarcely populated area versus DST. A livestock-dominated farming system is major property among its agriculture production in GSB. According to the specific conditions in two townships a calculation model using Excel table of Microsoft was developed to calculate Nr flows mainly through the major sections within the township. Nr flows in different households were ascertained based on mass flow and the law of matter conservation.

3. Results and discussions

3.1. Nr fluxes and balance on township scale

Over the year more than 90.8% of Nr, a substantial share, was imported in chemical fertilizer for crop farming in DST, which showed that chemical fertilizer was preferred by local farmers (Nr flux see the Fig. 1 below). We assumed that this is because fertilizer application is more convenient and less time-consuming and also more economical alternative compared to organic fertilizer due to the subsidization of chemical fertilizer (Zhang, *et al*., 2012; Sun *et al*., 2012; Li *et al*., 2013), which just like the results showed that 11.6% of Nr in manure would rather be sold out of the township for unknown fates. Overuse of fertilizer has been documented by other researches in NPC (Zhao *et al.*, 1997; Gao *et al.*, 1999; Zhao, *et al.*, 2006; Ju *et al.*, 2007; Ju *et al.*, 2009; Chen *et al.*, 2011), excessive use of N fertilizer was also found in the two townships, for instance, 225~856 kg N

[1] Corresponding author, E-mail address: juxt@cau.edu.cn

ha^{-1} per sowing season was applied in vegetable production both in two townships. The phenomenon of surface-spreading of N fertilizer was universally found here. The time of application of N fertilizer was hardly synchronized to demand of crop, for example, farmers would like apply N fertilizer far before regreen stage of wheat, which also had been found by Niu (2012). Therefore Nr losses to the environment were derived from the cropland subsystem as a result of over-application and irrational practices of N fertilizer. Same result has been reported by Ongley, *et al.* (2010). Another important Nr loss was derived from human and animal wastes mainly caused by lack of storage and treatment facilities. Dry toilet was used currently in rural of NPC and the vast of animal manure was open storage outside of farming houses without any management in GSB. Even worse, human excreta was extracted out from storage pool and discharged into ditches near farmland due to lack of sewage disposal even if some household had used the water toilet in rural of NPC.

Over the investigating year the Nr in chemical fertilizer, feed and manure accounted for 44.9%, 18.7% and 24.4% of gross imported Nr respectively in GSB, which highlighted predominant animal husbandry in agro-pastoral interlocked area. About 90.1% of Nr produced (account for 55.8% of Nr in total input) entered the environment which suggested that the converting efficiency of Nr was very low and much of them were predominantly environmental pollutants in GSB.

3.2. Nr fluxes, transfers and fates in cropland subsystem

We divided the whole township system into three subsystems (cropland subsystem, livestock subsystem and human food consuming subsystem) in order to conveniently analyze the Nr fluxes and transfers in different sections through townships and trace flow of various Nr species.

Nr conversion and loss In cropland subsystem, total biomass conversion of Nr was about 50.3% and economic section (ie. edible parts as human food) conversion of crop was about 31.3% in DST, and 32.3% and 21.3% respectively in GSB. The result showed that N use efficiency of wheat and maize averaged to 31.8 kg/kg (yield / fertilizer N applied). Chen *et al.* (2011) reported that Nitrogen fertilizer use efficiency averagely was 26 kg/kg in NCP and 27.3 kg/kg reported by Niu (2012) in DST. We thought that the weather condition over the studying year was better and the yield of wheat plus maize was 15.4 t ha^{-1}, the highest yields historically in DST.

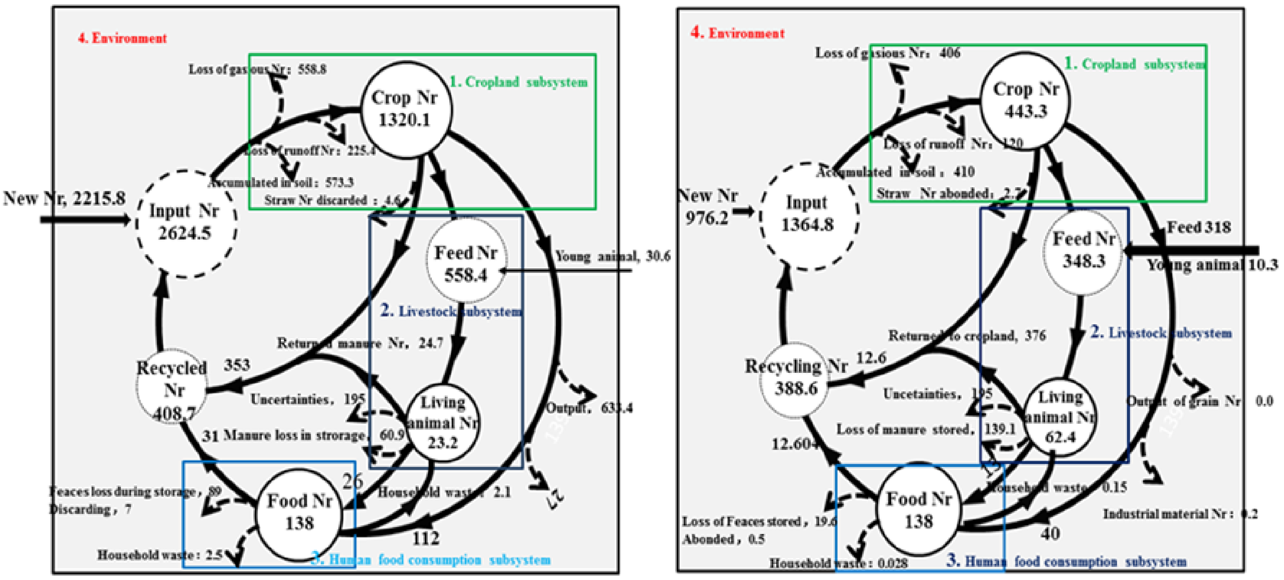

Fig. 1 Flows and transfers of Nr in two different townships. The right fig. is for Nr flows in DST and the left for GSB. The edge and background in gray of the biggest rectangles means boundary and environment respectively of township system, and the other 3 rectangles in different edge colors indicate 3 subsystems. The sagittal curves indicate different Nr flows and the directions of sagittal arrows mean directions of Nr flows in system.The words and figures (in t/yr of unit) near the sagittal arrows mean Nr behaviors and corresponded fluxes respectively of the Nr flows meant by sagittal curves.

The conversion ratio of Nr in cropland subsystem in GSB apparently was lower than that in DST probably due to differences in cropping system between two sites (crop farming was dominated by hulless oat, fodder maize and flax that covered about 56.1% of cultivated area in GSB and dominated by wheat and grain mentioned above in DST).

The results revealed that more than 50.3% in DST and 68.6% in GSB of imported Nr were lost in cropland subsystem, among of which more than 70% missed in gaseous species of Nr. This was attributed to predominantly surface application of nitrogen found in this investigation and also reported by others in NCP (Ongley, *et al*,. 2010; Zhang *et al*., 2013. Ju *et al*., 2014). We estimated that about 20.5 % of Nr imported in DST and about 30.1% in GSB in this subsystem accumulated in soil mainly concerned with excessive use of fertilizer, which also reported by others in NPC (Zhao *et al*., 2009; Ju *et al*., 2014; Ju *et al.*, 2009; Chen *et al*., 2011).

Utilizations and fates of output Nr About 73.2% of Nr in crop residues was returned to the cropland in DST and only 8.3% in GSB, while 2.6% were utilized as feed in DST and 63.6% as feed in GSB. This highlighted the difference in farming systems between GSB (livestock-dominated) and DST (crop-dominated). Other fates of crop residues mainly were used as firewood (10.4% of total Nr in residues) or as industrial raw materials (12.8% of the total Nr in residues) in DST and 26.1% and 0.1% respectively in GSB. The rest of residues (less than 1.8% of total crop residue Nr) were abandoned to environment both in two townships. Therefore the recycling ratio of crop residues achieved more than 98.2% in two townships.

3.3. Fluxes and fates of Nr in livestock subsystem

Nr fluxes About 31.4 t of Nr $yr^{-1}$was surplus (total input- output of Nr) in DST and 131.7 t $yr^{-1}$of Nr surplus in GSB. We assumed that the surplus may be lost as feed wastes during animal feeding. The results clearly showed there was lower converting efficiency of feed in GSB (10.6%) than that in DST (32.7%), which suggested that extensive breeding widely performed in DST where modern innovations and technologies were applied had higher use efficiency of feed Nr than traditional and outdated scatter breeding, currently adopted widely in GSB.

Recycling and loss of manure More than 58.3% and 84.8% of total output Nr was in manure respectively in DST and in GSB, however about 32.4% of Nr in total manure in DST and nearly 27.0% of total manure Nr in GSB were lost during shortage due to inadequate the facilities (open storage of animal manure generally). About 59.2% of total Nr in manure was sold out of the township in DST. So just 7.5% of total Nr in manure were returned to cropland and, as above-mentioned, farmers preferred synthetic fertilizer to manure for a variety of reasons.

3.4. Nr fluxes and fate in human consumption subsystem

Nr fluxes More animal-derived food was consumed in GSB and conversely more plant-derived food was preferred in DST. The result indicated that about 81.2% in DST and 74.9% in GSB of imported Nr was derived from plant and the rest was animal-derived food. The habitants from GSB would prefer to more animal food. More waste food was produced during food processing and consuming in DST (with about 14.3% of gross output Nr produced) than that in GSB where just about 4.9% of gross output Nr was yielded. For this we assumed that people in GSB would like save more food from procession and consumption. This probably was concerned with long-term developed thrifty living habits in GSB where we found that the conservativeness and thrifty of living way had been still kept by most households.

Utilizations, fates of output Nr The most of Nr in human feces lost to the environment mainly during the storage. The result showed that about 70.0% in DST and 59.9% in GSB of total Nr in human feces had been lost to environment during storage and management before returning to farmland. We found that dry toilets were still universally used currently and most habitants hardly had public health awareness in rural in NCP. Subsequently, just about 24.7% in DST and 38.5% in GSB of Nr in human feces were returned to cropland, and remains were abandoned at will.

3.5. Food production and environmental loads

Both resources and environment for producing food costed higher in GSB than that in DST. About 4.89 kg Nr was consumed for yielding 1 kg food Nr in GSB while produced more than 4.36 kg of environmental pollutants Nr, which was about 1.85 times and 2.40 times as much as those respectively in DST. We supposed that this could be attributed to the differences between two framing systems, and to lower efficiency of resources use in farmland and livestock husbandry in GSB.

Both population and area of land have influenced the environmental Nr loads. The environmental Nr loads with about 21.7 t $N/km^2/yr$ in DST based on administrative land was 39.1% higher than that in GSB. And inversely the Nr loads based on population with more than 109.1 t N per capita yr^{-1} in GSB was 2.78 times as much as that in DST. That was due to scarcely populated area in GSB as noted in method.

The results suggested that the environmental pollutants Nr mainly derived from cropland subsystem (83.8% of total loads in DST and 82.5% in GSB), which were primarily concerned with overuse and irrational application of fertilizer, secondly from livestock subsystem, David, *et al.* (2015) had a similar result, and thirdly from the food consumption mainly due to unreasonable managements of night soil during storage.

4. Conclusions and suggestions

Nr imported into township was mainly from mineral fertilizer especially in plant-dominated DST. More organic fertilizer would be used and to improve recycling use of agricultural production waste was urgently essential for deceasing environment pressure. The environmental Nr loads mainly come from cropland subsystem which concern with excessive nitrogen fertilizer application and irrational applying such as surface application of fertilizer universally used in NCP, so decreasing application rates of nitrogen fertilizer and alternatives of scientific and advanced application methods were needed. The results highlight the huge losses of Nr during storage of human feces and animal manure involved with lack of treating facilities and ignoring the rational management of the wastes, accordingly sewage treatment in rural new countryside construction and developing of flush toilets in dry region in NCP should given a priority consideration henceforth and extension of new extensive technologies of livestock husbandry for achieving higher converting ratio of feed and provided with facilities of treating manure with great efforts are all necessity especially in agro-pasturing interlocked area.

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